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ANCHOR Life

Advanced Noise Control strategies in HarbOuR

Guideline for a common Port Noise Impact Assessment method

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Content

1. Executive Summary

This document is one of the deliverables of action B.3 of ANCHOR project (LIFE17 GIE/IT/000562).

The aim of action B3 is to update NoMEPorts (LIFE05 ENV/NL/000018) Good Practice Guide (GPG) [1] taking into account the innovation introduced by the European Directive 2015/996/EC[2], which emends the Annex II of the Environmental Noise Directive (END) 2002/49/EC [3]. In particular, the developed guideline will define a common Port Noise Impact Assessment (PNIA) method.

Some chapter of these guidelines are dedicated to how the noise simulations should be performed. Noise calculations should be tailored for the noise assessment method; the realization of a noise mapping activity should not be separated from the realization of a noise action plan. If these two activities are performed together, the risk of incompatibilities between noise simulations and noise assessments will be minimum. The aim of the deliverable is to define how input data should be collected to realize noise mapping activities in ports in compliance with the END taking into account the updates contained in the 2015/996 Directive.

Moreover, the Deliverable reports a method developed within Action B3 of the project to define areas where noise mitigation measures are required. These areas are named *hot spots* in the project. The procedure developed in the project allows to define a ranking between these hotspots and to select the authority in charge for mitigation actions. This procedure is based on the outcomes of NADIA (Life 09 ENV IT 000102) project [4], in which CIRIAF was the partner in charge of scientific and technical actions. NADIA project was related to road noise; nevertheless, its procedure has been adjusted to be used in port areas.

Chapter 2 reports a brief outlook on the NoMEPorts Good Practice Guide. Chapter 3 specifies how geographical and building data should be collected for the realization of a noise map of a port area. Chapter 4 is focused on the characterization of noise sources. Chapter 5 describes how a noise calculation of a port should be performed. Chapter 6 is focused on the definition of a Port Noise Assessment method. This procedure was tested on the Melilla port area; the outcomes are reported in Chapter 7.

2. The NoMEPorts Good Practice Guide

The NoMEPorts Good Practice Guide (GPG) provides a guidance for the management of noise issues in ports on their related industrial areas. The project has been funded by the EU LIFE Environment 2005 Programme.

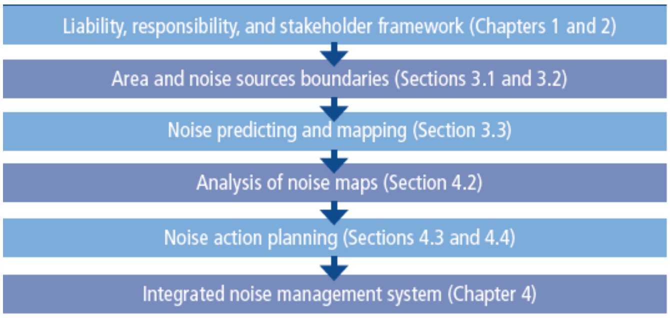


Figure 1:NoMEPorts phased approach to port area noise mapping and management

The most important outcomes of this guideline are:

- the definition of a procedure for the realization of reliable noise maps compliant to the END;
- the selection of measures addressed to prevent and/or tackle noise issues derived by port activities;
- the definition of a guidance for the development of Noise Action Plans for ports.

The approach of the project is reported in Figure 1; the section or the chapter of the GPG devoted to each phase is reported in parentheses.

The most relevant outcomes are reported in the following paragraphs; further details can be found in the deliverables of the project available at [1]

2.1 Responsibilities and Legislation

The reference for the NoMEPorts GPG was the Directive 2002/49/EC [3] (before the 2015 amendment) so it was structured to product outcomes that were compliant with it. As said earlier, the Directive requires noise mapping activities (see Figure 2) for several kinds of noise sources, but not for ports. Port should be included in END mapping project only if they are inside agglomerations. It is important to specify that each Member State has defined its competent authority and its procedure for the identifications of agglomerations and for the definition of their delimitation.

Area / source to be investigated	Strategic noise maps until	Action plans until
Agglomerations		
>250,000 inhabitants	30 June 2007	18 July 2008
>100,000 inhabitants	30 June 2012	18 July 2013
Major roads		
>6,000,000 vehicle passages per year	30 June 2007	18 July 2008
>3,000,000 vehicle passages per year	30 June 2012	18 July 2013
Major railways		
>60,000 train passages per year	30 June 2007	18 July 2008
>30,000 train passages per year	30 June 2012	18 July 2013
Major airports		
>50,000 movements per year	30 June 2007	18 July 2008

Figure 2: Time-scale defined by the END. All the documents have to be updated at least every 5 years.

2.2 Definition of boundaries and noise mapping

From the acoustic point of view, the boundaries of the port areas are not the ones identified by the property fences. People living on port surroundings may be deeply affected by its noise emission; nevertheless, considering all the city as the study area of the port noise simulation is counter-productive, because of the huge amount of time needed for the calculations.

The GPG suggests to perform a preliminary calculation without screening object on a flat ground; the perimeter of the area with L_{den} > 55 dB and L_{night} > 50 dB of the preliminary calculation will be the boundary of the definitive noise mapping for the port area.

Figure 3 reports a brief synthesis of the procedure to follow for port noise mapping; as far as other kind of acoustic sources, it starts from the collection of geographical data, preferably in GIS format. Concerning the relevant noise sources, it is important to state out that the collected data should include their location (height included), working hours and the sound power level. These data should be reliable and accurate.

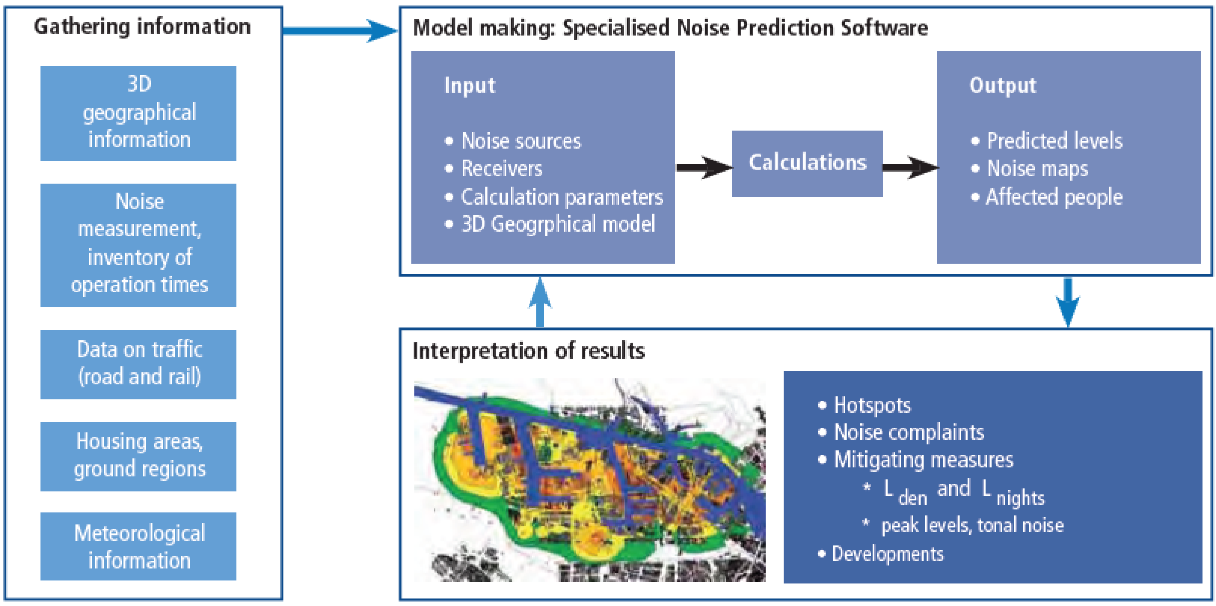


Figure 3: Scheme of the noise mapping procedure defined by NoMEPorts GPG

2.3 Noise Management

The GPG recognizes that the port noise impacts can be efficiently tackled through management actions. These ones work in terms of noise prevention and/or mitigation; their benefits are listed in Figure 4.

- Cost savings through the prevention of a negative (environmental) influence from port-city planning on the prospects for the optimum functioning of the port
- Cost savings through prevention of future negative environmental influence of port development by having available evidence to support planning applications for port development
- Better control of production and optimization of port area planning
- Enhanced environmental quality of the port surroundings
- Greater transparency and, therefore, greater potential for acceptance by the public of the need for development of the port and its associated industrial activities
- Additional instrument to imporve the working environment by raising awareness of safety, health and environmental issues amongst employees

Figure 4: Benefits of implementing a noise management programme

The starting point of a good noise management programme is the definition of reliable noise maps that allow to identify the hot-spots (i.e. areas where noise limits are exceeded and, consequently, most urgently need noise mitigation actions), the most relevant noise sources and the estimation of the number of people exposed in compliance to the END requirements. It is important to state out that a noise source is relevant when its effect is relevant and not when its noise emission is higher than a threshold. Concerning the identification of hot-spots, the GPG does not give a unique procedure.

A comparative analysis performed in 2015 by D'Alessandro and Schiavoni [5] proved that the selection of the noise priority score influences the results in terms of identifying the most critical areas. Different noise scores applied in the same study area will lead to different rankings.

Concerning noise mitigation, the GPG identifies three different kinds of actions: source, propagation and receiver measures. These ones are briefly reported respectively in Figure 5, Figure 6 and Figure 7.

Terminals and plants:

- Covering of sound intensive components with insulation Reducing structure-borne sound radiation
- Reducing the speed of putting down a container and distance from surface of opening a bulk grab.
- Automatic positioning of the spreader
- Tyre pressures
- Put source into a building or barriers around source
- Silent exhaustion pipes
- Planting trees as a barrier (may act as both physical and perceived barrier)
- Use softer ground where activities allows (e.g. quiet asphalt)
- Use absorbing building materials
- Silent equipment (low noise versions cost little extra)
- Low noise driving (ECO-driving)
- Follow up service of noise reduction
- Avoid night-open terminal (Allow seaside activities, but no land-operations with trailers through gates)
- GPS of containers so you can reduce sound peaks
- Electricity in stead of diesel or diesel-electric moving equipment
- Authority port can request the companies to insulate better their
- Use water cooling instead of air cooling

Ships:

- Silent exhaustion pipes and ventilators
- Supply ship-shore energy during berthing
- Prevent loud speakers at berth

Figure 5: Source measures defined by NoMEPorts GPG

- Overall port design-planning
- City planning (new residential areas)
- Infrastructure planning (roads, railways)
- Noise barriers, by bounding roads and rails
- Modelling expansion scenarios
- Use noise mapping software as a decision support tool
- Change working period
- Change in production and/or operations
- Accept more noise in a time period waiting for moving a company or new technology
- Respect the speed limits inside the port area (setting up traffic speed indicators)
- Turn the source so the noise will be directed away from residential areas
- Reduce transport distances
- New non residential buildings as barriers
- Yard planning, e.g. positioning of container racks so they can act as a barrier
- Relocation of most noisy activities
- Move the entrance gate away from residential areas
- Installing 24 hours noise measuring systems at residential areas (to locate and document noise peaks)

Figure 6: Propagation measures defined by NoMEPorts GPG

- Setting up noise barriers between noise sources and dwellings (e.g. screens and buildings)
- Increasing the insulation of existing houses
- Sound insulating windows
- Noise mufflers on ventilators
- Decreasing of openings in existing housings
- Change attitude via communication
- Neighbourhood groups
- Introduce community to the port operations, e.g. bring inhabitants into the port and explain about port operations
- Ensure proactive communication on changes/incidents/plans
- Contact person in the port to increase trust

Figure 7: Receiver measures defined by NoMEPorts GPG

The definition of the noise maps and the mitigation measures is the starting point on the preparation of a Noise Action Plan, that, according to the definition given by the Directive 2002/49/EC, is a *"plan designed to manage noise issues and effects, including noise reduction if necessary"*. Nevertheless, the GPG states out that before working on a Noise Action Plan is important to set its goal and objectives in the short and in the long-terms. The counter-effects of noise mitigation measures, such as the economic ones, should always be considered. Summarised, for NoMEPorts GPG, the goals of noise management are to:

- identify ways of optimizing economic growth respecting the noise limits defined by the national legislation;
- reduce the impact of noise through technical or organisational measures;
- identify any potential conflicts between future city developments in areas close to commercial port activities and identify the options for sustainable development.

Moreover, it is important to state out that dissemination and public participation are essential in the preparation of the final version of a Noise Action Plan as requested by the END.

2.4 Final outlook on NoMEPorts Guidelines

Port areas are major nodes in the logistic chain and important economic centres. Port Authorities play a decisive role in port noise management and without their proactive support an adequate Noise Action Plan cannot be prepared. The outcomes of NoMEPorts project defined a procedure for the whole process, from the collection of data to the dissemination. The project proposed a harmonized approach that can be successfully used also outside the range of the application of the END. Nevertheless, the substitution of the Annex II of the END made by the 2015/996 [2] and the importance of the procedure for hot-spot identification and ranking provided in [5] evidenced that the GPG should be updated.

3. Geographical data

Geographical data are contained in digital maps where the position of the 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. The EPSG Geodetic Parameter Dataset (also EPSG registry) is a public registry of spatial reference systems, Earth ellipsoids, coordinate transformations and related units of measurement All the input 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 trough open source software. The GIS technology allows to relate cartographical data with other information (population inside a building, traffic flow of a road, kind of road surface, etc.). Last but not least, shapefiles can be imported into every noise simulation software.

3.1 The Digital Ground Model

The digital ground model (DGM) is not only for assessment of noise propagation, but it can affect also noise emission (for instance, the higher the road gradient, the higher is the associated noise emission) and evaluation. The DGM should be prepared using elevation points, isohypses or LIDAR (Light Detection And Ranging) data contained in digitalised maps. The area where the DGM should be calculated should be considerably bigger than the port area.

LIDAR have to be refined to avoid errors in the evaluation of noise emissions, propagation and evaluation. The height data of the linear noise sources such as railways or roads may or may not be available; in view of this, two different approaches can be used:

- height data are not available: the noise sources are laid on the draft version of the DGM. Concerning roads, 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. Some simulation software has specific commands to perform these operations. When the height data of road and rails are fixed, all the existing data inside the road carriageways 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;
- height data are available: the abovementioned procedure can be used without laying the noise source on the draft version of the DGM.

In both cases, attention must be paid to road and rail segments inside tunnels or on bridges; they may be indicated by the Authority in charge for data collection and excluded in the realization of the DGM.

Before laying the road on 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 10 to 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. At this purpose, some simulations software allow 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.

3.2 Building classification and characterization

3.2.1 Introduction

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.

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

3.2.2 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 area, 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 and their height properly assigned into the simulation software. Noise simulation software usually allows buildings height to be used to estimate the number of floors.

3.2.3 Building inhabitants

The indicator "population exposure 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.

3.2.4 Updating building information

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 repository, such as Open Street Map, can contain digital information of buildings with a good degree of approximation; furthermore, data are constantly updated by users.

3.3 Noise limits

The best option is that buildings attributes should include the noise limits. If this information is not directly available, digital maps reporting areas characterized by the same noise limits should be used. An example is reported in Figure 8. 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.

3.4 Land use

The type of ground surface deeply influences sound propagation. Water is a high sound reflective surface, but in the port areas surroundings may be green areas with a complete different noise absorbing behaviour. The parameter that allows to take into account 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 smallest 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 (Table 1).

Table 1: Assignment of Ground Factor [7]

Land Usage	Ground Factor
Forest	1
Agriculture	1
Park	1
Heat land	1
Residential	0,5
Paving	0
Urban	0
Industrial	0
Water	0

		Tipo de área acústica	Extensión (km^2)	Objetivos de calidad acústica (dBA)		
				L_d	L_e	L_n
	a	Sectores del territorio con predominio de suelo de uso **residencial**	4,82	65	65	55
	b	Sectores del territorio con predominio de suelo de uso **industrial**	0,56	75	75	65
	c	Sectores del territorio con predominio de suelo de uso **recreativo y de espectáculos**.	0,29	73	73	63
	d	Sectores del territorio con predominio de suelo de uso **terciario** distinto del contemplado en c)	0,45	70	70	65
	e	Sectores del territorio con predominio de suelo de uso **sanitario, docente y cultural** que requiera una especial protección contra la contaminación acústica	0,13	60	60	50
	f	Sectores del territorio afectados a sistemas generales de **infraestructuras de** transporte, u otros **equipamientos públicos** que los reclamen.	0,92	17		
	g	**Espacios naturales** que requieran una especial protección contra la contaminación acústica.	0,91	18		
	h	Zonas de Uso **militar**	1,54	19		

Figure 8: Part of the Acoustic Zoning of the Municipality of Melilla

4. Noise source 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.

4.1 Road

The 2015/996 method considers four different categories of vehicles: light, medium heavy, heavy, two-wheel vehicles. An open category is also available for other kind of vehicle 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.

4.2 Rail

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". Figure 9 and Figure 10 report respectively the parameters that influence the noise emission of a railway due to vehicles and track characteristics.

Digit	1	2	3	4
Descriptor	**Vehicle type**	**Number of axles per vehicle**	**Brake type**	**Wheel measure**
Explanation of the descriptor	A letter that describes the type	The actual number of axles	A letter that describes the brake type	A letter that describes the noise reduction measure type
Possible descriptors	**h** high speed vehicle (> 200 km/h)	1	**c** cast-iron block	**n** no measure
	m self-propelled passenger coaches	2	**k** composite or sinter metal block	**d** dampers
	p hauled passenger coaches	3	**n** non-tread braked, like disc, drum, magnetic	**s** screens
	c city tram or light metro self-propelled and non-self-propelled coach	4		**o** other
	d diesel loco	etc.		
	e electric loco			
	a any generic freight vehicle			
	o other (i.e. maintenance vehicles etc.)			

Figure 9: Classification and descriptors for railway vehicles [2]

Digit	1	2	3	4	5	6
Descriptor	**Track base**	**Railhead Roughness**	**Rail pad type**	**Additional measures**	**Rail joints**	**Curvature**
Explanation of the descriptor	Type of track base	Indicator for roughness	Represents an indication of the 'acoustic' stiffness	A letter describing acoustic device	Presence of joints and spacing	Indicate the radius of curvature in m
Codes al-lowed	**B** Ballast	**E** Well main-tained and very smooth	**S** Soft (150-250 MN/m)	**N** None	**N** None	**N** Straight track
	S Slab track	**M** Normally maintained	**M** Medium (250 to 800 MN/m)	**D** Rail damper	**S** Single joint or switch	**L** Low (1 000-500 m)
	L Ballasted bridge	**N** Not well maintained	**H** Stiff (800-1 000 MN/m)	**B** Low barrier	**D** Two joints or switches per 100 m	**M** Medium (Less than 500 m and more than 300 m)
	N Non-ballasted bridge	**B** Not main-tained and bad condi-tion		**A** Absorber plate on slab track	**M** More than two joints or switches per 100 m	**H** High (Less than 300 m)
	T Embedded track			**E** Embedded rail		
	O Other			**O** Other		

Figure 10: Parameters to be used to define the effect of track on noise emissions [2]

4.3 Industrial Noise Source

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

A. manufacturers' data sheets;
B. estimation from direct measurements;
C. database of noise sources;
D. estimation from similar noise source.

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 [8]. 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;
- oise measurement methods.

Table 2 and Table 3 synthetized the data that should be collected; a brief outlook on the measurement is given in Table 4.

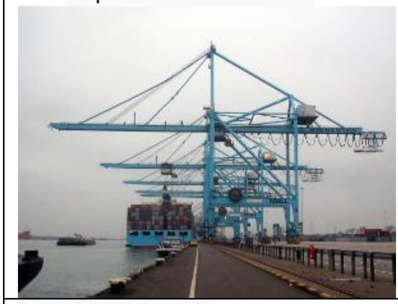
Table 2: Data required for the characterization of noise impact of ship in port areas [8]

Source type	**Data to be collected**	**Measurement method**
Ship	• Type: ships can be classified according to the types used by the Automatic Identification System (AIS). • Number and location within the port: for each docking area, it is necessary to have a list of the ships that docked within a year with the temporal distribution throughout the day. • Dimensions: it is necessary to know the main dimensions of the ship because they can influence the noise produced and its propagation.	The measurement techniques must provide for the acoustic characterization of the ship both when approaching the piers (ship in motion) and the ship moored on the dock.

Table 3: Data required for the characterization of noise impact of load handling unit in port areas [8]

Source type	**Data to be collected**	**Measurement method**
Straddle carrier 	• Number of vehicles • Model • Daily operativity • Identification of routes in the port area	The measurement of the noise emitted must include: • pass-by test with container • pass-by test without container • measurement of an entire operating cycle: container handling; shift; container laying.

Source type	Data to be collected	Measurement method
Front lift for the handling of empty containers 	• Number of vehicles • Model • Daily operativity • Identification of routes in the port area	The measurement of the noise emitted must include: • pass-by test with container • pass-by test without container • measurement of an entire operating cycle: container handling; shift; container laying.
Contstacker for the handling of empty containers 	• Number of vehicles • Model • Daily operativity • Identification of routes in the port area	The measurement of the noise emitted must include: • pass-by test with container • pass-by test without container • measurement of an entire operating cycle: container handling; shift; container laying.
Fork lifts 	• Number of vehicles • Model • Daily operativity • Identification of routes in the port area	The measurement of the noise emitted must include: • pass-by test with container • pass-by test without container • measurement of an entire operating cycle: container handling; shift; container laying.
Transtainer • On tire • On rail 	• Number of vehicles; • Model • Daily operativity • Number of movements • Identification of routes in the port area	The measurement of the noise emitted must include: • pass-by test with load • no-load pass-by test • measurement of an entire operating cycle: taking charge; shift; laying load.

Source type	Data to be collected	Measurement method
Gantry cranes This type of crane is classified according to the size of the ship on which they can operate: • panamax • post-panamax • Super-Post-Panamax 	• Number of vehicles; • Model • Daily operativity • Number of movements • Identification of routes in the port area	The measurement of the noise emitted must include: • pass-by test with load • no-load pass-by test • measurement of an entire operating cycle: taking charge; shift; laying load.
Wheeled cranes 	• Number of vehicles; • Model • Daily operativity • Number of movements • Identification of routes in the port area	The measurement of the noise emitted must include: • pass-by test with load • no-load pass-by test • measurement of an entire operating cycle: taking charge; shift; laying load.
Tractors 	• Number of vehicles; • Model • Daily operativity • Number of movements • Identification of routes in the port area	The measurement of the noise emitted must include: • pass-by test with load • no-load pass-by test • measurement of an entire operating cycle: taking charge; shift; laying load.

Source type	Data to be collected	Measurement method
Bulldozers for dry load handling 	• Number of vehicles; • Model • Daily operativity • Number of movements • Identification of routes in the port area	The measurement of the noise emitted must include: • pass-by test with load • no-load pass-by test • measurement of an entire operating cycle: taking charge; shift; laying load.
Conveyor belts (coal, etc.)	• Model • Daily operativity • Position	The measurements must include an acoustic characterization according to the different operating conditions (flow rate).
Areas used for working activities such as building sites, shipyard, industries, etc.	• Specification of the activity performed • Daily operativity • Position	See Table 4

Table 4: Measurement standards of acoustic emission characterization of noise sources in port areas [8]

Regulation	Title	Source	Analogy
UNI EN ISO 2922:2013	Acoustics - Measurement of airborne sound emitted by vessels on inland waterways and harbours	Ships - External noise	Own application
ISO 362-1:2015	Measurement of noise emitted by accelerating road vehicles — Engineering method — Part 1: M and N categories	Road vehicles in motion	Ship in pass-by
UNI EN ISO 3095:2013	Acoustics -- Railway applications -- Measurement of noise emitted by railbound vehicles	Rail vehicles.	Ship in pass by and on dock - Consider both moving and stationary vehicles
ISO 3891:1978	Acoustics — Procedure for describing aircraft noise heard on the ground	Airport	Analogy between airport and port
ISO 5130:2007	Acoustics — Measurements of sound pressure level emitted by stationary road vehicles	Stationary vehicles	Ship on quay

Regulation	Title	Source	Analogy
ISO 6393:2008	Earth-moving machinery — Determination of sound power level — Stationary test conditions	Earth moving machines - stationary.	Noise emitted into the environment by cranes and trucks
EN 13000:2010	Cranes - Mobile cranes	Mobile cranes	Standard withdrawn in 2014, but contains notes on noise that can be interesting
ISO 6395:2008	Earth-moving machinery — Determination of sound power level — Dynamic test conditions	Earth moving machines - on the move	Noise emitted into the environment by cranes and trolleys - Different measurement conditions are considered for the different machines
ISO 7188:1994	Acoustics -- Measurement of noise emitted by passenger cars under conditions representative of urban driving	Cars in urban traffic conditions	Ship in pass by
ISO 7216:2015	Agricultural and forestry tractors — Measurement of noise emitted when in motion	Moving tractors	Forklifts and constackers
ISO 9645:1990	Acoustics — Measurement of noise emitted by two-wheeled mopeds in motion — Engineering method	Bicycles in motion	Ships in pass by
ISO 3744: 2010	Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane	Fixed sources – Survey level	Cranes and any other type of fixed source
ISO 8297:1994	Acoustics — Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment — Engineering method	Industrial plants characterized by multiple sources	Own application

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 knots of 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 11.

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 were considered as the reference point for the definition of the calculation parameters listed in the paragraphs 5.1 and 5.2.

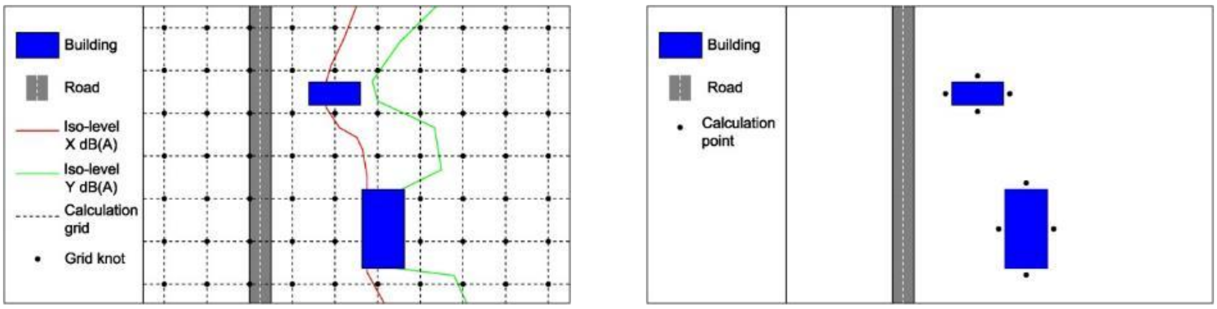


Figure 11: Examples of Grid Noise Map (GNM, left) and of Façade Noise Map (FNM, right) [9]. The real position of the calculation point is on the façade for FNM compliant to the END.

5.1 Grid Noise Map

- Reflection order: 1. This parameter defines the number of reflections considered by the algorithm;
- max distance between receiver (calculation grid knot) 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 knots. This value can be assessed equal to 10 m for big ports;
- grid height from the DGM: 4 m. Height of the grid knots 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.

5.2 Façade Noise Map

- 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 taken into account;
- 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.

6. Description of the Port Noise Assessment method

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, group 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 exceeds 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 trough open source software;
- performing façade noise simulations using the calculation parameters as defined in chapter 5;
- individuation of noise critical areas (hot spots).

6.2 Definition of noise critical areas

The method was developed taking into account the outcomes of the Deliverable 4 of NADIA Project [4]. 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 noise limits overtaking 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 source to the noise limits exceeds 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 done for each critical building perimeter (Figure 12). If two or more areas created by the offset procedure intersect, they have been merged to a unique area (Figure 13).

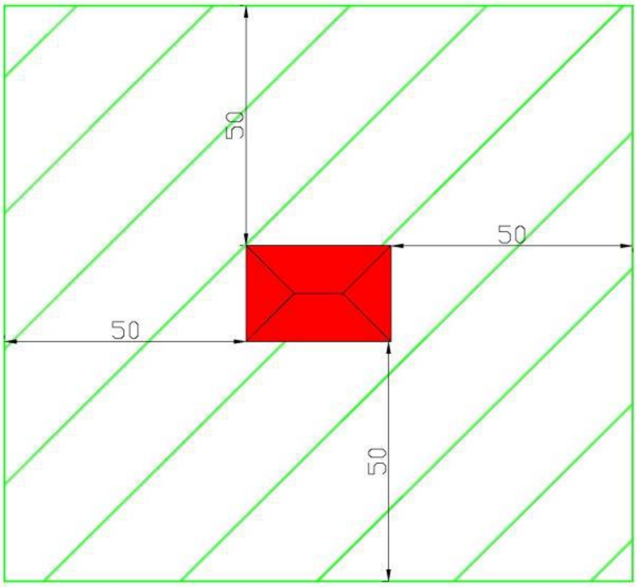


Figure 12: In red the critical building, in green its offset [4]

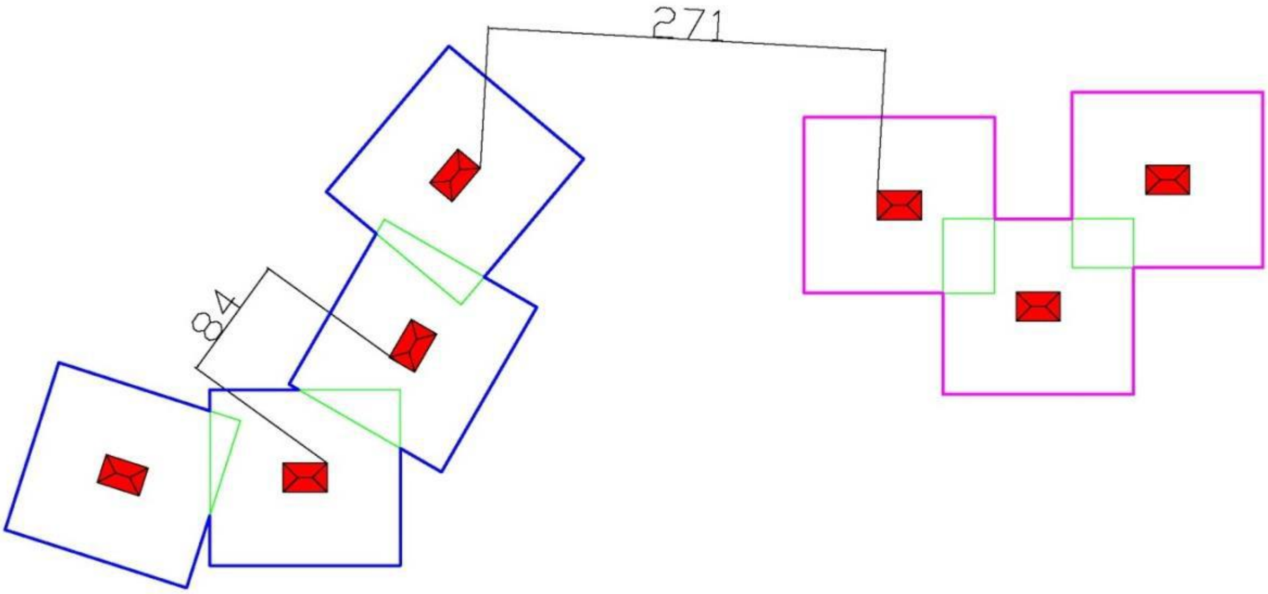


Figure 13: Example of critical areas definition. The contours of two critical areas are coloured in blue and magenta [4]

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 takes into account the outcomes of NADIA project and the method described by Asdrubali et al. [10]. Each critical building defined using the procedure reported in the paragraph 6.2 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:

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

where:

- Q_j is calculated with:

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

- 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 excess 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 grade, kindergarten included) and 4 for hospitals, retirement home and similar. 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 building or to the residential ones.

After the identification of the noise critical areas and 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:

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

wherre

- 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:

$$IF_{x,i,j} = \left. 10^{L_{x,i,j}} \middle/ \sum_{j=1}^{k} 10^{L_{x,i,j}} \right.$$

wherre $L_{x,i,j}$ 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;
- what are the noise sources having emissions needs to be mitigated;
- what 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 as the CBI one proposed by the Deliverable 4 of NADIA project [4]:

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

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.

7. Application of the Port Noise Assessment method in a case study

7.1 Description of the real case study

The Port Impact Assessment suggested in this guideline has been tested in the Melilla Port Area, considering the current port layout. Melilla port is located in the homonymous autonomous city in North Africa, occupying a strategic location at the confluence 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; every year the port manages 850,000 passengers and up to 1 Mtonnes of goods.

The Melilla port area was the object of a noise mapping study performed by a private company, in 2017 [10], that realized an acoustical characterization of the port noise sources.

Noise limits were taken from the acoustic zoning plan of the acoustic zoning plan of the Municipality of Melilla (Figure 8).

7.2 Realization of noise simulations

Noise simulations were realized using the indication defined in chapter 5. Noise emission data were the ones used for the 2017 strategic noise maps. Figure 14 reported the noise sources characterized by this study. Data available for the characterization of the noise sources do not allow to group the sources in terms of their managing authority. The sources were grouped as performed in the 2017 strategic noise mapping study as reported in Figure 14:

A. TRAFICO: the group is made of the roads inside the port area and it is represented by green lines;
B. EMISOARES: the group is made by the linear noise sources and it is represented by orange lines;
C. BARCOES: the group is made by ship in docking. The permanence time in each docking was considered. It is represented by cyan areas the name of the docking is reported in the figure with a red text;
D. EMISUPERFICIALES: the group is made of all the other types of surface noise sources considered in the study. It is represented by purple areas. The name of each sources is reported with a black text. The “Ocio” area was created in order to take into account the effects of some leisure activities. The “Indusria” one allows to consider the noise emission of a cement plant.

Figure 15 reports the buildings where the sound pressure level was assessed on their façades through noise simulations.

Figure 14: View of the study area.

Figure 15: Definition of the study area. Compared to Figure 14, here buildings where the sound pressure level was assessed through simulation in their façades are evidenced in grey.

7.3 Identification of critical areas

The comparison of the façade noise simulation and the acoustical zoning evidences that the noise limits were exceeded in six buildings (Figure 16). The offset procedure allows to define two critical areas, as shown in Figure 17. The small one was named A and it contains only one building. The big one was named B and it contains 5 buildings.

Figure 16: Compared to Figure 15, critical buildings are evidenced in red.

Figure 17: Critical areas and critical buildings.

7.4 Calculation of the Priority Index

Table 5 reports for each calculation point of each critical building the sound pressure level caused by each group of sources and the global one referred to the night period. The results referred to the other period were assessed, but they are not shown there since in these two periods the noise limits exceedings are lower than the night period. Moreover, the table specifies the critical area belonging to the critical buildings. The position of each critical building is reported in Figure 18.

Figure 18: Identification of critical buildings

Table 5: Outcomes of noise calculations and determination of the $IP_{all,cp,}I$ parameter

Building name	Floor	Direction	SPL All sources Night	SPL Limit	Max noise limit exceeds	$IP_{all,cp,i}$	Critical Area	SPL Barcoes Night	SPL Emisoares Night	SPL Emisuperficiales Night	SPL Trafico Night
181	1	NW	51.4	50	1.4	1.5	A	51.3	20.2	24.7	23.4
181	2	NW	51.5	50	1.5	1.6	A	51.5	21.4	29.5	29
181	Ground	SW	56.5	50	6.5	7.1	A	56.4	17.4	41.4	36.8
181	1	SW	53.5	50	3.5	3.8	A	53.2	18.3	41.1	35.9
181	2	SW	53.2	50	3.2	3.5	A	52.8	19.7	41.3	37.1
181	Ground	SW	55.1	50	5.1	5.6	A	54.9	17.2	41.5	33.3
181	1	SW	53.8	50	3.8	4.2	A	53.5	18.5	41.2	36.1
181	2	SW	53.4	50	3.4	3.7	A	53	19.5	41.4	37.5
181	Ground	SW	53.5	50	3.5	3.8	A	53.2	16.9	41.5	32.8
181	1	SW	54.1	50	4.1	4.5	A	53.8	17.9	41.4	36.3
181	2	SW	53.5	50	3.5	3.8	A	53.1	18.4	41.5	37.8
181	Ground	SW	53.6	50	3.6	4.0	A	53.3	17	40.9	36.2
181	1	SW	54.3	50	4.3	4.7	A	54	17.2	41.1	38.1
181	2	SW	54	50	4	4.4	A	53.6	17.8	41.3	39
181	2	SE	56	50	6	6.6	A	55.7	18.8	43.3	35.6
237	Ground	SE	56.9	55	1.9	2.1	B	56.7	37.4	40.5	34.1
237	1	SE	55.4	55	0.4	0.4	B	55.2	36.8	39.1	31.4
237	Ground	SE	56.7	55	1.7	1.9	B	56.6	37.2	39.5	34.3
237	1	SE	55.4	55	0.4	0.4	B	55.2	36.7	39.3	31.4
237	Ground	SE	56.6	55	1.6	1.8	B	56.5	35.5	39.2	34.4
237	1	SE	55.4	55	0.4	0.4	B	55.2	36.3	39.2	31.9
237	Ground	SE	56.6	55	1.6	1.8	B	56.5	34.8	39.3	34.3
237	Ground	SE	57.1	55	2.1	2.3	B	57	32.4	39	33.3
237	Ground	SE	56.9	55	1.9	2.1	B	56.8	20.8	39.2	31.9
238	Ground	SW	57	55	2	2.2	B	57	14	37.5	11
238	1	SW	55.1	55	0.1	0.1	B	55.1	13.6	36.6	10.6
238	Ground	SW	57.2	55	2.2	2.4	B	57.2	14	37.2	23.1
238	1	SW	55.2	55	0.2	0.2	B	55.1	13.6	37.2	16.1
238	Ground	SE	57.5	55	2.5	2.7	B	57.4	36.8	37.5	33.5
238	1	SE	55.8	55	0.8	0.9	B	55.7	36.5	38.6	30.9
238	4	SE	55.1	55	0.1	0.1	B	54.9	34.7	39.2	30.6
238	Ground	SE	57.5	55	2.5	2.7	B	57.4	36.9	37.8	33.7
238	1	SE	55.8	55	0.8	0.9	B	55.6	36.6	39.1	31
238	Ground	SE	57.1	55	2.1	2.3	B	57	37	39.6	33.9
238	1	SE	55.6	55	0.6	0.7	B	55.4	36.5	38.6	31.2
238	Ground	SE	57	55	2	2.2	B	56.9	37.3	39.6	33.9
238	1	SE	55.5	55	0.5	0.5	B	55.4	36.6	39.1	31.3
238	Ground	SE	57	55	2	2.2	B	56.8	37.4	39.4	33.9
238	1	SE	55.5	55	0.5	0.5	B	55.3	36.7	38.7	31.3
238	Ground	SE	56.9	55	1.9	2.1	B	56.7	37.4	40.6	34.1
238	1	SE	55.5	55	0.5	0.5	B	55.3	37.1	38.6	31.3
247	Ground	SE	55.2	55	0.2	0.2	B	55.2	21.9	23.1	21.2
247	Ground	SE	55.6	55	0.6	0.7	B	55.6	16	23.1	21.3
247	Ground	SE	55.7	55	0.7	0.8	B	55.6	14.4	37.1	28
284	Ground	SE	55.8	55	0.8	0.9	B	55.7	13.7	38.9	31.1
284	Ground	SE	55.8	55	0.8	0.9	B	55.6	14.7	39.6	31.4
294	Ground	SW	55.1	55	0.1	0.1	B	55.1	25.7	29.3	11.9
294	Ground	SW	55.3	55	0.3	0.3	B	55.3	32.7	30.5	12.1
294	Ground	SW	55.5	55	0.5	0.5	B	55.5	20	30.9	26.6
294	Ground	SW	55.7	55	0.7	0.8	B	55.7	13.5	29.5	10.5
294	Ground	SW	56.7	55	1.7	1.9	B	56.7	13.8	29.3	9.5
294	Ground	SW	56.6	55	1.6	1.8	B	56.6	14.6	30.3	15.8
294	Ground	SW	57.4	55	2.4	2.6	B	57.4	16.2	33.2	14.7
294	1	SW	55.4	55	0.4	0.4	B	55.4	13.4	34.7	14.6
294	Ground	SW	57.5	55	2.5	2.7	B	57.5	22.3	39.3	29.8
294	1	SW	55.6	55	0.6	0.7	B	55.5	18.6	38.8	28
294	Ground	SE	57.8	55	2.8	3.1	B	57.7	35	40	33.6

Building name	Floor	Direction	SPL All sources Night	SPL Limit	Max noise limit exceeds	$IP_{all,cp,i}$	Critical Area	SPL Barcoes Night	SPL Emisoares Night	SPL Emisuperficiales Night	SPL Trafico Night
294	1	SE	55.9	55	0.9	1.0	B	55.8	34.4	38.9	31.3
294	2	SE	55.1	55	0.1	0.1	B	54.9	33.8	39.6	30
294	3	SE	55.1	55	0.1	0.1	B	54.9	33.2	39.8	29.9
294	4	SE	55.1	55	0.1	0.1	B	54.9	32.8	40.4	29.5
294	5	SE	55.1	55	0.1	0.1	B	54.9	32.5	41	29.5
294	Ground	SE	57.8	55	2.8	3.1	B	57.7	35.3	39.8	33.3
294	1	SE	56	55	1	1.1	B	55.9	34.7	38.6	31
294	2	SE	55.3	55	0.3	0.3	B	55.1	34.2	39.4	30
294	3	SE	55.2	55	0.2	0.2	B	55.1	33.5	39.6	29.9
294	4	SE	55.4	55	0.4	0.4	B	55.2	33.1	40.2	29.6
294	5	SE	55.4	55	0.4	0.4	B	55.2	32.7	40.7	29.7
294	Ground	SE	57.8	55	2.8	3.1	B	57.7	35.9	39.5	33.4
294	1	SE	56.1	55	1.1	1.2	B	55.9	34.9	38.4	31
294	2	SE	55.2	55	0.2	0.2	B	55.1	34.4	39.3	29.9
294	3	SE	55.2	55	0.2	0.2	B	55	33.8	39.7	29.9
294	4	SE	55.3	55	0.3	0.3	B	55.2	33.4	40.2	29.8
294	5	SE	55.4	55	0.4	0.4	B	55.2	33	40.9	29.9
294	Ground	SE	57.7	55	2.7	3.0	B	57.6	35.6	39.2	33.3
294	1	SE	55.9	55	0.9	1.0	B	55.8	35.4	39.1	30.9
294	2	SE	55.3	55	0.3	0.3	B	55.1	34.7	39.4	29.9
294	3	SE	55.2	55	0.2	0.2	B	55	34.1	39.2	29.9
294	4	SE	55.3	55	0.3	0.3	B	55.2	33.6	40	29.9
294	5	SE	55.4	55	0.4	0.4	B	55.2	33.2	40.5	30
294	Ground	SE	57.6	55	2.6	2.9	B	57.5	36	39	33.2
294	1	SE	55.9	55	0.9	1.0	B	55.8	35.5	39.5	30.8
294	2	SE	55.3	55	0.3	0.3	B	55.1	35	38.7	29.7
294	3	SE	55.2	55	0.2	0.2	B	55	34.4	39.1	29.9
294	4	SE	55.4	55	0.4	0.4	B	55.2	33.9	40.1	30
294	5	SE	55.3	55	0.3	0.3	B	55.1	33.4	40.7	30.1
294	Ground	SE	57.7	55	2.7	3.0	B	57.6	36.2	39.4	33.1
294	1	SE	55.9	55	0.9	1.0	B	55.8	35.9	38.3	30.7
294	2	SE	55.1	55	0.1	0.1	B	55	35.2	38.4	29.9
294	3	SE	55.1	55	0.1	0.1	B	54.9	34.6	39.3	30
294	4	SE	55.3	55	0.3	0.3	B	55.1	34.1	39.8	30.1
294	5	SE	55.2	55	0.2	0.2	B	55	33.6	40.5	30.2
294	Ground	SE	57.6	55	2.6	2.9	B	57.6	36.2	38.3	33.2
294	1	SE	56	55	1	1.1	B	55.8	36	39.1	30.8
294	2	SE	55.1	55	0.1	0.1	B	55	35.5	38.8	29.8
294	3	SE	55.1	55	0.1	0.1	B	54.9	34.8	38.8	30
294	4	SE	55.3	55	0.3	0.3	B	55.1	34.1	39.7	30.2
294	5	SE	55.2	55	0.2	0.2	B	55	33.6	40.4	30.3
294	Ground	SE	57.5	55	2.5	2.7	B	57.4	36.2	38.2	33.4
294	1	SE	56.1	55	1.1	1.2	B	55.9	36	38.7	30.8
294	2	SE	55.1	55	0.1	0.1	B	55	35.5	38.3	30
294	4	SE	55.2	55	0.2	0.2	B	55.1	34.2	39.7	30.3
294	5	SE	55.2	55	0.2	0.2	B	55	33.7	41.2	30.4
294	Ground	SE	57.5	55	2.5	2.7	B	57.4	36.4	38.7	33.1
294	1	SE	56	55	1	1.1	B	55.9	36.2	38.2	30.9
294	2	SE	55.1	55	0.1	0.1	B	54.9	35.7	37.8	30.2
294	4	SE	55.2	55	0.2	0.2	B	55.1	34.3	39.8	30.5
294	5	SE	55.2	55	0.2	0.2	B	55	33.8	41	30.4
294	Ground	NE	57.2	55	2.2	2.4	B	57.1	36.8	24.8	32.4
294	1	NE	55.4	55	0.4	0.4	B	55.3	36.3	24.4	30.4

The estimation of the sound pressure level reported in Table 5 were used to detect the $IF_{x,i,j}$ required for the determination of the priority index of each group noise sources. In each calculation point, the index of priority related to the impact of the x-th group of noise sources $IP_{x,i,i}$ was detected multiplying the $IF_{x,i,j}$ parameter with the global factor $IP_{all,cp,j}$.

Table 6: Calculation of the $IF_{x,j}$ and of the $IP_{x,j}$ parameters

B. name	Floor	Dire	$IP_{all,cp,i}$	Cr. Area	$IF_{x,i,j}$ Barcoes	$IF_{x,i,j}$ Emisoares	$IF_{x,i,j}$ Emisuperficiales	$IF_{x,i,j}$ Trafico	$IP_{x,i,j}$ Barcoes	$IP_{x,i,j}$ Emisoares	$IP_{x,i,j}$ Emisuperficiales	$IP_{x,i,j}$ Trafico
181	1	NW	1.5	A	1.00	0.00	0.00	0.00	1.5	0.0	0.0	0.0
181	2	NW	1.6	A	0.99	0.00	0.01	0.01	1.6	0.0	0.0	0.0
181	Ground	SW	7.1	A	0.96	0.00	0.03	0.01	6.8	0.0	0.2	0.1
181	1	SW	3.8	A	0.93	0.00	0.06	0.02	3.6	0.0	0.2	0.1
181	2	SW	3.5	A	0.91	0.00	0.06	0.02	3.2	0.0	0.2	0.1
181	Ground	SW	5.6	A	0.95	0.00	0.04	0.01	5.3	0.0	0.2	0.0
181	1	SW	4.2	A	0.93	0.00	0.05	0.02	3.9	0.0	0.2	0.1
181	2	SW	3.7	A	0.91	0.00	0.06	0.03	3.4	0.0	0.2	0.1
181	Ground	SW	3.8	A	0.93	0.00	0.06	0.01	3.6	0.0	0.2	0.0
181	1	SW	4.5	A	0.93	0.00	0.05	0.02	4.2	0.0	0.2	0.1
181	2	SW	3.8	A	0.91	0.00	0.06	0.03	3.5	0.0	0.2	0.1
181	Ground	SW	4.0	A	0.93	0.00	0.05	0.02	3.7	0.0	0.2	0.1
181	1	SW	4.7	A	0.93	0.00	0.05	0.02	4.4	0.0	0.2	0.1
181	2	SW	4.4	A	0.91	0.00	0.05	0.03	4.0	0.0	0.2	0.1
181	2	SE	6.6	A	0.94	0.00	0.05	0.01	6.2	0.0	0.4	0.1
237	Ground	SE	2.1	B	0.96	0.01	0.02	0.01	2.0	0.0	0.0	0.0
237	1	SE	0.4	B	0.96	0.01	0.02	0.00	0.4	0.0	0.0	0.0
237	Ground	SE	1.9	B	0.96	0.01	0.02	0.01	1.8	0.0	0.0	0.0
237	1	SE	0.4	B	0.96	0.01	0.02	0.00	0.4	0.0	0.0	0.0
237	Ground	SE	1.8	B	0.97	0.01	0.02	0.01	1.7	0.0	0.0	0.0
237	1	SE	0.4	B	0.96	0.01	0.02	0.00	0.4	0.0	0.0	0.0
237	Ground	SE	1.8	B	0.97	0.01	0.02	0.01	1.7	0.0	0.0	0.0
237	Ground	SE	2.3	B	0.98	0.00	0.02	0.00	2.3	0.0	0.0	0.0
237	Ground	SE	2.1	B	0.98	0.00	0.02	0.00	2.0	0.0	0.0	0.0
238	Ground	SW	2.2	B	0.99	0.00	0.01	0.00	2.2	0.0	0.0	0.0
238	1	SW	0.1	B	0.99	0.00	0.01	0.00	0.1	0.0	0.0	0.0
238	Ground	SW	2.4	B	0.99	0.00	0.01	0.00	2.4	0.0	0.0	0.0
238	1	SW	0.2	B	0.98	0.00	0.02	0.00	0.2	0.0	0.0	0.0
238	Ground	SE	2.7	B	0.98	0.01	0.01	0.00	2.7	0.0	0.0	0.0
238	1	SE	0.9	B	0.97	0.01	0.02	0.00	0.8	0.0	0.0	0.0
238	4	SE	0.1	B	0.96	0.01	0.03	0.00	0.1	0.0	0.0	0.0
238	Ground	SE	2.7	B	0.98	0.01	0.01	0.00	2.7	0.0	0.0	0.0
238	1	SE	0.9	B	0.96	0.01	0.02	0.00	0.8	0.0	0.0	0.0
238	Ground	SE	2.3	B	0.97	0.01	0.02	0.00	2.2	0.0	0.0	0.0
238	1	SE	0.7	B	0.96	0.01	0.02	0.00	0.6	0.0	0.0	0.0
238	Ground	SE	2.2	B	0.97	0.01	0.02	0.00	2.1	0.0	0.0	0.0
238	1	SE	0.5	B	0.96	0.01	0.02	0.00	0.5	0.0	0.0	0.0
238	Ground	SE	2.2	B	0.97	0.01	0.02	0.00	2.1	0.0	0.0	0.0
238	1	SE	0.5	B	0.96	0.01	0.02	0.00	0.5	0.0	0.0	0.0
238	Ground	SE	2.1	B	0.96	0.01	0.02	0.01	2.0	0.0	0.0	0.0
238	1	SE	0.5	B	0.96	0.01	0.02	0.00	0.5	0.0	0.0	0.0
247	Ground	SE	0.2	B	1.00	0.00	0.00	0.00	0.2	0.0	0.0	0.0
247	Ground	SE	0.7	B	1.00	0.00	0.00	0.00	0.7	0.0	0.0	0.0
247	Ground	SE	0.8	B	0.98	0.00	0.01	0.00	0.8	0.0	0.0	0.0
284	Ground	SE	0.9	B	0.98	0.00	0.02	0.00	0.9	0.0	0.0	0.0
284	Ground	SE	0.9	B	0.97	0.00	0.02	0.00	0.9	0.0	0.0	0.0
294	Ground	SW	0.1	B	1.00	0.00	0.00	0.00	0.1	0.0	0.0	0.0
294	Ground	SW	0.3	B	0.99	0.01	0.00	0.00	0.3	0.0	0.0	0.0
294	Ground	SW	0.5	B	0.99	0.00	0.00	0.00	0.5	0.0	0.0	0.0
294	Ground	SW	0.8	B	1.00	0.00	0.00	0.00	0.8	0.0	0.0	0.0
294	Ground	SW	1.9	B	1.00	0.00	0.00	0.00	1.9	0.0	0.0	0.0
294	Ground	SW	1.8	B	1.00	0.00	0.00	0.00	1.8	0.0	0.0	0.0
294	Ground	SW	2.6	B	1.00	0.00	0.00	0.00	2.6	0.0	0.0	0.0
294	1	SW	0.4	B	0.99	0.00	0.01	0.00	0.4	0.0	0.0	0.0
294	Ground	SW	2.7	B	0.98	0.00	0.01	0.00	2.7	0.0	0.0	0.0
294	1	SW	0.7	B	0.98	0.00	0.02	0.00	0.6	0.0	0.0	0.0
294	Ground	SE	3.1	B	0.97	0.01	0.02	0.00	3.0	0.0	0.1	0.0
294	1	SE	1.0	B	0.97	0.01	0.02	0.00	1.0	0.0	0.0	0.0
294	2	SE	0.1	B	0.96	0.01	0.03	0.00	0.1	0.0	0.0	0.0
294	3	SE	0.1	B	0.96	0.01	0.03	0.00	0.1	0.0	0.0	0.0
294	4	SE	0.1	B	0.96	0.01	0.03	0.00	0.1	0.0	0.0	0.0
294	5	SE	0.1	B	0.95	0.01	0.04	0.00	0.1	0.0	0.0	0.0
294	Ground	SE	3.1	B	0.98	0.01	0.02	0.00	3.0	0.0	0.0	0.0
294	1	SE	1.1	B	0.97	0.01	0.02	0.00	1.1	0.0	0.0	0.0
294	2	SE	0.3	B	0.96	0.01	0.03	0.00	0.3	0.0	0.0	0.0
294	3	SE	0.2	B	0.96	0.01	0.03	0.00	0.2	0.0	0.0	0.0
294	4	SE	0.4	B	0.96	0.01	0.03	0.00	0.4	0.0	0.0	0.0
294	5	SE	0.4	B	0.96	0.01	0.03	0.00	0.4	0.0	0.0	0.0
294	Ground	SE	3.1	B	0.98	0.01	0.01	0.00	3.0	0.0	0.0	0.0
294	1	SE	1.2	B	0.97	0.01	0.02	0.00	1.2	0.0	0.0	0.0

B. name	Floor	Dire	$IP_{all,cp,i}$	Cr. Area	$IF_{x,i,j}$ Barcoes	$IF_{x,i,j}$ Emisoares	$IF_{x,i,j}$ Emisuperficiales	$IF_{x,i,j}$ Trafico	$IP_{x,i,j}$ Barcoes	$IP_{x,i,j}$ Emisoares	$IP_{x,i,j}$ Emisuperficiales	$IP_{x,i,j}$ Trafico
294	2	SE	0.2	B	0.96	0.01	0.03	0.00	0.2	0.0	0.0	0.0
294	3	SE	0.2	B	0.96	0.01	0.03	0.00	0.2	0.0	0.0	0.0
294	4	SE	0.3	B	0.96	0.01	0.03	0.00	0.3	0.0	0.0	0.0
294	5	SE	0.4	B	0.96	0.01	0.04	0.00	0.4	0.0	0.0	0.0
294	Ground	SE	3.0	B	0.98	0.01	0.01	0.00	2.9	0.0	0.0	0.0
294	1	SE	1.0	B	0.97	0.01	0.02	0.00	1.0	0.0	0.0	0.0
294	2	SE	0.3	B	0.96	0.01	0.03	0.00	0.3	0.0	0.0	0.0
294	3	SE	0.2	B	0.96	0.01	0.03	0.00	0.2	0.0	0.0	0.0
294	4	SE	0.3	B	0.96	0.01	0.03	0.00	0.3	0.0	0.0	0.0
294	5	SE	0.4	B	0.96	0.01	0.03	0.00	0.4	0.0	0.0	0.0
294	Ground	SE	2.9	B	0.98	0.01	0.01	0.00	2.8	0.0	0.0	0.0
294	1	SE	1.0	B	0.97	0.01	0.02	0.00	1.0	0.0	0.0	0.0
294	2	SE	0.3	B	0.97	0.01	0.02	0.00	0.3	0.0	0.0	0.0
294	3	SE	0.2	B	0.96	0.01	0.02	0.00	0.2	0.0	0.0	0.0
294	4	SE	0.4	B	0.96	0.01	0.03	0.00	0.4	0.0	0.0	0.0
294	5	SE	0.3	B	0.96	0.01	0.03	0.00	0.3	0.0	0.0	0.0
294	Ground	SE	3.0	B	0.97	0.01	0.01	0.00	2.9	0.0	0.0	0.0
294	1	SE	1.0	B	0.97	0.01	0.02	0.00	1.0	0.0	0.0	0.0
294	2	SE	0.1	B	0.97	0.01	0.02	0.00	0.1	0.0	0.0	0.0
294	3	SE	0.1	B	0.96	0.01	0.03	0.00	0.1	0.0	0.0	0.0
294	4	SE	0.3	B	0.96	0.01	0.03	0.00	0.3	0.0	0.0	0.0
294	5	SE	0.2	B	0.96	0.01	0.03	0.00	0.2	0.0	0.0	0.0
294	Ground	SE	2.9	B	0.98	0.01	0.01	0.00	2.8	0.0	0.0	0.0
294	1	SE	1.1	B	0.97	0.01	0.02	0.00	1.1	0.0	0.0	0.0
294	2	SE	0.1	B	0.96	0.01	0.02	0.00	0.1	0.0	0.0	0.0
294	3	SE	0.1	B	0.96	0.01	0.02	0.00	0.1	0.0	0.0	0.0
294	4	SE	0.3	B	0.96	0.01	0.03	0.00	0.3	0.0	0.0	0.0
294	5	SE	0.2	B	0.96	0.01	0.03	0.00	0.2	0.0	0.0	0.0
294	Ground	SE	2.7	B	0.98	0.01	0.01	0.00	2.7	0.0	0.0	0.0
294	1	SE	1.2	B	0.97	0.01	0.02	0.00	1.2	0.0	0.0	0.0
294	2	SE	0.1	B	0.97	0.01	0.02	0.00	0.1	0.0	0.0	0.0
294	4	SE	0.2	B	0.96	0.01	0.03	0.00	0.2	0.0	0.0	0.0
294	5	SE	0.2	B	0.95	0.01	0.04	0.00	0.2	0.0	0.0	0.0
294	Ground	SE	2.7	B	0.98	0.01	0.01	0.00	2.7	0.0	0.0	0.0
294	1	SE	1.1	B	0.97	0.01	0.02	0.00	1.1	0.0	0.0	0.0
294	2	SE	0.1	B	0.97	0.01	0.02	0.00	0.1	0.0	0.0	0.0
294	4	SE	0.2	B	0.96	0.01	0.03	0.00	0.2	0.0	0.0	0.0
294	5	SE	0.2	B	0.95	0.01	0.04	0.00	0.2	0.0	0.0	0.0
294	Ground	NE	2.4	B	0.99	0.01	0.00	0.00	2.4	0.0	0.0	0.0
294	1	NE	0.4	B	0.98	0.01	0.00	0.00	0.4	0.0	0.0	0.0

Data reported in Table 6 were then used to calculate the IP_x value related to the x-th group of noise sources in each critical area. The outcomes reported in Table 7 shown that the “Barcoes” is the most impacting group of sources. The mitigation of its impact is more urgent in the critical area “B”.

Table 7: Calculation of the index of priority in the case study

Ranking	Group Name	Critical areas	IP_x
1	BARCOES	B	96.5
2	BARCOES	A	58.8
4	EMISUPERFICIALES	A	3.1
5	EMISUPERFICIALES	B	1.5
6	TRAFICO	A	1.0
7	EMISOARES	B	0.6
8	TRAFICO	B	0.3
9	EMISOARES	A	0.0

The outcomes of the analysis were considered not completely sufficient to define the mitigation measures, consequently, noise simulations were repeated considering separately the noise sources comprised in "BARCOES" group. The name of each noise source belonging to the "BARCOES" group is reported in Figure 19. The procedure executed to calculate the IP_x value for each critical area was repeated considering the new groups and the outcomes are reported in Table 8.

Figure 19: The red text indicates the name of all the sub-groups belonging to the "BARCOES" group

The ranking of the index of priority IP reported in Table 8 reports that the noise sources belonging to the sub-group "RIBERA I" are the more impacting ones.

The anti-noise actions aimed at reducing the noise immissions of "RIBERA I" in the critical areas "B" and "A" are respectively the first and the second more urgent measures. The contribution of the other sources is practically negligible.

The application on the case study evidenced that a sub-grouping procedure after a first stage analysis may be useful to have a clearer scenario of the noise exposure caused by the acoustic emission of all the noise sources in a port area. This procedure eases the identification of areas where anti-noise measures are more urgent in comparison to other one and addresses the authority in charge for noise mitigation plans and projects in the definition of a noise mitigation plan.

Table 8 : Detailed Calculation of the index of priority in the case study

Ranking	**Group Name**	**Critical areas**	**IP_x**
1	RIBERA I	B	96.1
2	RIBERA I	A	58.8
3	EMISUPERFICIALES	A	3.1
4	EMISUPERFICIALES	B	1.5
5	TRAFICO	A	1.0
6	EMISOARES	B	0.6
7	ESPIGON	B	0.4
8	TRAFICO	B	0.3

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Particip. Role	Particip. Number	Participant name	Participant short name	Country	Date enter project	Date exit project
CO	1	Istituto Superiore per la Protezione e la Ricerca Ambientale - Italian National Institute for Environmental Protection and Research	ISPRA	Italy	1	36
AB	2	Autorità di Sistema Portuale Mar Tirreno Settentrionale	ADSPMTS	Italy	1	36
AB	3	Centro Interuniversitario di Ricerca sull'Inquinamento e sull'Ambiente "Mauro Felli"	CIRIAF	Italy	1	36
AB	4	INGENIA srl	INGENIA	Italy	1	36
AB	5	Autoridad Portuaria de Melilla	MPA	Spain	1	36
AB	6	Municipality of Patras	MUPAT	Greece	1	36