



PROESTOP **Runway Occupancy Time Estimator**

**DEVELOPMENT OF AN ALGORITHM TO MODEL
THE LANDING OPERATIONS, BASED ON
STATISTICAL ANALYSIS OF ACTUAL DATA
SURVEY**

*7th ATM R&D Seminar
Barcelona July, 2ND 2007*



0. AGENDA

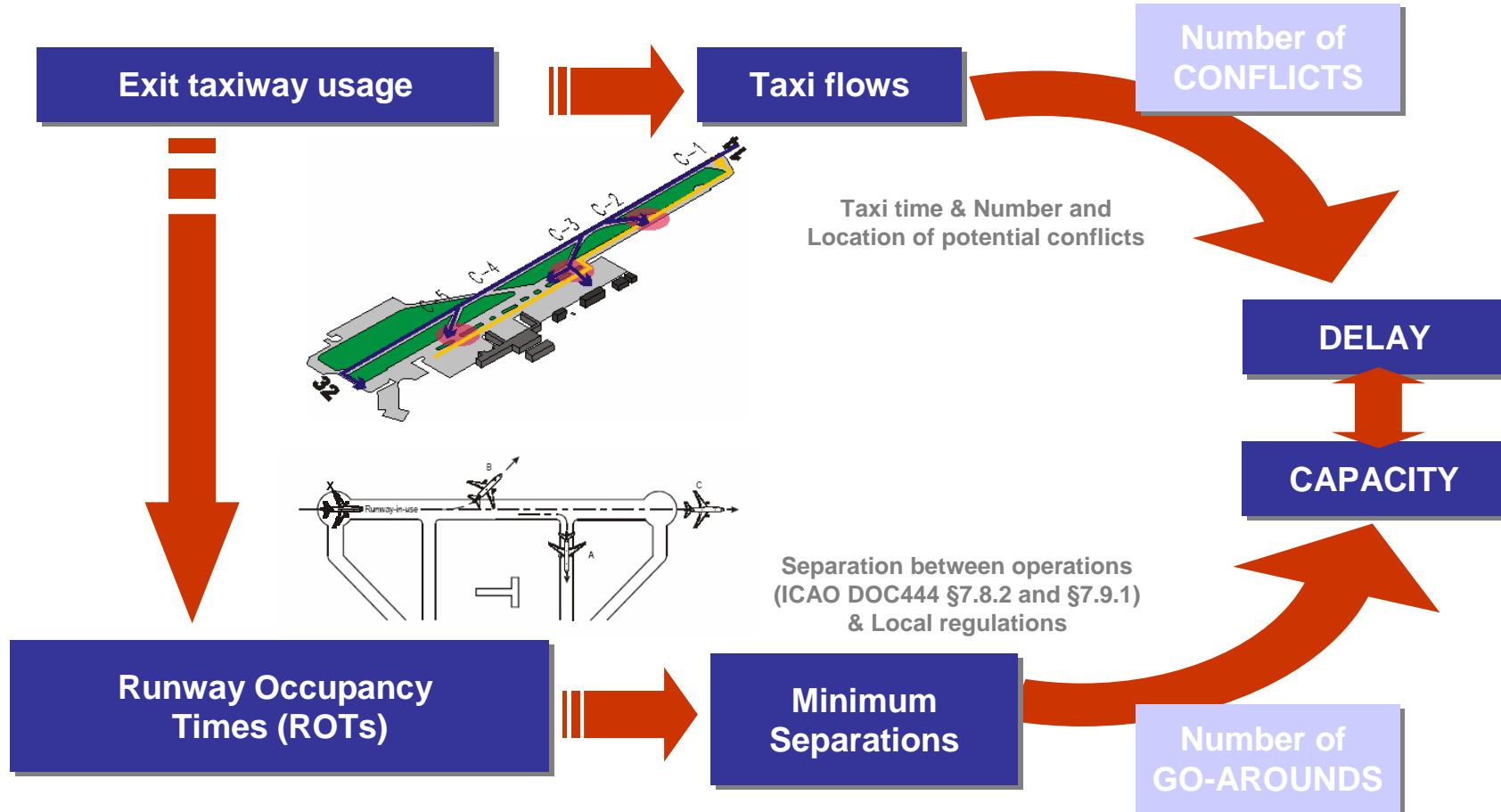
1. INFLUENCE OF ROT ON RUNWAY CAPACITY
2. EXISTING METHODS & TOOLS
3. PROESTOP ALGORITHM DEVELOPMENT
4. VALIDATION
5. APPLICATIONS



1 INFLUENCE OF ROT ON RUNWAY CAPACITY

1. INFLUENCE OF ROT ON AIRPORT CAPACITY

Runway operations affect overall Airport Capacity



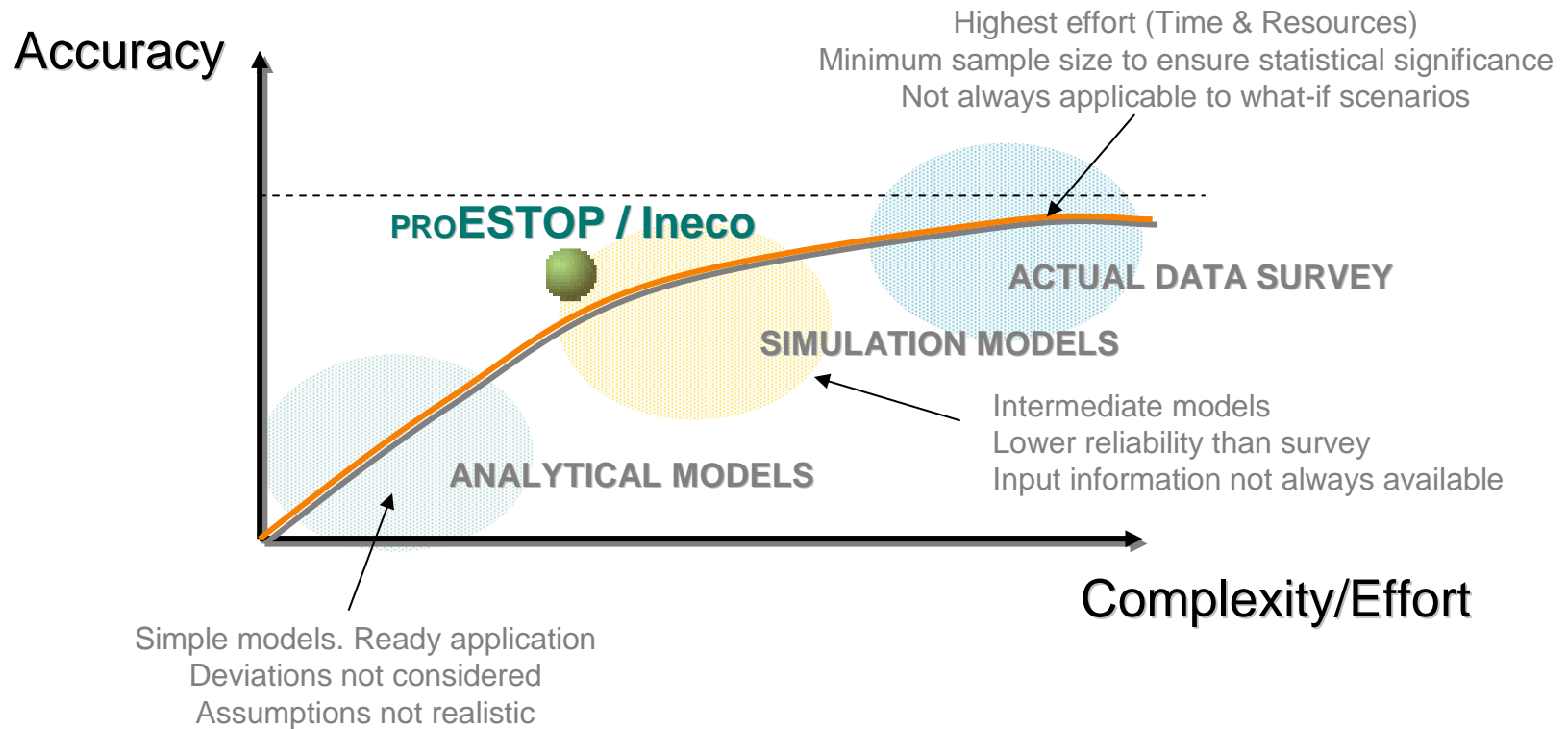


2 EXISTING METHODS & TOOLS



PROESTOP: a cost-effective mathematical tool

None of the tools and/or methodologies currently in use entirely satisfy planning needs.





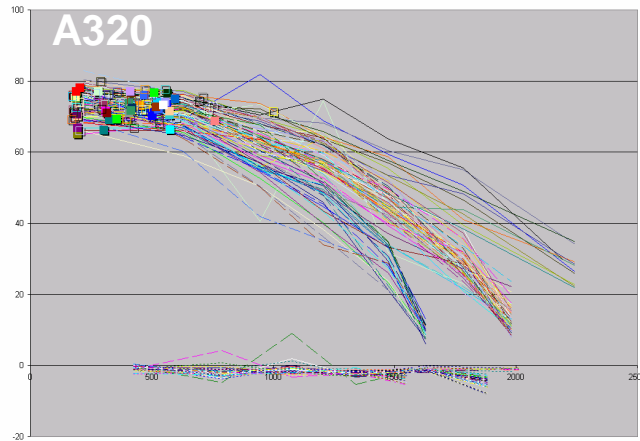
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PROESTOP ALGORITHM DEVELOPMENT



3. ALGORITHM DEVELOPMENT

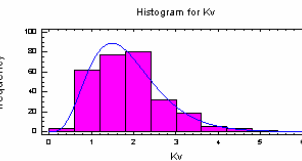
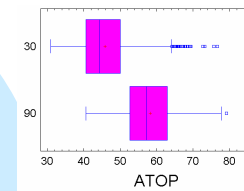
ACTUAL DATA SURVEY



FACTOR ANALYSIS

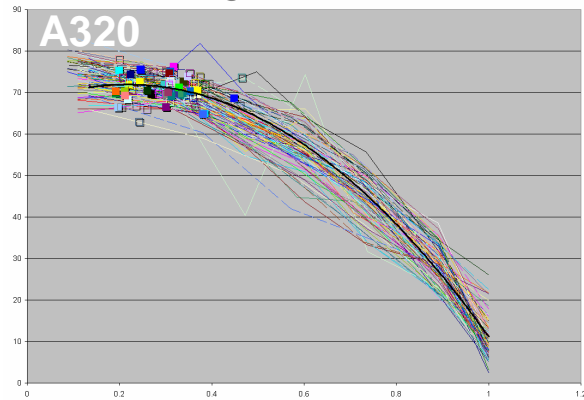
Significant variables identification and modelling

- Vthr
- TDZ
- LD
- TOP
- ACFT
- Vw L
- Vw T
- Vex
- jex
- Amed
- Aex
- CIA
- NUMPAXL
- CDIORG
- CDSTAND
- Vapp
- MTOW
- MLW
- LDA



MODELLING OF SPEED PROFILE

For a given ACFT, exit

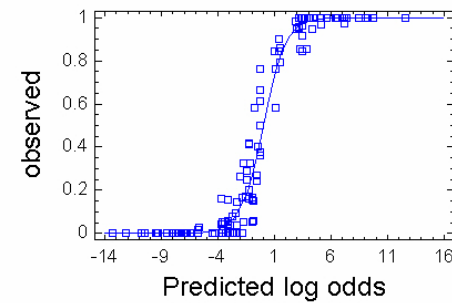


$$V(x) = f(A/C, V_{thr}, K_v, V_{ex}, V_w, h, T)$$

REGRESSION OF EXIT USAGE ESTIMATION

For a given ACFT group, exit

Plot of PORCENTAJE/100



3.1 ACTUAL DATA SURVEY



An actual data survey was performed at LEMD.

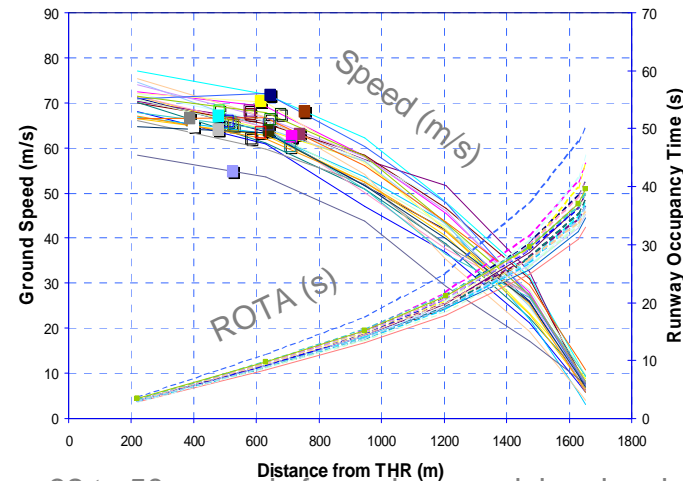
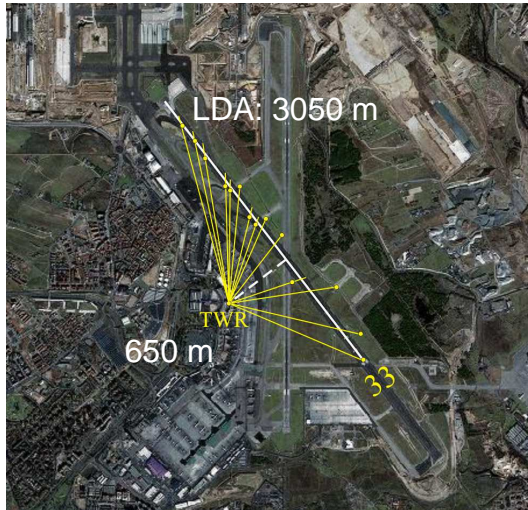
OBJECTIVE

To assess factors affecting landing operations

Sample size	ROTA			Maximum Visual Error
	Mean	Standard deviation	Sampling error	
1500	46.5 s	7.9 s	±0.4 s	0.3 s

- 1500 landing operations:
 - ACFT model
 - ROTA
 - Intermediate points + exit points
 - Meteorological conditions (wind, runway conditions)

- Due to the variability in the speed profile along the runway, ROTA shows a great dispersion



✓ Based on visual observations from the tower cab

Example: ROTA from actual survey data varied from 32 to 50 seconds for a given model and a given RET (RET 1650 meters from THR. Embraer RJ145 Amazon)

3.2 FACTOR ANALYSIS



Statistical analysis of the survey outputs allowed to identify the input variables and other qualitative conclusions.

OBJECTIVE

To identify the variables that should be taken into account in the model

● Main factors affecting runway occupancy (ROTA & Exit selection):

- ✓ Aircraft characteristic and performances, FV, Wind, deceleration, FW, Stand location and familiarity with the airport

● In addition some qualitative conclusions:

- ✓ Wind does affect the landing distance, but not ROTA directly. Therefore, a better variable to model speed over threshold should be FV. On the contrary, $V_{TAILWIND}$ has an impact on the exit taxiway selection.
- ✓ Touchdown distance depends on pilot techniques and familiarity with the layout, but has not a significant impact on ROTA.
- ✓ Pilots adjust the speed profile when vacating by a given exit. Therefore deceleration rate and V_{EXIT} depend on the exit location.
- ✓ Pilot's overall behaviour are affected by other operational factors such as the familiarity with the airport and the stand location. Therefore, clear indication on exit locations and design is a key factor to enhance the runway performance
- ✓ Estimations based on average performance are not realistic



3.3 CLUSTERING OF AIRCRAFT TYPES

Survey data were classified according to a cluster analysis, attending their characteristics and runway performances

OBJECTIVE

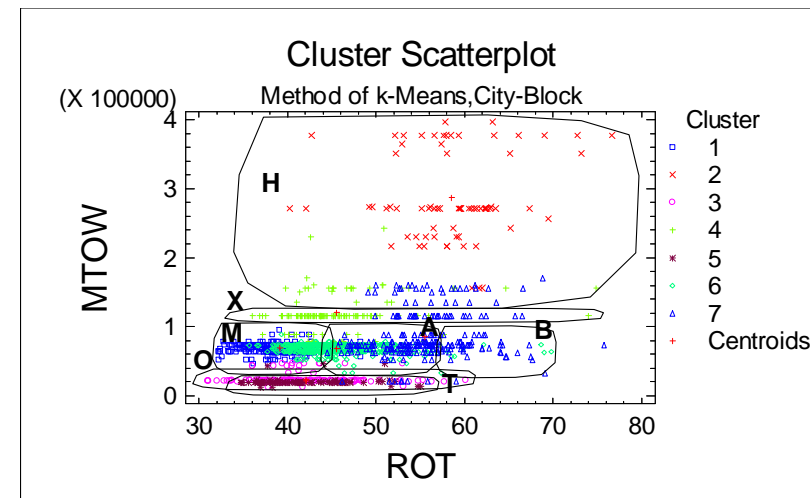
To cluster Aircraft models in order to obtain the operational parameters distributions

- The cluster analysis was performed using the K-Means method
- Several clustering were performed: different numbers of clusters and methods.
The final number of clusters (7) was obtained as a trade-off between the uniformity of the aircraft within each cluster and the amount of data available in each cluster.

- For simplification and based on the distribution of traffic within each cluster, an alternative classification was adopted, attending

- ✓ ICAO wake vortex category
- ✓ engine type
- ✓ constructor

Aircraft Group	Acronym
Heavy	H
B757	X
MD80s (Medium Jet)	M
Airbus Medium Jet	A
Boeing Medium Jet	B
Other Medium Jet	O
Medium Turboprop	T
Light	Lt





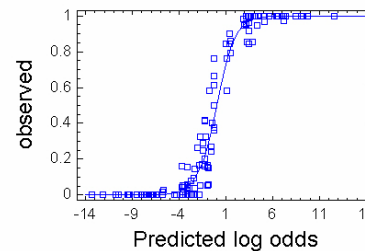
Estimated Logistic regression model of actual exit taxiway usage.

OBJECTIVE

The probability density function of the exits for each aircraft group.

- Computed as difference from CDF, instead of the density function (regardless the number and location of their exits)
- The regression model is based on actual data from 23 different Spanish airports (more than 22.000 landings)

$$Y = \frac{e^{\Sigma(C_i X_i)}}{1 + e^{\Sigma(C_i X_i)}}$$



- Parameters comprises geometrical and meteorological factors. (The model was simplified removing the variables with highest p-value until the highest order term was statistically significant)
 - ✓ runway length, exit location and geometry, number of exit, apron relative location, slope, etc.
 - ✓ elevation, temperature, mean tailwind speed
- In order to ensure the operational validity of the output, the value obtained from the regression is corrected by some heuristics.



3.5 MODELLING OF SPEED PROFILES

Non-linear speed function to model the landing speed from the threshold to a given exit taxiway for each aircraft group.

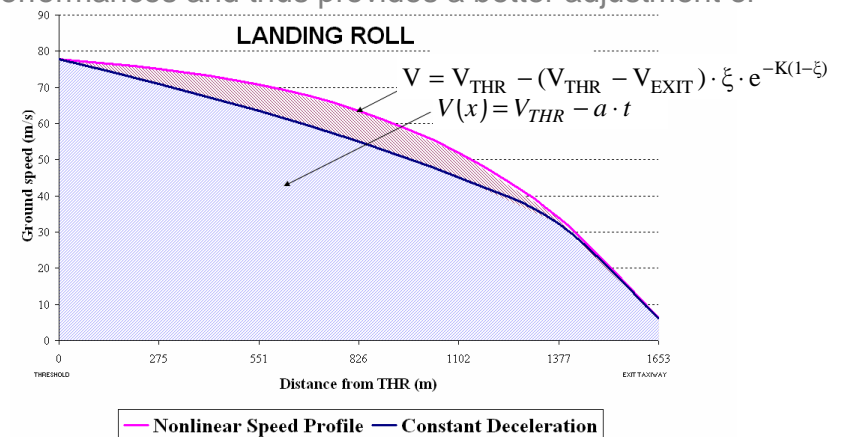
OBJECTIVE

Landing speed function along the runway for each aircraft group vacating by a given exit taxiway.

- The non-linear model fits better the usual aircraft landing performances and thus provides a better adjustment of ROTA.

- Iterative process allowed to estimate the parameters for each recorded flight :

- ✓ Dimensionless speed $F_V = V_{THR} / V_{REF}$
- ✓ Ground Speed V_{EXIT}
- ✓ Deceleration constant K



- Resulting distributions for each aircraft group were fitted to probability distributions

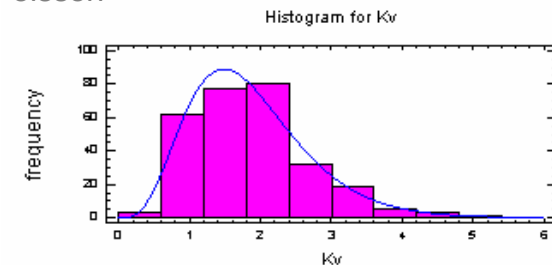
- ✓ Standard: Normal, Erlang, Lognormal, Weibull, Uniform, Gamma and Poisson

- ✓ Johnson Curves: system of distributions based on the method of moments. The general form of the transformation is given by

$$z = \gamma + \eta\tau(x; \epsilon, \lambda)$$

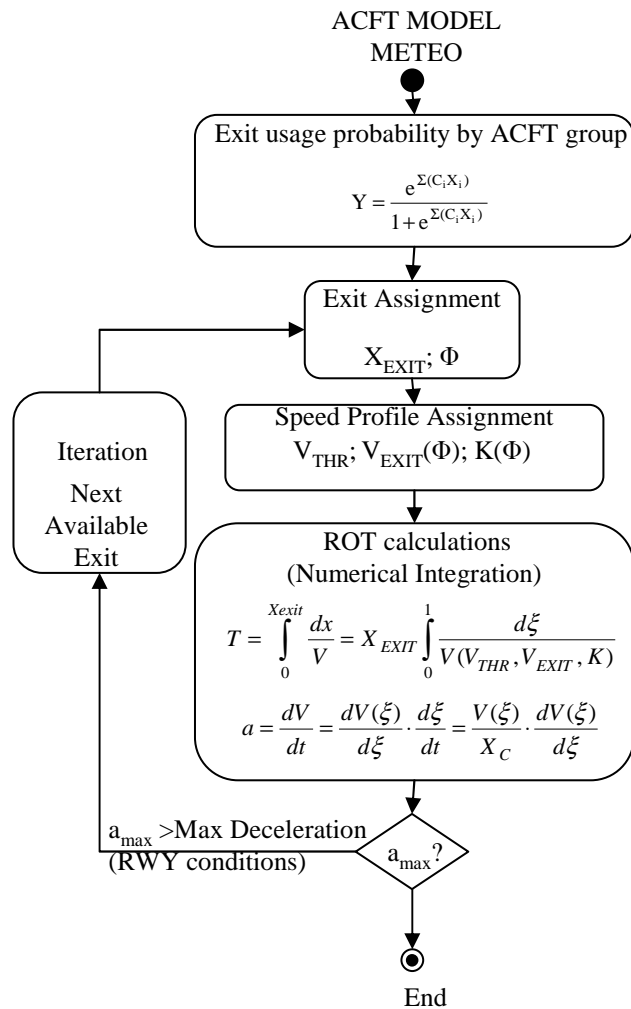
$$\eta > 0, \quad -\infty < \gamma < \infty$$

$$\lambda > 0, \quad -\infty < \epsilon < \infty$$





Stochastic simulations based on operational parameters distributions



● Simulations based on Monte Carlo method

- ✓ the model generates pseudo-random numbers by simulation techniques to mimic the statistical distribution of the input variables.
- ✓ Then, it obtains the correspondent output variables by computing the algorithm.
- ✓ After a sufficient number of replications, the sampling results will reproduce the distribution of the statistic outputs.

● Margin of error on average values: 3-5%

● Simulation time: 2 min

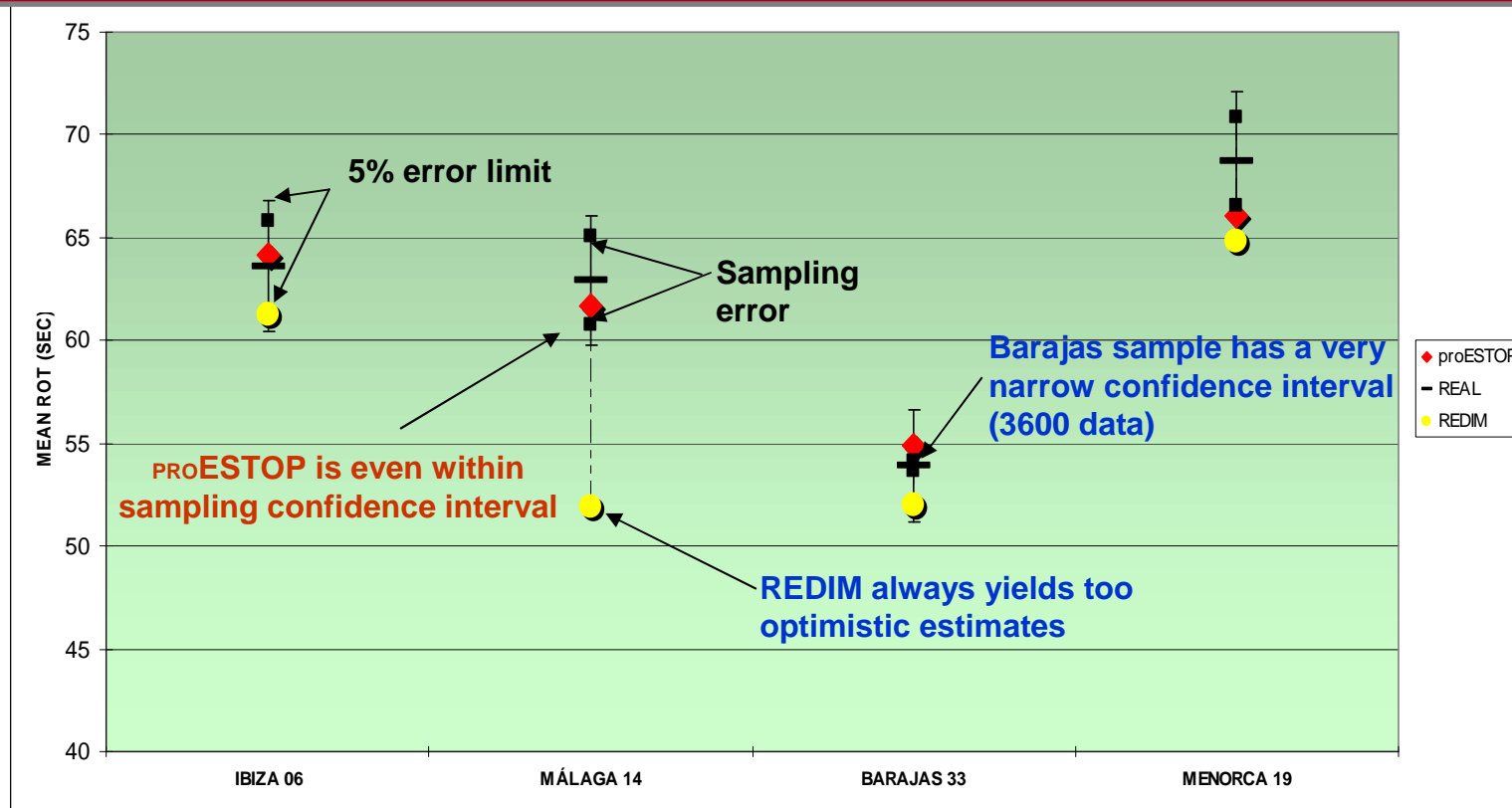


4 VALIDATION

4. VALIDATION



Output Validation consisted on the comparison of the data obtained by PROESTOP with actual operational data and REDIM model.



- Performance benchmark was based on different airports encompassing different conditions (Temperature and Elevation) and layouts (Number, Geometry and Location of exits)
- Further works included modelling of **light traffic, wet runways and departures operations**



5 APPLICATIONS

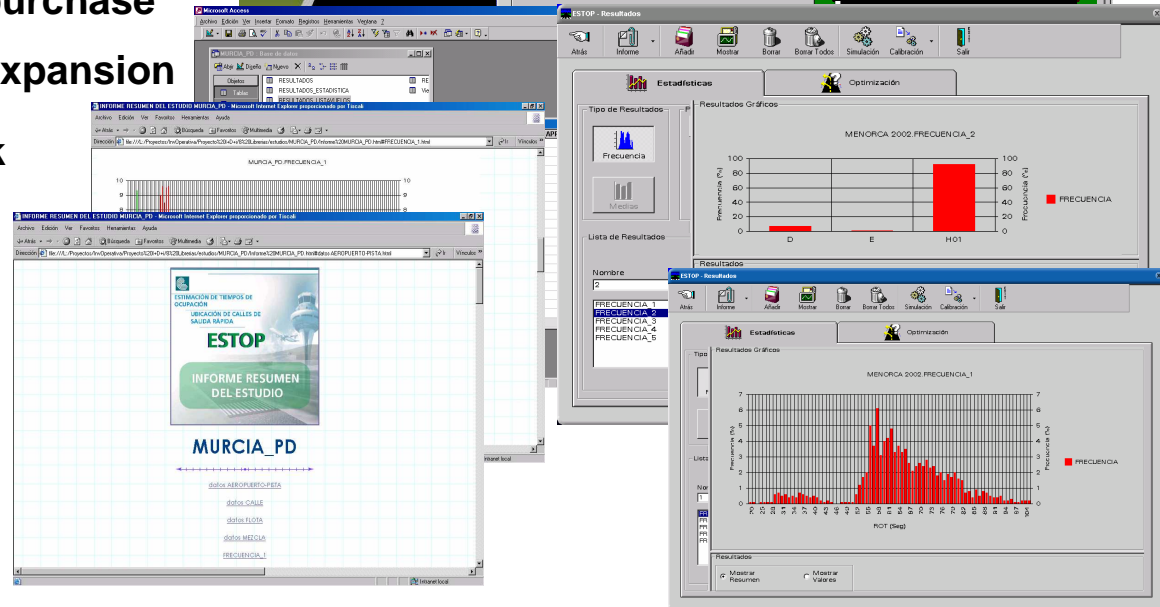
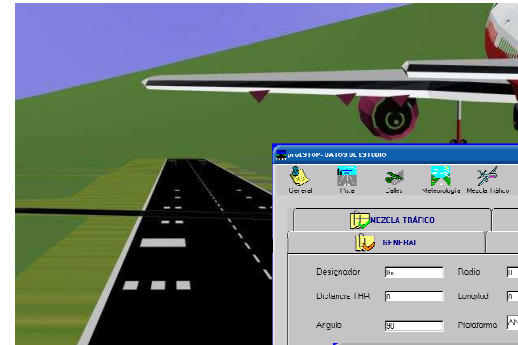


5. APPLICATIONS

Supporting tool to runway performance evaluation and planning processes

APPLICATIONS:

- Review of Spanish Airport Master Plans by **Aena** (ANSP)
- **Eurocontrol**'s license purchase
- **Puerto Vallarta (PVR)** Expansion
- **SPADE** (6TH Framework Project EC)





FURTHER INFORMATION



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