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## Dynamic Safety Risk Assessment

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1. The Risk Index (RI) is formulated as :

To involve the latent impacts of safety-related accidents and incidents, impact on business was added to the formula. These changes and modifications could be introduced as:

$$\text{Risk Index} = RI = (p^{1/\alpha} \cdot S^{\frac{1}{\beta}}) + I^{1/\gamma}$$

Where P denotes probability, S – severity, and I – impact on business, and  $\alpha, \beta, \gamma$  – the weighting factors for probability, severity and impact on business, respectively

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2. The field risk (FR) is formulated as:

$$\text{Field Risk Index} = (FR)_i = \frac{\sum_{t=1}^N (RI)_t}{N}$$

Where  $RI$  is the safety risk index of a safety report and  $N$  is the total number of safety reports received in a definite field

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3. The Overall Safety Index (OSI) of the organization:

The safety Field risks from different sectors: engineering and maintenance, flight operations, security, airport services, dispatch, training, air medical centers, and areas, such as ramp, hangar, etc., are summed up to obtain the Overall Safety Index of the organization:

$$\text{Overall Safety Index} = OSI = \sum_{i=1}^P (w_i \cdot FRI)$$

Where  $FRI$  is the safety field risk,  $w_i$  indicates the corresponding weighing coefficients for each field derived by the FANP comparison method, and  $P$  is the number of operational fields (sectors/departments/areas).

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## Fuzzy Analytical Network Process (FANP)

Triangular Fuzzy scale definitions as :

The Fuzzy numbers used in this method are triangular Fuzzy numbers and the Fuzzy scale utilized in this method. These scales are used for pair comparison. Suppose two triangular fuzzy numbers

$$M_1 = (L_1, m_1, U_1) \quad M_2 = (L_2, m_2, U_2)$$

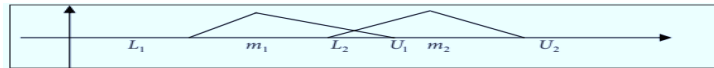
$$M_1 + M_2 = (L_1 + L_2, m_1 + m_2, U_1 + U_2)$$

$$M_1 \times M_2 = (L_1 L_2, m_1 m_2, U_1 U_2)$$

Linguistic scale	Reciprocal scale
Just equal	$\sim A(1,1,1)$
Equally important	$\sim B(2,1,3/2)$
Strongly more important	$\sim C(3,2,2,5/2)$
Very strongly more important	$\sim D(5,3,3,7/2)$
Absolutely more important	$\sim E(7,3,4,9/2)$

A=	1.00	1.00	1.00
B=	0.67	1.00	1.50
C=	1.50	2.00	2.50
D=	2.50	3.00	3.50
E=	3.50	4.00	4.50

1/A=	1.00	1.00	1.00
1/B=	0.67	1.00	1.50
1/C=	0.40	0.50	0.67
1/D=	0.29	0.33	0.40
1/E=	0.22	0.25	0.29



Two triangular fuzzy numbers in coordinate axis

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Step 1: The value of fuzzy synthetic extent with respect to the  $i^{th}$  object is defined as:

$$S_i = \sum_{j=1}^m M_{ij} \times \left[ \sum_{i=1}^n \sum_{j=1}^m M_{ij} \right]^{-1}$$

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Step2: The degree of possibility of  $S_2 \geq S_1$  is defined as:

$$V = (S_j \geq S_i) = \text{height} (S_i \cap S_j) = U(d) = \begin{cases} 1 & m_j \geq m_i \\ 0 & L_i \geq U_j \\ \frac{l_i - u_j}{(m_j - u_j) - (m_i - l_i)} & \text{otherwise} \end{cases}$$

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Step 3: The degree of possibility for a convex Fuzzy number to be greater than K convex fuzzy numbers  $M_i$  ( $i=1,2,\dots,k$ ) can be defined by :

$$V = (S)S_1, S_2, \dots, S_k = V[(S)S_1 \text{ and } \dots (S)S_k] = \min V(S)S_i \text{ for } i=1,2,\dots,k$$

$$d'(A_i) = \min (S \geq S_i) \text{ for } i=1,2,3,\dots,k$$

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Step 4: Via normalization, the normalized weight vectors are :

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^T$$

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Step 5 : Where  $W$  is a non-fuzzy number :

$$w = ((d(A_1)', d'(A_2)'), \dots, d'(A_n))' ^T$$

## Fuzzy Analytical Network Process (FANP)

Linguistic scale	Reciprocal scale
Just equal	=A(1,1,1)
Equally important	=B(2/3,1,3/2)
Strongly more important	=C(3/2,2,5/2)
Very strongly more important	=D(5/2,3,7/2)
Absolutely more important	=E(7/2,4,9/2)

A=	1.00	1.00	1.00
B=	0.67	1.00	1.50
C=	1.50	2.00	2.50
D=	2.50	3.00	3.50
E=	3.50	4.00	4.50

1/A=	1.00	1.00	1.00
1/B=	0.67	1.00	1.50
1/C=	0.40	0.50	0.67
1/D=	0.29	0.33	0.40
1/E=	0.22	0.25	0.29

Engineering and Maintenance field	Probability			Severity			Impact on business		
Probability	1.00	1.00	1.00	1	1	1	0.67	1.00	1.50
Severity	1.00	1.00	1.00	1.00	1.00	1.00	1.50	2.00	2.50
Impact on business	0.67	1	1.5	0.40	0.50	0.67	1.00	1.00	1.00

	L			M			U			SUM	inverse summation
S1	2.67			2.40			3.17			8.24	0.09
S2		3.00			2.50			4.00		9.50	0.11
S3			3.50			2.67			5.00	11.17	0.12

	2.67	3.00	3.50
	3.50	4.00	4.50
	2.07	2.50	3.17
sum	8.24	9.5	11.17

	L	M	U
S1	0.239033124	0.315789474	0.424757282
S2	0.313339302	0.421052632	0.546116505
S3	0.185317816	0.263157895	0.384708738

$$S_i = \sum_{j=1}^m M_{ij} \left( \sum_{i=1}^n \sum_{j=1}^m M_{ij} \right)^{-1}$$

s1>s2	0.514202487
s1>s3	1
s2>s1	1
s2>s3	1
s3>s1	0.734595713
s3>s2	0.311297815

$$V = (S_j)S_i = height(S_i \cap S_j) = U(d) = \begin{cases} 1 & m_j > m_i \\ 0 & L_i \geq U_j \\ \frac{l_i - u_j}{(m_j - u_j) - (m_i - l_i)} & otherwise \end{cases}$$

S1	0.514202487
S2	1
S3	0.311297815
SUM	1.825500302

$$V = (S)S_1, S_2, \dots, S_k = V[(S)S_1] \text{ and } \dots (S)S_k = \min V(S)S_i \text{ for } i = 1, 2, \dots, k$$

$$d'(A_i) = \min (S \geq S_i) \text{ for } i = 1, 2, 3, \dots, k$$

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^T$$

Probability	0.281677569
Severity	0.547795034
Impact on business	0.170527397

$$W = ((d(A'_1), d'(A_2)', \dots, d'(A_n)))^T$$

## 1 Corresponding weighing coefficients for each options- Each field:

Options- Each Field	corresponding coefficients-weight for each field
Engineering and Maintenance	36.67
Flight Operations	61.33
Airport Services	1.33
Security	0.67

As follow stages :



## 2 Triangular Fuzzy scale definitions:

Linguistic scale	Reciprocal scale
Just equal	=A(1,1,1)
Equally important	=B(2/3,1,3/2)
Strongly more important	=C(3/2,2,5/2)
Very strongly more important	=D(5/2,3,7/2)
Absolutely more important	=E(7/2,4,9/2)

A	1.00	1.00	1.00
B	0.67	1.00	1.50
C	1.50	2.00	2.50
D	2.50	3.00	3.50
E	3.50	4.00	4.50

1/A	1.00	1.00	1.00
1/B	0.67	1.00	1.50
1/C	0.40	0.50	0.67
1/D	0.29	0.33	0.40
1/E	0.22	0.25	0.29

## 3 ALL options-field matrix

Probability	Engineering and Maintenance	Flight Operations	Airport Services	Security
Engineering and Maintenance	A	A	1/C	1/D
Flight Operations	A	A	1/C	1/D
Airport Services	C	1/C	A	1/B
Security	D	1/D	B	A

Severity	Engineering and Maintenance	Flight Operations	Airport Services	Security
Engineering and Maintenance	A	B	1/C	1/D
Flight Operations	1/B	A	1/D	1/D
Airport Services	C	D	A	1/B
Security	D	D	B	A

Impact on Business	Engineering and Maintenance	Flight Operations	Airport Services	Security
Engineering and Maintenance	A	1/B	1/C	1/D
Flight Operations	B	A	1/C	1/D
Airport Services	C	C	A	1/B
Security	D	D	B	A

STAGE 1 :

	Engineering and Maintenance	Flight Operations	Airport Services	Security
Engineering and Maintenance	A	A	1/C	1/D
Flight Operations	A	A	1/C	1/D
Airport Services	C	1/C	A	1/B
Security	D	1/D	B	A

STAGE2 :

M ij	6	7	8	16.71667	0.043215
M ij	6	7	8	19.66	0.050865
M ij	2.466666667	3	3.84	23.14	0.059821
M ij	2.25	2.66	3.3		

STAGE3 :

	L	M	U
S1	0.259291271	0.356052899	0.478564
S2	0.259291271	0.356052899	0.478564
S3	0.106597522	0.1525941	0.229711
S4	0.097234226	0.135300102	0.197408

STAGE4 :

s1>s2	1				
s1>s3	1				
s1>s4	1				
s2>s1	1				
s2>s3	1				
s2>s4	1				
s3>s1	0				
s3>s2	0				
s3>s4	1				
s4>s1	1				
s4>s2	0				
s4>s3	0.840024813				

STAGE5 :

S1	36.66666667
S2	61.33333333
S3	1.333333333
S4	0.666667
SUM	1

Engineering and Maintenance	36.67
Flight Operations	61.33
Airport Services	1.33
Security	0.67

1 *Corresponding coefficients - weighing for each criteria- safety risk parameters :*

Options	Criteria	coefficients for each criteria
ENGINEERING & MAINTENANCE	PROBABILITY	17
	SEVERITY	82
	IMPACT ON BUSINESS	1
FLIGHT OPERATIONS	PROBABILITY	90
	SEVERITY	9
	IMPACT ON BUSINESS	1
AIRPORT SERVICES	PROBABILITY	54
	SEVERITY	40
	IMPACT ON BUSINESS	6
SECURITY	PROBABILITY	28
	SEVERITY	55
	IMPACT ON BUSINESS	17

As follow stages :



2 *Triangular Fuzzy scale definitions:*

Linguistic scale	Reciprocal scale
Just equal	=A(1,1,1)
Equally important	=B(2/3,1,3/2)
Strongly more important	=C(3/2,2,5/2)
Very strongly more important	=D(5/2,3,7/2)
Absolutely more important	=E(7/2,4,9/2)

A	1.00	1.00	1.00
B	0.67	1.00	1.50
C	1.50	2.00	2.50
D	2.50	3.00	3.50
E	3.50	4.00	4.50
1/A	1.00	1.00	1.00
1/B	0.67	1.00	1.50
1/C	0.40	0.50	0.67
1/D	0.29	0.33	0.40
1/E	0.22	0.25	0.29

3 *All criteria - safety risk parameters matrix*

Engineering and Maintenance DEPARTMENT	Probability	Severity	Impact on business
Probability	A	1/C	C
Severity	C	A	D
Impact on business	1/C	1/D	A
Flight Operations DEPARTMENT	Probability	Severity	Impact on business
Probability	A	D	E
Severity	1/D	A	D
Impact on business	1/E	1/D	A
Airport Services DEPARTMENT	Probability	Severity	Impact on business
Probability	A	C	C
Severity	1/C	A	E
Impact on business	1/C	1/E	A
Security DEPARTMENT	Probability	Severity	Impact on business
Probability	A	A	B
Severity	1/A	A	C
Impact on business	1/B	1/C	A

4	<i>Safety Risk index measurement :</i>
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Options: RiskField	corresponding - weighting coefficients for each field
Engineering and Maintenance	0.37
Flight Operations	0.61
Airport Services	0.02
Security	0.01



		Churned	At Risk	SAFETY OVERSIGHT	Risk Index: $\frac{1}{2} \left( \frac{C}{A} + \frac{A}{S} \right) \times \frac{C}{A} \times \frac{A}{S}$	Per-Risk Index = $\frac{1}{2} \left( \frac{C}{A} + \frac{A}{S} \right)$
STANDARDIZATION OF WORK	W1	0.00	0.00	0.00	0.00	0.00
	W2	0.00	0.00	0.00	0.00	
	W3	0.00	0.00	0.00	0.00	
	W4	0.00	0.00	0.00	0.00	
STANDARDIZATION OF WORK	W5	0.00	0.00	0.00	0.00	0.00
	W6	0.00	0.00	0.00	0.00	
	W7	0.00	0.00	0.00	0.00	
	W8	0.00	0.00	0.00	0.00	
STANDARDIZATION OF WORK	W9	0.00	0.00	0.00	0.00	0.00
	W10	0.00	0.00	0.00	0.00	
	W11	0.00	0.00	0.00	0.00	
	W12	0.00	0.00	0.00	0.00	
STANDARDIZATION OF WORK	W13	0.00	0.00	0.00	0.00	0.00
	W14	0.00	0.00	0.00	0.00	
	W15	0.00	0.00	0.00	0.00	
	W16	0.00	0.00	0.00	0.00	
STANDARDIZATION OF WORK	W17	0.00	0.00	0.00	0.00	0.00
	W18	0.00	0.00	0.00	0.00	
	W19	0.00	0.00	0.00	0.00	
	W20	0.00	0.00	0.00	0.00	

RI & FR

Field Risk Index=(FRI) = $\frac{\text{FRI}}{\text{Index}} \times 100$	
Field	FRI
ENGINEERING & MAINTENANCE	0.00
FLIGHT OPERATIONS	0.00
AIRPORT SERVICES	0.02
SECURITY	0.00



$$\text{Overall Safety Index} = \text{OSI} = \sum_{i=1}^n (w_i \times FRC_i)$$

2	Triangular Fuzzy scale definitions:
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Triangular scale	Reciprocal scale
Just equal	=A(1, 1, 1)
Slightly important	=B(2/3, 1, 3/2)
Strongly more important	=C(3/2, 2, 5/2)
Very strongly more important	=D(5/2, 3, 7/2)
Absolutely more important	=E(7/2, 4, 9/2)

a	1.00	1.00	1.00
b	0.67	1.00	1.00
c	1.00	2.00	2.00
d	2.00	3.00	3.00
e	3.00	4.00	4.00

1/4	1.00	1.00	1.00
1/8	0.87	1.00	1.00
1/16	0.80	0.90	0.87
1/32	0.79	0.88	0.80
1/64	0.77	0.75	0.79

1	ALL criteria - safety risk parameters matrix
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Engineering and Maintenance

Probability	Response 1	Response 2	Response 3	Response 4	Response 5
Response 1	A	C	D	D	A
Response 2	C/D	A	B	B	C/D
Response 3	D/D	B/D	A	A	D/D
Response 4	D/D	A	A/D	A	D/D
Response 5	A	C	D	D	A

Activity	Region 1	Region 2	Region 3	Region 4	Region 5
Region 1	A	C2	D3	E4	F5
Region 2	A	C	D4	E5	F6
Region 3	A	B	D	E6	F7
Region 4	A	C	B	E	F8
Region 5	B	C	B	D	F9
Region 6	B	B	C	D	A

Input on Diagnosis	Report 1	Report 2	Report 3	Report 4	Report 5
Report 1	A	B	B	B	B
Report 2	A	A	C	A	A
Report 3	B	A	A	C/A	C/A
Report 4	B	B	A	A	A
Report 5	B	A/B	C	A	A

FLEET Operations

Trials/Steps	Step 1	Step 2	Step 3	Step 4	Step 5
Position 1	A	C	C	B	B
Position 2	C/D	A	A	C	B/C
Position 3	C/D	A/D	A	C	C/D
Position 4	B/C	C/D	C/D	A	B/D
Position 5	A	B	C	D	A

	Report 1	Report 2	Report 3	Report 4	Report 5
Report 1	A	DE	1/1	3/2	5/3
Report 2	B	A	2/1	4/3	6/3
Report 3	C	B	A	A	5/1
Report 4	D	C	A	A	5/1
Report 5	E	D	B	B	A

Report 1	A	D	C	D	C
Report 2	DE	A	DE	A	DE
Report 3	CE	B	A	B	A
Report 4	DE	A	DE	A	DE
Report 5	CE	B	A	B	A

	Probability
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	A	D	D	E	C
Response 2	NO	A	A	NO	NO
Response 3	NO	A	A	NO	NO
Response 4	NO	NO	NO	A	NO
Response 5	NO	B	B	C	A

Report 1	A	B	B1	A	C15
Report 2	B	A	A	B	C15
Report 3	A	B	A	B	C15
Report 4	B	A	B1	A	C15
Report 5	B	C	C	D	A

Report on Basis 1	Report 1	Report 2	Report 3	Report 4	Report 5
Basis 1	A	B	C	C	C

Response 1	D1	B	A	B	A
Response 2	C1	C	D1	A	B
Response 3	D1	B	A	D1	A

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Response 3	80	A	A	80	80
Response 4	120	80	B	A	120
Response 5	90	120	B	D	A

Locality	Response 1	Response 2	Response 3	Response 4	Response 5
Response 1	40	120	80	120	80
Response 2	40	A	80	80	120
Response 3	40	A	A	80	120
Response 4	40	A	A	80	120
Response 5	40	A	A	80	120

Impact on Business	Region 1	Region 2	Region 3	Region 4	Region 5
Region 1	A	D	D	C	D
Region 2	B1	A	B1	C1	B1
Region 3	B1	B	A	B	A
Region 4	C1	C	B1	A	B
Region 5	B1	B	A	B1	A

1

**Overall Safety Index (OSI) trend-monthly :**

Month	Safety Risk Index-OSI
Jan	1.13
Feb	1.7
Mar	1.6
Apr	1.5
May	1.2
Jun	1.09
Jul	1.09
Aug	2
Sep	1.9
Oct	1.8
Nov	1.8
Dec	1.9



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**NORMALIZED- Overall Safety Index (OSI) trend-monthly :**

Month	Safety Risk Index-OSI	Safety Rate
Jan	1.00	
Feb	1.50396827	50.40
Mar	1.415499548	41.55
Apr	1.327030826	32.70
May	1.061624661	6.16
Jun	0.964309067	-3.57
Jul	0.964309067	-3.57
Aug	1.769374435	76.94
Sep	1.680905713	68.09
Oct	1.592436991	59.24
Nov	1.592436991	59.24
Dec	1.680905713	68.09

