DYNAMAP: SENSITIVITY ANALYSIS OF THE ACOUSTIC CALCULATION MODEL WITH RESPECT TO ENVIRONMENTAL VARIABLES INSIDE AND OUTSIDE URBAN AREAS

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Within the DYNAMAP project, which aims to produce a dynamic noise map in different physical context, it is useful to preliminarily define the sensitivity of the acoustic model, with respect to some environmental variables. Starting with an analysis of the relevance of noise attenuation factors, function of the distance and the type of sources, it was decided to explore the sensitivity of the acoustic model with respect to weather conditions, in suburban context, and vehicular traffic flow conditions, in urban context. The noise calculation algorithm adopted is XPS 31-133/NMPB.

The sensitivity of the model with respect to the occurrence of favourable or homogeneous weather conditions, has been assessed through repeated simulations in which only weather conditions vary. The refraction of sound rays in the atmosphere layers (favourable conditions) results in a greater persistence of the sound wave near the ground and therefore in a greater interaction with it. Hence the characteristics of land cover appear to be a discriminating factor to evaluate the influence of weather conditions on noise propagation. Several scenarios have been simulated calculating noise levels at an array of receptors with varying weather conditions, ground type and relative source-receiver height. Source conditions were instead kept constant. The results can guide the acquisition of local weather information required in the simulation process according to the different weather conditions settings.

In urban areas instead, traffic flow conditions have a direct influence on the sound power of the road source. Through different scenarios, the relationship between sound power of road source is then calculated in function of: type of flow (continuous, accelerated, decelerated and interrupted), percentage of heavy vehicles, average speed. Some possible approaches to modelling of traffic conditions in urban context are here proposed and evaluated.

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1. Introduction

DYNAMAP is a LIFE+ five year project aimed at demonstrating the feasibility of real time noise mapping.

The updating of noise maps can be automated by developing an integrated system for data acquisition and processing, able to detect and report in real time the acoustic impact of noise sources. Only road traffic sources will be investigated. The system will be composed of low-cost sensors network measuring the sound pressure levels emitted by the noise sources and of a software tool based on a GIS platform able to perform real-time noise maps.

Design and implementation of the DYNAMAP system will be accomplished in two pilot areas located in the city of Milan and in the surroundings of Rome.

A model of each pilot area will be implemented in an acoustic calculation software and will be the base for the surface noise maps production. Baseline noise maps are updated in real time as a function of local noise levels acquired from source oriented low cost stations. Some parameters of the calculation model will be changed according to significant variations of the environmental conditions; thereby a new baseline map, independent from acquired acoustic data variation, has to be produced.

The baseline acoustic model will be performed using XPS 31-133/NMPB algorithm, which includes both the road sound power computation in function of traffic input data, and the calculation of the environmental noise attenuation along each source-receiver propagation path.

The implementation of Dynamap system in two different environmental contexts requires the identification of the most significant and relevant parameters to be analyzed: meteorological conditions in extra-urban areas; traffic conditions in urban areas.

In this paper the sensitivity of the adopted acoustic model is analyzed with respect to these two variables, that is considering how the values of the terms "weather conditions" and "traffic conditions" influence the environmental noise level or the noise level emitted by the source.

2. Sensitivity analysis with respect to meteorological conditions

XPS 31-133 algorithm takes into account the occurrence of homogeneous or favourable to propagation weather conditions. At a physical level, weather conditions that influence noise propagation are related to the wind speed and temperature vertical gradients. When a fixed threshold is reached, sound ray is refracted downward causing the enlargement of the affected area.

Sound ray refraction induced by atmosphere layers determines a longer persistence of the sound wave at the ground level. The effects of the terrain on the noise propagation path are therefore increased. Interferences between sound wave and terrain, identified as reflection and absorption, are also related to the source height with respect to the receiver height. Consequently, the height of the source, that is the roadway, relative to the ground level, modifies the effects and the dimension of the weather conditions influence field. This is due to the combined effects of reflection, absorption, diffraction and interference.

In long term noise levels calculation, as required by END 49/2002, weather conditions influence is determined from the weighted energetic average of the favourable and homogeneous (not favourable to propagation) yearly average levels. The effect on the long term period of favourable conditions is expressed as an occurrence factor (in percentage) calculated from a statistical analysis of meteorological data. These can be measured or evaluated according to general principles and refer to each angular sector of the noise field. In the study case the favourable conditions calculation has been done with an occurrence factor of 100%.

In order to evaluate the model sensitivity with respect to favourable or homogeneous weather conditions, specific calculations have been carried out keeping other parameters fixed and varying just those related to meteorological conditions and other factors directly connected with them.

Source parameters (single line source, road geometrical parameters, traffic flow and traffic composition) as well as calculation settings have been kept fixed. Some series of calculations have been done implementing XPS 31-133 algorithm in *CadnaA* noise modelling software with the following settings.

Constant parameters:

- Noise source: grade-level road, 10 km length, Lw'=100,3 dB(A).
- Calculation parameters: search ray distance, maximum reflection order.
- Array of 50 receivers, spaced 10 meters apart, from 10 to 500 m distance; receiver height: 4 meters.

Variables:

- Road height (H): ground level, road embankment 2m, 4m, 6m, 8m, 10m.
- Ground factor (G): 0,0 - 0,2 - 0,4 - 0,6 - 0,8 - 1,0.
- Meteorology: favourable/homogeneous conditions.

Source-receiver relative height varies from -4 to +6 m.

In total 72 runs have been carried out. In the following graphs (Figs. 1-3) some results are presented as difference between noise levels in favourable and homogeneous conditions. In the x-axis the source-receiver distance is shown. Graph curves represent the trend lines calculated as a three-element moving average.

It can be noticed how an increase of noise levels occurs in favourable weather conditions; it becomes significant starting from noise paths greater than 100 meters. This effect is greatly amplified in presence of absorbing soils and low elevation level road sources.

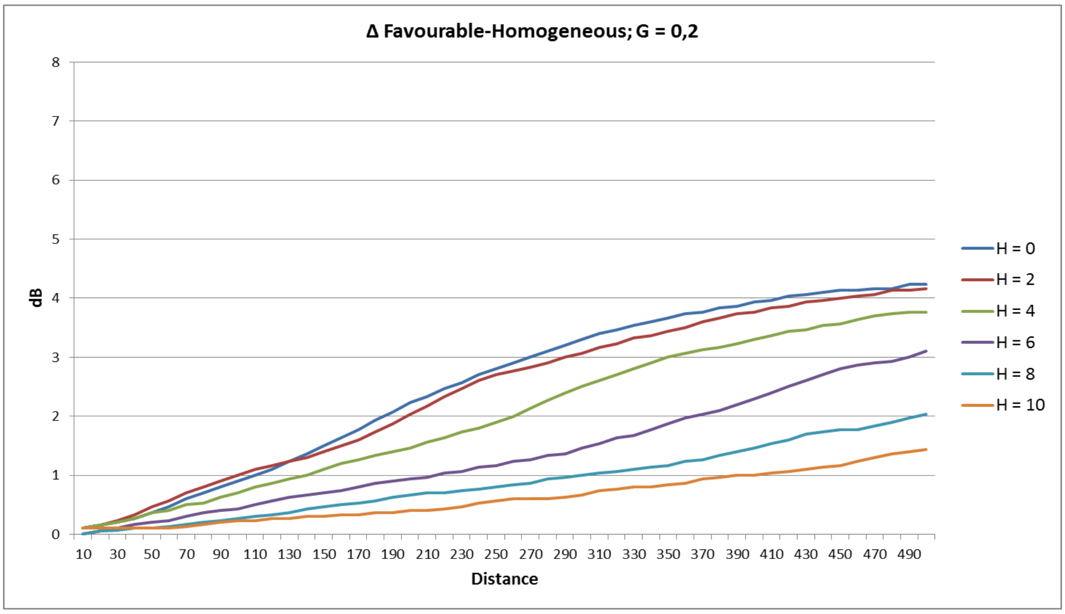


Figure 1. Differences between favourable and homogeneous conditions calculated noise levels. Ground Factor = 0,2

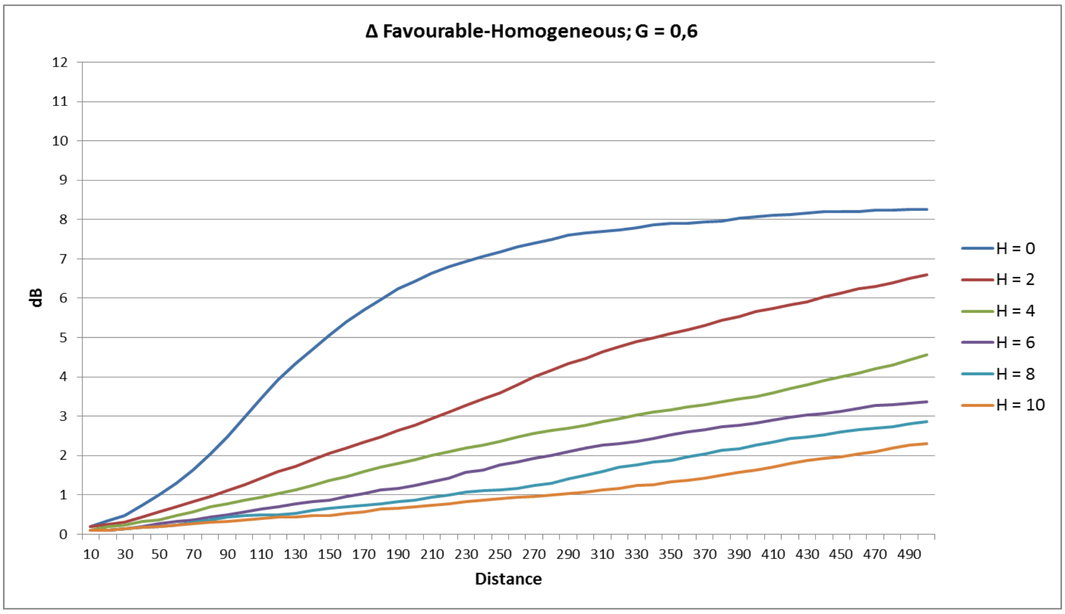


Figure 2. Differences between favourable and homogeneous conditions calculated noise levels. Ground Factor = 0,6

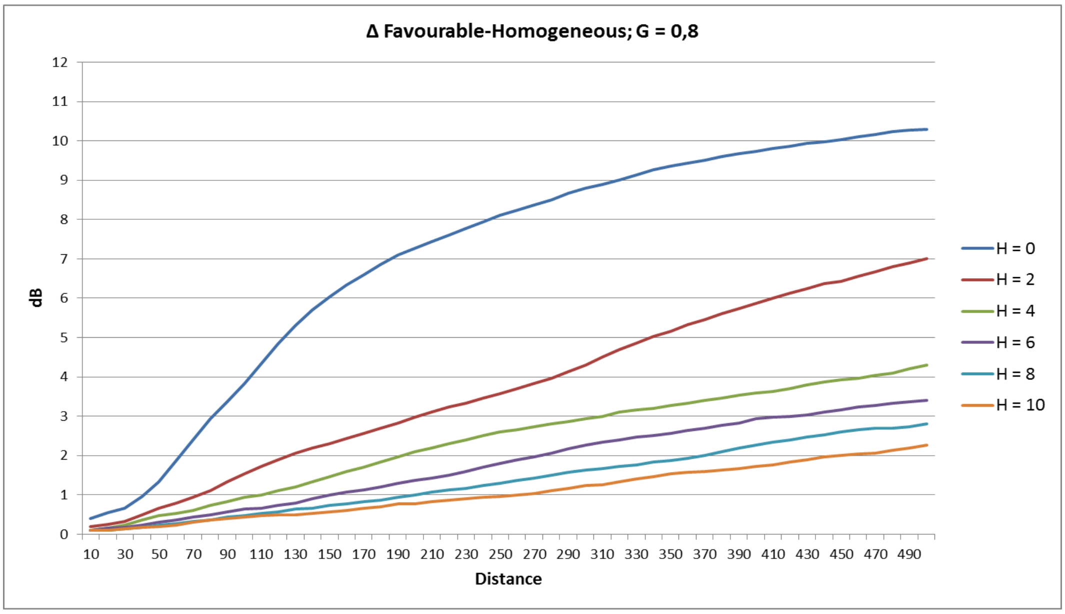


Figure 3. Differences between favourable and homogeneous conditions calculated noise levels. Ground Factor = 0,8

3. Sensitivity analysis with respect to traffic conditions

In typical urban areas, traffic conditions vary significantly with respect to the presence of connections, junctions, traffic lights and to the length of the road stretches. The temporal variability of flow conditions depends on short-time effects (traffic light duration) and on long-time effects, such as peak or low traffic periods. According to the XPS 31-133 method, these traffic conditions directly influence the computation of sound power emitted by a single road segment. The algorithm considers four flow conditions: continuous, accelerated, decelerated and interrupted. Other variables related to the traffic conditions and strictly connected to the estimated sound emission are: percentage of heavy vehicles, average speed.

Computations are carried out considering six percentage classes of heavy vehicles (from 0% to 5%; step 1%). For each of them, the relationship between LAw' (linear sound power level) and the variable average speed (five classes from 30 km/h to 50 km/h, step 5 km/h) was assessed considering the four traffic flow conditions.

Overall, 120 calculations of the noise emission level of the road source were performed.

The examined average speed and percentage of heavy vehicles ranges are typical of Milan urban traffic. The parameter "traffic flow conditions" results to be the most relevant in the calculation of emission levels; the effect of this parameter, in general, decreases with increasing average speed.

In the following graphs (Figs. 4-5), as an example, estimated sound power levels are presented in relation to the vehicles speed. The other parameters in the computation of sound power absolute values have been kept fixed (traffic flow = 1000 veh/h).

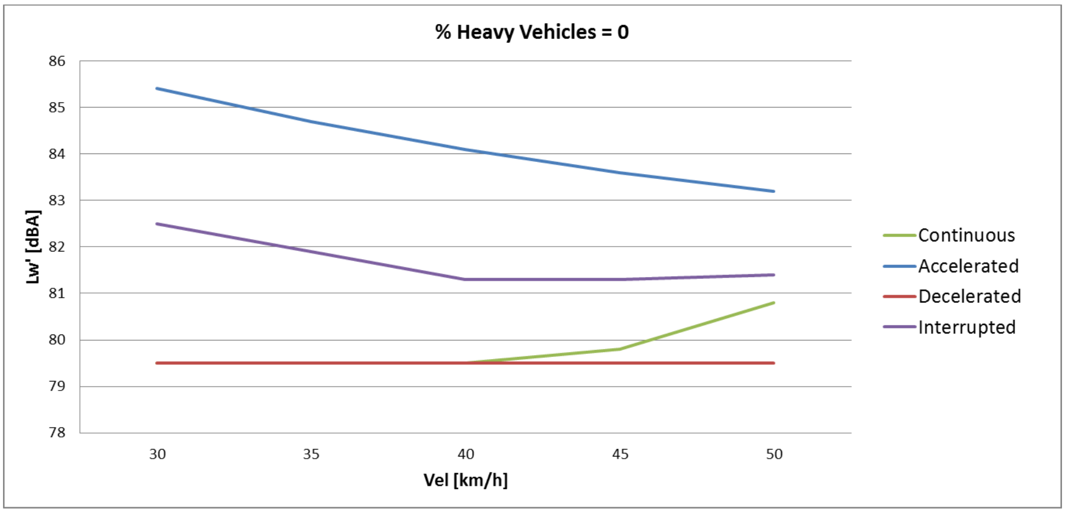


Figure 4. Calculated sound power levels in different traffic flow conditions. Heavy vehicles = 0%

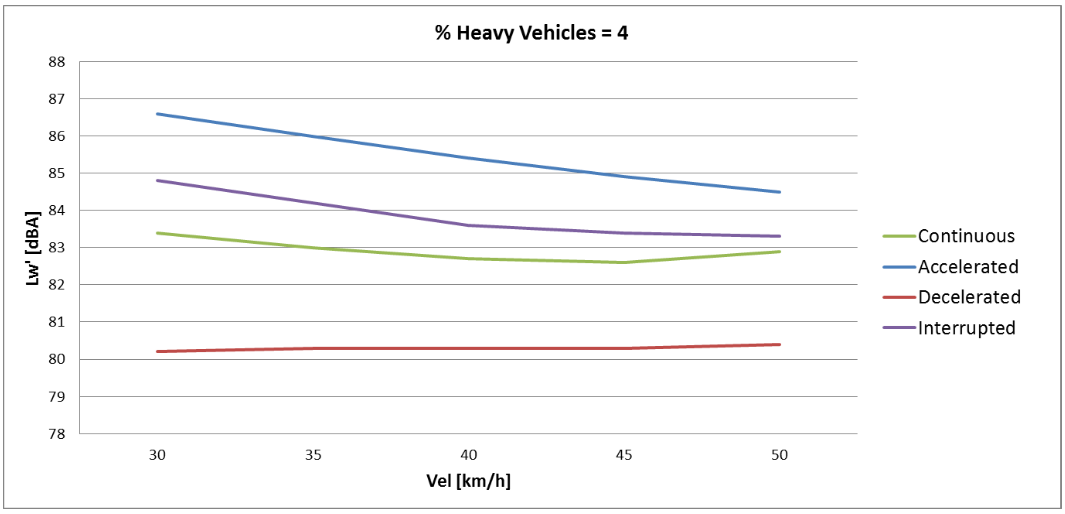


Figure 5. Calculated sound power levels in different traffic flow conditions. Heavy vehicles = 4%

As it can be noticed from the comparison between Fig. 4 and Fig. 5, high percentages of heavy vehicles determine higher sound power levels -even in case of continuous traffic flow conditions- which increase as the speed values decrease (see the green line relative to speed values lower than 45 km/h).

3.1 Urban traffic flow conditions: two simulation approaches

Two different approaches for the simulation of the vehicular traffic, as representative examples, are proposed here. In the first approach flow conditions are assumed to be “continuous” in each road segment and the speed value is consistent with the urban speed limit. In the second one they are assumed to be “interrupted” nearby a crossroad and the speed value is 30 km/h; these settings are applied to the 100 meter long road segments starting from the center of the intersection. Interrupted condition results to be an average between accelerated and decelerated conditions, so it smoothes the differences in case of track roads flows.

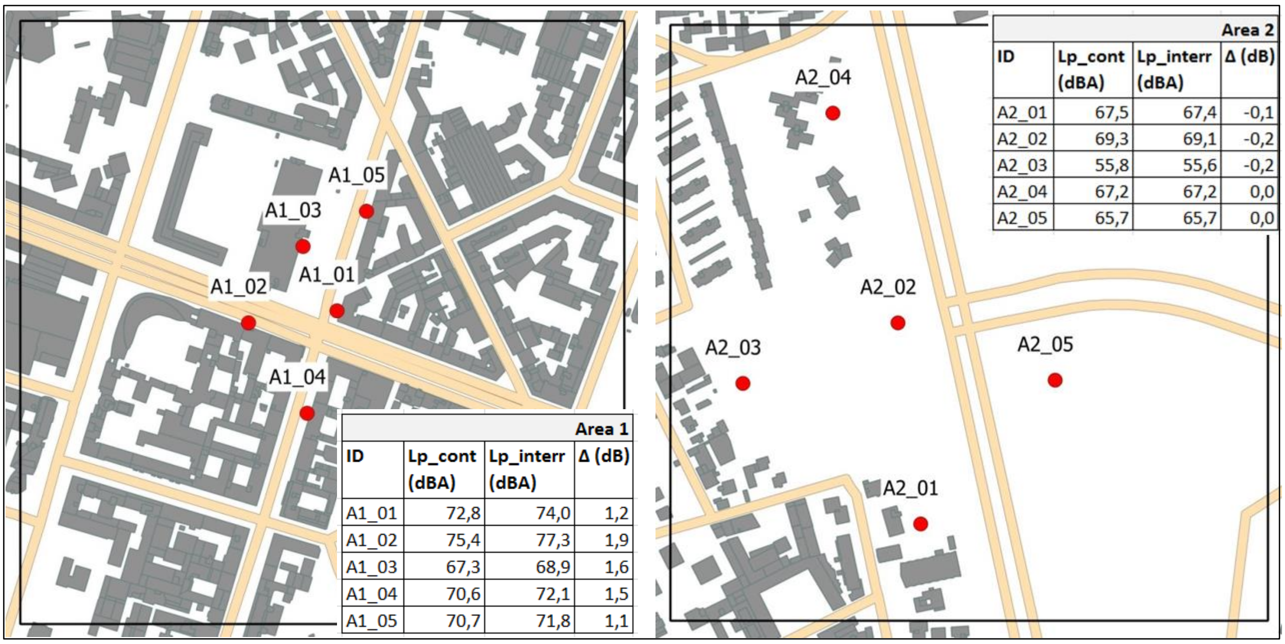
The effects of the two different simulation techniques are studied on two areas that show differences in terms of building density and road category (see Fig. 6):

- Area 1: high density urban area, vehicles’ speed of 50 km/h in average conditions.
- Area 2: suburban area, low building density, vehicles’ speed of 70 km/h in average conditions.

Each area is then modelled following the two approaches suggested.

The differences in sound pressure levels (*Lp_interr*, for the “interrupted” traffic flow – *LP_cont*, for the “continuous” traffic flow), calculated at 5 points for each area, allow to evaluate the effects of the different settings, as shown in the results tables inside Fig. 6.

Significant differences (>1,0 dB) are found exclusively in Area 1 which is characterized by high building density and traffic speed values typical of local roads (50 km/h). On the contrary, on high flow roads (Area 2) we can observe how changes from continuous to interrupted traffic conditions don’t determine relevant differences in the sound pressure levels estimated.



Area 1			
ID	Lp_cont (dBA)	Lp_interr (dBA)	Δ (dB)
A1_01	72,8	74,0	1,2
A1_02	75,4	77,3	1,9
A1_03	67,3	68,9	1,6
A1_04	70,6	72,1	1,5
A1_05	70,7	71,8	1,1

Area 2			
ID	Lp_cont (dBA)	Lp_interr (dBA)	Δ (dB)
A2_01	67,5	67,4	-0,1
A2_02	69,3	69,1	-0,2
A2_03	55,8	55,6	-0,2
A2_04	67,2	67,2	0,0
A2_05	65,7	65,7	0,0

Figure 6. Urban context scenario simulations

4. Conclusions

Some useful considerations may arise from the results of the sensitivity analysis of the acoustic model.

The calculation of the year noise maps (as required by 49/2002 END) is also affected by the meteorological conditions, in particular by the percentage occurrence of favourable to propagation conditions compared to homogeneous conditions. To produce noise maps which are dynamically calculated relatively to a short period of time (at the longest one hour), as a purpose of Dynamap project, the availability of historical or measured meteorological data of the investigated area permits to obtain different baseline noise maps according to different meteorological conditions. The model performer, according to the available data set or to weather data acquisition mode, can arrange such baseline maps with a daily or seasonal time variation.

In relation to the different traffic conditions that occur in the urban area, the results of two scenario simulations have been here presented. The first one reproducing continuous flow conditions on all the road segments; the second one reproducing variable conditions with interrupted flow at the junctions and continuous flow on the straight sections. Also in this case, the results obtained can guide the drawing of different baseline maps of the urban environment, which take into account the occurrence of interrupted flow conditions during certain times of day, for example in presence of traffic congestion, slowdown or rush periods.

Acknowledgement

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