INM reliability on single flight noise prediction

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FAA Integrated Noise Model is worldwide used to foresee medium-long term average noise levels around airports. Italian Airport Noise Committees use INM in what-if analysis for single flight in order to determine the best takeoff procedures, either in term of profile analysis or track analysis. The aim of the study about INM reliability is to determine the single flight prediction error comparing INM output levels and NMS, Noise Monitoring System, measured levels. The case of Milan Malpensa International Airport has been studied. NMS time-correlation between radar and noise data, according to minimum distance criterion, has been provided by the Airport Noise Observatory. Malpensa NMS meteorological and radar data had been input in INM to determine flight by flight takeoff procedures and to reproduce 3D paths. Airport Noise Committee has been asked to provide performance data of the most common aircrafts in order to reduce the difference between real and simulated flight. GIS, Geographic Information System, has been used to handle and to represent geo-referenced data; in particular, radar tracks have been reproduced over the NMS terminals (set up as Location Points in INM outputs) and a statistical sample of NMS data has been selected.The final step consists in the determination of error as function of spatial parameters as lateral distance and elevation angle.

The aim of this paper is to present some studies conducted to examine INM capability to characterize noise levels around Milan Malpensa airport (MXP).

In order to identify the model systematic error and to distinguish it from the statistical one, it has been decided to examine the differences between measured and calculated levels in a short range of time. To accomplish this purpose single day analysis is not significant due to the fact that a consistent range of variation can be registered for relevant variables as tracks, vertical profile, thrust, speed as well as meteorological conditions, even in presence of the same combinations of operations and aircraft type.

Then, going deeply in what the Airport Noise Observatory of ARPA (ARPA is acronym of the Italian regional environment protection agency) has done to figure out the differences between predicted and measured noise levels of Italian metric LVAj, a single event analysis has been conducted to calculate the average error occurring in foreseeing noise levels at one of the most annoying aircraft operating in the airport. In a similar way LVAj as LDN accounts for arrival and departure operations in a certain day scenario.

It turned out that Airport Noise Observatory analysis led to observe that LVAjs can be underestimated up to 4-5 dB. The fact that noise monitoring terminals, NMT, lay aside from the route ground projection suggests that errors should be ascribed to INM lateral attenuation model. In addition, the study could be affected by the fact that the characteristics of real profile, especially in departure operations, are not taken into account. Examining radar data has allowed to define more precisely the flight profile even if the lack of flight weight and thrust settings data doesn't permit to reproduce exactly the real flight conditions.

Standard Instrumental Departure, SID, over Radial, RDL, 310 MXP VOR from 35L Runway End, RWE, and SID over RDL 358 MXP VOR from 35R RWE have been considered.

A Geographic Information System, GIS Arc View 3.2, has been used to support managing, storing and querying radar and acoustical data. A WGS 1984 geo-referenced system has been set at MXP Aerodrome Reference Point.

INM Location Point function has allowed to compare measured and calculated noise level data at NMT.

An area of 30 square kilometers around Malpensa airport has been fully characterized through the input of a 3CD binary orographic file. It should be noticed that INM considers elevation data just to correct source receiver-distance but it doesn't account shielding effects as well as absorption and reflection of different type of ground, both accounted in the lateral attenuation factor.

Mc Donnell Douglas MD 82, the aircraft with the highest operational frequency at the airport, has been considered to make out a statistically significant test. Alitalia MD 82 turned out to be the most representative for this type of aircraft; its features have been reported in the following table.

Table 1, Alitalia MD82 features

Mc Donnell Douglas MD82	
Length (m)	45.1
Height (m)	9.0
Width (m)	32.9
MTOW (kg)	72.600
Fuel (lt)	22.129
Max Pax Number	161
Trip Length (km)	2800
Speed (km/h)	820

INM Noise identifier 2JT8D2 complies with Alitalia MD 82 engine, Pratt and Whitney JT8D, so that INM database airframe-engine association has been verified. Beyond any doubt, according also to Airport Noise Observatory long period analysis, one of the most relevant source of error in the INM noise level forecasting is the lack of precision in modeling departures of certain type of aircraft – mainly constructed by US manufacturers – vertical profile.

Matter of fact INM MD 82 database contains just standard vertical profile which should be considered coincident to the noise abatement procedure ICAO B. Italian Aeronautical Information Publication, AIP, as well as Alitalia flight manual affirm that ICAO A procedure must be respected. According to ICAO PANS OPS 8168, as well as examining radar data, an user profile has been implemented in the way described, step by step, in the following table.

Table 2, ICAO A user profile

n° STEP	STEP	FLAP	1 THRUST settings	h, speed (CAS), climb rate
1	Take off	11	Max Take Off	
2	*Climb*	11	Max Take Off	h = 1500 ft
3	*Climb*	11	Max Climb	h = 3000 ft
4	*Accelerate*	0	Max Climb	CAS = 250 kts; climb rate = 1250 ft/min
5	*Climb*	0	Max Climb	10000 ft

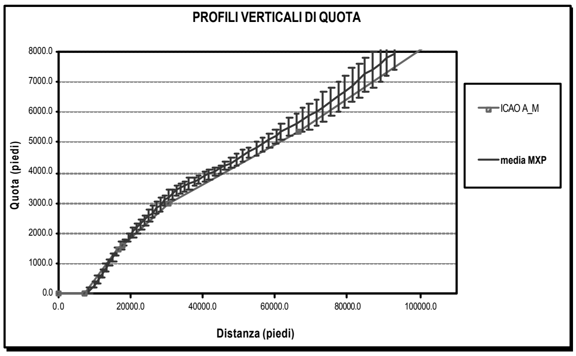


Figure 1, Vertical dispersion of MD 80 radar tracks and user profile

In figure 1, vertical segments represent dispersion on an average profile. A narrow vertical dispersion of the tracks can be observed, consistently with the fact that most of the tracks are Milan-Rome shuttle flights, characterized by very similar conditions specially in terms of weight and takeoff thrust settings, that have been unknown due to the absence of flight airport database and Flight Data Recorder data.

An average flight profile, represented by a darker line in figure 1, has been used to calculate noise levels for 24 cases with different meteor-climatic conditions.

A 138000 lb weighted user takeoff profile, corresponding to an average condition between INM Standard Stage 3 and Stage 4, has been chosen. As easily observed in the following graphic where INM user speed profile (refer to the darkest line) is compared to aircraft speed values (scattered black points) determined from radar data, there is a relevant matching turned out even if it has not been possible to figure out real weight and thrust settings (as well as flap settings).

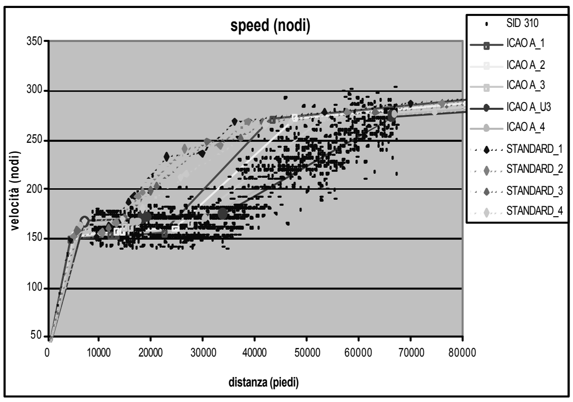


Figure 2, Comparison of several type of INM outputs and RDL 310 radar data speed profile

Since error has been calculated in relation to the shortest distance between flight ground projection and noise monitoring terminal location (lateral distance, *d*), considering the radar average profile seems to be a better procedure than that proposed in INM User Guide based on the length of the trip, where flight profile stage is identified according to the fact that fuel is a relevant part of aircraft weight.

A Microsoft Access Relational Database has been realized to manage radar, measured and INM output data. Hence instead of reproducing single track by manual input, INM study database has been set automatically allowing as well to verify a larger amount of data.

Results have been ordered by every noise monitoring terminal. In function of every SID, analysis has been conducted referring to the average track of the considered swath, as the one calculated through INM *radar.csv* file import function. For every study case the reference profile came out by matching this average track with the calculated vertical profile.

Every noise monitoring terminal has been described in function of parameters *d* and *b*, respectively the lateral distance, and the angle between the shortest conjunction line to the vertical profile and the horizontal plan. *b* has been called elevation angle, in accordance with SAE AIR 1845 definition.

It can be emphatized how parameter *d* results not to be a good INM systematic error indicator due to its dependence on NMT position respecting to track ground projection and its lack of connection to vertical profile geometry. *b* angle, is not related to NMT position, resulting in the same way a not good descriptor. Then *d* and *b* variables turn out to be not well correlated to INM systematic error. A solution has been determined relating differences between measured and calculated SEL values to parameter *d/b*.

Thus at every NMT *d/b* parameter has been calculated referencing to the average profile.

Among Malpensa 17 NMTs, 2 of them have been kept out from statistical analysis in order to avoid to consider start of roll factor, mainly due to the fact that not all departures start from RNE but for some of them a displaced threshold should have been considered. Unfortunately radar data don't permit to know whether departures take place from RNE or not. Other significant factor is aircraft takeoff thrust setting. Alitalia, as well other airliners, declared to Airport Noise Committee that most of takeoffs occur at reduce power, so vertical profile turns out to be flatter than in the case of full power settings. We cannot evaluate real offset between a flatter, and then closer to ground, aircraft profile and reduced aircraft noise emissions. Definitely disregarding of ground acceleration sector allows us not to consider a likely source of error.

A Ms Access specific function has been implemented to automatically match measured and calculated data. 808 departures have been considered, leading to more than 4000 SEL values.

Figure 3 shows the statistical distribution of the differences between calculated and measured data in the case of a single NMT.

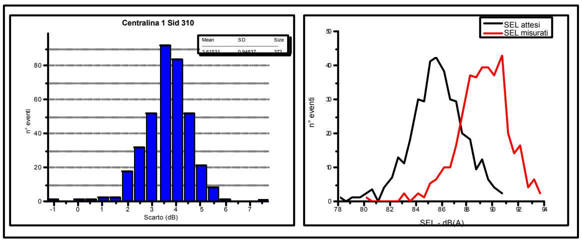
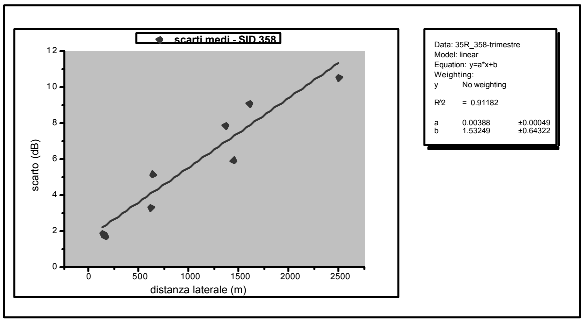


Figure 3, Differences between calculated and measured data statistical distribution

Taking separately into consideration SID 310 and SID 358 data, SEL differences have been correlated to the spatial parameters.

Error analysis of a sample of flight data is depicted in the following figures.

Figure 4, Correlation SEL differences-distance



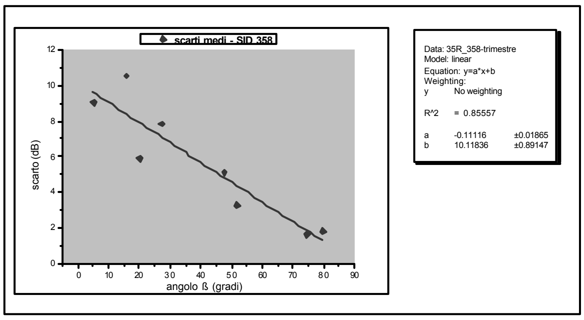


Figure 5, Correlation SEL differences -elevation angle

It can be asserted that the adoption of an average vertical profile in the INM simulation has widened the range in SEL levels scattering. Nevertheless an average error can be considered statistically relevant.

Results show how SEL differences rise with the distance and decrease with the elevation angle, mainly because affected by the model excessive lateral attenuation.

Therefore the aim of this study has been to define a correction factor to be introduced in the calculated SEL values.

Taking into account a linear regression model, as shown in figure 4, a SEL differences have been defined as a *d* function.

The same procedure has been adopted to calculate differences as function of the elevation angle *b*, whereas in the case of *b/d* a fractional exponent power function model has turned out to fit better than a linear regression model, as shown in the following figure 6.

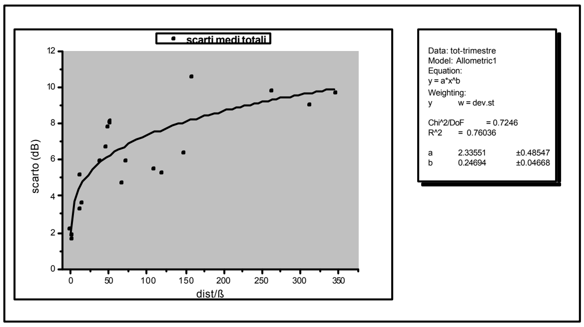


Figure 6, Correlation SEL differences-lateral distance/elevation angle

SEL differences functions of *b/d*, determined for each SID data collection, turned out to be significantly comparable, so that the Milan Malpensa differences between measured and calculated SEL values trend empirical model can be well represented as described in the following equation:

$$\Delta SEL(dB) = 2.35 \cdot (\mathrm{d}/b)^{0.25} \qquad (1)$$

Equation 1, as well as those relating SEL differences to lateral distance *d* and to elevation angle *b,* have eventually been verified using a different sample of data, considering then a different meteorological scenario and a likely different average vertical profile.

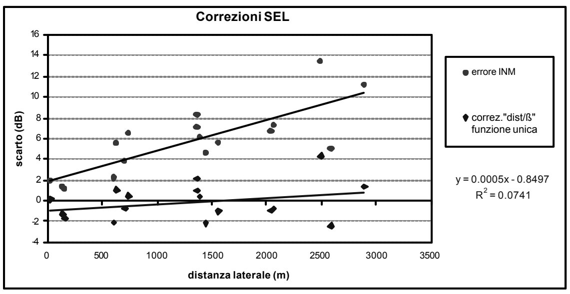


Figure 7, Application of the error correction factor

In figure 7, where circle points represent the differences between measured and calculated SEL values at NMT, it can be observed how applying correction factor, as determined by equation 1, to these differences leads –refer to square points- to a zero leveling trend of the function, showing therefore a good estimation as furthermore analytically indicated by:

- a very small linear regression function angular coefficient
- very small R^2 value,

pointing out then a scarce error dependence on lateral distance parameter.

References

[1] International Civil Aviation Organization, ICAO DOC 8168 OPS- 611 Volume 1 - Aircraft operations.

[2] AIP Italia, updated May 2005, ENAV, Ente Nazionale Assistenza al Volo.

[3] INM User's Guide, Integrated Noise Model 6.0, Office of Environment and Energy, Federal Aviation Administration.

[4] INM Technical Manual, Integrated Noise Model 6.0, Office of Environment and Energy, Federal Aviation Administration.

[5] Society of Automotive Engineers, SAE AIR 1845, Procedure for the calculation of airplane noise in the vicinity of airports.

[6] Decreto Ministero dell'Ambiente 31 ottobre 1997, Metodologia di misura del rumore aeroportuale.