Research Article

Samuele Schiavoni*, Giorgio Baldinelli, Andrea Presciutti, and Francesco D’Alessandro

Acoustic mitigation of noise in ports: an original methodology for the identification of intervention priorities

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Abstract: The paper presents an original methodology for the identification of intervention priorities through a tailored priority index IP in areas that are highly-exposed to port noise. The methodology is applied to a case study developed in the framework of the European project ANCHOR, acronym of Advanced Noise Control strategies in HarbOuR, funded as part of the announcement Life 2017.
In detail, the paper discusses the results of its application in the assessment of the evolution of port noise impacts in the city of Melilla, Spain. The methodology has been applied considering the port with or without the realization of an expansion project on three different time periods; differences between standard and the summer traffic peak season have been considered. Finally, the paper evaluates the realization of cold ironing in the most impacting port area, the passenger (Ro-Pax) terminal. The results of the analyses demonstrate how the measure is a key action to mitigate noise in port areas.
The methodology is not limited to the identification of city areas that needs to be protected; it also aims to identify port areas where anti-noise actions would produce the greatest effect.
The index also allows to build a ranking to understand where anti-noise actions are more useful and urgent.

Keywords: Port noise assessment; noise modelling; noise mapping; priority index; LIFE project

***Corresponding Author: Samuele Schiavoni:** METEXIS, Perugia, Italy; Email: schiavoni@metexis.it
Giorgio Baldinelli: CIRIAF – Inter University Research Centre for Environment and Pollution “Mauro Felli”, Via G. Duranti 67, 06125, Perugia, Italy
Andrea Presciutti: METEXIS, Perugia, Italy; Universitas Mercatorum, P.za E. Mattei 1, Roma, Italy
Francesco D’Alessandro: METEXIS, Perugia, Italy; Italian National Research Council (CNR) – Institute on Atmospheric Pollution at Italian Ministry of Environment and Energy Security, Via Cristoforo Colombo 44, 00147, Rome, Italy

Acronyms

END	Environmental Noise Directive 2002/49/EC
FNM	Façade noise map
IP	Priority Index. Index to create a rating of the port areas where anti-noise actions are more urgent
Lo-Lo	ships designed to transport goods (containers) that needs a crane to be moved from the deck in board and vice versa
Ro-Pax	Vessels devoted to transport mainly passengers and their vehicles
TEU	Twenty-foot equivalent unit. It is the volume of a 6.1 m (20 foot) intermodal container

1 Introduction

Ports are crucial for a city’s economic development, but they also come with environmental obligations to the community. Due to its effects on the nearby metropolitan areas, environmental noise produced by shipping ports is becoming a critical subject [1], particularly when there is considerable marine activity or frequent loading and unloading [2]. Both technically and in terms of the regulatory approach, port noise and its effects on humans are difficult issues [3]. The Environmental Noise Directive (END) [4], updated by European Commission in 2015 [5], does not require to assess separately the noise emitted by ports from other industrial or commercial sectors. In reality, there are various normative methods available at the municipal, national, and European levels (as requested for other transportation infrastructures). Additionally, up until 2015, each Member State was free to employ its own noise model to simulate noise exposure, which made it difficult to compare the results of different nations’ noise mapping projects. In order to address this problem, the 2015 Directive amended Annex II of the END and added new noise emission and propagation modelling techniques drawn from the CNOS-

SOS project [6, 7], specifying common noise assessment methods. Since December 31, 2018, these techniques are mandatory for the creation of the strategic noise maps and all other data needed to comply with the END Directive. The END directive does not call for the creation of specific maps for port areas, in contrast to major road and rail infrastructures and airports. Nevertheless, noise impact of ports must be taken into account when creating the strategic noise maps of agglomerates, where ports are regarded as industrial sources.

From the technical point of view, the main challenge for acoustic operators is source identification and characterization [8]. The complexity of realizing an acoustic assessment of ports is caused by the high number of noise sources and infrastructures involved. The majority of them have undergone rigorous acoustical characterisation, whereas ships are in a quite different condition because they lack a common characterization [9, 10].

Environmental noise generated by ports was the subject of a great number of funded programs and research studies. The goal of the Life NoMEPorts [11] project was to establish a “Good Practice Guide” based on noise calculation algorithms provided by END and replaced by 996/2015/EC for the purpose of defining a harmonized common strategy on port area noise mapping and management.

The SILENV [12, 13] and EFFORTS [14] initiatives concentrated on lessening the environmental impact of ships because noise produced by sea transport accounts for a significant portion of the noise pollution emitted into the ports.

Through a combination of technological, administrative, and communication solutions, the MESP project [2, 15] produced guidelines to improve sustainable management of Mediterranean ports to decrease air, water, and noise pollution. In order to assist management authorities and users of port areas and infrastructures in achieving a greater level of sustainability and reducing environmental pollution, a number of recommended practices were identified [16].

In accordance with best practices, the Greater Rotterdam Area requested in 2009 that local authorities implement the Cityharbour (Stadshavens) Rotterdam project [17], to improve the quality of life for residents impacted by the noise pollution caused by port operations. As compensatory measures, for instance, the addition of green spaces and improved public services was suggested.

In another project in Vancouver [18], a specialised company assisted port staff in managing noise data and tracking changes in noise levels by providing technical guidance and best practises. The company also helped the port set up a system to handle noise complaints and provided quarterly reports and annual summaries.

Several studies have attempted to define and enhance methods for noise measurement and mapping in port areas in academic literature [19–22]. Fredianelli *et al.* [23] proposed a detailed classification of noise sources, to help the competent authorities to correctly identify responsibilities for noise emission and noise exposure of citizens. At the same time, the work suggests an analytical approach in the identification of the most suitable position for the sound level meters. A recent research work [24] reports a guideline for the characterization of noise sources needed as inputs for noise maps, as developed in the framework of the INTERREG Maritime programme Italy-France 2014–2020.

In this scenario, the ANCHOR LIFE project [25] worked to spread information about noise pollution from ports and to increase public awareness of the issue. It is aimed at government agencies, decision-makers, port authorities, private businesses, and other stakeholders generally involved in port activities, as well as at citizens and academics.

To direct the process and enhance relationships among all port actors, including companies, local communities, and port authorities, three Best Practices for Noise Governance and Information were created and put into place, one for each partner port authority involved in the project.

More specifically, ANCHOR LIFE seeks to create “Figures of Merits,” or incentives that port administrations offer to private businesses operating in port areas for implementing noise-reducing measures. Additionally, a Guideline for the Definition of a Common Approach in Port Noise Monitoring and Assessment was implemented as part of the project, and a Smart Port Noise Monitoring System was installed in the port of Patras.

The ANCHOR LIFE project deliverable “Guideline for a Common Port Noise Impact Assessment method” is described in Schiavoni *et al.* [26], where the method has been applied to the proposed expansion of the port of Melilla [27].

Utilizing the algorithms established by the European Directive 2015/996/EC [5], the outcome is the definition of the overall noise impact in the Melilla port area taking into account three different time scenarios of the port expansion (each one representing a decade: 10, 20, 30 years).

The creation and use of a novel methodology for the determination of intervention priorities within mitigation efforts for critical areas for the three various time scenarios constitutes a part of the work.

This paper presents the outcomes of its application to critical areas of the port of Melilla locations under various expansion scenarios.

Figure 1: Aerial view of the existing Melilla port

2 Case Study

Melilla is ideally situated to serve the markets of the Western Mediterranean, North and Central Africa, and Northern Europe. It is situated at the eastern end of the Strait of Gibraltar. In the heart of the city is Melilla's port. The road at the base of "Melilla la Vieja's" citadel is used by inbound traffic, and it has two lanes in each direction for outbound traffic. It currently stands out as being one of the safest ports in the Mediterranean and Europe, with a 130% increase in passenger traffic over the past decade, and as the second port to expand. The port authority has started an ambitious expansion project as a result of the port of Melilla's ongoing increase in port traffic, which pushes port facilities to the point of saturation and the city's severe lack of industrial land.

With respect to its land location, the port is conditioned by its proximity to the city centre of Melilla. It has two main functional areas, a commercial port and a marina, and it handles up to 1 million tonnes of cargo and 850,000 passengers annually.

The Melilla port area was the object of a noise mapping study performed by CECOR, a private company, in 2017 [28]. The noise simulations were performed using the methods listed in the old Annex II of the END Directive (ISO 9613-2 for industrial, NMPB-Routes 96 for road noise). Figure 1 reports an aerial view of the current port.

3 Methodology

The methodology described in the ANCHOR LIFE project deliverable "Guideline for a common Port Noise Impact Assessment method" has been used to define the overall impact of the Melilla port.

The Guideline's main objective is to specify a standard method for carrying out noise mapping tasks in port areas. This paragraph provides a brief overview of this deliverable's rules and procedures; in Schiavoni *et al.* [26] a more in-depth discussion is given.

3.1 Digital ground model and buildings characterization

The Digital Ground Model of the study area was defined considering and processing:

- an existing digital model of the terrain with a mesh size of 5x5 meters provided by the Spanish National Geographic Institute;
- isohypses available from CECOR study;
- altimetric data contained in port layout drawings;
- altimetric data contained in Cadastre maps;
- altimetric data contained in the Melilla expansion project.

As there are noise sources in ports that are 30 metres above the ground, it was important to pay close attention to the building height during the process of collecting building data in port areas. In these conditions, compared to situations where noise sources are road and rail infrastructures, the first row of buildings does not offer any shielding effect. Demographic data is also present in some digital records about residential structures. The number of floors in each building must be taken into account in this case. Additionally, census data must be used. It is important to collect information on how many people attend schools and other similar structures on average. The number of beds for hospitals, retirement homes, and other comparable buildings is, in any case, the most crucial piece of information. These details were manually assigned to each structure once they were known (from photographs or other direct sources).

In this context, land use is crucial, and water is a significant reflective surface.

3.2 Transport infrastructure and industrial noise sources

Numerous noise sources, including working machinery, car traffic, railroad, vessel-quay ramps, cargo handling, and vessels, contribute to the noise environment in port areas.

In this situation, it cannot be assumed that traffic will stay constant throughout the year on a daily or even weekly basis. Peak seasons with significant tourist activity are typically what define port activities. During these times, traffic volumes may be more than twice as high as they are during the standard period. Industrial noise sources may exhibit the same seasonality and variability in port areas. The variability of traffic flows in port areas is revealed by an analysis of the Ro-Pax vessels arriving at and departing from the port. For instance, more Ro-Pax ships are berthed, arriving, and departing the port during the busiest tourist seasons. This variation might not apply to other kinds of vessels, such as Lo-Lo and oil tankers. A relevant contribution has been given by [29–31] regarding the noise emission of ships.

No rail infrastructure is present in the port of Melilla; consequently, rail noise was not considered in the simulations.

Since noise sources may vary location in time and space, the schedule of port operation has been considered.

Noise emission data of each source to be assessed was obtained by (in order of priority):

- manufacturers data sheets;
- direct measurements;
- database of noise sources;
- estimation from similar noise source.

The noise emission characterization of machinery and facilities operating in the port area is the noise mapping task that presents the greatest challenge. Findings from the MON ACUMEN Interreg project [32] were used because they offer crucial documentation and information on the emission characterization of port noise sources. Furthermore, one of the main outcomes of the ANCHOR LIFE project was the creation of a specific database thanks to a thorough analysis of the scientific literature [32, 33] official reports of port companies, and in-field measurements.

3.3 Port noise assessment method

The method was developed considering the outcomes of the Deliverable 4 of NADIA Project [34]. The ANCHOR LIFE project, however, regards the effects of each category of noise sources as independent. The ANCHOR LIFE procedure is distinguished by a first step of grouping noise sources managed by the same authority and a subsequent step of determining the exposure and noise limits in front of pertinent building façades. “Critical buildings” are defined as residential and special buildings with sound pressure levels above the limits, and a "critical area" is defined as any area where the distance between a critical building and the one closest to it is less than 100 metres. By better understanding how each group of noise sources contributed to the eventual exceeding of noise restrictions, it is possible to select the most effective anti-noise measure.

The priority index is used to manage the intervention strategy by assigning a score to each critical area, in order to create a ranking of urgency levels of mitigation actions. The detailed procedure to calculate the index of priority IP is reported in Schiavoni *et al.* [26].

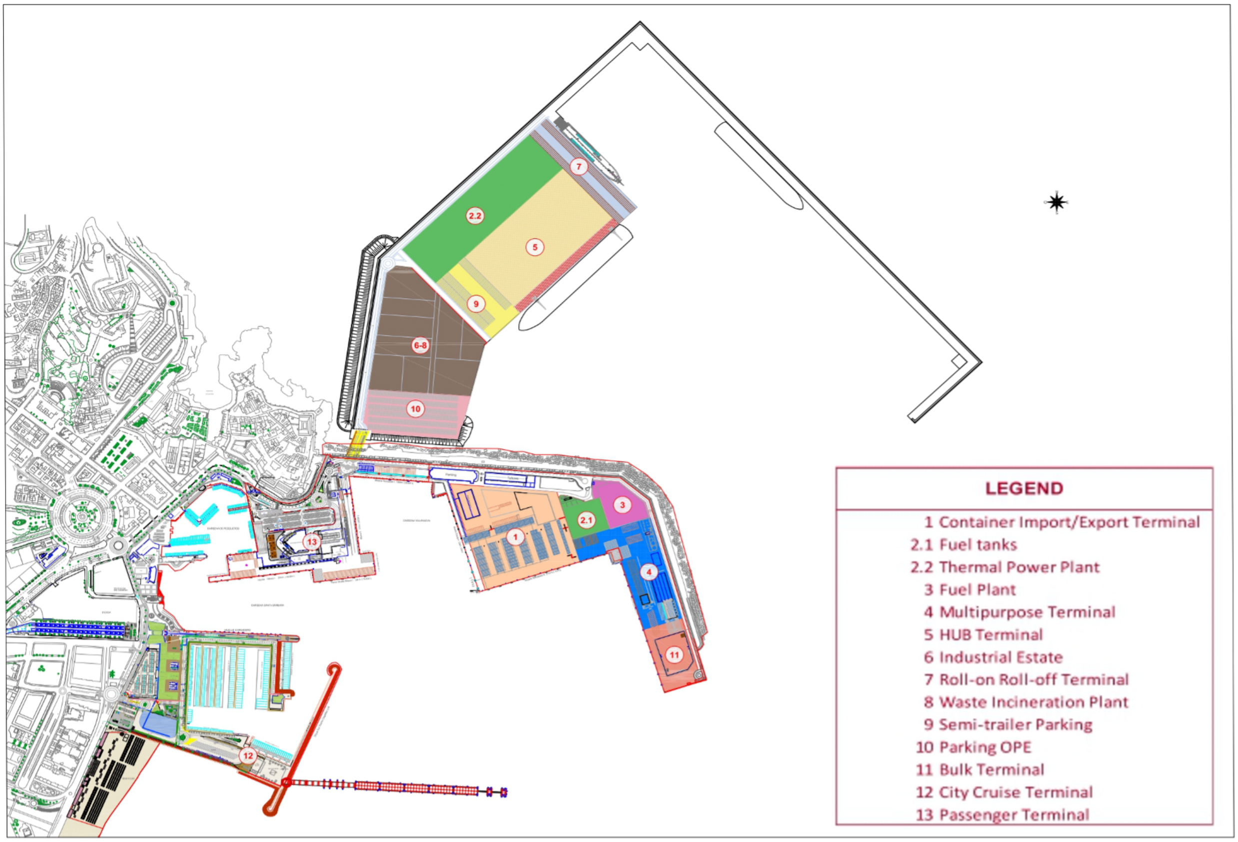

Figure 2: Project of the expansion scenario

4 The port expansion scenario

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

- three different time scenarios each one representing a decade (10, 20, 30 years);
- 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.

Figure 2 reports a view of the Melilla port expansion project supplied by Melilla Port Authority. The project outlines the activities that will take place in each location as well as the locations where each type of ship will berth. Each facility and device's operational hours and how they change throughout the year have been taken into account. It should be noted that:

- through three separate assessments with a 10-year step, the port expansion project covers and represents the area over the course of the next 30 years. The equipment installed and the quantity of ships/passengers served are reported for each of these steps;
- both normal and peak conditions' operational levels, as well as the quantity of facilities and equipment used in each step, are reported. There is a peak in port traffic and activities during the four summer months that must be taken into account in noise mapping procedures;
- for both typical and peak conditions, the average daily working hours for each device and moored ship during the day, evening, and night period have been estimated.

The noise mapping procedure performed within the activities of the ANCHOR LIFE project considered the areas reported in Figure 2. The port expansion project designs the following port areas:

- Bulk Terminal: this port area is where cement carriers, *i.e.*, ships built specifically to transport cement materials, are loaded and unloaded using pumped air;
- City Cruise terminal: it is the terminal where the cruise ships are managed;
- Fuel tanks: area devoted to the storage of fuels;

- HUB terminal: it is the terminal where goods from Lo-Lo ships that have been unloaded are stored before being loaded onto another Lo-Lo ship. The Lo-Lo ship docks are located at the terminal. Ships called Lo-Lo (Lift-on/Lift-off) are made to carry cargo (containers) that must be hoisted by a crane from the deck to the deck and vice versa;
- Industrial estate: space intended for a future industrial plant. The industrial estate is not included in the project because it will not yet be determined what kind of activity will be carried out there, which will affect the noise emission. The project's results will assist the Melilla Port Authority in determining the maximum amount of noise that can be emitted from that location;
- Multipurpose Terminal: The Multipurpose terminal (MLT) is used to manage the materials carried by tankers (cargo ships designed to carry fluids) and other ships that cannot be handled in the other port areas;
- Parking OPE: it is the parking area used during the peak traffic period (summer);
- Passenger or Ro-Pax terminal: areas in ports where ships that are primarily used to transport people and their vehicles are managed. Wheeled cargo may also be carried by them. Ramps are used to load and unload cargo instead of cranes;
- Ro-Ro (Roll-on/Roll-off) terminal: areas of ports where ships designed to transport wheeled cargo are managed. Without the use of cranes, goods are loaded and unloaded using ramps. Tractors can be used to move cargo on wheels;
- Semi-trailer parking: park and management area for the trailers working inside the port;
- TCM or Container Import Export terminal: it is the location where goods from Lo-Lo ships are unloaded and addressed for Melilla. Additionally, this location handles and stores goods that are shipped by Lo-Lo out of the city of Melilla;
- Waste Incineration Plant: port area where the city of Melilla's current waste incineration plant will be relocated from its current location.

The "Noise mapping of Melilla port expansion" ANCHOR LIFE outcome provides a detailed analysis of the evolution of ship traffic, the rise in passenger numbers, and the industrial and trading activities.

In more detail, the future scenario of port was analysed setting the structural modifications on following port areas:

- TCM: Container Terminal;
- ROPX: Ro-Pax Terminal;
- HUB: Hub Terminal;
- MLT: Multipurpose Terminal (cement carrier and tanker);
- RORO: Ro-Ro Terminal;
- CRU: Cruise Terminal (new);
- CMN: Cement plant;
- TPP: Thermal energy plant;
- WIP: Waste incineration plant.

Data about the future port evolution with and without the realization of the port expansion are reported in Appendix A.

5 Assesments of the noise impact

5.1 Introduction

The Façade Noise Map (FNM) is the best tool for making decisions and evaluating how much noise a source or group of sources will produce. The outcomes of NoMEPorts [11] and NADIA project [34, 35] were considered as the reference point. The FNM in NADIA is set up to produce results that can be used to implement noise action plans using a methodical process.

The façade noise maps were realised using the following calculation parameters:

- reflection order: 2;
- calculation point placed on each relevant building façade. The noise reflection of the façade where the calculation point is placed has been not considered;
- relevant façade: façade with 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 each receiver and noise source: 1000 m;
- max distance of reflections from the receiver: 200 m. Only the effect of 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 reflections placed at a distance lower than the threshold value is considered;
- noise indicators: L_d, L_e, L_n and L_{den} considering the Spanish day, evening and night periods (07-19, 19-23 and 23-07);
- air attenuation effect calculated in compliance to ISO 9613-1.

Table 1: IP Values of the critical areas (AC) for the no expansion scenario in 10 years

Critical Area	IP Day period	IP Even. period	IP Night period
N_AC1	0	0	12.4
N_AC2	0	0	2.7
N_AC3	0	0	260.8
N_AC4	0	0	0.2
N_AC5	0	0	685.5
N_AC6	0	0	0.7

Table 2: Assessment of the most impacting port areas of the 10 years no expansion scenario

	IP Night period	IP TCM	IP TPP	IP MLT	IP RORO	IP CMN	IP ROPX	IP CRU
N_AC1	12.4	0	**10.4**	0	0	0	**2**	0
N_AC2	2.7	0	**2.3**	0	0	0	**0.4**	0
N_AC3	260.8	1.6	9.2	0.1	0	0	**249.9**	0
N_AC4	0.2	0	0	0	0	0	**0.2**	0
N_AC5	685.5	1.1	2.7	0.2	0.1	0	**680.4**	0
N_AC6	0.7	0	0	0	0	0	**0.7**	0

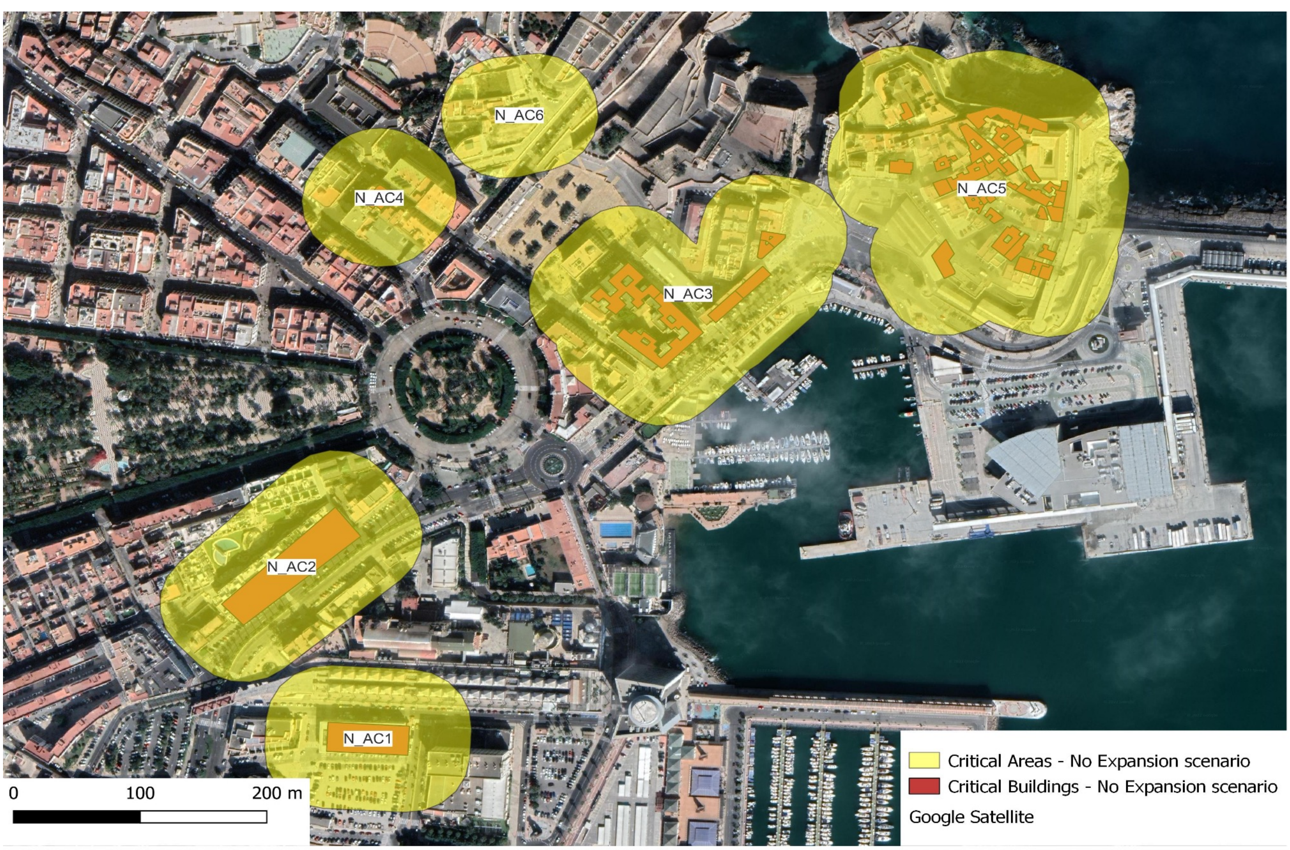

Figure 3: Location of the critical areas in the no expansion scenario

Table 3: IP Values of the critical areas for the Yes expansion scenario in 10 years

	IP Day period	IP Even. period	IP Night period
Y10_AC1	0	0	252.6
Y10_AC2	0	0	0.2
Y10_AC3	0	0	720.8
Y10_AC4	0	0	9.3

Table 4: Assessment of the most impacting port areas of the evaluated scenario

	IP Night period	IP TCM	IP TPP	IP MLT	IP RORO	IP CMN	IP ROPX	IP HUB	IP WIP	IP CRU
Y10_AC1	252.6	2.2	0.7	0	0	0	249.2	0.4	0	0
Y10_AC2	0.2	0	0	0	0	0	0.2	0	0	0
Y10_AC3	720.8	3.8	1.3	0.4	0	0	679.7	32.3	2.8	0
Y10_AC4	9.3	0	0	0.1	0	0	6.9	2.3	0.1	0

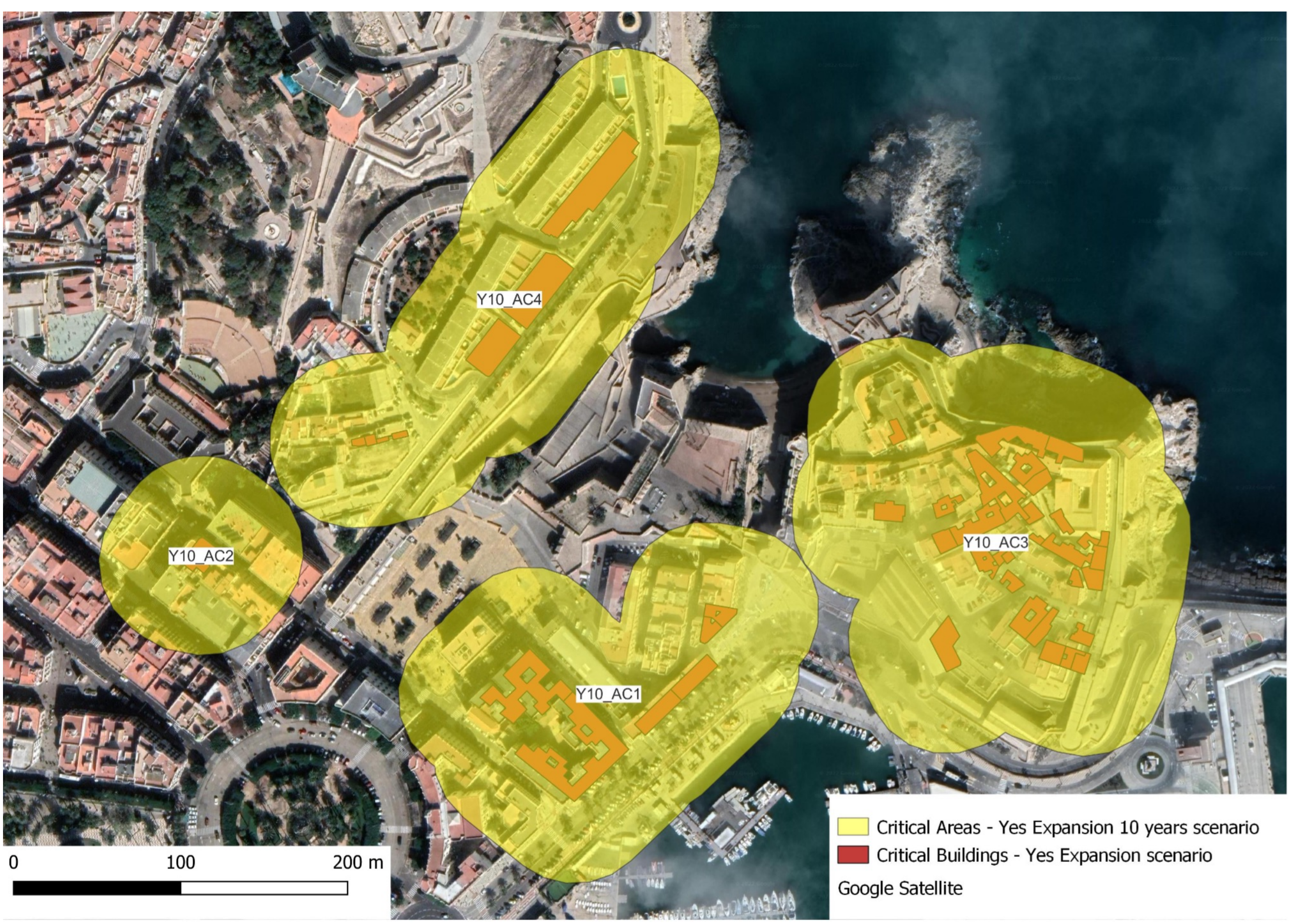

Figure 4: Location of the critical areas in the expansion scenario after 10 years

Table 5: IP Values of the critical areas for the expansion scenario in 20 years

	IP Day period	IP Even. period	IP Night period
Y20/30_AC1	0	0	269.4
Y20/30_AC2	0	0	0.3
Y20/30_AC3	0	0	739.6
Y20/30_AC4	0	0	8

Table 6: Assessment of the most impacting port areas of the evaluated scenario

	IP Night period	IP TCM	IP TPP	IP MLT	IP RORO	IP CMN	IP ROPX	IP HUB	IP WIP	IP CRU
Y20/30_AC1	269.4	2.8	0.7	0	0	0	265.5	0.3	0	0
Y20/30_AC2	0.3	0	0	0	0	0	0.3	0	0	0
Y20/30_AC3	739.6	5.1	1	0.4	0	0	706.1	23.9	2.5	0
Y20/30_AC4	8	0	0	0.1	0	0	6.5	1.4	0	0

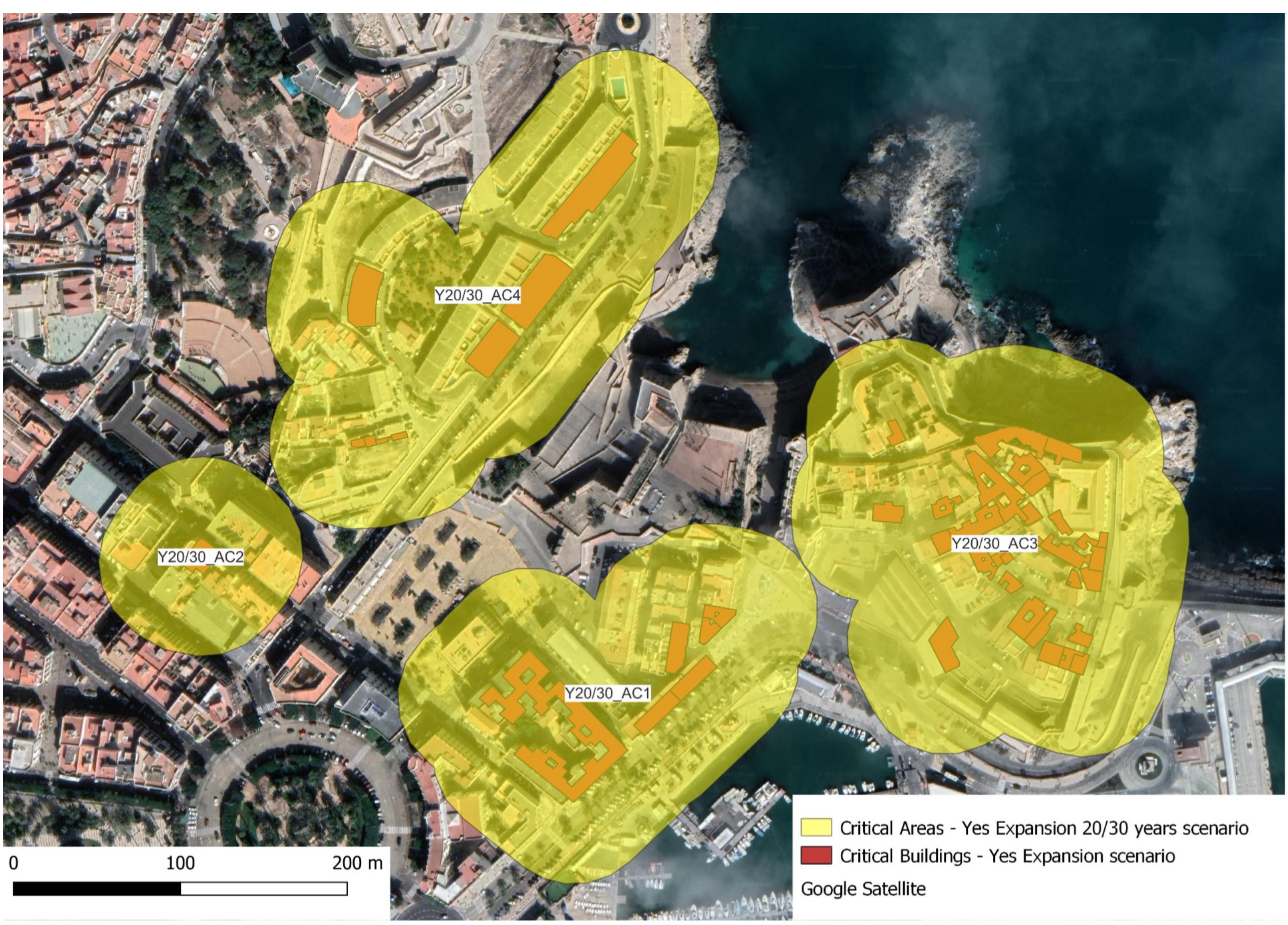

Figure 5: Location of the critical areas in the expansion scenario after 20 and 30 years

The global index values calculated for each port expansion scenario (yes/no) and time period (10, 20 and 30 years) are reported in the following paragraphs. The impact on the peak season was taken into account when calculating the IP values.

Noise simulations were performed using the SoundPLAN® software 8.2 [36].

5.2 Noise mapping results

5.2.1 No expansion scenario, 10, 20 and 30 years

Considering the no expansion scenario in 10 years, six critical areas (AC: Area with Critical issue) have been identified. Table 1 reports the IP values calculated for these areas.

Table 2 summarises the in-depth analysis. Bold text is used to emphasise the areas that will have the greatest impact. The Ro-Pax terminal has the biggest impact on the port. The continuous emissions from thermal power plants during the night have a significant impact. Figure 3 reports the locations of the critical areas.

Considering the no expansion scenario in 20 and 30 years, six critical areas have been identified. These are the ones already identified in the No expansion 10 years scenario. The IP values of these areas are the same reported in Table 1 and 2, where the most impacting port area is again the Ro-Pax terminal.

5.2.2 Expansion scenario, 10 years

Considering the expansion scenario in 10 years, four critical areas have been identified. Figure 4 reports the location of these areas whereas Table 3 shows the corresponding IP values.

Table 4 summarises the in-depth analysis. Bold text is used to emphasise the areas that will have the greatest impact. The Ro-Pax terminal is the port area that has the greatest impact, but it is important to note that the HUB terminal's impact is also significant.

5.2.3 Expansion scenario, 20 years

Considering the expansion scenario in 20 years, four critical areas have been identified. Figure 5 reports the locations of these areas whereas Table 5 shows the corresponding IP values.

Table 6 summarises the in-depth analysis. Bold text is used to emphasise the areas that will have the greatest impact. As in the case of the 10 years expansion scenario, the Ro-Pax terminal is the port area that has the greatest impact, but it is important to note that the HUB terminal's impact is also significant.

5.2.4 Expansion scenario, 30 years

Considering the expansion scenario in 30 years, there are the same critical areas identified for the 20 years scenario. Table 7 reports the corresponding IP values.

Table 7: IP Values of the critical areas for the expansion scenario in 30 years

	IP Day period	IP Even. period	IP Night period
Y20/30_AC1	0	0	**271.9**
Y20/30_AC2	0	0	**0.3**
Y20/30_AC3	0	0	**748.2**
Y20/30_AC4	0	0	**9.1**

Table 8: Assessment of the most impacting port areas of the evaluated scenario

	IP Night period	IP TCM	IP TPP	IP MLT	IP RORO	IP CMN	IP ROPX	IP HUB	IP WIP	IP CRU
Y20/30_AC1	271.9	3.8	1	0	0	0	**266.8**	0.3	0	0
Y20/30_AC2	0.3	0	0	0	0	0	**0.3**	0	0	0
Y20/30_AC3	748.2	6.5	1.4	0.4	0	0	**708.5**	27.8	2.6	0
Y20/30_AC4	9.1	0	0	0.1	0	0	**7.3**	1.7	0.1	0

Table 8 summarises the in-depth analysis. Bold text is used to emphasise the areas that will have the greatest impact. The Ro-Pax terminal is the port area that has the greatest impact, but it is important to note that the impact of the HUB terminal is slightly more significant than the impact observed in the 20-year scenario.

5.3 Analysis of the assessed scenarios

The Ro-Pax terminal was the port area having the greatest impact on citizens in each scenario in terms of IP index.

Table 9 and Table 10 allow to analyse how the dock electrification of the Ro-Pax terminal affects the people's exposure to noise. If the implementation of dock electrification in the Ro-Pax terminal results in an increase in the number of people exposed to noise compared to the reference situation, the data in the aforementioned tables are positive. When a measure reduces the number of people exposed to noise, negative values result.

Each of the evaluated scenarios is subjected to analysis (expansion and no expansion in all the three-time steps). L_{den} indicator is commonly used to understand the overall impact on an annual basis; L_n is the indicator used for the assessment of sleep disturbance.

Data in Table 9 and Table 10 highlight that:

- in every scenario, the electrification of the Ro-Pax docks significantly reduces the number of people exposed to L_{den} values above 65 dB(A);
- in every scenario, the electrification of the Ro-Pax docks results in an increase in the number of individuals exposed to L_{den} values below 65 dB(A); this is because individuals exposed in the reference situation to L_{den} values above 65 dB(A) now fall into these classes;
- the effect of electrifying the Ro-Pax terminal is more relevant in terms of the L_n indicator. There is at least an 88% decrease in the number of individuals exposed to L_n values greater than 55 dB(A). The minimum reduction in the other classes is greater than 50%;
- the Ro-Pax terminal's characteristics account for the effect that is more significant in terms of L_n than the L_{den} indicator. In comparison to the other terminals, this one has the most significant night-time activity.

Figure 6 (expansion scenario) and Figure 7 (no expansion scenario) show the difference in the Ro-Pax terminal's noise emission reduction with and without electrifying the dock. The figures in both situations relate to the peak

Table 9: Effect of cold ironing in the Ro-Pax terminal: percentage variation of people exposure to noise. L_{den} indicator

Indicator	Scenario					
Lden	NO10	NO20	NO30	YES10	YES20	YES30
45-50	+54%	+53%	+51%	+17%	+9%	+8%
50-55	+101%	+105%	+107%	+59%	+49%	+53%
55-60	−2%	−1%	+1%	+28%	+35%	+41%
60-65	+13%	+17%	+17%	+27%	+36%	+30%
65-70	−70%	−71%	−70%	−81%	−82%	−82%
70-75	−54%	−54%	−55%	−63%	−55%	−56%
>75	−90%	−90%	−90%	−88%	−84%	−85%

Table 10: Effect of cold ironing in the Ro-Pax terminal: percentage variation of people exposure to noise. L_n indicator

Indicator	Scenario					
Ln	NO10	NO20	NO30	YES10	YES20	YES30
45-50	−71%	−71%	−70%	−76%	−78%	−78%
50-55	−53%	−53%	−54%	−80%	−67%	−69%
55-60	−93%	−93%	−93%	−98%	−88%	−88%
60-65	−100%	−100%	−100%	−100%	−100%	−100%
65-70	-	-	-	-	-	-
70-75	-	-	-	-	-	-
>75	-	-	-	-	-	-

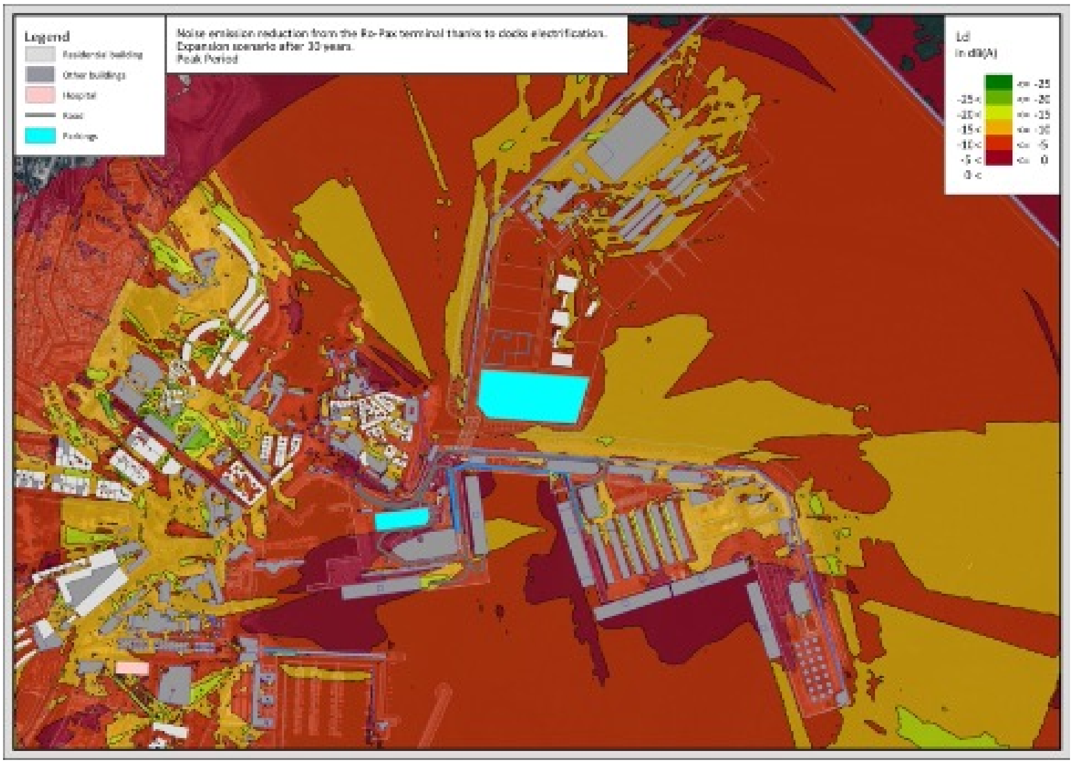

Figure 6: Effect of dock electrification of the Ro-Pax terminal: Expansion, 30 years, Peak season day period

Figure 7: Effect of dock electrification of the Ro-Pax terminal: No expansion, 30 years, Peak season day period

period, 30 year time step, and L_d noise indicator (indicator for the Spanish day time).

6 Conclusions

The current study presents the outcomes of the use of a novel methodology to identify intervention priorities on noise-critical port areas under various expansion scenarios using the Priority Index (IP).

The process makes it easier to identify areas where noise mitigation measures are more urgently needed than in other places, and it addresses the authority in charge of noise mitigation projects and plans.

The IP index methodology on Melilla Port specifically allowed for the identification of the following for each scenario:

- the buildings where the noise exposure is higher than the noise limits (critical buildings);
- the groups of buildings where noise exposure should be managed through the same anti-noise measure (critical areas);
- the contribution of each port areas on the observed noise limit exceedance.

In the scenario without expansion, six critical areas have been identified for all the time periods. The outcomes of the noise impacts assessment are reported as follows:

- the highest noise impacts in the critical areas were observed in the night period;
- the Ro-Pax terminal is the cause of the noise limits exceedance in four of the six critical areas;
- the other two critical areas are close to the thermal power plant. They are particularly exposed to its noise emissions at night.

Four critical areas have been identified with regard to the expansion scenario across all time periods. The following is a list of the findings of the noise impacts assessment:

- the highest noise impacts in the critical areas were observed in the night period;
- in all the critical areas, the impact of the Ro-Pax terminal is the most relevant one;
- in one critical area, the noise impact of the HUB terminal may be considered not negligible.

The results of the noise impact assessment therefore recommend that the following actions be taken:

- relocate the thermal power plant within the port area; this option is taken into consideration in the expansion scenario;
- reduce the noise emission of the Ro-Pax terminal, considering the cold ironing option. Due to the characteristics of the port of Melilla, no other solution that does not take traffic flow reduction into consideration can be regarded as practical. The impact of cold ironing on the Ro-Pax terminal has been studied as part of the ANCHOR LIFE project activity.

The application of the cold ironing on the Ro-Pax terminal has been assessed. The most significant effects for all scenarios are:

- a reduction of between 70 and 100% of individuals exposed to L_{den} values greater than 65 dB(A);
- a reduction of at least 88% of individuals exposed to L_n values greater than 55 dB(A).

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APPENDIX A

Table A1: Expected Container Terminal Capacities in the TCM port area for port expansion scenarios in terms of TEU

Container terminal capacity			
Port layout	**Year 10**	**Year 20**	**Year 30**
No expansion	53,686	59,055	64,424
Expansion	59,822	83,751	107,680

Table A2: Expected average number of container ship working in the TCM port area per year

Average number of container ship			
Port layout	**Year 10**	**Year 20**	**Year 30**
No expansion	152	167	182
Expansion	169	236	303

Table A3: Expected General bulk traffic in tonnes in the Multipurpose port area

Multipurpose terminal capacity			
Port layout	**Year 10**	**Year 20**	**Year 30**
No expansion	47,468	75,113	91,560
Expansion	215,516	90,134	160,807

Table A4: Expected average number of vessels working in the Multipurpose terminal

	Cement and bulk carrier			Tanker ship		
Port layout	**Year 10**	**Year 20**	**Year 30**	**Year 10**	**Year 20**	**Year 30**
No expansion	29	47	56	50	51	53
Expansion	103	44	87	149	165	180

Table A5: Expected HUB Terminal Capacities for port expansion scenarios in terms of TEU (Expansion scenario only)

Container terminal capacity			
Port layout	**Year 10**	**Year 20**	**Year 30**
Expansion	185.318	212.531	239.743

Table A6: Expected Average number of container ship working in the HUB per year (Expansion scenario only)

Average number of container ship			
Port layout	**Year 10**	**Year 20**	**Year 30**
Transoceanic ship	85	98	110
Feeder ship	261	299	338

Table A7: Expected RO-RO Terminal Capacities for port expansion scenarios in terms of tonnage of goods transported

Ro-Ro terminal capacity			
Port layout	**Year 10**	**Year 20**	**Year 30**
No expansion	1,252,300	1,314,915	1,377,530
Expansion	1,556,430	2,179,000	2,614,802

Table A8: Expected average number of Ro-Ro ships working in the devoted port area per year

Average number of Ro-Ro ship			
Port layout	**Year 10**	**Year 20**	**Year 30**
No expansion	116	122	128
Expansion	133	140	147

Table A9: Expected average number of Cruise ships working in the devoted port area per year

Average number of Cruise ship call per month (only peak season)			
Port layout	**Year 10**	**Year 20**	**Year 30**
No expansion	6	6	7
Expansion	10	11	12

Table A10: Expected monthly average number of Ro-Pax ships working in the devoted port area

Average monthly number of Ro-Pax ship				
Season	**Port layout**	**Year 10**	**Year 20**	**Year 30**
Peak	No expansion	157	165	173
	Expansion	180	189	198
Standard	No expansion	116	122	128
	Expansion	133	140	147