ON FIELD EXPERIMENTAL CHARACTERISATION OF THE SHIP SOURCES OF ACOUSTIC POLLUTION WITHIN A COMMERCIAL HARBOUR

Massimo Viscardi, Tommaso Coppola, Franco Quaranta and Enrico Rizzuto*

University of Naples Frederick II – Dept. of Industrial Engineering (DII), Naples, Italy
**email: enrico.rizzuto@unina.it*

Daniela Siano

National Research Council (CNR) – Istituto Motori, Naples, Italy

The noise associated to ship operations within large commercial harbours is an issue because often these infrastructures affect strongly the overall acoustic levels of close residential areas. The dimensions and complexity of the ship noise sources and of the transmission path to the receiver make the sound pressure field particularly complex. In this situation, even an assessment of the acoustic impact of harbours may be particularly difficult to achieve, if based on a purely experimental approach. This situation calls for the use of prediction models that, with a proper calibration, allow exploring with continuity the acoustic field in the areas around the source. Moreover, models become essential when studying corrective actions and comparing their effectiveness. Within this general context, the present work illustrates the preliminary experimental activities carried out in a part of the Naples commercial harbour for the calibration of a numerical model of the noise field associated to the operation of a specific ship. The model, based on a Ray Tracing approach, includes both the main noise sources on board the ship and the surrounding physical structures (buildings and infrastructures characterizing the area). The paper describes the main characteristics of the model and presents the procedure envisaged for its development and calibration. Results of the on-field experimental campaign in a portion of the port of Naples are presented and discussed in view of the identification and characterisation of the ship sources detected and surveyed and of the first part of the propagation path around the ship.
Keywords: Acoustic impact from ports, Ship noise emissions, Noise propagation models

1. Introduction

Many ports, in particular in the Mediterranean Sea, are located close to urban areas, often as an integrated part of towns historically developed right around their harbours. Maritime, industrial and construction activities located in the port, therefore, take place often in the proximity of the town centre, thus affecting the environmental quality of quite densely populated areas. Ports, as a matter of facts, are major contributors of chemical and noise pollution [1], in particular in this situation of proximity.

When evaluating the acoustic impact from a port area, specific aspects regard the characterisation of sources. In harbours, in a relatively small area, several types of noise sources are present, with different characteristics: ships (sailing, manoeuvring or moored, with different emissions in the various situations), cargo handling equipment (cranes, buckets, conveyors, ramps, respectively for loading or unloading of containers, bulk cargo, cars and trucks), vehicles for transportation of goods in and out the port (trains, trucks), facilities for industrial activities (like maintenance, repairing, construction of vessels). Most of these potential sources of noise have typical transient or intermittent characteristics or anyway feature stationary emissions just for small periods of time (hours, instead of months, like for a typical industrial plant).

Among all these sources, ships are the most typical ones. They are complex sources, due to their dimension and to the number of plants and mechanisms active on board (incidentally, different for a sailing, manoeuvring or moored vessel, see e.g. [2]). Moreover, ships are moving sources not constrained by rails or lanes: even when they are placed in repetitive positions, (same ship on the same quay), or follow the same approaching manoeuvre in port, the situation may differ to some extent from case to case (as the same manoeuvre can be carried out differently and the position on the quay can vary, too.

As regards the propagation from the source to the potential receiver, relevant typical factors are the presence of the sea and of the quays (reflecting surfaces) in addition to the (more conventional) presence of buildings within the port and in the surroundings.

From a normative viewpoint, the acoustic pollution from ports (impact on the potential receivers i.e. the inhabitants of the surrounding urban areas) is not regulated by specific requirements, being generally applied those set for industrial plants [3]. This poses a few problems, related to the specific features of the emissions from ports, in particular related to the spread and number of sources and the time variation of the emission. Another specific aspect is that, within the port, a number of regulatory bodies are involved (Port Authority, Coast Guard, Class Societies, Environmental Agencies,…), making the issue of requirements and their enforcement quite problematic [2].

Even limiting the analysis to the propagation problem, for the above mentioned characteristics the noise field in the proximity of ports is particularly complex and difficult to be assessed. Experimental investigations can obviously cover discrete positions in space and time, but a full assessment of the acoustical impact calls for predictive models able to investigate with continuity different emitting and receiving positions. On the other hand, the development of numerical models of noise propagation from ports is particularly challenging right because of the complexity of the noise field [4].

The paper focuses on acoustic pollution originating from an area of the port of Naples and affecting the surrounding portion of the town (including a major touristic attraction of the municipality of Naples: the 'Maschio Angioino' castle). This investigation is a part of a wider impact analysis being carried out by the University of Naples on the port of Naples and taking into account also the effect of chemical pollution in the surrounding area [5], [6].

The paper presents a theoretical/experimental activity carried out in a specific area of the port of Naples and aimed at exploring the possibility of developing an effective model for the prediction of the noise field from ships.

2. Object of the investigation

The port of Naples (Figure 1), featuring an annual traffic capacity of around 25 million tons of cargo, is one of the largest in Italy and in the Mediterranean Sea. The port employs more than 4,800 people providing services to more than 64,000 ships per year. The port of Naples is divided into two main areas, distinct for type of traffic and geographical location.

The west end, closer to downtown, is dedicated to passenger traffic and features three sub-areas:

- Molo Beverello, with hydrofoil service connecting the town to the three main islands in the Gulf. Every day hundreds of people, (tourists and commuters) embark from this pier;
- Molo Angioino, pier for cruise ships. A large passenger terminal was recently built on it
- Calata Porta di Massa and Calata Piliero, two more piers used for long range ferry boats.

The East area (much wider) is dedicated to cargo vessels, equipped with several basins and facilities for handling and storage of liquid and dry goods and containers.

The present investigation is focussed on different locations of the west end. Notwithstanding the relative wide variety of passenger ships present in this part of the port, the absence of other sources of industrial type or dedicated to cargo handling allow to focus particularly on ship sources.

Figure 1 - Port of Naples

3. Experimental campaign

On July 6th and 7th 2016, an experimental campaign has been carried out within the passenger port area (west end, see circle in Figure 1) of the port of Naples. The purpose of the campaign in the context of the present study was to provide data for a first characterisation of ship source and for a calibration of a propagation model.

3.1 Measuring locations

A first target of measurements were the ferry ships anchoring and mooring in the area of Magazzini Generali (position 2). The activity in this location is repetitive every day: a ferry arrives around 6 am and departs at 18/20 pm. During this period, the electric power generators run all the time on the moored ship, emitting a stationary noise. The closest receiver (buildings located in the road aside the port) is about 250 m far away, with no main obstacles in between.

To characterize this noise source, measurement were carried out in various locations, (reference is made to areas 1, 2 and 3 circled in red in Figure 2), at different distances and at different angles from the ship (refer to the position of the white ship in the same figure).

Other measurements carried out in area 4 of Figure 2.were dedicated to the characterization of the Beverello harbour, specifically dedicated to the traffic of fast boats heading to the gulf islands

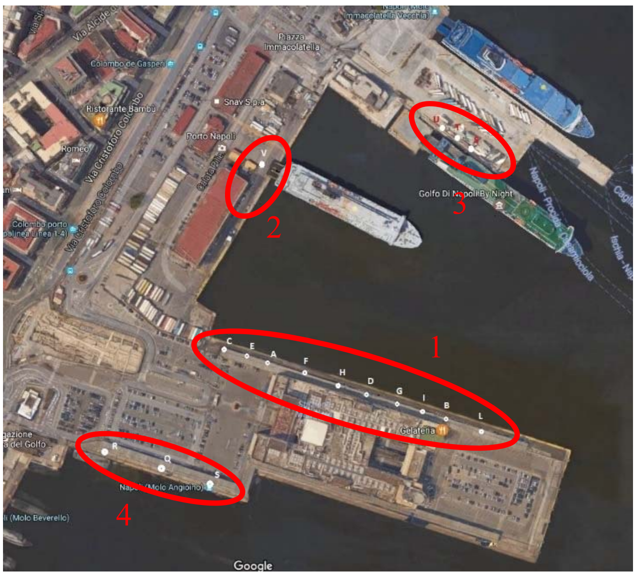

Figure 2 - Measuring points in the Port of Naples

In particular, the manoeuvres of a single incoming vessel, (access to the area, turn, reverse gear, anchor lowering, astern motion at different speeds and berth) have been surveyed from positions A and B in area 1 and from position V in area 2.

The same vessel was later surveyed while moored, with electric generators running and with and without garage fans in function. These surveys were carried out in positions C,D,E,F,H and, at different times, in positions I,D,L,G and U,T,S.

3.2 Acquisition tools and data processing

During the experimental campaign three sound level meters (two Larson Davies 824 and one LTX) were used; these instruments provide a quantification of all the significant acoustic parameters and the spectral parameters.

4. Ship source identification

A first set of results of the experimental campaign is presented in this section. The aim is to characterise the noise emission from a ferry boat, both during the manoeuvre following the entrance in the port and during the subsequent stationary period spent at quay.

As known (see e.g. [4]), the noise emitted from ships is significantly different according to the operating conditions. Such conditions can be grouped into main categories:

- Navigation
- Manoeuvre
- Ship stationary at quay (no cargo handling)
- Loading/unloading

The characterisation of the ship as a source of airborne noise in the various phases is a challenging activity and not always it is possible to carry out dedicated measurements, as in [7] for a ship moving and in [8] for a ship at quay.

In the present study, on field surveys were carried out from stationary positions on ground, during the normal operation of the ship, with the twofold aim of a first characterisation of the ship source and of obtaining for the specific case elements of the transmission field in the port area.

4.1 Ship in motion

Surveys were carried out on a ferry boat entering the port and manoeuvring in order to moor in the area of Magazzini Generali in a position similar to that occupied by the white ship in Figure 2. Noise records with time length of 30 seconds were stored in form of third octave band spectra. Comparing the single records it is possible to group them into time periods corresponding to emissions comparatively stable, identifying a particular acoustic phase of the manoeuvre. Figure 3 and Figure 4 present a summary of the results derived from surveys in position A, figure Figure 5 gives an outlook of the acoustic impact of the whole manoeuvre of the ship on points A and V; figure Figure 6 captures a particular moment of the evolution, when the motion of the ship is being reversed.

As it can be seen from the comparison of Figure 3 and Figure 4, the noise emissions (as recorded in position A) fluctuated during the manoeuvre of more than 20 dB in the range 50-5000 Hz. These results are in line with those obtained in [7] in another situation.

The differences in the spectra reflect different conditions of the propulsion plant, as shown in Figure 3. In particular, in the figure different emissions are detectable in forward speed and in reverse gear, the latter situation being more severe for the plant and for the noise radiation. Other differences are due to other events occurred during the manoeuvre. They are dominated by navigational issues (e.g. the period when the anchor is lowered: Figure 4, with stronger contributions in the range 100-5000 Hz) or other aspects (f.i. a loudspeaker announcement to passengers, inducing a considerable rise in levels in the range 300-3000 Hz in a different 30 s record).

It is important to note that, when comparing curves like those of figures Figure 5 and Figure 6, the differences are not only due to the different emission from the ship, but also to the different distance of the evolving ship from the fixed receiving position (except when consecutive records are compared: in that case the distance can be considered as constant).

Figure 5 shows this effect: as the ship gets closer to position V, the surveys (shown in terms of dB(A)) tend to provide higher values.

It is also interesting to note that the relative position between the source and the receivers has an effect on the spectral components recorded: in Figure 6 the spectra derived by two records with duration of 1 min of the same phase are presented: Position A is locate on the right side of the ship, at beam. Position V is located at the stern of the ship at a different distance.

The different shape of the spectrum in position V indicates a directivity in the ship radiation depending on frequency.

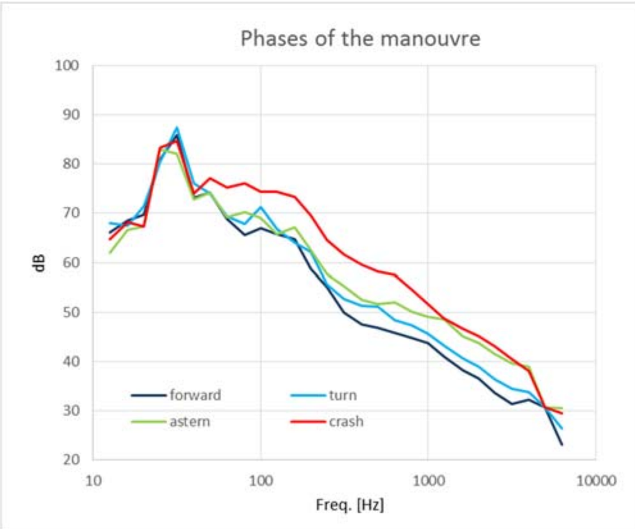

Figure 3 - Different conditions of propulsion plant

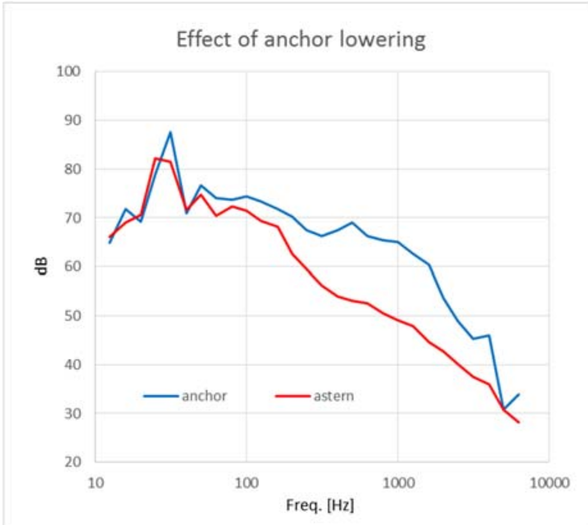

Figure 4 - Effect of anchor lowering

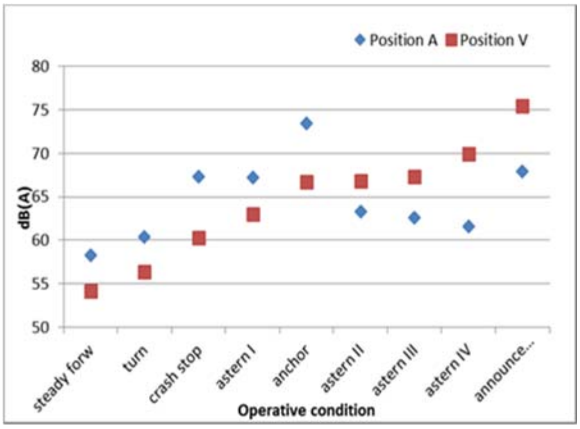

Figure 5 - Effect of the relative position source-receiver: whole manoeuvre, values in dB(A).

Figure 6 - Effect of the relative position source-receiver: single phase of the manoeuvre, spectra surveyed in positions A and V

4.2 Ship at quay

In this section the results of the characterisation of the same ship of the previous section are presented for the vessel stationary at quay. Two operating conditions were surveyed, corresponding to:

- Condition 1: Electric generators running and garage fans in function
- Condition 2: Electric generators running and garage fans shut down

Results are presented in Figure 7 to Figure 9. As it can be seen, in both conditions the surveys show a quite diffused noise field (with no major differences in the spectra measured in the various positions of zone 2, on the pier across the basin).

The garage fans, whose operation represents the difference between condition 1 and 2, generate noise in the frequency range 200 to 10000 Hz, as shown in Figure 8 for the average of all measuring positions.

Figure 9 reports a comparison between a few spectra emitted by the ship during manoeuvre and those regarding the ship at quay. As apparent, the phases involving operation of the propulsion plant show stronger contributions in the frequency range up to 100 Hz, while the ship at quay generates higher emissions at higher frequencies, in particular in the range 200-5000 Hz. In such frequency range the emissions of electric generators and/or fans dominate.

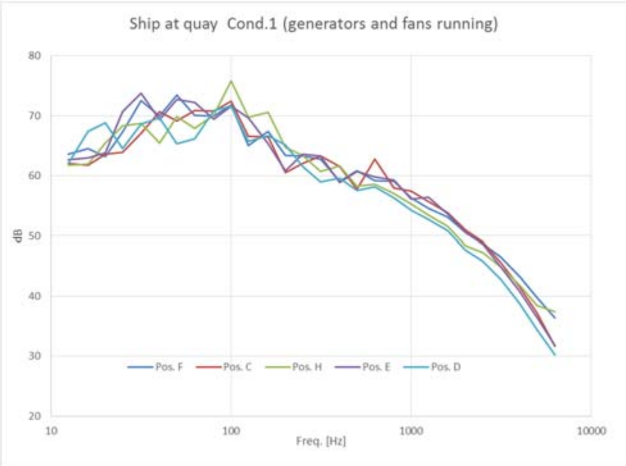

Figure 7 - Records of the moored ship in condition 1 (different positions)

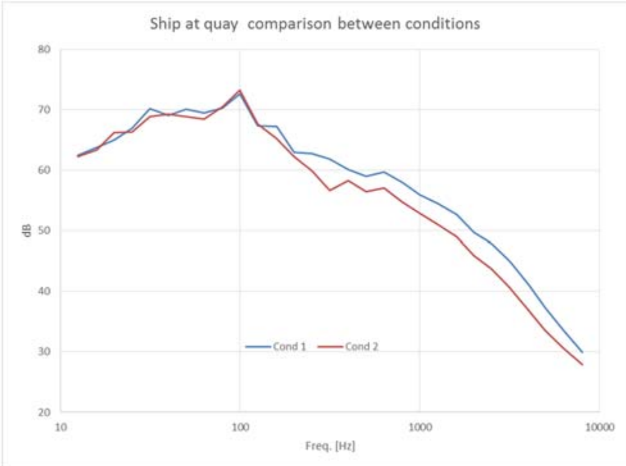

Figure 8 - Comparison between operating conditions of the moored ship (average of different positions)

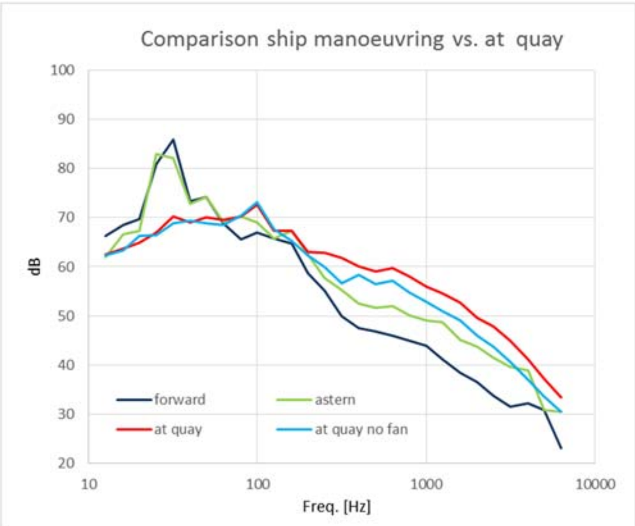

Figure 9 - Comparison between different conditions: in motion and at quay (Pos. A)

4.3 Manoeuvring of fast boats

The fast boat traffic, mainly located in the Beverello side of the harbour (lower left corner of Figure 2), is characterized by a large number of trips per day, because of the frequent connections to the gulf islands. The boats that are used for this service differ very much from one another, in terms of dimensions, architecture, power and, accordingly, noise radiation. The following graphs (Figure

10 to Figure 12) present a first comparison in terms of interval equivalent levels and overall equivalent levels for different boats in consecutive records of departure and arrival manoeuvres.

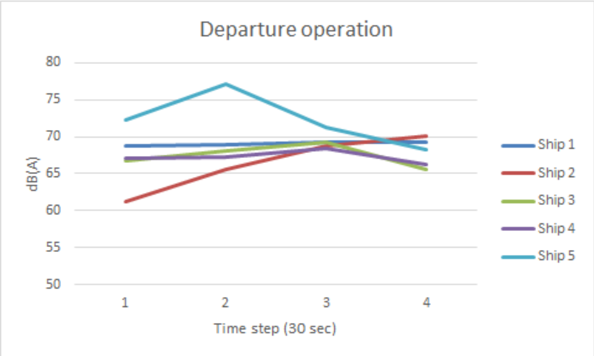

Figure 10 - Departure operation (Point Q)

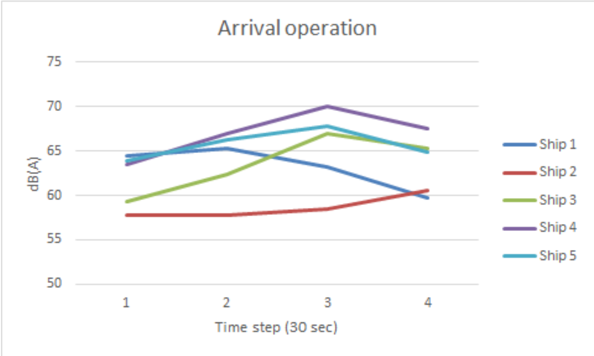

Figure 11 - Arrival Operation (Point Q)

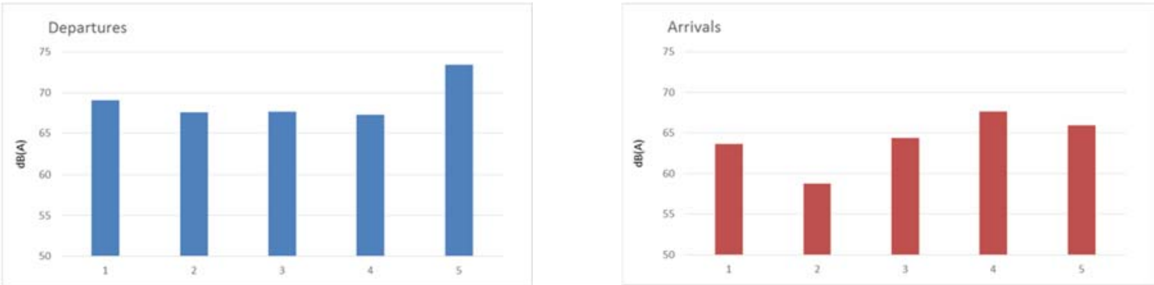

Figure 12 - Comparison of overall L_{aeq} at Point Q for different phases of arrival and departure

It is evident that for these boats too, fluctuations can be quite strong during the same manoeuvre (see Figure 10 and Figure 11). Further, differences between the noisiest and the quietest boat can reach 20 dB(A), see Figure 12. This indicates the need for a detailed work of characterisation of these sources, too.

5. Future developments: numerical model

As mentioned above, the long term goal of the study is to investigate with continuity the acoustic field in the areas surrounding the port. The experimental data here reported and possibly more data collected in future campaigns will therefore be used to calibrate and validate a numerical model by which a more detailed investigation will be enabled.

A first use of the data here reported regarding a ferry boat in various phases of the mooring manoeuvre and of the stay is aimed at the characterisation of this type of ship source in the various operating conditions. As mentioned above, for the measurements during the manoeuvre, the fact that surveys were carried out from fixed positions while the ship was evolving (moving and, to some extent, turning) prevents to consider the results as a direct characterisation of the source. Variation in levels among the various records may be due to a variation in the source emission as well as to a variation in the source-receiver relative position (not only in distance, but also in angle).

A complete interpretation of results for the manoeuvre is therefore postponed to the development of a propagation model in the area of measurements. Measurements carried out on the ship moored at quay from different angles can, on the other hand, be used to calibrate the propagation model and in particular the model of the source. The latter step represents the next phase of the investigation, which has just begun with the use of the Terrain software by Olive Tree Lab-Suite. After the satellite map of the area has been imported, the buildings and the characteristics of the environment have been defined (Figure 13). At the same time, virtual Sound Level meters have been placed, in the locations corresponding to the actual surveys

. The adopted software is based on the ray-tracing procedure, in which, as known, sound beams are modelled: the sound intensity decrement with distance is computed, as well as absorption by the atmosphere, reflections and diffractions due to interactions with 3D solid objects. The model is based on high frequency resolution calculations, but results can also be represented in 1/1 and 1/3 octave, both as sound spectra and cartographic maps. Figure 14 shows an example of propagation, based on a simple single point source placed on the funnel of the ship.

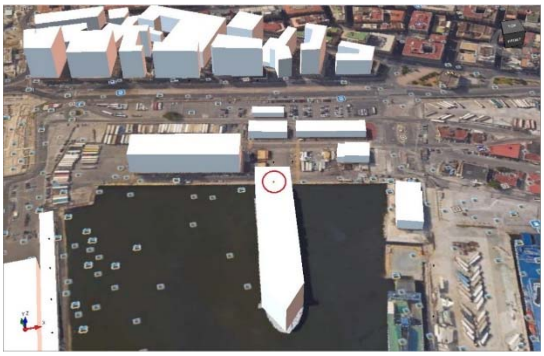

Figure 13 - CAD model

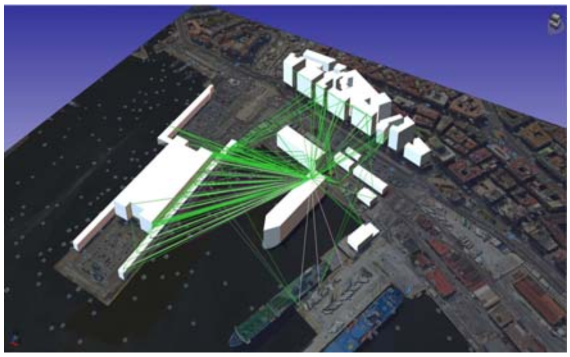

Figure 14 - Ray propagation (example)

6. Conclusions

Within the paper, first results concerning the acoustic characterization of a few noise sources active in the Naples commercial harbour have been presented. Two areas of the passenger port have been investigated during the campaign: one where large ferry boats anchor and unload and the other where small fast boats connecting the gulf islands operate. A large ferry, in particular, has been well characterised in terms of noise signature surveyed in different positions and in different phases of the approaching manoeuvre as well as in the subsequent states of the ship while moored. These data will be used in a second part of the on-going activity that will involve the calibration of a numerical model of the area and of the acoustic propagation. The process of calibration will include a proper identification of noise sources distributed of along the ship, with specific characteristics in terms of source levels and spectral contents, so that the field measured ashore can be properly reproduced. The numerical model, once calibrated, will permit to predict noise propagation scenarios as well to evaluate noise level at specific target point.

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