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Assessing air traffic noise around airports: a fuzzy approach

- *Assane DIOP, ASECNA, Dakar, Sénégal, tapadiop2000@yahoo.fr*
- Carlos Alberto Nunes Consenza, *Labfuzzy, COPPE, Universidade Federal do Rio de Janeiro, Brazil, cosenza@pep.ufrj.br*
- *Roger Marcelin FayeUniversité Cheikh Anta Diop, Ecole Supérieure Polytechnique, Dakar, Sénégal, roger.faye@ucad.edu.sn*
- Félix Mora-Camino*MAIAA, Ecole Nationale de l'Aviation Civile, Toulouse, France, felix.mora@enac.fr*

STS N°

CONTENTS

EVALUATION OF ELEMENTARY NOISE

Some concepts

- Sound Exposure : $SE(l,T) = \int_{t_1}^{t_2} p_A^2(l,t)\,dt$; $T=[t_1,t_2]$
- Sound Exposure Level (***SEL***) : $SEL(l,T) = 10\log_{10}\left(SE(l,T)/p_0^2\right) = 10\log_{10}\left(\int_{t_1}^{t_1+T} (p_A(l,t)^2/p_0^2)\,dt\right)$

We have two ways: deterministic and fuzzy evaluation

Deterministic evaluation of noise impact

If $A = \bigcup_{r\in R_A} A_{Rr} \bigcup_{m\in R_D} D_{Rm}$ and $E(r,a,l) = SEL(l,T(a,r,l))$ are two sets, where

A_{Rr} : set of aircraft types allowed on arrival route r

D_{Rm} : set of aircraft types allowed on departure route m, then

for each feasible triplet (r,a,l), $r\in R, a\in A, l\in L$ an elementary sound exposure level $E(r,a,l) = SEL(l,T(a,r,l))$ (expressed in dB) is computed.

EVALUATION OF ELEMENTARY NOISE

- **Fuzzy evaluation of elementary noise impact**

❑ Why?

- the presence of a significant degree of uncertainty

❑ Because of the result :

- of aircraft track's dispersion along the nominal routes
- of wind intensity and direction

❑ How to assess the uncertainty?

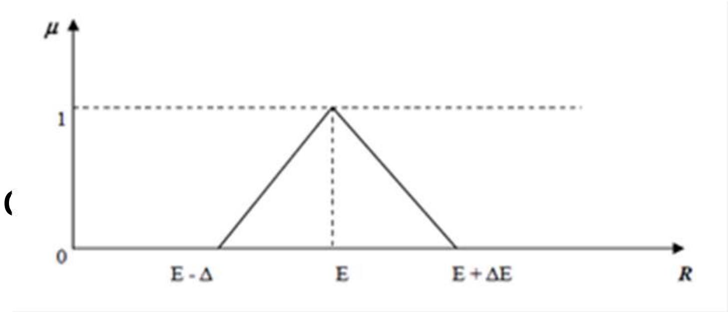
- the fuzzy noise elementary impact is : $\tilde{E}(r,a,l) = SEL(l,T(a,r,l)) + \varepsilon \cdot \Delta SEL(l,T(a,r,l))$

and $\Delta SEL(l,T(a,r,l))$ (with positive value) is the degree of uncertainty.

EVALUATION OF ELEMENTARY NOIS

Fuzzy evaluation of elementary noise impact

- **Triangular fuzzy dual number**



μ : the classical membership function of fuzzy sets.

- **Estimate of dual number :**

  - real part of the mean value ;
  - standard deviation.

ESTIMATION OF CRITICAL NOISE IMPACTS

- **Characterizing critical noise impacts**

- the upper expected bound of a local impact :

$$E^{+}(r,a,l) = E(r,a,l) + \Delta E(a,r,l) \qquad r \in R, a \in A, l \in L$$

- Type of indexes computed:

  - the critical noise event ;

$$\{r^*, a^*, l^*\} \longrightarrow \{r^*, a^*, l^*\} = \arg \max_{r \in R, a \in A, l \in L} \left(\pi_{lr} \cdot E^{+}(r,a,l) \right)$$

  - the maximum noise impact which can be expected

$$10 \log \left(\sum_{l \in L} \pi_{lr} \, 10^{E^{+}(r,a,l)/10} \right) , \quad a \in A_{Rr}, r \in R_A \quad or \; a \in A_{Dr}, r \in R_D$$

ESTIMATION OF CRITICAL NOISE IMPACTS

Characterizing critical noise impacts

Resulting noise critical elements

Resulting noise critical elements

Designation	Expression
Noise critical aircraft for route *n*	$a_n^c = \arg\max_{a\in A_{Rr}\, or\, a\in A_{Dr}} 10\log\left(\sum_{l\in L}\pi_{lr}\, 10^{E^{+}(r,a,l)/10}\right)$
Noise optimal aircraft of route *n*:	$a_n^o = \arg\min_{a\in A_{Rr}\, or\, a\in A_{Dr}} 10\log\left(\sum_{l\in L}\pi_{lr}\, 10^{E^{+}(r,a,l)/10}\right)$
noise critical approach route	$n_{Aa}^c = \arg\max_{r\in R_A, a\in A_{Rr}} \left(10\log\left(\sum_{l\in L}\pi_{lr}\, 10^{E^{+}(r,a,l)/10}\right)\right)$
noise critical departure route	$n_{Da}^c = \arg\max_{r\in R_D, a\in A_{Dr}} \left(10\log\left(\sum_{l\in L}\pi_{lr}\, 10^{E^{+}(r,a,l)/10}\right)\right)$

ESTIMATION OF CRITICAL NOISE IMPACTS

Comparison of noise impacts

To compare and rank partially the different dual fuzzy noise impacts :

- To adopt the dual differential extension of a function *g* / $\tilde{g}(x+\varepsilon y)=g(x)+\varepsilon y g'(x)$
- Ranking rules providing partial orderings between triangular fuzzy dual numbers :
  - strong partial order $\lesssim$ defined over the set $\tilde{\Delta}$ $(a+\varepsilon b),\ a\in R,\ b\in R^{+}$
  - weak partial order :$\gtrsim$
  - a fuzzy equality written : $\cong$

GLOBAL EVALUATIONS OF NOISE IMPACT

Two ways :

- Deterministic evaluation of global noise impact
- Fuzzy evaluation of global noise impact

❖ **Deterministic evaluation of global noise impact**

$(\phi_{ra})_{r \in R, a \in A}$ **:** a given traffic flow pattern for one airport

- The local global noise index impact at receptor *l* :

$$G = 10 \log \left(\sum_{r \in R} \sum_{a \in A} \sum_{l \in L} \pi_{lr} \phi_{ra} 10^{E(r,a,l)/10} \right)$$

- **Improvement :** more objective than global noise index based on the size of the surface over a given noise level

GLOBAL EVALUATIONS OF NOISE IMPACT

Fuzzy evaluation of global noise impact

GLOBAL EVALUATIONS OF NOISE IMPA

Local fuzzy noise impact at receptor *l* : $\tilde{N}_l = 10\, \mathrm{lo}\tilde{\mathrm{g}}\left(\sum_{r\in R} \sum_{a\in A} \pi_{lr}\phi_{ra} 10^{E(r,a,l)/10}\left(1+\varepsilon \frac{Log(10)}{10}\Delta E(r,a,l)\right) \right) \qquad l \in L$

Global noise impact ➡ $\tilde{G} = 10\, \mathrm{lo}\tilde{\mathrm{g}}\left(\sum_{r\in R} \sum_{a\in A} \sum_{l\in L} \pi_{lr}\phi_{ra} 10^{E(r,a,l)/10}\left(1+\varepsilon \frac{Log(10)}{10}\Delta E(r,a,l)\right) \right)$

With $\tilde{G} = G + \varepsilon\, \Delta G$

Uncertainty about the global noise impact resulting from the uncertainty with respect to the elementary noise impacts :

$$\Delta G = Log(10) \cdot \left(\sum_{r\in R} \sum_{a\in A} \sum_{l\in L} \pi_{lr}\phi_{ra} 10^{E(r,a,l)/10} \Delta E(r,a,l) \right) \Big/ \left(\sum_{r\in R} \sum_{a\in A} \sum_{l\in L} \pi_{lr}\phi_{ra} 10^{E(r,a,l)/10} \right)$$

The validity of this result depends on choice of triplet (r, a, l)

CASE STUDY

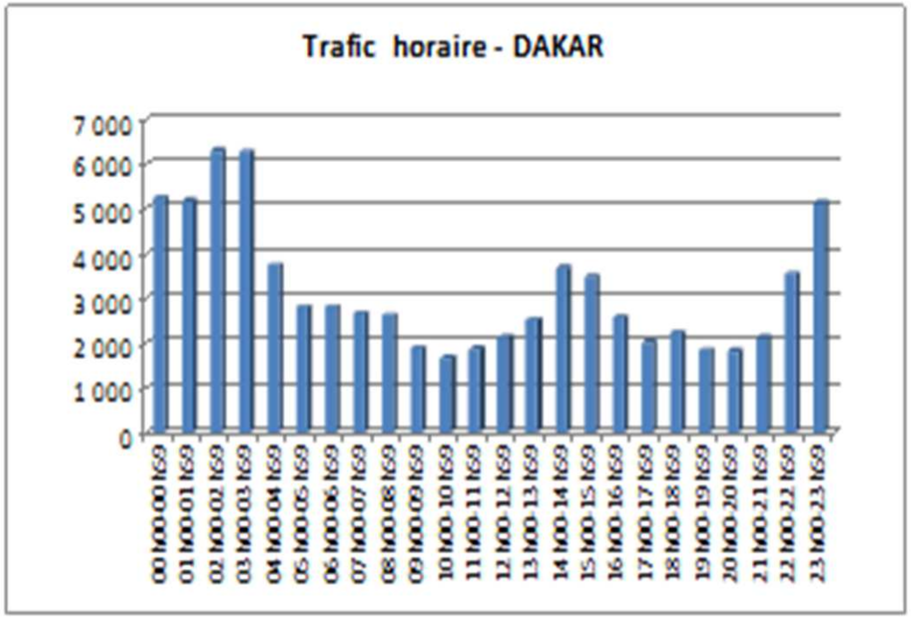
- **Leopold S. Senghor Airport in Dakar-Senegal**

Tightly surrounded by

different suburbs of Dakar

CASE STUDY

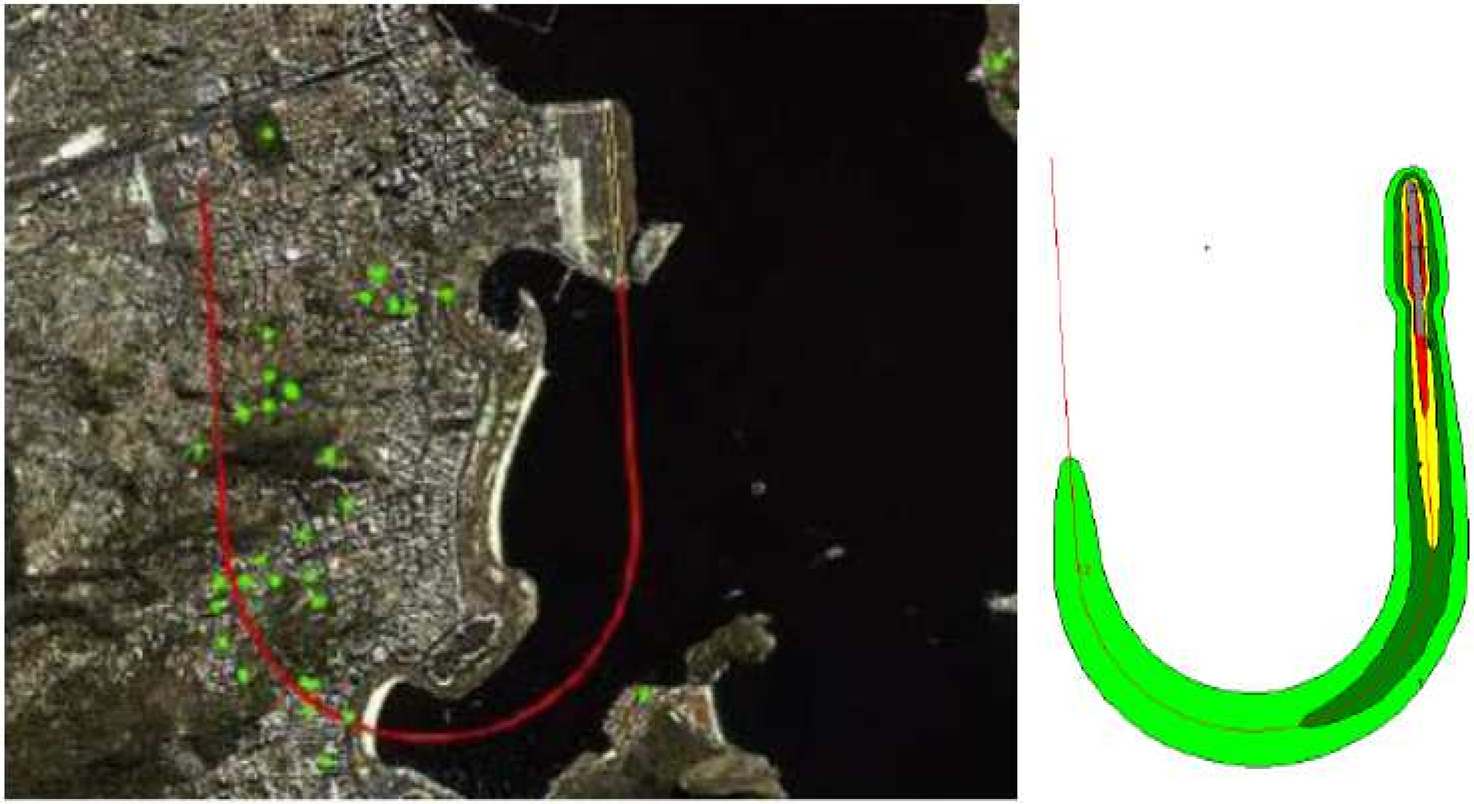
- **Hourly distribution of traffic at Dakar Airport**



- **<u>Results</u>**

-important noise impact of airport activities ;

-need to assess new scenarios about arrivals and departure traffic



Santos Dumont Domestic Airport

Please insert here your affiliation logo

Please insert here your affiliation logo

Aeronaves	737300	737700	737800	A319	ATR42	EMB120	EMB190	F10065	GASEPEV			
Nº de vôos (média p/dia)	8,452	25,032	5,903	31,323	3,387	2,774	5,839	8,032	7,258			
					Níveis sonoros no receptores dB(A)							
Botafogo					Métrica SEL					DNL	LAeqD	LAeqN
BOT1	55,5	67,1	59,1	52,5	47,6	45,9	50,9	52,8	53,1	36,5	35,2	28,1
BOT2	58,8	70,3	62,0	55,6	50,3	47,5	53,9	55,9	55,9	38,3	37,0	29,9
BOT3	72,4	83,8	74,6	68,5	62,6	63,5	66,4	68,8	67,8	45,3	43,7	37,2
BOT4	55,2	66,8	58,8	52,3	47,3	37,9	50,7	52,5	52,7	37,1	35,8	28,6
BOT5	73,7	85,1	75,7	69,7	63,8	64,2	67,6	70,0	68,8	46,4	44,7	38,2
Laranjeiras												
LAR1	76,6	88,0	78,6	72,5	66,4	68,0	70,5	72,8	71,2	47,9	45,9	39,9
LAR2	88,9	100,2	89,5	84,1	78,4	83,5	83,5	85,8	81,7	58,6	56,6	50,7
LAR3	68,2	79,7	70,9	64,4	58,6	57,9	62,7	64,9	64,2	42,0	40,3	33,8
LAR4	81,4	92,7	82,9	77,1	71,0	74,6	75,1	77,5	75,2	51,9	49,9	44,0
Cosme Velho												
CV1	62,2	73,6	65,2	58,5	53,4	46,6	57,0	59,1	58,9	38,2	36,7	29,9
CV2	62,7	74,2	65,7	59,0	53,9	45,8	57,5	59,7	59,4	38,5	37,0	30,2
Centro												
C1	81,0	92,4	82,6	76,6	70,5	72,9	74,9	77,6	75,3	52,6	50,7	44,6
C2	76,0	87,4	78,3	71,9	66,1	66,4	69,7	72,5	71,8	47,3	45,3	39,4
C4	76,8	88,1	78,9	72,5	66,7	67,3	70,5	73,4	72,1	51,4	49,9	43,2
C5	81,4	92,7	83,1	77,1	70,8	73,0	75,2	77,9	75,6	52,7	50,9	44,8
C6	83,2	94,5	84,9	79,2	72,9	75,3	77,7	79,9	77,4	53,8	51,8	45,9
C7	81,0	92,4	82,6	76,6	70,5	72,8	74,8	77,6	75,3	52,6	50,7	44,6
C8	83,9	95,3	85,3	79,6	73,3	76,5	78,0	80,7	77,6	54,1	52,1	46,3
C10	73,4	84,7	75,3	68,4	62,7	61,9	66,3	70,2	68,1	54,5	53,3	46,0
C11	84,6	95,9	85,8	80,3	74,0	77,4	78,9	81,4	78,1	54,7	52,7	46,8
Gloria												
G1	82,0	93,3	83,5	77,3	71,4	74,2	75,8	78,6	76,0	53,2	51,3	45,2
G2	85,5	96,8	86,6	80,9	74,8	78,7	79,7	82,3	78,7	55,7	53,7	47,8

CONCLUSIONS

- To provide a quantitative tool to predict the objective noise impact
- This tool adopts the fuzzy dual formalism
- To perform analysis and predictions →
- to identify critical locations with respect to noise

Thank You
for your attention