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A comparison of noise simulation models

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Abstract
The Institute for the Environmental Protection and Research has organized a research activity, on assignment of Ministry of the Environment, in order to compare the results of the main noise simulation models. The comparison has taken in account of all noise sources – roads, railways, industries and airports. The results have allowed to evaluate the differences due to operator choices, most common commercial software tools – implementing the same models – and various infrastructure configurations.

Keywords: noise simulation models.

1 Introduction

The Italian Institute for Environmental Protection and Research, ISPRA, on behalf of the Ministry of Environment and in collaboration with the system of Regional Environmental Agencies (ARPA), have carried out a comparison among the simulation models for four types of noise source (roads, railways, industries and airports). The comparison has been made on the basis of scenarios prepared by the JRC Ispra (Italy) on behalf of the European Commission [1].

2 Comparison on road noise simulation models

The comparison national models for calculating the road noise has been made with the participation of 21 laboratories (11 ARPA and ISPRA). Four different commercial software tools for modelling have been compared.
The work has been carried out using 14 predefined scenarios differentiated by the source characteristics, noise propagation environment, weather conditions, type of vehicle flows, etc.
The obtained data have been first analyzed to evaluate the anomalies, both by the z-scores criterion [2] and a systematic analysis of the approaches taken by each laboratory. Then the results have been analyzed and compared through the methods of descriptive statistics for scenario, macroscenario and the whole pattern.
The results define a range of variables related to individual commercial software tools, as a whole and individually, and highlight the limitations of models, user errors and different approaches to the problems of input values implementation.

2.1 Comparison settings

The laboratories participating to the comparison have been grouped according to the software tools and algorithm used. IMMI has been used by 8 laboratories, CadnaA by 7, SoundPlan by 5 and Mithra by 1. All laboratories have referred to the NMPB96 Standard [3], except two of SoundPlan users who have used RLS90 [4].
The 14 scenarios have been grouped into 3 macroscenarios depending on the type of road: a typical configuration of a great communication road in open areas and urbanized areas (Motorway macroscenario), two-way road through an urban area (City macroscenario), a 4-lane highway in a hilly environment, running at a midway height between the valley bottom and the top of the hill (Hill macroscenario).
For each macroscenario various configurations based on traffic conditions, atmospheric propagation and infrastructure configuration – flat, depressed and embankement – are provided too.

2.2 Data analysis

For detecting outliers the z-score criterion has been adopted: the percentage of points with critical data (2 < z-score <3) and very critical ones (z-score > 3) has been calculated for each laboratory. A laboratory has been considered anomalous when at least one of the following conditions are present:

1. percentage of very critical data more than 10%;
2. percentage of very critical data over 5% and percentage of critical data higher than 15%.

In addition to the procedure with z-score an assessment of anomalies has been carried out by examining the modelling approaches adopted by each laboratory: Thus it has been possible to identify user errors and misinterpretation in the implementation of scenarios.
Among the identified errors, the most frequent and significant in terms of data analysis are related to the absorption ground, the reflections and source modelling.
The subsequent analysis has been carried out by evaluating, for each scenario, macroscenario and the whole pattern, data dispersion among different laboratories (average

standard deviations and ranges of variability in the data) and the average absolute deviations for each laboratory. Moreover, for each point of modelling it has been carried out a graphical comparison of average results provided by each commercial models of calculation, in order to analyze the response of the models in the various considered scenarios.

2.3 Results

Through the whole analysis of the z-score criterion for all modelling scenarios (Fig. 1), two laboratories have been characterized by a number of critical points above the acceptability thresholds (Lab. 5 and 6).

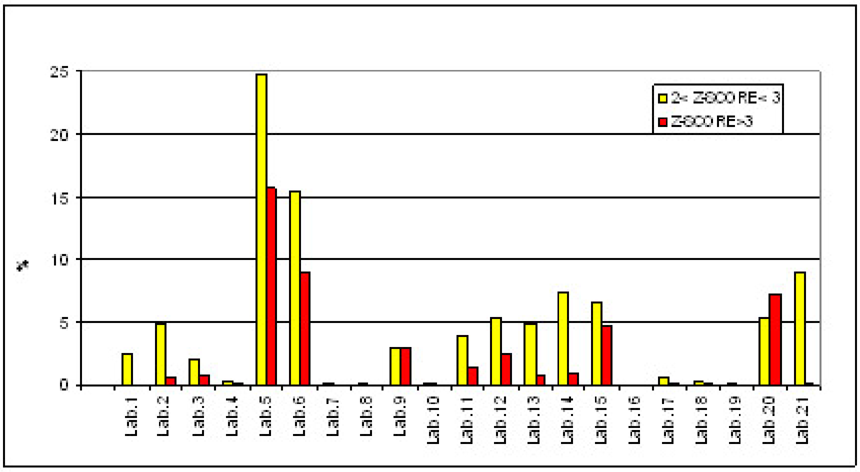

Figure 1: Analysis of the z-score for each laboratory refering to all modeling scenarios

Regarding the average standard deviations, the obtained values without critical data are between 1 dB and 3 dB, depending on the specific scenario, with an average of 2 dB. The variations among individual scenarios are therefore limited and mainly due to the complexity of the territorial context in which the source is inserted (Fig. 2).
The analysis of differences between the two most widely used software tools IMMI and CadnaA, implementing NMPB96, shows a substantial consistency between the results provided. For the other models the significance of the results are not assessable for the small number of participants and the further reduction of data after statistical analysis.

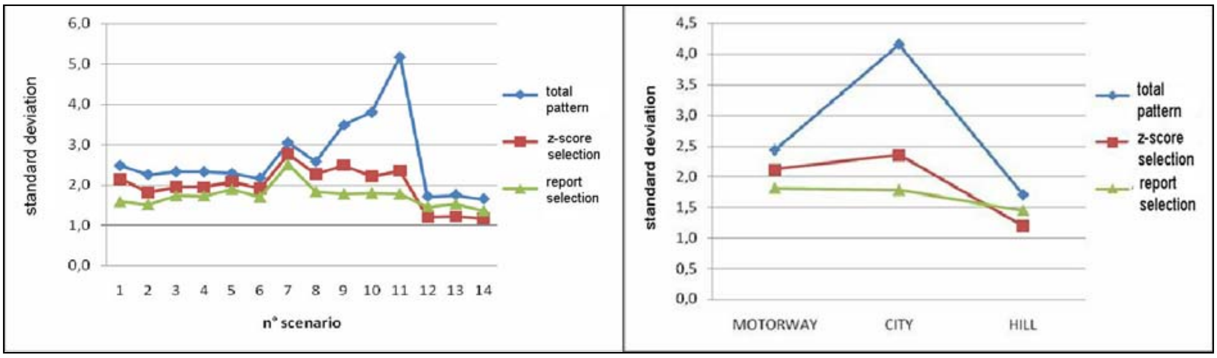

Figure 2: Average standard deviation for scenario and macroscenario

The comparison allowed to highlight some critical points associated with noise modelling: the data are significantly affected by human error and by the approximations by different models in the algorithms implementation; the differences increase with the complexity of the propagation and the distance from the source; IMMI and CadnaA are apparently a better guide for user through the choices in developing settings – and also, consequently, less flexible – than SoundPlan.

3 Comparison on railway noise simulation models

The railway noise simulations have been performed by 6 laboratories. Three laboratories have used the simulation software SoundPlan, two laboratories IMMI and a laboratory CadnaA, all implementing "ad interim" RMR model [5].

3.1 Simulation scenarios

Nine simulation scenarios have been considered, with three train categories (passenger, freight and high speed), typically present on the Italian railway system, and line configurations (flat, depressed and embankment). Moreover there are sections with and without barriers, with the presence of buildings (more or less dense) and without buildings. Always favorable meteorological conditions have been assigned.
The Tab. 1 shows the sections belonging to simulation scenarios.

Table 1 – Description of cross sections belonging to simulation scenarios

Section	*Section description*
Free field	
A	Free field, absorptive and reflective ground.
B	Free field, absorptive and reflective ground and single absorptive noise barrier on the side of the absorptive ground.
C	Free field, reflective and absorptive ground and single absorptive noise barrier on the side of the reflective ground.
Spread built area	
D	Open site, built area, two rows of buildings parallel to the railway and two buildings orthogonal to the railway, reflective ground.
E	Open site, built area, two rows of buildings parallel to the railway and two buildings orthogonal to the railway, reflective ground. Absorptive barrier on both sides of the railway. 2 m height noise barriers.
F	Open site, built area, two rows of buildings parallel to the railway and two buildings orthogonal to the railway, reflective ground. Absorptive barrier on both sides of the railway. 4 m height noise barriers.
Dense city centre	
G	Dense city centre, reflective ground and 4m height absorptive noise barriers.
H	Dense city centre, reflective ground.
Railway station	
I	Railway station, two rows of buildings parallel to the railway and a set of dwellings, reflective ground, 6 tracks.
Curve	
L	500 m radius curve, reflective ground.

3.2 Results

The data processing has involved the calculation of average standard deviations, corresponding to the individual cross sections, calculated for different types of tracing. The Fig. 3 shows the values obtained from the average standard deviation for cases of passenger and freight trains; the Fig. 4 shows the case concerning high speed trains.

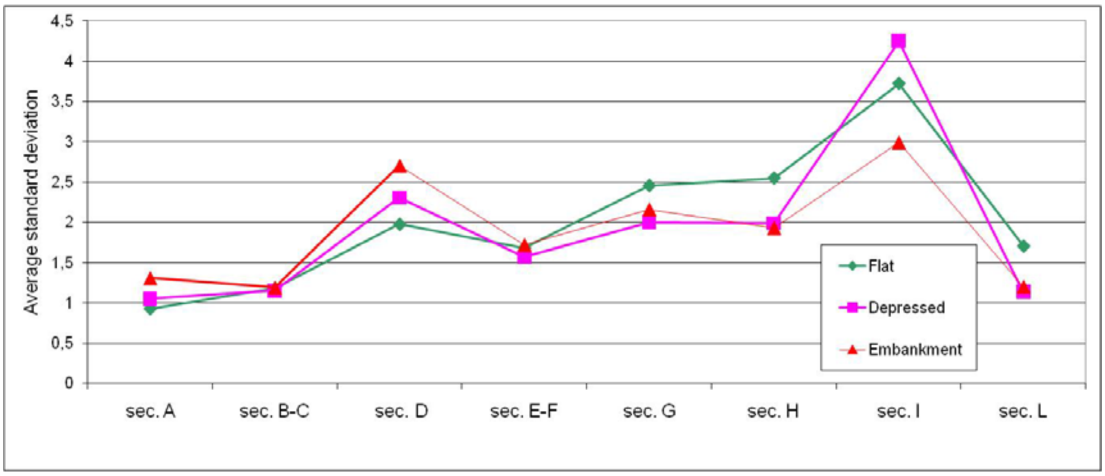

Figure 3: Average standard deviation for passenger and freight train category

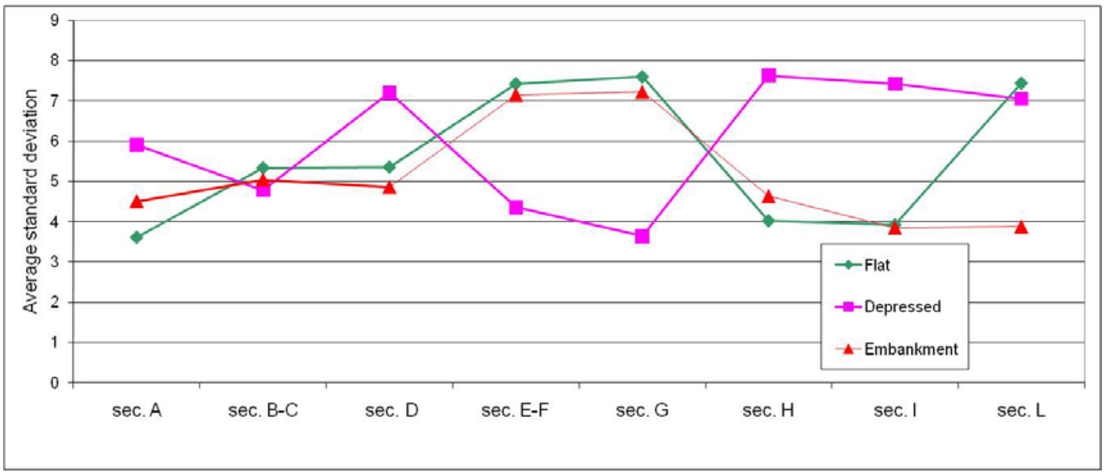

Figure 4: Average standard deviation for high speed train category

From previous figures can be deduced the following comments:

- Sections in free field (A, B, C): the average standard deviation is contained within 1.5 dB; it is slightly lower for the flat, while it increases with the embankment source;
- Sections in spread built areas (D, E, F): the average standard deviation have values greater than the free field sections, 2 dB to about 3 dB for the section D; also in this case the standard deviation shows a tendency to be lower with the flat configuration, while it increases with the embankment source;
- Sections in dense built areas (G, H): the average standard deviation has values between 2dB and 3 dB; unlike the previous sections, the average values tend to be higher in the case of flat and slightly lower with the embankment source;

- Station (Section I): receptors located at the station show the average standard deviation values higher than other sections, within 3 dB and 4,5 dB and higher for the depressed source;
- Curve (Section L): the value of standard deviation has a smaller range, between 1dB and 2 dB.

More complex is the trend of the average standard deviation for high speed trains (Fig. 5). In this case it is noted that the values of the average standard deviations are much higher than passenger/freight trains, being always higher than 3 dB and reaching, in some sections, beyond 7 dB. \Furthermore, for almost all sections, very different values of the average standard deviation are noted for depressed source than flat and embankment ones.

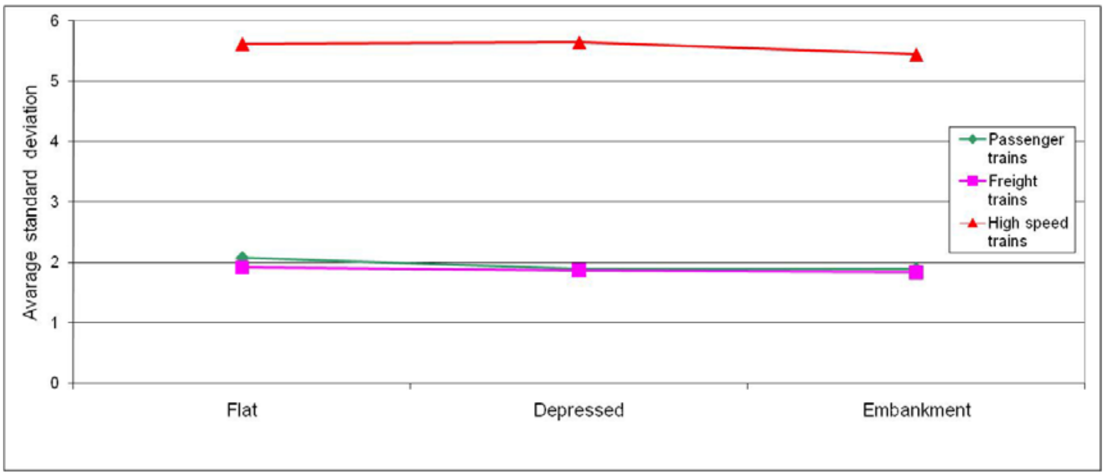

Figure 5: Average standard deviation for train category and tracking configurations

A careful analysis of simulations has allowed to verify that the differences in the case of high speed trains, compared to other categories, are mainly due to operator inaccuracies on the choice of category of high-speed trains and on calculating flow times of trains, especially for laboratories that have used the software IMMI.

4 Comparison on industrial noise simulation models

The comparison has been carried out with the participation of 12 laboratories, in particular three different commercial tools have been compared: CadnaA (4 laboratories), IMMI (6 laboratories) and SoundPlan (2 laboratories), all implementing ISO 9613 [6].
The results obtained by each laboratory have been analyzed first of all for scenario, according to traditional statistical techniques, and then compared either in the same commercial implementation or considering various commercial software tools; in both cases it has been possible to define a range variability of results, highlighting the different approaches to the problems of implementation of the input values, users errors and limitations of these models.

4.1 Comparison settings

The comparison was performed on 3 scenarios, divided into sections having different characteristics for the position of noise source, receptor type (in free field and at façade of buildings) and presence of barriers.

Scenarios 1 and 2, covering an environment with flat areas with different absorption, present 8 sections (from section A to H) and are distinguished only by their conditions of sound propagation: 100% favorable for scenario 1 and 50% favorable and 50% homogeneous for scenario 2. In particular, A and B sections present receptors in free field and industrial source, modeled as point source at façade of reflective building. In C and D sections receptors are always in free field and the source is respectively positioned above and behind the industrial building. Section E presents receptors at façades of two rows of buildings and source in front of these ones. Sections F and G are characterized by receptors in the front of two rows of buildings on areas with different absorption and a source to the perimeter of a reflective industrial area. Section H presents receptors at façade of a complex of buildings that approximate an urbanized area with a source positioned in front of the completely reflective industrial building. Scenario 3 concerns a hilly area with receptors at various distances from the source and different heights of the hill.

4.2 Results

The simulation results have been analyzed for each scenario through the traditional statistical techniques. The Fig. 6 shows the standard deviation for each section/group of homogeneous sections, considering total pattern and, separately, individual commercial tools.

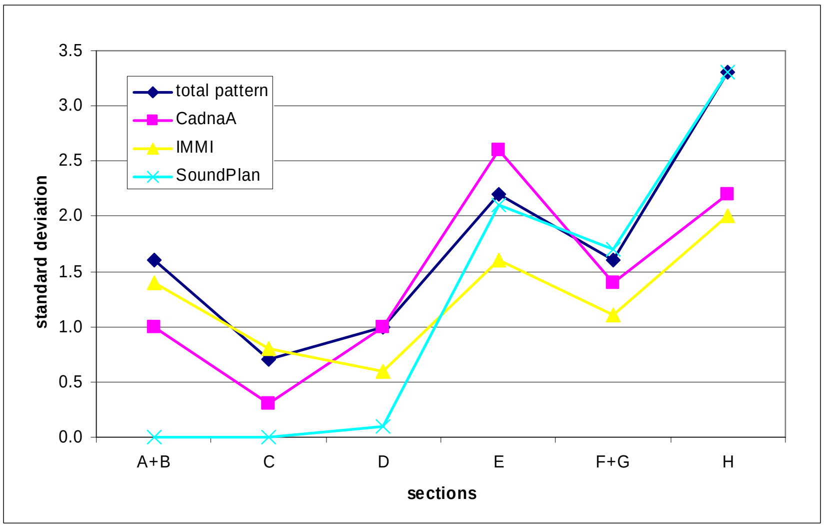

Figure 6: Scenario 1, average standard deviation for section/group of homogeneous sections

Then a systematic analysis of the configuration settings has been carried out, both to assess the types of errors and their weight on modelling, and to compare, on equal calculation settings, the results of software tools. Most significant errors are: the definition of sound power source either as total power or spectrum in octave bands; the setting of the reflection number and the sound evaluation at building façade. Following this analysis, the simulations results have been cleared by data relative to laboratory with calculation settings errors.
The Fig. 7 shows the estimated standard deviation for each section/ group of homogeneous sections for the total pattern, the sample purged from critical data (report selection) and, separately, for IMMI implementations – the software tool with most users –, with and without critical data. It is noted that the standard deviation of the sample without critical data represents the differences due to the diversity of software tools; these differences increase with the complexity of the concerned section for the presence of buildings and obstacles to propagation.

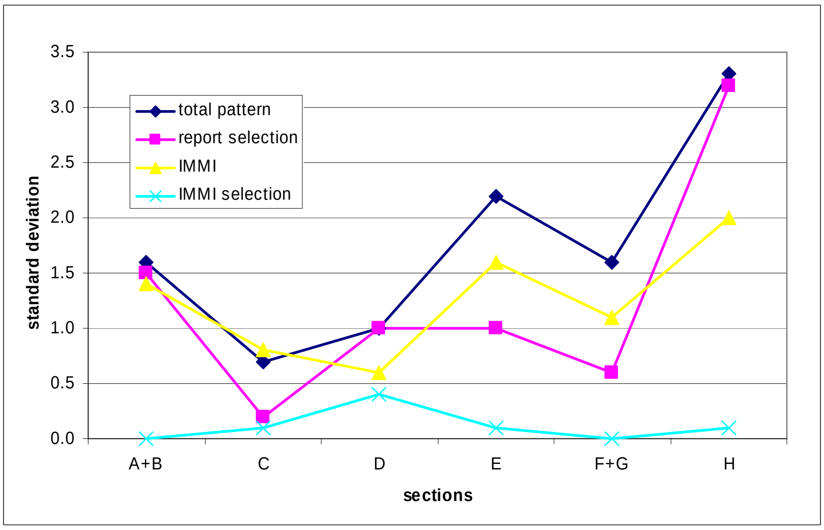

Figure 7 Scenario 1, average standard deviation for section/group of homogeneous sections

The Fig. 8 shows the average standard deviations for scenario and highlights that, at different scenarios, there is no significant difference of standard deviation, always lower than 2 dB and comparable among different software tools.

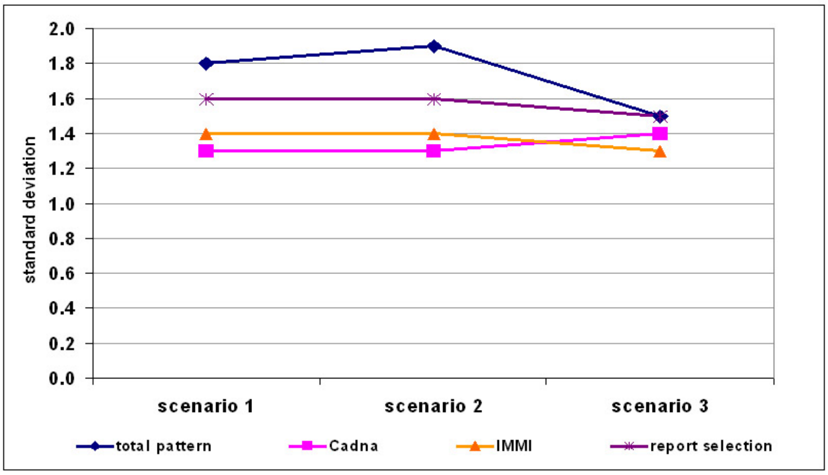

Figure 8: Average standard deviation for scenario

The Fig. 9 shows the sound pressure levels in receptors for each software tool used only considerating labotories without critical data. It's fairly clear that IMMI tends to underestimate average of 2 dB compared to CadnaA, probably because of the different calculation configuration settings about the reflected sound at building façade. On the contrary, SoundPlan seems to underestimate the sound pressure levels in some receptors of section H, probably not for an error of calculation settings, but bacause of a not sufficient refinement of user settings related to the propagation in a complex environment.

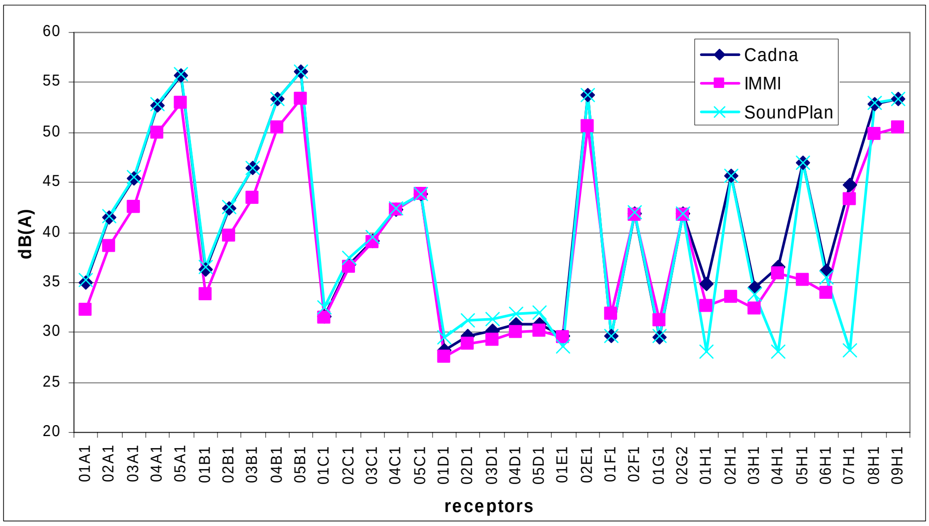

Figure 9: Scenario 1, sound pressure levels at receptors

The comparison, although the limitations due to the reduced number of participants, has allowed to analyze the main problems related to the modeling of industrial source for the three most common commercial software tools.
The results allow nevertheless to do the following considerations, both about the approach to user in the modeling industrial source and about the different response of commercial implementations used:

- most significant and frequent errors are relative to the reflection number, the definition of sound power source and the sound assessment at building façade;
- for all scenarios and software considered, dispersions increase with the environmental complexity of propagation in relation to the presence of buildings and obstacles and the distance from the source;
- the average standard deviation of the pattern without critical data, representing of difference among software tools, is lower than 2 dB;
- IMMI and SoundPlan underestimate, probably because of the different configuration calculation settings for the reflected sound at building façade.

5 Comparison on airport noise simulation models

The activity on airport noise has been attended by twelve laboratories: nine using INM software – six 7.0a, two 6.2a and one 6.1 version – two CadnaA-laboratories and a SoundPlan-laboratory. The main objectives are the analysis and comparison of simulation results carried out by different operators on the selected scenarios, using different software, and also the comparison of results obtained by the adopted simulation models with those produced by the “ad interim” model prescribed by European Commission – document ECAC.CEAC Doc 29, 2nd version [7]. Nine scenarios have been defined, one of which presents features more responsive to airport sources in the national territory. Taking the same settings for the airport seat and weather conditions, scenarios are characterized by different trajectories of airport take off and landing, aircraft types and number of movements per day. The deliverables are the values of sound pressure levels in LAeq (06-22) for each receptor and – relatively to the chosen configurations – with receiving points located on a rectangular grids. An initial data analysis has identified differences in values due to errors in interpretation of data input, so severe as to suggest subsequent ongoing simulations that, decreasing the influ-ence of choices made by the operators, are able to provide information on different stages and components of noisy event.

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