Research Article

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Guidelines for a common port noise impact assessment: the ANCHOR LIFE project

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Abstract: The paper reports the main contents of the guidelines developed in the framework of the project ANCHOR, acronym of Advanced Noise Control strategies in HarbOuR, which is a European Project funded as part of the announcement Life 2017.
The guidelines represent an updated version of those elaborated in the NoMEPorts project named 'Good Practice Guide on Port Area Noise Mapping and Management'; the aim is to define a common approach in port noise monitoring and assessment, considering the outcomes of previous EU funded projects and the algorithms defined by the European Directive 2015/996, in order to produce Port Noise Impact Assessments to be included in ports Environmental Management Systems (EMS).
The procedures described in the guidelines will guide professionals in organizing and managing geographical data, in characterizing noise sources and defining, for each of them, the correct noise emission power level, in evaluating noise propagation and people exposure to noise and, finally, in selecting the most efficient mitigation action by means of a cost benefit analysis.
Moreover, the paper reports the results of a comparison between noise mapping outcomes obtained using the new noise mapping algorithms defined by the 2015/996 Directive and the old 2002/49/EC Annex II ones; especially at long distances from the source the differences between the two methodologies are not negligible.

Keywords: Port noise assessment, noise modelling; noise mapping; noise Action Plan; LIFE project

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1 Introduction

In 2022 the European Commission issued the Environmental Noise Directive (END) [1] to the define the exposure of European citizens to this pollutant through a standardized approach. Nevertheless, the directive allowed each Member State to realize noise mapping activities with its own noise model. This approach caused some difficulties in developing comparisons between the noise mapping outcomes from different countries. In order to tackle this situation, the European Directive 2015/996/EC introduced common algorithms for noise emission and propagation models for roads, railways, industrial areas and airports [2]. These algorithms came from the outcomes of the CNOSSOS project [3, 4].

The END does not require to assess separately the noise emitted by ports (as requested for other transportation infrastructures); nevertheless, when dealing with agglomerations they are considered as industrial activities (strategic noise mapping).

ESPO/Ecoports Port Environmental Review 2021 collected data from 99 European ports to define the main environmental priorities. The report highlights that noise is ranked 4th after air quality, climate change and energy consumption. Relationships with local community are in 5th place [5].

Ports are complex infrastructures, which can be considered as real cities within cities. Ports are of fundamental importance for a city economic growth but they have precise environmental responsibilities towards the citizens.

This is particularly true for urban ports, i.e. ports incorporated in urban fabric, located in proximity of houses and other sensitive receivers. The port areas noise environment is generated by a number of space and time varying noise sources, such as working machines, car traffic, rail-

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way, vessel-quay ramps, cargo handling and vessels. Nowadays, citizens living in nearby urban areas are affected by this problem but concrete awareness campaigns on this field towards both port actors and community have been carried on. Several funded projects and scientific studies dealt with port generated environmental noise.

The Life NoMEPorts [6] produced a 'Good Practice Guide on Port Area Noise Mapping and Management' trying to give a methodological approach for producing noise maps for assessing and managing port noise, based on algorithms for noise calculation given by END, which are now replaced by 996/2015/EC.

SILENV [7] and EFFORTS [8] projects developed tailored procedures for assessing noise emission of port activities, including vessels.

MESP project [9] addressed the pollution reduction from port activities through the implementation of a multidisciplinary approach in air, noise and water sectors with the aim to create homogeneous best practices and procedure guidelines considering contributions from different subjects such as harbour cities, port authorities and scientific skills. Pilot projects have been implemented in Patras and Tripoli (LB) to validate the selected procedures and methodologies.

Concerning good practices, the Cityharbour (Stadshavens) Rotterdam project [10] launched by Greater Rotterdam Area in 2009 faced the spatial planning and noise policies integration by requiring the local authorities to compensate noise levels with benefits in other aspects influencing quality of life, for instance houses with good view, green areas, etc.

Another example is given by Port Metro Vancouver [11], which analysed potential noise management strategies by means of 3 approaches: corporate social responsibility, regulatory and integrated planning approach. The developed policy assessment aims at clarifying which individual strategies should not be pursued in support of an approach and which strategies must be successfully implemented in order for the overall program to meet its objectives and corporate expectations.

As far as academic literature, few studies have been conducted to assess port noise potential health effects. In a 2014 study investigating the noise emissions from the port of Dublin, authors used noise measurements and interviews to citizens. The paper demonstrated that environmental noise in shipping ports has the potential to be a significant public health concern, in particular at night time causing sleep disturbance and unwanted awakenings. Authors highlighted the occurrence of significant low frequency components (10-200 Hz), which:

- can propagate at longer distance
- are more scarcely attenuated by building envelopes
- may have even more detrimental impacts on public health than medium and high frequency noise [12, 13].

Considering this framework, the ANCHOR project (LIFE17 GIE/IT/000562) [14] main objective is to raise awareness, communicate and disseminate the topic of noise pollution coming from ports affecting urban nearby territories among public Administrations and land management decision makers, port authorities, private companies involved in port activities, citizens living in port cities and academics. The process will be led by the development and application of three Best Practices for Noise Governance and Information, one for each partner port authority, in order to enhance relationships among all the port actors, i.e. port authorities, companies and local communities.

In detail, ANCHOR LIFE aims:

- to develop rewarding "Figures of Merits" in port noise governance, which have been successfully implemented in other environmental sectors in ports, and to apply them in Livorno, Piombino and Portoferraio ports. They will stimulate private companies to adopt noise decreasing practices in return for economic benefits or other advantages;
- to design and install a Smart Port Noise Monitoring System in the port of Patras;
- to prepare a Guideline that updates the NoMEPorts one, for the definition of a common approach in port noise monitoring and assessment, considering the outcomes of previous EU funded projects and the algorithms defined by the European Directive 2015/996, in order to produce Port Noise Impact Assessments to be included in ports Environmental Management Systems (EMS). The method will be applied to the proposed expansion of the port of Melilla.

Six partners are involved in the project: a technical coordinator, ISPRA (Italian National Institute for Environmental Protection and Research), three different authorities managing respectively the ports of Melilla, Patras and Livorno, and two technical partners expert on noise assessment (CIRIAF and INGENIA srl).

The paper is focused on how the guidelines has been realized within the realization of the noise mapping activity of Melilla port expansion project.

The noise mapping activities has been developed to represent the evolution of the port in the next 30 years considering:

- three different time scenarios each one representing a decade;
- the different impacts of the standard and the peak seasons (three months on summer);
- in all the aforementioned conditions, the option zero has been considered and modelled.

These three scenarios represent the evolution of the port in the next 30 years; the port evolution has been studied also without the realization of the port expansion.

Another goal of the study is to perform a comparison between noise mapping outcomes obtained using the 2015/996 Directive and the old ones defined by the END.

2 Guidelines

2.1 Geographical data

Geographical data are contained in digital maps where the position of each object is defined through a coordinate system. Before starting the collection of data, the coordinate system has to be decided and all the input data should be referred to it. The EPSG code should be used to define it.

2.1.1 Digital ground model

Obtaining a realistic digital ground model (DGM) represents a key point in noise modelling. It doesn't only affect the behaviour of the noise propagation, because the emission of some kind of noise sources depends on it. For instance, all the most important noise models for roads consider the road gradient as a positive driver in noise emission. However, a too detailed DGM can slow excessively the calculation time and increase the size of the project.

A balance between these two aspects have to be found in noise modelling and a rule of thumb about it cannot be given. The accuracy chosen for the DGM depends on the orography of the area interested by the noise emission study and on the available input data.

Using only elevation points causes excessively irregular DGMs; it is suggested to use as input isohypses or LIDAR (Light Detection and Ranging) data contained in digitalised maps. The extension of the DGM should be bigger than the port area.

The input elevation data contained in digitalised maps need to be analysed and refined. These data sometimes do not contain any useful information allowing to define the vertical profile of railways or roads. In order to optimize the DGM in areas containing rail, roads or other sources having an emission dependent on the orography, one of the following procedures can be chosen:

- If the noise source is given in plan without a vertical profile, it should be laid on a draft version of the DGM. Concerning roads and rails, their gradient should be checked and if unrealistic values are observed (slopes in flat areas or slope higher than 25% or lower than −25%) data should be corrected. After defining an approximate vertical profile, all the existing data inside the road or rail area should be deleted and not considered in the final DGM calculation. Moreover, it is suggested to perform two offsets of the fixed road axis at a distance equal to the width of the lane and to consider these lines as elevation lines. This operation allows avoiding height variation perpendicularly to the road axis. A similar approach can be used for railways;
- If the vertical profile of the noise source is available, the abovementioned procedure can be used without laying the noise source on the draft version of the DGM.

Attention must be paid to road and rail segments inside tunnels or on bridges.

Before calculating the vertical profile of a road from the DGM, it is strongly recommended to divide the road axis in segments characterized by the same length. The maximum allowed length of the road segment depends on the extension of noise sources; it should be comprised generally between 5 and 50 m. This is due to the laying operation of simulation software. They consider a road as a succession of points, so when the laying operation is performed, they change the height of the points and not the height of the segments between them.

It is always suggested to check height information of elevation points or isohypses placed inside each building area. They can be related to:

- buildings height: in this case, they should be used only for the calculation of the building height and not for the calculation of the DGM. They have to be separated from the other altimetry data and used only for the definition of building height property;
- ground height: in this case, they are not referred to the real situation, but they are the results of an extrapolation process. These data should be deleted.

A too detailed DGM can cause an increase on noise calculation time without a sensible improvement of its affordability. For this purpose, some simulations software allows filter operations. It is suggested to filter isohypses in order that it is not possible that two consecutive points of the same line are distant less than 1 meter.

2.1.2 Building classification and characterization

Buildings in digital maps are commonly defined through the coordinates of their vertexes. Position, shape and use of building can be acquired from digital maps of National Cadastre or from urban plans. Buildings should be classified as follows:

- residential;
- schools (kindergarten included);
- hospitals (nursing and retirement homes included);
- others, such as industrial and commercial buildings.

Buildings classified as "others" should not be considered for the calculation of noise exposure. They will be considered only as a barrier to noise propagation.

Recent buildings may not be included in the available digital maps. If some areas are deeply affected by this lack of data, information should be updated through the analysis of satellite images. Open GIS data repositories, such as Open Street Map, can contain digital information of buildings with a good degree of approximation; furthermore, data are constantly updated by users.

2.1.3 Building height

The definition of building height is crucial since it does not only affect noise propagation, but also evaluation processes. This parameter may be evaluated in different ways:

- use of satellite images or Google Street View services (where available). The procedure is accurate but it is not technically feasible for large study areas, such as an entire agglomerate territory. It should be limited to selected locations where the population density is higher;
- divide the study areas in zones of homogeneous building height. All the buildings belonging to the same area will be characterized by the same height;
- assign a fixed height to all the buildings.

Buildings higher than 18 m should be identified singularly; in this case the current height of the building must be used in the simulation software. Noise simulation software usually allows buildings height to be used to estimate the number of floors.

2.1.4 Building population

The indicator "population exposed to noise" can be calculated matching the noise exposure of each agglomerate building with its population data. Concerning residential buildings, the number of inhabitants of each building may be estimated by surveys, but the procedure can prove too expensive in terms of time and resources. Data from State Statistical Offices may be useful at this purpose: they can provide the number of inhabitants in some sub-municipality areas (*census areas)*. This information should be matched with data related to building height (number of floors) in this way:

- evaluate the entire residential area of each census area, multiplying for each residential building the number of floors by the surface area;
- calculate the population density of each census area by dividing the number of inhabitants by the entire surface area;
- multiplying, for each building, its residential area by the population density of the census area.

This procedure can be made using GIS or noise simulation software.

If data related to these sub-municipality areas are not available, an average population density, in terms of inhabitants per residential square meter, should be used for the whole agglomeration. This average value is evaluated dividing the number of inhabitants in the agglomeration by the total residential area.

2.1.5 Noise limits

The best option is that buildings attributes include noise limits. If this information is not directly available, digital maps reporting areas characterized by the same noise limits should be used. This information should be collected in .esri format or in other format editable with an open GIS software. File in .pdf or in .jpg format should be avoided.

2.1.6 Land use

The type of ground surface deeply influences sound propagation. Water is a sound reflective surface, but in the port areas surroundings green areas with a completely different noise absorbing behaviour can exist. The parameter that allows to consider the effect of the ground is the "Ground Factor" (GF). The highest value of GF is 1 and it means that the ground is completely absorbing. The lowest value is 0 (ground completely reflecting). The land usage maps should be used to determine if an area have a high noise absorption or not.

2.2 Road data

Port areas are made of road, rail, and industrial noise sources. The new directive 2015/996 defines the algorithms for the realization of noise maps compliant to the END. Concerning roads and rails, each Member State have to define its own National emission library, but the algorithms used to calculate the noise propagation are the same.

The 2015/996 method considers four different categories of vehicles: light, medium heavy, heavy, two-wheeled vehicles. An open category is also available for other kind of vehicles such as the electric ones. Each one of these categories have to be characterized in terms of traffic flow, velocity, road pavement surface and characteristic of the traffic flow.

2.3 Railways

The 2015/996 algorithms require the definition of each vehicle passing through the railway. The "vehicle is defined as any single railway sub-unit of a train (typically a locomotive, a self-propelled coach, a hauled coach or a freight wagon) that can be moved independently and can be detached from the rest of the train".

2.4 Industrial noise sources

The real challenge on the categorization of industrial noise sources in ports is caused by their extreme variability of dimensions and typology. Sound power levels or sound pressure levels generated by each source can be collected from (in order of priority):

1. manufacturers' data sheets;
2. estimation from direct measurements;
3. databases of noise sources;
4. estimation from similar noise sources.

If manufacturer's data sheet is not available, the sound power level of noise sources can be obtained using the procedures suggested by the outcomes of the MON ACUMEN (MONitorage Actif Conjoint Urbain-MaritimE de la Nuisance) Interreg project [15]. The project defined for each relevant noise source that can be found in a port area:

- data to be collected for a complete noise characterization;
- noise measurement methods.

A detailed analysis about how to characterize noise sources in port areas is reported in [16]; the procedures are tailored to the following different port noise sources:

- Ships: The Automatic Identification System should be used to define the typology.
  - noise measurements should be carried out to define their emission at berth and in movement.
  - noise emission characterization should consider their position during the year of reference. Ship dimension should be considered since its effect on noise propagation cannot be considered negligible.
- Straddle carriers, Front Lifts, Contstackers, Forklifts:
  - three noise measurements should be realized. Two of them should be pass-by tests with unloaded and loaded device (the latter can be excluded for Straddle carriers). The third ones should be used to characterize their complete operating cycle;
  - noise emission characterization should consider their usage time in all the reference periods. Their routes should be identified.
- Transtainers, Gantry cranes, Wheeled cranes, Tractors, Dozers
  - three noise measurements should be realized. Two of them should be pass-by tests with unloaded and loaded device. The third ones should be used to characterize their complete operating cycle;
  - noise emission characterization should consider their movements and their average usage time in all the reference periods. Their routes should be identified;
  - gantry cranes should be classified considering their size. Transtainer should be classified considering if they move by tyres or by rails.
- Ports usually comprise also areas devoted to industrial activities and building sites. The characterization of these areas should be performed considering the existing standards e.g. EN 12354-4, ISO 8297, etc.)

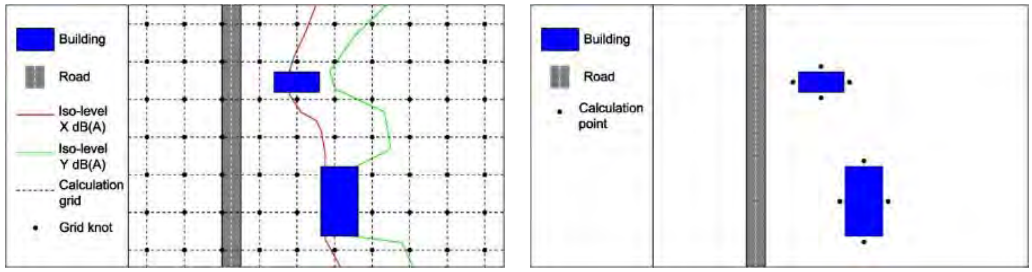

Figure 1: Examples of grid noise map (GNM, left) and of façade noise map (FNM, right) [18]. The real position of the calculation point is on the façade for FNM compliant to the END

2.5 Noise calculation parameters

Noise simulations can be performed through grid noise maps (GNM) and façade noise maps (FNM). The GNM allows to define an evaluation of the sound pressure level in the nodes of a regular grid, while in the other ones the noise levels are evaluated on the building façade. An example of the difference between these two kinds of maps is given in Figure 1.

Through the graphical maps, i.e. GNM, the value of the noise level is evaluated inside a calculation area. This kind of evaluation requires high calculation time even reducing the accuracy of the simulation; nevertheless, the graphical maps are easier to be analysed by people not expert in acoustics. Graphical maps are useful in particular for dissemination activities.

Façade noise maps allow to evaluate the acoustical issues combining the results of the noise simulation with other different information. Façade noise maps are the most suitable instruments for decisional processes and for the assessment of the noise impacts of a source or of a group of sources.

Since the GNM requires the noise level calculation in a higher number of points compared to the FNM, two different sets of parameters are suggested for these two kinds of simulations.

The outcomes of NADIA project [16] were considered as the reference point for the definition of the calculation parameters defined in the guidelines.

2.5.1 Noise calculation parameters for grid noise map

The noise calculation parameters suggested for the realization of port noise maps are reported as follows:

- reflection order: 1. This parameter defines the number of reflections considered by the algorithm;
- max distance between receiver (calculation grid node) and noise source: 1000 m. Only the effect of the noise sources placed at a distance lower than the threshold value is considered;
- max distance of reflections from the receiver: 200 m. Only the effect of the reflections occurring at a distance lower than the threshold value is considered;
- max distance of reflections from the receiver: 50 m. Only the effect of the reflections occurring at a distance lower than the threshold value is considered;
- noise indicator: L_{day}, $L_{evening}$, L_{night} and L_{den} considering the Member state time scaling;
- grid spacing: 5 m. Distance between two grid nodes. This value can be assessed equal to 10 m for big ports;
- grid height from the DGM: 4 m. Height of the grid nodes from the DGM;
- air attenuation effect calculated in compliance to ISO 9613-1;
- meteorological conditions: in absence of more accurate data, days with favourable meteorological conditions equal to 50, 75 and 100% respectively for day, evening and night period.

2.5.2 Noise calculation parameters for façade noise map

The noise calculation parameters suggested for the realization of port noise maps are reported as follows:

- reflection order: 2;
- calculation point placed on each relevant building façade. The reflection of the façade where the calculation point is placed has been not considered;
- relevant façade: façade having a minimum length of 2,5 meters. Long buildings façades were divided to have a calculation point at least every 3 meters of façade;
- one calculation point for each façade floor;
- max distance between receiver and noise source: 1000 m;

- max distance of reflections from the receiver: 200 m. Only the effect of the reflections placed at a distance lower than the threshold value is considered;
- max distance of reflections from the receiver: 100 m. Only the effect of the reflections placed at a distance lower than the threshold value is considered;
- noise indicator: L_{day}, $L_{evening}$, L_{night} and L_{den} considering the Member state time scaling;
- air attenuation effect calculated in compliance to ISO 9613-1;
- meteorological conditions: in absence of more accurate data, days with favourable meteorological conditions equal to 50, 75 and 100% respectively for day, evening and night period.

2.6 Port noise assessment method

2.6.1 Introduction

An indicator was developed to understand which noise sources needs to be more urgently treated to reduce the exposure of population to noise inside port areas. The procedure is based on:

- defining, before performing noise simulations, groups of noise sources made of all the noise sources managed by the same authority. This method allows to define who is responsible for noise limits exceeding and for the realization of anti-noise measures. The groups may be divided in other sub-groups if at the end of the procedure the results do not allow the clear identification of the anti-noise measures;
- considering the existing noise limits. These data should be given in a GIS (Geographic Information System) format (or shapefile, file extension .esri and related), in order to analyse and verify them even through open source software;
- performing façade noise simulations;
- individuation of noise critical areas (hot spots).

2.6.2 Definition of noise critical areas

The method was developed considering the outcomes of the Deliverable 4 of NADIA Project [16, 19]. The areas that require noise abatement measures are identified comparing the results of noise simulations with the noise limits defined by the competent authority according to the national laws.

The noise evaluations should be carried out for residential buildings and for schools, hospitals, kindergartens and nursing homes. These buildings are referred as “special buildings” in the following. The evaluation of quiet areas is excluded from the described methodology.

The residential and special buildings characterized by sound pressure levels higher than the limits are called “critical buildings”. Critical buildings that can be acoustically rehabilitated using the same anti-noise measure should be gathered in groups forming a “critical area”. The sound pressure level used for the definition of the overtaking noise limits are the one considering all the assessed noise sources existing in the port area.

Compared to the NADIA method, in the ANCHOR project the contribution of each group of noise sources will be considered separately. This will allow to understand more clearly the contribution of each group of noise sources to the noise limits exceeding and consequently the selection of the most efficient anti-noise measure.

The boundaries of each critical area are defined through the following criterion: “Inside a critical area, the distance between a critical building and the one nearest to it is lower than 100 m”. The critical buildings should be identified and separated from the others. An offset of 50 m should be used for each critical building perimeter (Figure 2). If two or more areas created by the offset procedure intersect, they must be merged to a unique area (Figure 3).

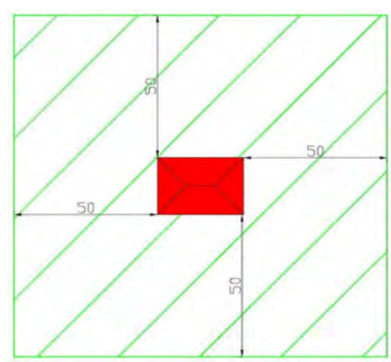

Figure 2: In red the critical building, in green its offset

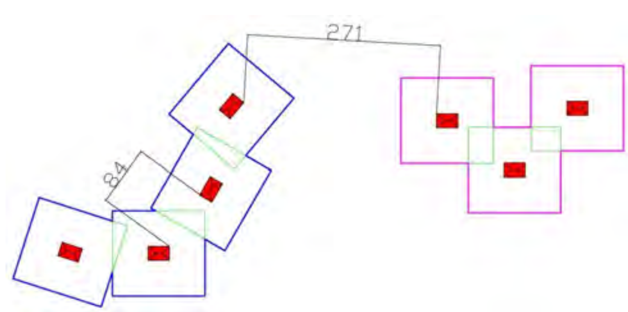

Figure 3: Example of critical areas definition. The contours of two critical areas are coloured in blue and magenta

2.6.3 Definition of the priority index

The priority index is a scoring system allowing to highlight areas or buildings where mitigation actions are more advisable or urgent.

The suggested procedure for the assessment of the priority index considers the outcomes of NADIA project and the method described by Asdrubali *et al.* [18]. Each critical building defined using the procedure reported in the previous paragraph have to be characterized by an Index of priority (IP_{all}) that has to be calculated using the following equation:

$$IP_{all} = \sum_{i=1}^{n} IP_{all,i}$$

where:
n is the number of critical buildings included in the critical area under consideration;
$IP_{all,i}$ is the value of the index of priority for the i-th building considering all the noise sources.

The calculation of the $IP_{all,I}$ is implemented through the following equation:

$$IP_{all,i} = \sum_{j=1}^{k} IP_{all,cp,j} = \sum_{j=1}^{k} a_j \star Q_j \star l_j \star \Delta L_{all,j}$$

where:
Q_j is calculated with:

$$Q_j = \frac{N_j}{P_j \star n_j}$$

N_j is the number of residents of the building where the j-th calculation point is placed;
P_j is the perimeter of the building where the j-th calculation point is placed;
a_j is a coefficient depending on the building use;
n_j is the number of floors of the building where the j-th calculation point is placed;
l_j is the length of the façade where the j-th calculation point is placed;
k is the number of calculation points belonging to the i-th critical area;
$\Delta L_{all.j}$ is the maximum of the noise limit exceeding assessed considering the contribution of all the noise sources for the j-th calculation point in all the periods where there is a legislative limit.

The product between Q_j and l_j represents the number of people exposed to noise level assessed in the j-th calculation point of the i-th building. The a_j parameters are used to pay more attention on noise sensitive buildings; they are considered equal to 1 for residential buildings, 3 for schools (all the grades, kindergarten included) and 4 for hospitals, retirement homes and similar buildings. These values are based on the Italian normative and on the outcomes of NADIA project; nevertheless, they can be varied if the authority in charge for noise action plan wants to give more relevance to special buildings or to the residential ones.

After the identification of the noise critical areas and once the calculation of the $IP_{,all}$ is realized, the contribution of each selected group of noise sources is performed as defined in the following equation:

$$IP_x = \sum_{i=1}^{n} IP_{x,i} = \sum_{i=1}^{n} \left(\sum_{j=1}^{k} IP_{x,i,j} \right) = \sum_{i=1}^{n} \left(\sum_{j=1}^{k} IF_{x,i,j} \star IP_{all,cp,j} \right)$$

where
IP_x is the index of priority of the x-th group of noise source;
$IP_{x,i}$ is the index of priority of the x-th group of noise source calculated for the i-th building;
$IP_{x,i,j}$ is the index of priority of the x-th group of noise source calculated for j-th calculation points belonging to the i-th building;
$IF_{x,i,j}$ is the relative contribution of the x-th group of source on the overall sound pressure level assessed in the j-th calculation point of the i-th building for the the period where the highest noise limit exceed is observed. The $IF_{x,i,j}$ is calculated through the following equation:

$$IF_{x,i,j} = \frac{10^{L_{x,i,j}}}{\sum_{j=1}^{k} 10^{L_{x,i,j}}}$$

where $L_{x,i,j}$ is the noise level caused by the x-th group of noise sources in the j-th calculation point of the i-th building.

The source grouping should allow to define:

- where anti-noise measures are needed;
- who is the subject responsible for their realization;
- which are the noise sources having emissions needs to be mitigated;
- which is the ranking of priority of these anti-noise actions.

If at the end of the procedure these points are not clear, it is suggested to divide the groups in subgroups and to repeat the procedure.

In every critical area there is an IP_x value for each one of the groups of noise sources considered. The higher the IP_x value, the more important the noise impact of the x-th group of noise sources on the critical areas.

The final ranking includes all the IP_x of each critical area; this allows to understand where anti-noise measures are more urgent and who is in charge for realizing them.

After selecting the most adequate anti-noise measure, the IP_x values can be compared with its cost and effectiveness to calculate a parameter such as the *CBI* one proposed by the deliverable 4 of NADIA project:

$$CBI = \frac{cost\ of\ the\ measure\ [€]}{\left(IP_{before\ the\ measure} - IP_{after\ the\ measure}\right) * k}$$

The penalization coefficient k was introduced in the calculation of the benefits: its value is 0.50 for normal windows and 0.75 for auto-ventilating windows. This means that the installation of windows leads to only half (or ¾ for auto-ventilating windows) of its potential benefits in terms of reduction of priority index. Indeed, the measures that have the lowest values of *CBI* are to be preferred.

3 Noise emission data

The aim of the paper is not to provide a detailed review of all the available data about port noise sources emissions. However, the following works describe a huge amount of data about the noise emissions of ships and other facilities and devices that can be found in port areas:

- REPORT project [20]. Part of the project activities were focused on performing noise measurements tailored to the noise emission characterization of port sources such as transtainers, reach stackers, reefers and gantry cranes;
- EFFORTS project [21]. Deliverable 2.4.3 of the project "*Source ranking data*" contains the sound power level spectra of a noise source equivalent to the ramps used by tractors and heavyweight vehicles to enter inside Ro-Ro ships. The spectra are defined with the 95% confidence intervals. The project deliverable contains also the sound power level estimation of other port noise sources derived from tailored measurements;
- an approximate approach to assess the noise emission of container ships is given by J. Witte in the paper "Container Terminals and Noise" [22]. The approach is based on measurements on several container ships characterized by different Dead Weight Tonnage values;
- the Report "Technical noise investigations at Hamburg City cruise terminals" defined some procedures developed within the INTERREG Green Cruise Port [23] to characterize the noise emission of cruise ships;
- the best practice guide developed within the NEPTUNES project [24] aims at characterize noise mitigation measures for port noise sources;
- a methodology to realize noise simulations of ships at berth is defined in the paper "Airborne noise emissions from ships: Experimental characterization of the source and propagation over land" [25].
- the paper "Evaluation and control of cruise ships noise in urban areas" [26] contains sound power levels spectra of cruise ships of different size;
- the report "Noise from ship in ports" reporting the sound power level spectra of engine room and hold ventilation fans of moored ships. The document also reports some solution to mitigate these noise emissions such as engine silencers, on-shore power etc. [27];
- the class notation of the Lloyd's Register describes how the noise emission of a moored ship have to be modelled [28];
- the report "Assessment of the acoustic benefit of the power supply to ships moored in ports (cold ironing)" [29] and the related paper presented at the Euronoise 2018 [30]. These works are mainly focused on the effectiveness of cold-ironing solutions in reducing the noise emission of ships at berth;
- the paper "Pass-by Characterization of Noise Emitted by Different Categories of Seagoing Ships in Ports" [31] reporting the sound power levels of several typology of seagoing ships. Data are provided with uncertainties;
- the outcomes of the FP7 SILENV project for the moored ships [32–36] and ISPRA data based on the FP7 SILENV project [37, 38]. The project defined a methodology to assess the sound power level spectrum of several typologies of ships at berth.

4 Comparison between the algorithms 2015/996 and the ones of the old Annex II of the END

4.1 Introduction

Apart from the definition of the guidelines described in the previous sections of this paper, another activity developed in the ANCHOR Life project was the comparison of noise simulation outcomes calculated using the algorithms of the Directive 2015/996 [2] and of the ones listed in the old annex of the END [1].

The comparison has been performed considering the same calculation area for the GNM and the same calculation points for FNM. Moreover, it is important to state out that the noise emission data of all the noise sources considered was the same. Road emission data were defined using the same traffic data and geographical profile.

The study area was the one reported in chapter 2, the procedure chosen to perform the noise simulation was the one in chapter 3 and the noise emission data was taken from a noise mapping activity realized in the 2017 by a private company.

Simulations were performed using SoundPLAN 8.2 [39].

4.2 Study area

Melilla port is located in the homonymous autonomous city in North Africa, occupying a strategic location at the conflu-

Figure 4: Current state of Melilla Port Area

Figure 5: Port expansion project

Table 1: Comparison of port areas between existing and expanded layout

Without port expansion (the port remains as it is, but with more traffic and devices)	With port expansion
Container Terminal	Container Terminal (TCM)
Ro-Pax and Ro-Ro terminal	HUB Terminal (new)
Multipurpose T. (cement carrier and tanker)	Ro-Pax Terminal
Cement plant	Ro-Ro Terminal
Thermal energy plant (outside)	Multipurpose Terminal
Waste incineration plant (outside)	Cruise Terminal (new)
	Cement plant
	Thermal energy plant
	Waste incineration plant

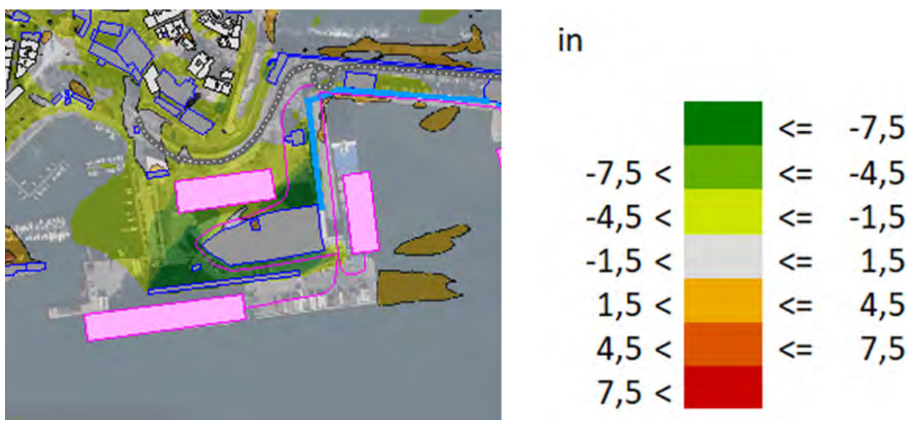

Figure 6: Detail of Figure A6 evidencing in green the higher sound pressure level estimation due to the old Annex II of the END compared to the one of the Directive 2015/996 in the back of screening object (in grey and in cyan) close to noise sources (pink)

ence of commercial maritime routes between the Mediterranean Sea and the Atlantic Ocean. With respect to its land location, the port is conditioned by its proximity to the city of Melilla centre and consists of two main functional areas, a commercial port and a marina. Before the COVID emergency the port managed 850,000 passengers and up to 1 tonnes of goods every year and it was the second port in expansion over the last 10 years.

Figure 4 and Figure 5 reports respectively the existing port and the layout of the expansion project; a comparison between the port areas between these situations is briefly reported in Table 1.

4.3 Grid noise maps

Grid noise maps for the L_{den} indicator obtained using the 2015/996 and the old Annex II algorithms are reported respectively in Figure A1 and in Figure A2.

Concerning the L_{night} indicator the grid noise maps are reported in Figure A4 and Figure A5.

The difference between the outcomes of the two algorithms for the L_{den} and the L_{night} indicator is reported in the annex (respectively Figure A3 and Figure A6). Positive values indicate areas where the outcomes of the 2015/996 simulation are higher than the one of the old Annex II of the END; negative values the vice versa.

The most relevant outcomes are:

1. the differences between the two models are negligible close to the noise sources, except in the back of screening objects;
2. on the back of screening objects, the old Annex II algorithms give a sound pressure level higher than the one of the 2015/996. The difference is more relevant for screening object close to the noise sources (Figure 6);
3. at a long distance from the noise source, in absence of screening objects, the outcomes of the 2015/996 algorithms give higher values than the other one. This effect is more evident in the L_{night} map.

4.4 Façade noise maps

Considering absolute values of the difference between the outcomes of the two simulations, the average difference respectively for L_{den} and L_{night} indicator was 2.8±3.0 dB(A) and 3.0±3.2 dB(A). The high value of the standard deviation showed that the difference between the noise simulations is very variable and needs to be analysed in detail.

Table 2 and Table 3 respectively report the difference between the outcomes of the two noise simulations in terms

Table 2: Comparison of population exposed to noise using Lden indicator through the two calculation algorithms

Class L_{den}	Number of people exposed to noise		
	Directive 2015/996 algorithms	Old annex II of the END algorithms	Difference between 2015/996 and old Annex II of the END
<55	2488	2774	−286
55–59	368	106	262
60–64	80	56	24
65–69	0	0	0
70–74	0	0	0
>75	0	0	0

Table 3: Comparison of population exposed to noise using Lnight indicator through the two calculation algorithms

Class L_{night}	Number of people exposed to noise		
	Directive 2015/996 algorithms	Old annex II of the END algorithms	Difference between 2015/996 and old Annex II of the END
<45	2176	2479	−303
45–49	446	341	105
50–54	275	102	173
55–59	39	14	25
60–64	0	0	0
65–69	0	0	0
>70	0	0	0

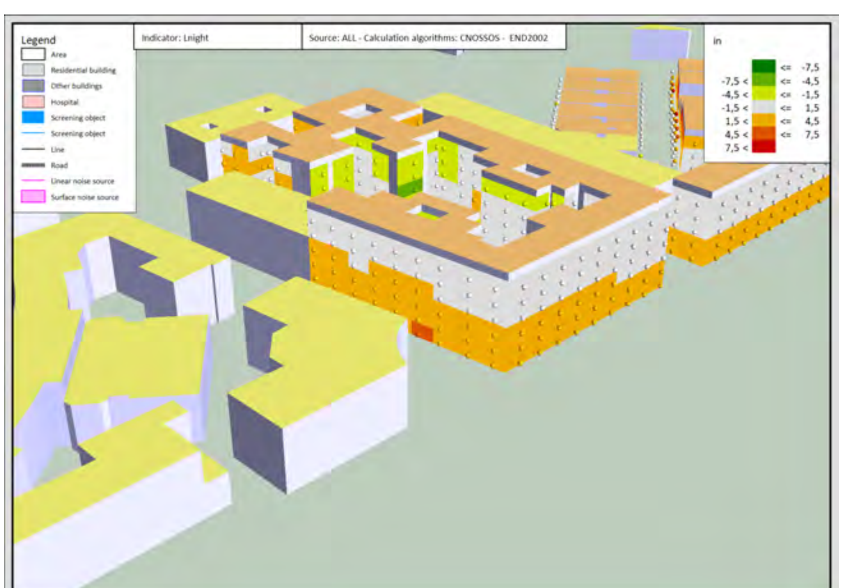

Figure 7: Comparison between the outcomes of the two simulation: detailed analysis

of population exposed to noise. The population of each building was uniformly distributed on their façade. A calculation point has been placed in each relevant façade. Building floors were considered.

Generally, the outcomes of the FNM calculation developed with the 2015/996 showed a higher noise exposure in the study area compared to the other one. This is caused by the existing long distance between the most of the receivers from the noise sources; in these conditions the noise levels simulated using the 2015/996 algorithms are higher than the other ones.

This effect can be observed also in Figure 7 where the calculation building façades have been coloured considering the difference between the outcomes of the 2015/996 Directive algorithms and the ones of the old Annex II of the END. Buildings are placed at a distance of about 350 m from the closest noise source. On the building façade directly exposed to the noise emission, the sound pressure levels estimated using the 2015/996 method are higher than the other ones. Figure 7 also shows that on the façades in the back of the building, the sound pressure levels estimated with the old annex II of the END algorithms are higher than the other ones.

5 Conclusions and further developments

The paper reported the contents of the guidelines for a port noise mapping activity developed within the ANCHOR Life project. The document allows to support noise experts approaching the noise simulation of a port area, highlighting data that needs to be collected and defining a procedure to identify and prioritize the noise critical areas.

A review of the emission data of noise sources in port areas was performed allowing the realization of a database. The database defines the sound power level of several facilities, equipment and also ships in several operating conditions.

The project performed also a comparative analysis of noise mapping outcomes of a port area using the algorithms defined by the 2015/996 Directive and the one of the old Annex II of the END.

In particular:

1. in absence of screening objects, if a receiver is not close to a noise source, the sound pressure level estimated on it by the 2015/996 Directive algorithms is higher than the one of the old annex II of the END. This effect is more consistent in the night period. This situation is typical of port areas where a lot of residential houses and other sensible buildings are faced (but not close) to port areas;
2. in absence of screening objects, if a receiver is placed close to a noise source, the differences between the two noise simulations are similar;
3. on the back of screening objects, the algorithms of the old annex II of the END tend to give higher sound pressure levels than the other ones. This effect should be considered in the design of anti-noise measures.

The assessment of the Index of Priority developed within ANCHOR LIFE project should be completed before the end of April 2022; the approach will be used also to assess the impact of several noise reduction measures tailored for the Melilla port area and defined by Melilla Port Authority. It will be of interest in the future to apply the guidelines on ports bigger than the Melilla one, since they were developed to be used also in these conditions. For this purpose, the interaction with other research projects related to port noise will be fostered to increase the knowledge on this topic, to deepen the relationship between noise limits and noise prioritization index and to assess alternative approaches to define the critical areas.

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ANNEX: GRID NOISE MAPS

Figure A1: GNM of Melilla port area considering all the noise sources using the algorithms of the 2015/996 Directive, L_{den} indicator

Figure A2: GNM of Melilla port area considering all the noise sources using the algorithms of the old Annex II of the END. L_{den} indicator

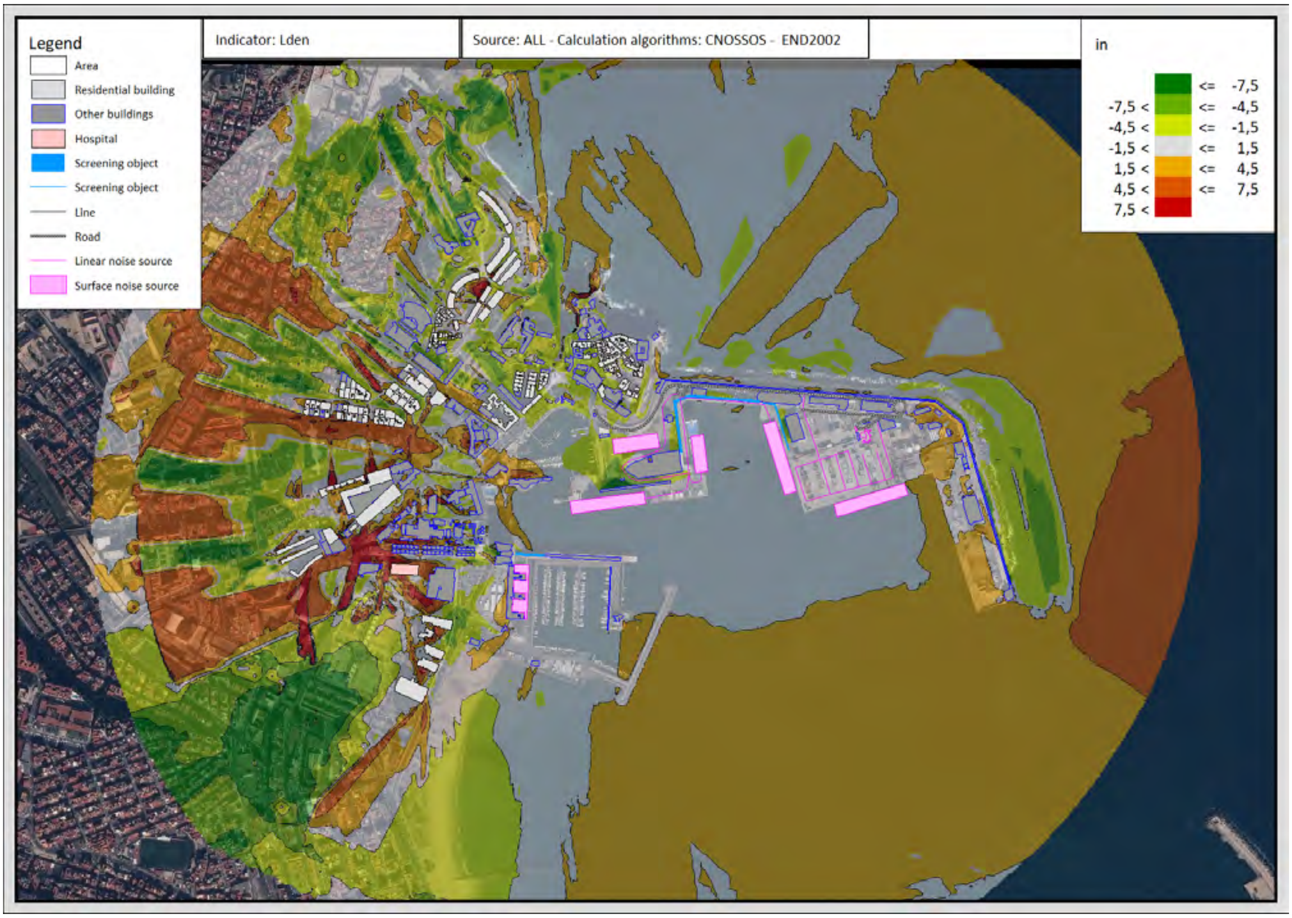

Figure A3: Difference between L_{den} estimation with 2015/996 algorithm and the one of the old Annex II of the END

Figure A4: GNM of Melilla port area considering all the noise sources using the algorithms of the 2015/996 Directive, L_{night} indicator

Figure A5: GNM of Melilla port area considering all the noise sources using the algorithms of the old Annex II of the END. L_{night} indicator

Figure A6: Difference between L_{night} estimation with 2015/996 algorithm and the one of the old Annex II of the END