In Situ Characterization and Noise Mapping of Ships Moored in the Port of Venice

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Acoustical characterization and mapping of noise emitted from ships were carried out on behalf of Venice Port Authority in the frame of the European Project Eco.Port (Cod. 41).
According to Directive 2002/49/EC (END), several noise sources (like roads, railways, aircraft, industrial sites, ports) have to be considered and mapped separately; so, in the first step, the acoustical characterization of ships is required.
Annex IV of the Directive, in particular, establishes that strategic noise maps for agglomerations shall put a special emphasis on noise emitted by industrial activities, including ports.
Four kinds of ships were investigated, using the combined Italian technical standards UNI 10855 and UNI 11143: (1) inland navigation ships (along wharves), (2) ferries (along wharves and when manoeuvring), (3) Cruises, small size (along wharves), (4) Cruises, large size (along wharves and when manoeuvring).
The geometrical and acoustical model of the city of Venice was developed, using SoundPLAN 6.4 applications package, and the information needed to comply with Directive 2002/49/EC was gathered.

1 Introduction

The acoustical characterization and the mapping of moored and transiting ships in Venice Port were carried out, on behalf of the Venice Port Authority promoting the European project Eco.Port (cod.41).

This project, co-financed by European Union within the Adriatic New Neighbourhood Programme INTERREG CARDS/PHARE 2000-2006, was jointly developed with Rijeka Port Authority (Croatia) and supervised by the Department of Technical Physics of the University of Padova.

The main task of the project is the characterization and the description of port-related noise by means of acoustic maps.

With its geographic position, Venice Port is interested by both cruise and business traffic, being a fundamental European crossroad. Venice Port Authority increased its competitiveness and improved the port activity's management and organization efficiency by putting private companies directly in charge.

Concerning the industrial and commercial traffic, carried wares are cereals and milled grains, coal, liquid or metal goods, as well as merchandise of any kind, travelling in containers or directly on vehicles.

As for passengers, cruise ships sail from Venice heading mainly for Adriatic and Mediterranean tourist destinations, ferries provide year round departures for Greece and the East Mediterranean, hydrofoils reach Croatian and Slovenian tourist resorts; the passenger terminal also offers facilities specifically for the large size yacht market.

The total passenger traffic in 2007 amounted to 1503371 people, about 6% more than in 2006; the cruise ship, ferry and hydrofoil traffic for the same year were 1351 boats in total.

2 Identification of the main noise sources and development of the simulation model

In order to plan and perform correctly all further analysis, the main noise sources were first identified by means of an exhaustive on site inspection.

Based on these preliminary surveys, it was decided to start with the acoustical characterization of four kinds of ships, each represented by a single vessel, the essential features of which are listed below:

i) inland navigation ship, registered ton ~ 1700 ts;

ii) ferry, registered ton ~ 30000 ts;

iii) small size cruise, registered ton ~ 1400 ts;

iv) large size cruise, registered ton ~ 109000 ts, overall length 290 m, maximum width 36 m, maximum speed 23 knots, maximum capacity more than 4000 people.

Fig.1 Cruise (large size) moored.

It was also planned to describe by means of *SEL* (Sound Exposure Level) the ships' transit along Canale della Giudecca and the entire route through the lagoon to the open sea, so including the part in front of Piazza San Marco and Riva degli Schiavoni (San Marco dock).

In order to place the investigated port related noise sources in their context, it was also deemed it necessary to model and to simulate even the main environmental noise sources, consisting of the vehicular traffic on Ponte della Libertà (between Piazzale Roma, Venice, and the mainland), and, above all, of the overall vessel traffic (public and private) in Canale della Giudecca and Canal Grande.

As a consequence, a wide territorial area was considered in the analysis, at a rough estimate matching the town centre, including Giudecca island.

Figure 2 shows the digital building model (DBM) considered, developed with the CAD module of SoundPLAN, which was then used for the subsequent acoustic simulations. Three areas are marked: the Marittima zone (M), where ferries and medium to large sized cruise are moored, the San Basilio zone (B), where hydrofoils and small to medium sized cruise are moored, and, finally, the area adjoining Riva dei Sette Martiri (R), where inland navigation ships and large sized yachts lie along wharves.

Fig.2 Venice DBM model.

The following data and information were collected in order to define a computerized modelling of the geometrical and acoustical features of the specified area and perform the simulations correctly:
a) Digital Ground Model (DGM), from cartography provided by Veneto Region;
b) Digital Building Model (DBM), from cartography provided by Veneto Region;
c) Noise limits established by the Urban Acoustical Plan, provided by the Local Authorities of Venice;
d) Number of residents and dwellings per district, provided by the Local Authorities of Venice;
e) Vehicle traffic flow and speed, subdividing "light" and "heavy" vehicles, along roads both internal and external to the Venice Port Authority's premises, provided by Venice Passenger Terminal and by Province of Venice;
f) Flow of ships through Canale della Giudecca and San Marco dock, provided by Venice Port Authority;
g) Course of the ships through Canale della Giudecca and San Marco dock, provided by Corporazione Piloti Estuario Veneto;
h) Meteorological data, ten year average, split into three periods of the day ("day" 6.00-20.00, "evening" 20.00-22.00, "night" 22.00-6.00), provided by ARPAV (Veneto Region Environmental Protection Agency);
i) Meteorological data, with one hour time step, during execution of the acoustic measurements for model calibration and validation, provided by CNR-ISMAR.

3 Moored ships characterization

Concerning the investigation methods employed for acoustic characterization of moored ships, several national and international technical standards were adopted.

The Italian technical standard UNI 11143 [1], for the assessment of environmental noise and noise impact, proved to be particularly relevant for choosing the measurement positions, made for each specific case bearing in mind the following three categories:
- *Reference Point*, point of measurement near the source that make it possible to estimate the sound power level of noise sources (paying attention, for example, to noise source directivity);
- *Verification Point*, significant point for checking the correctness of the hypotheses about geometrical features (e.g. presence of reflections and/or obstacles) and acoustical features of the site (e.g. meteorological conditions, ground characteristics);
- *Reception Point*, e.g. the point of measurement chosen near a receiver that is considered significant for checking the assessment of the acoustic emission of a noise source.

In the view of the optimal use of acoustic data, one of the basic concepts of the Italian standard UNI 10855 [2] was adopted. On the basis of the determination of the contribution from a noise source at a specific position, its sound power level may be estimated by the reverse use of the computation method provided by international standard ISO 9613-2 [3]. Assuming the geometric and acoustic characterization of the investigated sources is known, this hypothesis is verified and validated by calculating propagation from source to receiver according to ISO 9613, those receivers being selected according to the above mentioned UNI 11143. The calculated value is then compared to the one determined by measurements, which leads to model validation, if necessary by repeated steps.

Nevertheless, the UNI 11143 evaluation method cannot be always followed in a strict way in a complex context such as a port.

The main reasons are:
- high background noise, due to other ships moored and transiting, to vehicles and machinery in operation or standing with idle engine and to various activities typical of port areas;
- often adverse site geometry, due to large buildings and to water surfaces severely restricting the areas otherwise usable for noise measurements.

It is important to consider that the acoustic centre of the main sound sources are at a remarkable height and their directivity is mainly vertical, requiring measurements at rather great distances; this completes the picture about the difficulties in identifying useful positions for noise measurements.

The following figure shows the placement of the reference, verification and reception points aimed at the acoustic characterization of a large cruise ship. Reference points (eight in number and separated by forty metres except the first two) are placed along a line parallel to the ship at about 150 metres from it; the verification point, along the same line as the reference points, is 300 metres from the ground projection of the funnels (the noise source); the reception point is about 450 metres from the source.

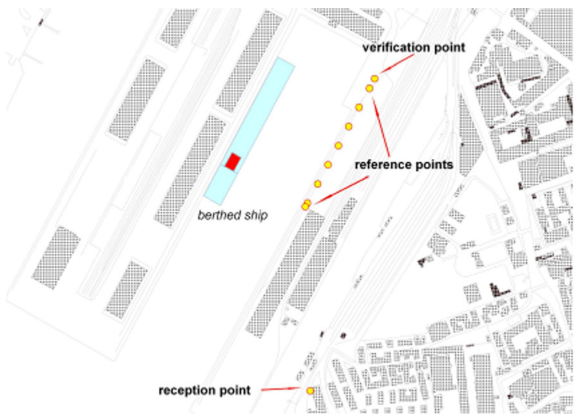

Fig.3 Reference, Verification and Reception Points.

4 Transiting ships characterization

A relevant part of the survey consisted in determining noise emissions from ships on their way seaward through Canale della Giudecca and San Marco dock.

As a first step, the geometry of the noise source under analysis was set. Basically, that meant to have knowledge of the exact routes of ships along Canale della Giudecca, together with data regarding the height of the acoustic centre of the noise source itself, e.g. the funnels.

Transiting ships were therefore modelled as a line coinciding with the ships' route and at a height equal to the acoustic centre of the noise source.

The very narrow angle at which involved receivers are viewed by the noise source makes the knowledge of the source directivity unnecessary. Then, the estimation of the sound power level per meter is sufficient for this study.

To that purpose one-week measurements were carried out, having the microphone placed at 6.3 metres height and 1 metre off the facade of a building in the first row of houses along Canale della Giudecca.

Fig.4 Canale della Giudecca as seen from the one-week measurement point.

The sound level meter was then set up to gather the main acoustic parameters, on a one-second-sampling-time basis.

To comply with the aim of the survey, time history of the one third octave band L_{eq} spectrum was essentially considered for further analysis.

In Table 1 *SEL* (Sound Exposure Level), A weighted, gathered during the one-week measurement are showed. Data refer to eight transits of two ferries, considering arriving and leaving; source-receiver distance is about 170 meters. Analogous results were obtained as concerning a large size cruise transiting.

Ship type	direction	SEL value
A	arriving	87 - 90 dB(A)
A	leaving	89 - 90 dB(A)
B	arriving	88 - 91 dB(A)
B	leaving	88 - 89 dB(A)
- SEL values are referred to a source-receiver distance of about 170 metres - SEL values are rounded to one unit		

Table 1 Ship transit *SEL* values (A weighting).

The *SEL* values average out at 89.2 dB(A) (arithmetic mean), standard deviation equals 1.2 dB, interval is 3.5 dB, minimum value 87.4 dB, maximum value 90.9 dB. Input data for calculations, e.g. sound power level per meter in the range 20 Hz - 5000 Hz, were obtained on the basis of those *SEL* measurements.

The spectrogram in Figure 5 clearly shows the typical spectrum of a transit; in particular, the marked presence of low frequency components is noticeable, even below 20 Hz.

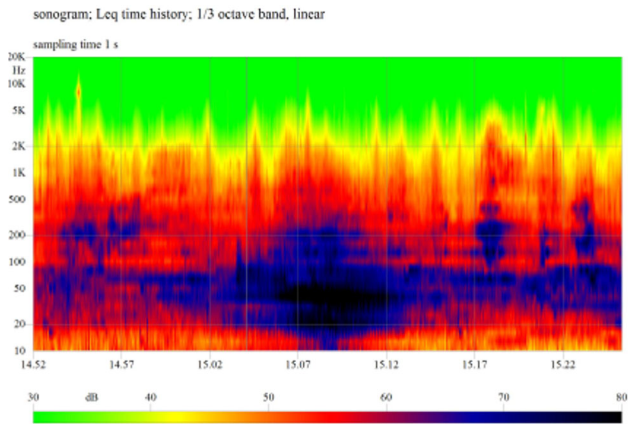

Fig.5 Spectrogram zoom showing a ship transit during the one-week measurements along Canale della Giudecca.

Similar methods and procedures were used to model transits of cruise ships and of the rest of public and private vessels in Canale della Giudecca and Canal Grande. The French standard NMPB Routes 96 was used to model vehicle traffic along public roads and those inside the port areas.

5 Notes on the acoustic modelling of a port area

The wide area considered in defining the computerized model and furthermore the conspicuous quantity of data collected make an important set of possibilities, available for meeting both the Italian regulations and European Directive 2002/49/EC [4]. The analyses concerning all the characterized and modelled noise sources are currently being carried out.

The difficulties of assessing the contribution of port related sources to environmental noise lie in the complexity of the urban context to which they pertain.

Here we aim of analyzing some modelling issues that arise when dealing with urban sites having a significant waterfront.

Setting up the algorithm for calculations, it is particularly important to define the number of reflections taken into account as well as the "reflection depth" parameter.

Here, to gain a first guess of the inaccuracy potentially due to different choices of these parameters, two calculations were performed over a vertical section, both in Canal Grande and in Canale della Giudecca. The first calculation was carried out considering two reflections and putting reflection depth equal to three; the second one was executed increasing the parameters considered by two units.

The worst cases showed differences between the more and the less accurate calculations of about 1 dB, which is tolerable.

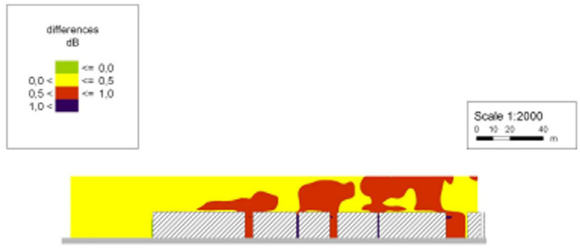

Fig.6 Differences between the L_d (daytime level) estimates, both in Canal Grande (upper figure) and in Canale della Giudecca (lower figure), showed in vertical section.

From a general point of view, it should be said that, in cases where the wider area involved in calculations would force to limit the number of reflections to one, the inaccuracy of the estimated sound levels could significantly increase.

In terms of the best descriptor to adopt for measuring annoyance levels, the inaccuracy related clearly affects the Highly Annoyed [HA%] less than the Annoyed percentage [A%].

From this point of view, withholding other relevant considerations, the first descriptor would seem preferable to the second.

6 Further developments

This analysis, as so far carried out, shows various noteworthy future developments. The following is a concise non exhaustive outline of the main cues offered by it.

Firstly, after grouping the Venetian canals into few classes by acoustic similarity, it is possible to use the approach adopted here to develop accurate maps of noise from vessels, both public and private, in the whole of Venice.

Furthermore, with the availability of *SEL* values and traffic data concerning public transportation boats and having already characterized transiting ships by *SEL*, as well as acquired flow rates, it is possible to apply the technique adopted here in order to split out each noise source (ships, public transportation boats, private vessels) and consider them in the context of the environmental noise.

Specifically concerning port noise, it is possible to refine the survey by grouping all cruise ships and ferries present at Venice port into a larger number of acoustic categories, again using the proven methods built upon UNI 11143.

These results may be checked and improved by studying the time evolution of the various situations examined, by means of short and/or long term measurements carried out at significant positions or in the neighbourhood of specific groups of receivers.

Nowadays the dose/effect relationships related to roads, railways and airport noise emissions are well known, nevertheless correlations with industrial noise and port noise, due to berthed and transiting ships, are lacking.

Developing adequate tools for acoustic characterization and analysis is therefore of primary importance towards determining sound levels and the population's exposure to noise, on which the described fundamental socio-acoustic investigations are based.

References

[1] UNI 11143, "Acustica - Metodo per la stima dell'impatto e del clima acustico per tipologia di sorgenti" (2005)

[2] UNI 10855, "Acustica - Misura e valutazione del contributo acustico di singole sorgenti" (1999)

[3] UNI ISO 9613-2, "Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation" (2006)

[4] Directive 2002/49/EC of the European Parliament and of the Council of June 25th 2002, relating to the assessment and management of environmental noise (2002)