ANALYSIS AND CHARACTERIZATION OF THE ROAD TRAFFIC IN THE NOISE MAPPING OF VENICE

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Noise mapping has become an essential requirement, the EU made provisions to allow suitable interim computation methods such as existing national methods to be used prior to the development of a common EU method. Noise simulations require knowledge of the sound power levels of the noise sources and of the propagation of sound from the source to the surroundings. In this paper are presented the results of a research performed by ARPAV, on behalf of the Municipality of Venice, within the Project of the Noise Mapping and the Noise Abatement Plan of Venice. Several noise surveys, long term and short term monitoring, were carried out to characterize the noise traffic in Venice mainland. This study describes the different methodologies applied and it is focused on the bus noise

1. Introduction

Growing environmental problems, both in term of noise and overall pollution, drives to develop public transport and to make it more attractive compared to car usage. Buses, tram and trains contribute to atmospheric pollution and noise but in a very much smaller way than the private car per passenger mile. [1] The correct evaluation of the noise contribution of the public transport to the overall noise, allows taking actions in the effective way.

Effective environmental management requires scientific evidence on which to make decisions, the identification of key performance indicators by which to demonstrate achievement, and appropriate monitoring in order to assess both the efficacy of management and the quality of the environment itself.

The study presented in this paper is a part of a wider project carried from ARPAV (*Regional Agency for the Environment Protection of Veneto Region*) on behalf of the Municipality of Venice In compliance with the provision of the Italian Framework Law n. 447/1995 [2], ARPAV has been appointed by the Municipality of Venice to undertake a preliminary study for the Municipal Noise Abatement Plan (PRAC).

The noise mapping of the City (mainland and islands) has been realized as part of this appointment. The study was carried out complying with the standards required for the implementation of strategic mappings referred to D.L. 194/05. The D.L 194/05 is the Environmental Noise Directive 2002/49/EC (END) [3] law transposition.

During the first round of noise mapping in the Environmental Noise Directive 2002/49/EC (END) framework, the French method NMPB 96 [4] in combination with emission data from *Guide du Bruit* [5] was selected as the interim method for road traffic noise prediction. The French method NMPB 96 (1997) was adopted for our study.

The contribution of the public transport (buses) was evaluated separately, in order to identify the possible actions to reduce the noise pollution.

2. Methodology

2.1 Noise emission model of a bus

The noise impact assessment is mostly based on the calculation of noise maps, using a set of standard calculation schemes for the evaluation of the contribution of different sources.

Traffic noise propagation is influenced by different parameters such as the traffic flows (percentage of heavy vehicles, vehicle speeds), the typology and geometry of the road (width, surface, gradient), the surroundings (obstacles, height of the buildings, coefficient of absorption of the façade, coefficient of absorption of the ground) and the weather conditions (temperature, humidity, wind).

The acoustic properties of any source can be usually defined in terms of source type (point, line, areas) source height from the ground, sound power, and spatial distribution of the sound radiation (directivity). For the evaluation of the traffic noise there are several acoustic tools implemented with different technical standards. The public transport noise was modelled as a line source with the standard tools.

From a mean value of the sound exposure level (SEL) [6] assigned to a specific category of bus is possible to calculate the sound power level to input to the model. The SEL is the single event over 1 second which would have the same energy contents as the whole event. The sound pressure levels used in calculations may need to be corrected for the distance attenuation.

The equation of the sound propagation in free field for incoherent line source (isotropic conditions) is defined as [7]:

(1) $L_p(F) = L_w - 10\log_{10}(d) - 6 + 10\log_{10}(F)[dB]$;

Where $L_p(F)$ is the sound pressure level calculated at a specific distance from the noise source referred to a specific flow (F) of transiting vehicles for transiting time unit; L_w is the sound power level for unit of length (1 transit/sec); d is the distance between the source and the receiver expressed in [m], and (F) is the total traffic flow of vehicles (transit/sec).

Considering the following equation:

(2) $L_p(F) = SEL + 10\log_{10}(F)\,[dB]$;

The sound power level for unit length (1 transit/sec) is defined as:

(3) $L_{w(1/sec)} = SEL + 10\log_{10}(d) + 6\,[dB]$

Finally is possible to derive the following equations:

(4) $L_{w\,day} = L_{w(1/sec)} - 47 + 10\log_{10}(F_{day})\,[dB]$;

(5) $L_{w\,evening} = L_{w(1/sec)} - 38.6 + 10\log_{10}(F_{evening})\,[dB]$;

(6) $L_{w\,night} = L_{w(1/sec)} - 44.6 + 10\log_{10}(F_{night})\,[dB]$;

2.2 Noise emission model of a bus stop

The equation of the sound propagation in free field for finite line source (isotropic conditions) is defined as:

(7) $L_p(F) = L_w - 10\log_{10}(\frac{a}{\left[arctg\left(\frac{D1}{a}\right)+arctg\left(\frac{D2}{a}\right)\right]} - 11 + 10\log_{10}(F)[dB]$;

Where Lp (F) is the sound pressure level calculated at a specific distance from the noise source referred to a specific flow (F) of transiting vehicles for transiting time unit; Lw is the sound power level for unit of length (1 transit/sec); (F) is the total traffic flow of vehicles (transit/sec). $\overline{D1D2}$ is the length of the finite line source, expressed in m. The parameters D_1 and D_2 are estimated with the method of the difference between sequences of measurements at different distances from the stop point.

A combination of equations (2), (7) yields the sound power level:

$$(8)\ L_{w\ (1/sec)} = SEL + 10\log_{10}\left(a/[\mathrm{arctg}\,(D_1/a) + \mathrm{arctg}\,(D_2/a)]\right) + 11\ [dB];$$

Then Formula (4), (5) and (6) were used to calculate the sound power levels for the daytime the evening time and the night time.

3. Case Study

3.1 Venice

The mainland of Venice is a large urban area, composed of five boroughs: '*Mestre-Carpenedo*', '*Marghera*', '*Chirignago-Zelarino*' and '*Favaro Veneto*'. *Mestre* is the most populated borough of the mainland of Venice. In Venice, Public Transport is managed by ACTV (*Azienda del Consorzio Trasporti Veneziano).*

The main bus terminal, '*Piazzale Roma*', is located on the western edge of the *Old City* at the intersection with other major transport hubs. Several bus lines link the mainland with the *Historical Center of Venice* via the road bridge '*Ponte della Libertà*'.

On the islands of Lido and Pellestrina, which form a barrier between the southern Venetian Lagoon and the Adriatic Sea the busses are also allowed.

The Municipality of Venice (Mobility Department) provided the overall traffic flows for the main roads estimated by a calculation model based on instrumental sample surveys. Additional surveys campaigns were carried out to complete this database with a realistic assessment of the traffic flows and speeds of all the low density traffic roads.

GIS (geographic information systems) is an essential tool in the noise mapping because it allows collecting all the spatial input data necessary to develop the noise model. A geo-referenced map with all the bus lines, the traffic flows for each of them (divided in day, evening and night periods) and the bus stops was developed in GIS software (Arcview).

3.2 Characterization of the bus fleet

In the NMPB 96' model the sound power level for unit of length is defined as:

$$(9)\ L_{wAi} = [(E_{LV} + 10\log_{10}(F_{LV}))(+)(E_{HV} + 10\log_{10}(F_{HV}))] + 20 + 10\log_{10}(l_i) + R(j);$$

Where (+) represents the energetic sum; L_{wAi} is the sound power level for the finite element of the road (length li); E_{LV}, E_{HV} are the sound pressure levels ($L_{Aeq,1hour}$)for one vehicle transiting (light vehicle, heavy vehicle) measured at 30 m from the edge of the kerb at 10 m height; F_{LV}, F_{HV} are the traffic flows (vehicle/h) for the light and heavy vehicles; R(j) is the sound spectrum normalized for the traffic flow.

Different measurements were carried out to check the consistency of the NMPB traffic model with the roads scheme of Venice.

The noise emission levels of the buses were determined by direct measurements (SEL) performed under controlled conditions.

The measurements were performed on a paved area (car park) free from buildings and other obstacles. The buses of different categories have been made to transit at different speeds and for each of them was evaluated the sound level emitted and the relative spectrum. In the urban environment the deceleration and acceleration phases of a bus give an important contribution to the noise levels, for this reason for each type of bus it has also been performed a test simulating a stop.

Fifteen different types of buses were characterised acoustically covering almost all of the fleet of ACTV. This was accomplished thanks to the cooperation of ACTV that has provided the vehicles for the measurements. It was possible to divide the different types of buses into six categories similar acoustically.

From the SEL measurements it was possible calculate E with the following formula:

(10) $$E = SEL - \log_{10}(3600) + \log_{10}(R/30)$$

Where R is the distance in m of the point of measure from the carriageway;

Figure 1 – An example of stop phase noise characterization

The microphones were positioned perpendicularly to the sound source to be measured, at 10 meters from the kerb at 3.3m height in free field condition.

A Radar Doppler was also installed to check the different speeds of the busses during the acoustic measurements. The following table shows the sound levels measured for the different bus categories at different speed.

Table 1 – Busses noise emissions (dB(A)) for the different categories - E (Rif. NMPB Routieres 96)

Type of bus	20 km/h	35 km/h	35 km/h + stop	50 km/h
Urban line 12 m length	40.3	39.7	46.3	41.4
Urban line 10 m length	40.8	40.1	47.0	43.0
Urban line 18 m length	40.4	40.8	46.5	39.5
Suburban line	39.4	38.6	43.8	39.5
Lido fleet	36.6	37.1	42.4	36.9
Night- lines	40.3	40.2	46.4	40.7

3.3 Noise Modelling and Calibration

A 3D acoustic model of Venice has been created using IMMI environmental prediction software. The software carries out calculations of environmental noise propagation using algorithms set out in ISO 9613-2 (1996) “Attenuation of sound during propagation outdoors”.

It allows the prediction of the equivalent continuous A-weighted sound pressure level at various receiver positions from known sound sources. It takes into account physical effects such as geometrical divergence, atmospheric absorption, ground effect, reflection from surfaces and screening obstacles.

The model requires input of local topography, ground absorption characteristics, major structures, locations of all noise sources and receivers. The digital ground model (DGM) and the digital building model (DGM) were defined from reference regional cartography, provided by Veneto Region.

The sound absorption of the land within the area of study has been modelled as hard (fully reflecting all sound).

Each section of road affected by bus transit has been associated with a specific sound emission value. A geo-referenced database of acoustic emission public transport was created. The bus noise source has been modelled as a line source at 0.5 m above the road level. The stops have been treated as additional sources of limited length of the linear type, adjacent to transit routes, with specific emission values. The sound power level assigned to bus the stops was derived by subtracting the expected value of E for the transit without stop from the value calculated with a stop.

In order to validate the calculations the simulated values were compared with field measurements.

Figure 2 –Example of bus noise as modelled in the acoustic software (IMMI)

4. Results

After running the simulation software we obtained noise levels in term of L_{day}, $L_{evening}$ and L_{night} over a grid of calculation 2m step. The calculation was performed at 4 m from the level of the ground as required from the European legislation. It was possible estimate the contribution of the busses to the traffic noise.

5. Conclusion

Road transport plays a central role in transport networks, and while providing a lot of positive benefits the operation of road vehicles can also lead to adverse environmental impacts. A range of alternative fuels is available for road transport vehicles. Noise mapping is an excellent tool for urban planning. It allows the quantification of the noise in the area of interest and the evaluation of the exposed population to the noise.

The contribution of the public road transport (buses) was evaluated separately, also in order to determine whether and in what circumstances a possible intervention on this traffic component, as part of the noise abatement plan, could result in a significant reduction of the noise level.

REFERENCES

1 McGraw Hill Professional Architecture – Urban Transportation Systems (2004).

2 Italian Framework Law n. 447/1995.

3 Noise Directive 2002/49/EC of the European parliament of the Council of 25th June 2002 relating to the assessment and management of environmental noise.

4 Licitra, G., Noise Mapping in the EU Models and Procedures, CRC Press, (2011).

5 CETUR, 1980, Guide du bruit des transports terrestres-Prevision de niveaux sonores in French.

6 Bies, D., Hansen, C. Engineering Noise Control, Spon Press (2014).

7 Watson R., Downey O., *The Little Red Book of Acoustics*, Blue Tree Acoustics (2008).