Survey of Environmental Noise in the Port of Barcelona

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Summary
Ports and harbours are logistic nodes characterized by noisy operations. Noise pollution analysis is complicated, because several types of noise usually can occur in the same area: ferries, cruises, fishing and trade ships coexist with industrial and auxiliary services. Noise pollution can have negative effects to the urban population inhabiting the port nearby but especially to the port workers and the passengers. The Port of Barcelona is an infrastructure with a surface of 1,082.15 ha and a length of docks 22,216 km, and serves trade, passengers and fishing. The purpose of this work is to describe the acoustic events recorded in the maritime stations of the port of Barcelona dedicated exclusively to passenger and vehicle transport. The traffic of arrivals and departures of ships with passengers – mainly cruises – is high in these maritime stations; the characterization of the events caused by this traffic, as well as the other events that may occur in the port, will draw the noise pollution perceived by the port workers and the cruise passengers themselves. This paper describes the recording campaign in the Port of Barcelona and proposes a quantitative study over all the recorded acoustic events in terms of typology, spectral characterization, duration and impact on the equivalent noise level.

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1. Introduction

Noise pollution derived from port activities can have serious effects to health, as well as annoyance for the citizens living nearby the port area and to the environment [1]. In this sense, several studies have addressed the present regulatory framework regarding ship noise both in air and in water [2]. Some ports have already approved measures to manage the noise pollution in several locations [3], but these types of study are very environment-dependant.

Some analysis have already been conducted in the framework of the impact of port noise to residents in relevant ports. These studies have revealed that the continuous level of noise in the surroundings of the port affect the nearby area, together with road traffic noise pollution. In [4] the noise coming from the Piraeus (one of the most significant ports in the Mediterranean) is analyzed together with the road traffic noise in terms of impact to the residents. In [5] a survey and several measurements of environmental noise have been conducted in the port of Tripoli. In this work, in the framework of the MESP project activities, a survey about noise annoyance was conducted among port visitors, shop workers and port workers. In [6] the authors present the information system I^2 applied to the Port of Rotterdam; it helps to plan and manage the noise efficiently, because it supports tasks licensing, advises spatial development and the monitoring of complex noise situations in an industrialized are with large population in the surroundings.

Recently, research in the impact of noise has been centered in the association between road traffic noise and several diseases in suburban and urban areas. Öhrström states that the influence of road-traffic noise implies an increase in tiredness and disturbs the sleep [7]. Also, Botteldooren *et al.* analyze the influence of road traffic on noise annoyance in neighborhoods [8], while Jakovljevic *et al.* conclude that the most significant noise source in urban areas is road traffic noise, according to the interviewed residents [9].

The Port of Barcelona [10] has a strategic geographical location in the Mediterranean ($41^o21'$N, $2^o10'$E). It is an important logistic hub, influencing the social and economic development of its surroundings. It has thirty specialized terminals, with high level of diversification and specialization. Its operation is divided into several activities. On the one hand, it is the first port in Europe in terms of cruise activity, and on the

Table I. Recording dates, times and locations

Day	*Location*	*Time*
12.01.18	Adossat dock terminal A	18:00
12.01.18	Contradic dock	16:00
12.01.18	Bosch&Alsina wharf	20:00
13.01.18	Adossat dock terminal B	18:00

other hand, it is a key distributor of energy goods and other types of cargo. In the aim of providing an analysis of the soundscape of the Port of Barcelona that could be of use for further research of possible future related services, this work presents a first step towards characterizing the type of founds sounds in this area. To that end, a recording campaign has been conducted and the derived audio database has been labelled and analyzed [11].

This paper is organized as follows. Section 2 details the information about the recording campaign in the Port of Barcelona. In Section 3 the dataset generation is detailed by means of a preliminary analysis of the spectral distribution and the impact of the noise events is performed, and Section 4 contains the spectral description and the preliminary impact analysis for several types of noise. Section 5 synthesizes the conclusions and the future lines of this work.

2. Recording of the noise events in the port area of Barcelona

The main goal of this recording campaign was to collect several samples of types of noise present in the Port of Barcelona in order to provide a general picture of its real-life soundscape. To that effect, during the 12th and 13th of January 2018, a total of four recordings were made across the Port of Barcelona, as shown in Figure 1. The four selected places were: Adossat dock terminals A and B, Contradic dock and Bosch&Alsina wharf.

The measurement device was a low-cost sensor [12] connected to a ZOOM H4n digital recorder. The sampling rate was 48 kHz with 24 bits/sample; the sensitivity verification was conducted using a 94 dBSPL and 1 kHz calibration tone. The input gain of the recorder was selected to guarantee room for the in-site audio dynamics avoiding saturation. The measurements were conducted using elevation angles of 0^o in the direction of the main noise source (depending on the location). Another factor taken into account when setting up the measurement device was to be close enough to any potential low-noise events, while keeping a distance from any continuous, high-noise events that can mask other sounds, like a stationary truck with the engine on. Finally, the device recorded around 30 minutes for each location.

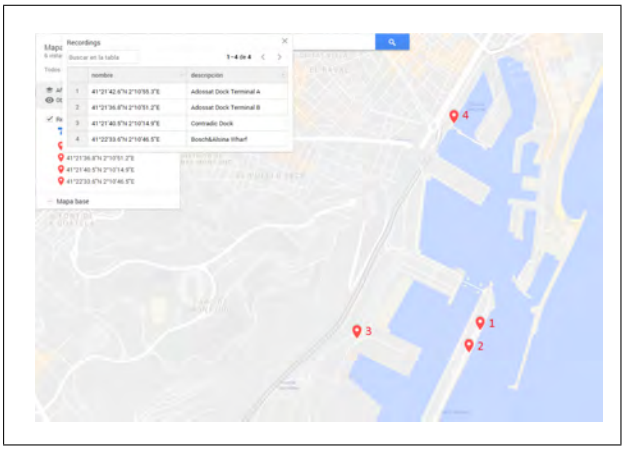

Figure 1. Recording locations in the port area of Barcelona.

Figure 2. Recording setup at terminal A of Adossat dock.

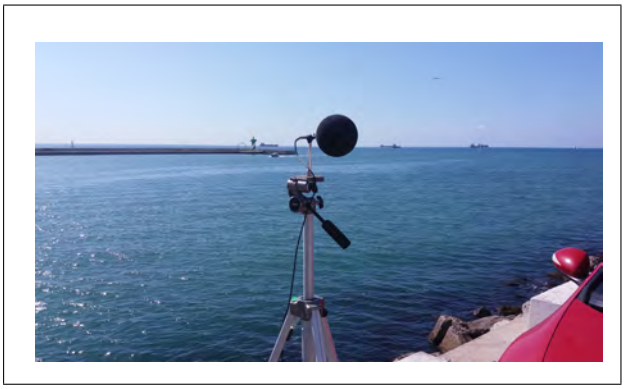

Figure 3. Recording setup at terminal B of Adossat dock.

In Figure 1 the recording locations in the Port of Barcelona are shown. The locations in the port were chosen using two criteria: *i)* the availability of measuring (some places in the port have their access limited) and *ii)* the location close to noise sources (e.g. helicopters, cruises, etc).

Figures 2, 3, 4 and 5 show the recording setups for terminal A of Adossat dock, terminal B of Adossat dock, Contradic dock and Bosch&Alsina wharf, respectively.

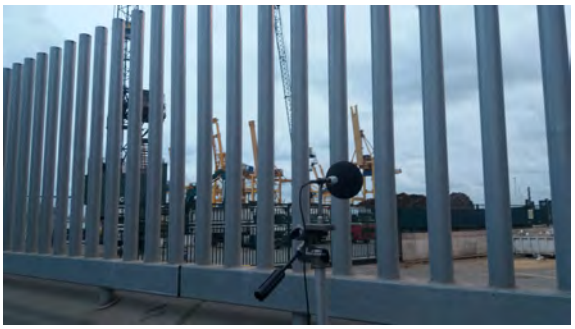

Figure 4. Recording setup at Contradic dock.

Figure 5. Recording setup at Bosch&Alsina wharf.

3. Real-Life Port Environmental Audio Dataset Generation

In the generation of the dataset of the real-life port environmental noise, the noise events recorded have been annotated and labeled with the Audacity software, using standard four-letter codes related to noises which can found in the recording campaign locations. After the analysis, those events were divided into 16 categories, a proof of the Port of Barcelona great diversity of sounds; specifically, the labels used and their meaning are:

- **acar**: car alarm.
- **brak**: braking sound of a vehicle.
- **busd**: opening bus or tramway door noise, or noise of pressurized air.
- **car**: car engine or wheels.
- **door**: noise of house or vehicle doors, or other object blows.
- **ferr**: ferry engine.
- **hcru**: cruise horns (usually three horns before they depart).
- **heli**: helicopter.
- **mbik**: motorbike engine and wheels.
- **peop**: people talking.
- **seag**: seagull birdsong.
- **sire**: siren (police cars, ambulances, etc).

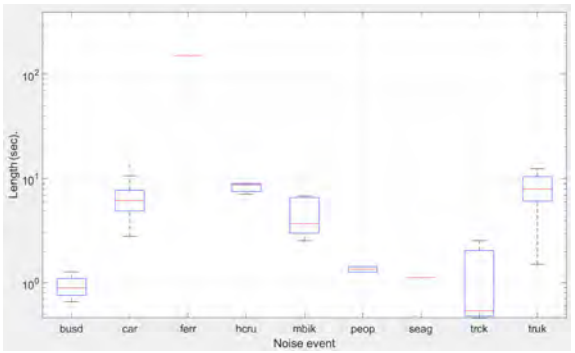

Figure 6. Boxplots of noise events and their lengths recorded in Adossat dock terminal A.

- **skat**: skate or sounds of wheels over nonuniform surfaces.
- **step**: people walking.
- **trck**: noise when vehicles run over a bump.
- **truk**: truck engine or wheels.

3.1. Analysis of the Recording Locations

In the following sections we detail the setup used to conduct the recording campaign and the typology of noise events, as well as their length and duration for each recording location.

3.1.1. Adossat dock terminal A

Adossat dock is the main entrance for the arrival and departure of cruises (see Figure 1). All four terminals are connected by road (see Figure 2), therefore the recording captured not only boat noise but also traffic noise.

Figures 6 and 7 show the distribution of the noise events lengths and the total duration of the recording per noise event in this recording location, respectively. The recordings show traffic noise due to the proximity of the road; another interesting contribution is the ferry sound, a single sample of more than 150s̃, as the boat was entering the dock very slowly while the recording was conducted.

The vertical axis in Figure 6 is shown in logarithmic scale to accommodate the variate lengths of all noise events. As Figure 7 shows clearly, some of the noise events are more common than others, specially those related to traffic.

3.1.2. Adossat dock terminal B

Adossat dock terminal B is located about one hundred meters from terminal A (see Figure 1), so the measurements in both locations show similar results. Besides road traffic noise, which is common in both terminals, in terminal B the microphone captured several helicopter noise, mainly devoted to tourism.

In Figure 3, the recording setup for terminal B in Adossat dock is shown. In Figures 8 and 9 the plots show the distribution of the noise event lengths and

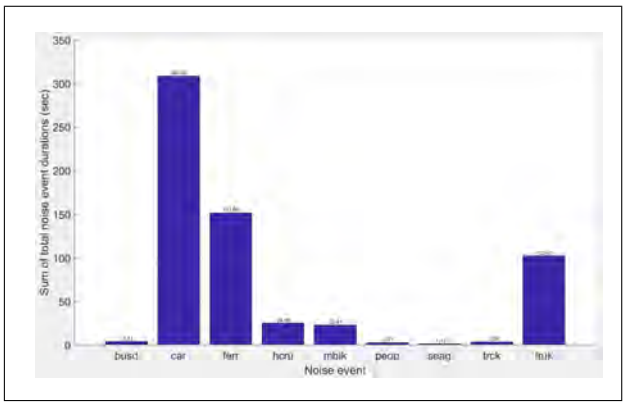

Figure 7. Noise events and their total duration at Adossat dock terminal A.

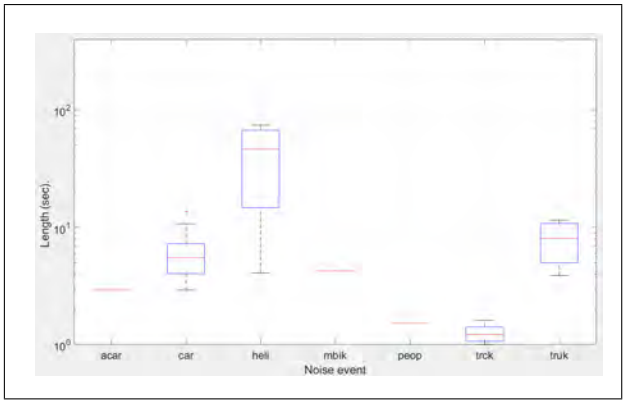

Figure 8. Boxplots of noise events and their lengths recorded in Adossat dock terminal B.

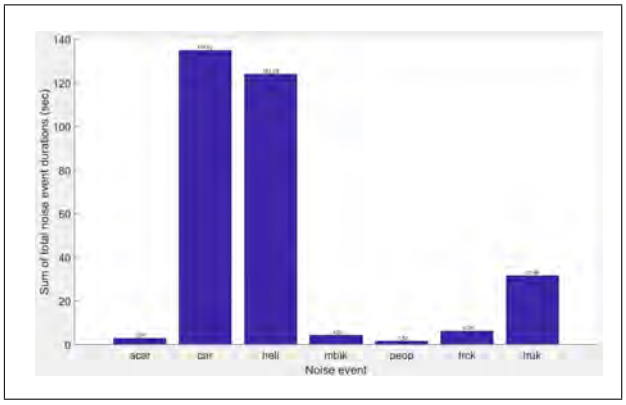

Figure 9. Noise events and their total duration at Adossat dock terminal B.

the total duration of the recording per noise in the Adossat dock terminal B location, respectively. In terminal B the longer noise events correspond to helicopter noise, followed by the traffic noise coming from trucks and cars. The other sounds show both short duration and also short accumulated audio recorded in that location, as it can be observed in Figures 8 and 9.

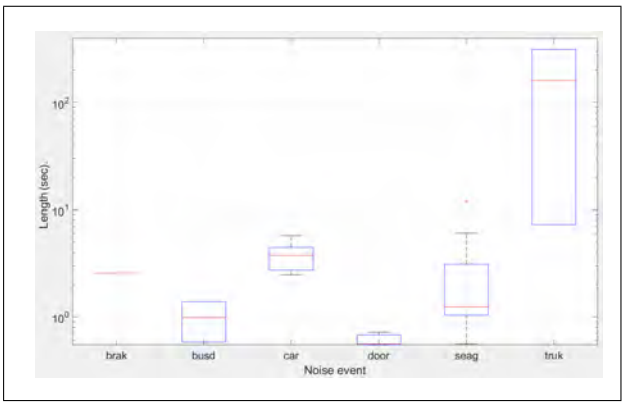

Figure 10. Boxplots of noise events and their lengths recorded in Contradic dock.

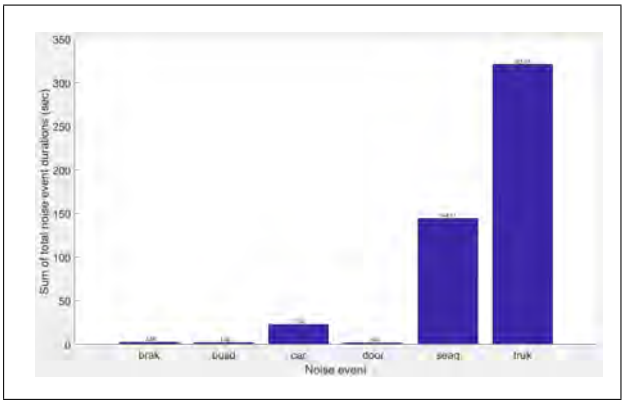

Figure 11. Noise events and their total duration at Contradic dock.

3.1.3. Contradic dock

The Contradic dock is a restricted area, with cranes used to load and unload the cargo of the ships. Even though the microphone was set far from the working area, several sound events coming from Contradic dock could be recorded. The two sounds that are clearly more prominent than the others are trucks for package transporting and the seagull birdsong, because it is close to the fishboat part of the Port. Figure 4 shows the recording setup for Contradic dock area, and Figures 10 and 11 plot the noise events duration, with maximums in seagull birdsong and road traffic noise coming from cars and trucks. These results also present maximums in the aggregated values of recorded audios.

3.1.4. Bosch&Alsina wharf

Bosch&Alsina wharf is a tourist area with docked boats and pathways where people stroll. Figure 5 is a picture of the recording setup for the measurements in Bosch&Alsina wharf. Figures 12 and 13 show the length distribution and the total recorded duration of each type of noise event, respectively. In this wharf, the noise coming from people is more predominant than in the other docks. People talking, skaters and steps are some of the most usual sounds, together with

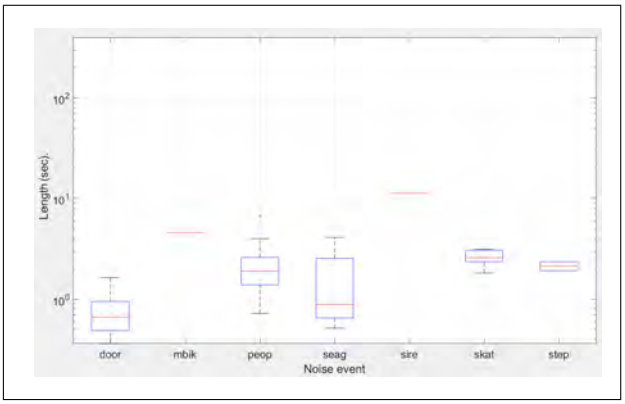

Figure 12. Boxplots of noise events and their lengths recorded in Bosch&Alsina wharf.

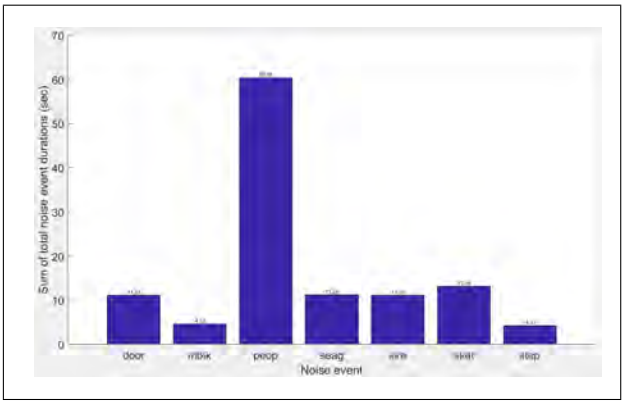

Figure 13. Noise events and their total duration at Bosch&Alsina wharf.

sirens and doors. This place corresponds to the soundscape of city life more than port life, probably because the dock is devoted mainly to tourism.

3.2. Aggregated Results for the Port of Barcelona

From the point of view of all aggregated results, as shown in Figure 15 and in Table II, cars and trucks are by far the most common event recorded due to its high frequency of appearance, followed by ferries, helicopters and seagulls. All the information regarding the exact number for each event are displayed in Table II, sorted by event and location. Besides, each event has its own duration distribution (see Figure 14) and it has to be taken into account when choosing which events are more relevant; for instance, an helicopter sound can last for over a minute, while a seagull birdsong has a duration of around a second.

All in all, Port of Barcelona have a wide range of noise events, where some types are more likely to appear depending on the location. In the dock terminals, the most common are vehicles and ships like ferries and cruises; in Contradic dock, we mainly find trucks and seagulls; and in the tourist wharf, people chatting is the most regular sound.

Table II. Number of noise event per location

Event	Ter.A	Ter.B	Contr.	B&A	Total
acar	0	1	0	0	1
brak	0	0	1	0	1
busd	4	0	2	0	6
car	47	22	6	0	75
door	0	0	3	15	18
ferr	1	0	0	0	1
hcru	3	0	0	0	3
heli	0	3	0	0	3
mbik	5	1	0	1	7
peop	2	1	0	27	30
seag	1	0	68	7	76
sire	0	0	0	1	1
skat	0	0	0	5	5
step	0	0	0	2	2
trck	3	5	0	0	8
truk	13	4	2	0	19

Table III. Average L_{Aeq} for each location

Location	Average L_{Aeq}
Adossat dock terminal A	85.51 dBA
Adossat dock terminal B	86.89 dBA
Contradic dock	93.15 dBA
Bosch&Alsina wharf	79.47 dBA

4. Detail of the Noise Events in the Port of Barcelona

In this section we study the spectral distribution of several noise events found in the recording campaign in the Port of Barcelona. We also study the impact over the L_{Aeq} value of some noise events for illustrative purposes, to show the individual impact of each noise event to the global equivalent level measurement. The A-weighted equivalent noise level (L_{Aeq}) is evaluated using the free Matlab *Continuous Sound and Vibration Analysis* toolbox developed by Edward L. Zechman[1] considering a 1 s evaluation time.

4.1. L_{Aeq} impact analysis for several noise event examples

Table III shows the mean L_{Aeq} value for each location. The results show a reasonable correlation with

[1] https://es.mathworks.com/matlabcentral/fileexchange/21384-continuous-sound-and-vibration-analysis

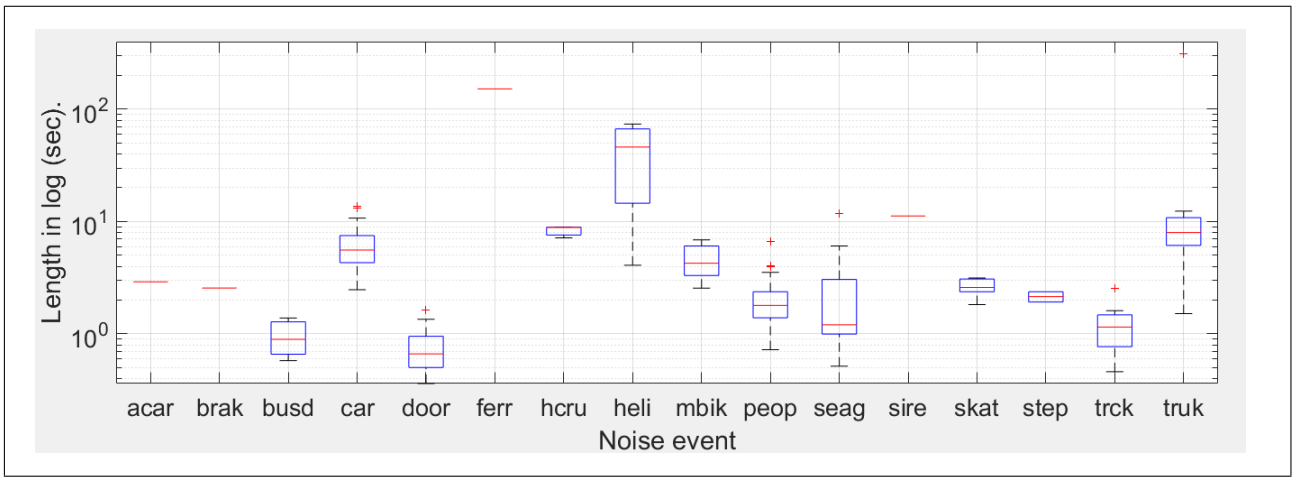

Figure 14. Total labelled events and their lengths of the recording campaign at Port of Barcelona.

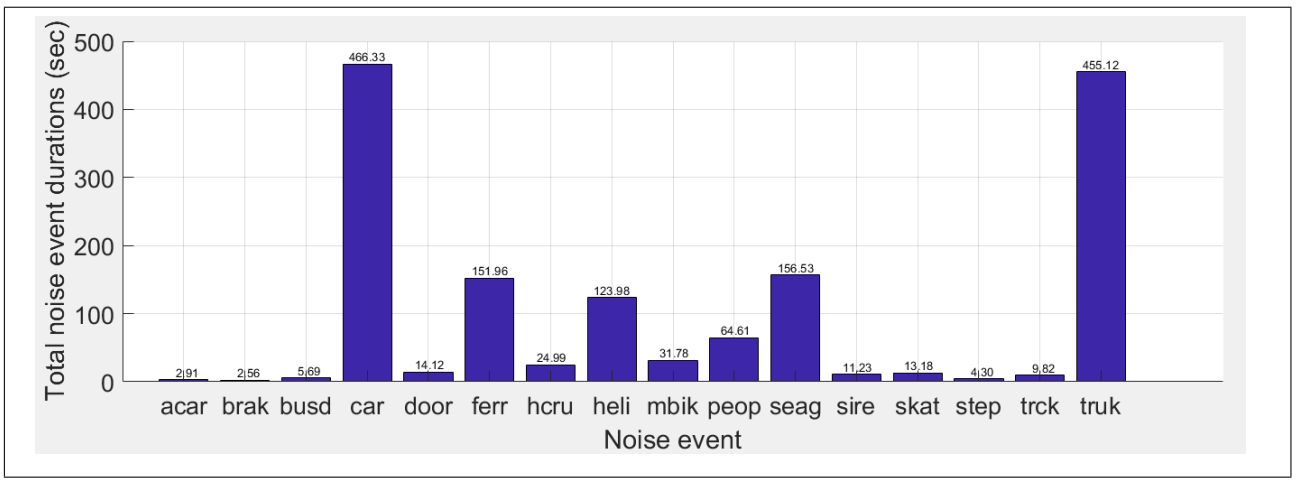

Figure 15. Total labelled events and their aggregated duration of the recording campaign at Port of Barcelona.

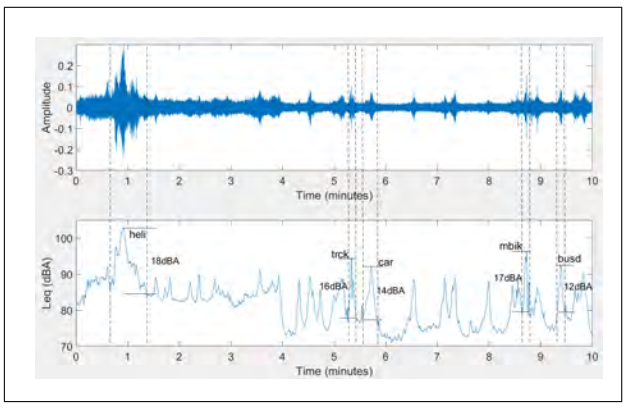

Figure 16. Time domain waveform (top) and L_{Aeq} curve (bottom) of and excerpt of Adossat terminal B recording.

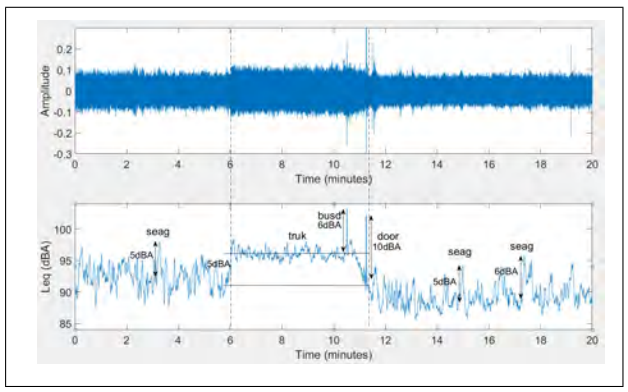

Figure 17. Time domain waveform (top) and L_{Aeq} curve (bottom) of and excerpt of Contradic dock recording.

the activity that each location develops. The touristic wharf is a quiet and pleasant area where noise generally comes from people talking, but the background noise is lower; Adossat dock (both terminals A and B) presents a higher mean L_{Aeq} due to road traffic and periodically sounds of ships and helicopters; and finally Contradic dock shows the highest L_{Aeq} values as it is an industrial area with noises from factories, machinery and trucks.

In Figure 16 we can observe an excerpt from a recording obtained in Adossat dock terminal B, where

several events appear. The figure shows the time signal waveform and also its evaluation using its corresponding L_{Aeq1s} curve. The helicopter increases the equivalent level for 18 dBA, and the noise of a truck and a car increase the L_{Aeq1s} in 16 dBA and 14 dBA respectively. There is also a motorbike sound with a salience of 17 dBA. In Figure 17, the most significant noise is a truck noise, that lasts for more than 5 minutes, and increases the equivalent level for 5 dBA for all the 5 minutes. Other events also stand out from the equivalent noise level envelope noise level significantly, as the seagull song (5 dBA or 6 dBA depending on the occurrence), or the noise of a door. These two pieces of audio and its analysis show us that the impact of the events on the equivalent level of the background noise is significant and has to be taken into account [11].

4.2. Spectral description for several noise events

In this section we show examples of noise events spectrograms recorded in the Port of Barcelona. From the point of view of the duration of the event, some events like pressurized air from trucks (Figure 18c), doors closing (Figure 18j) and vehicles running over bumps (Figure 18l) have an abrupt, very short duration, usually around one second; meanwhile, sounds like helicopters (Figure 18f) and ferries (Figure 18d) can last for several minutes, and they emerge and disappear more gradually. On the other hand, looking at the frequencies of those noises, car alarms (Figure 18h) and sirens (Figure 18k) have specific frequency patterns, as they are generated electronically, whereas human voice (Figure 18g) spectrogram have its energy scattered through the range of 300 Hz to 3 kHz.

5. Conclusions

This paper described a recording campaign in the Port of Barcelona, in four different locations, strategically chosen to have a diversity of sounds in the analysis. The result of this work focuses on the generation of a port noise dataset, manually labeled, which also allows us to describe the existing soundscape in the Port of Barcelona. Finally, a first preliminary study of the impact of several sound events occurring in the port to the equivalent level of noise of the background noise, which is different depending on the location of the measurement.

Acknowledgement

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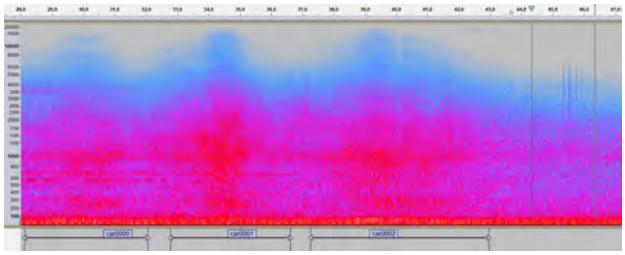
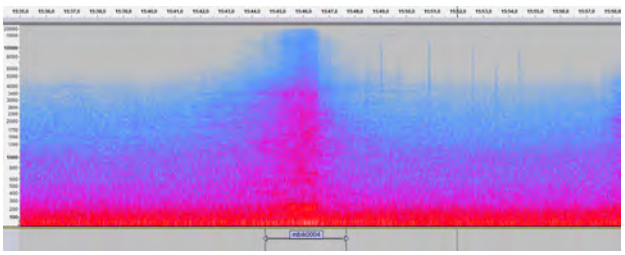
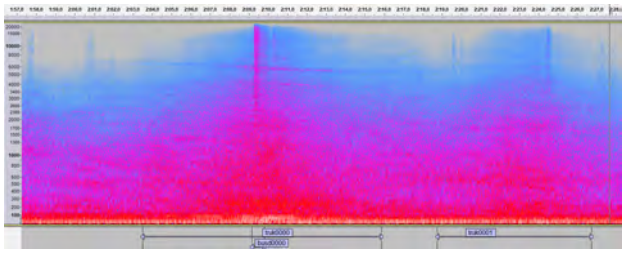


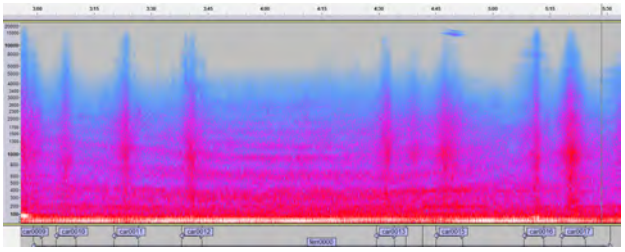
(a) Car noise.



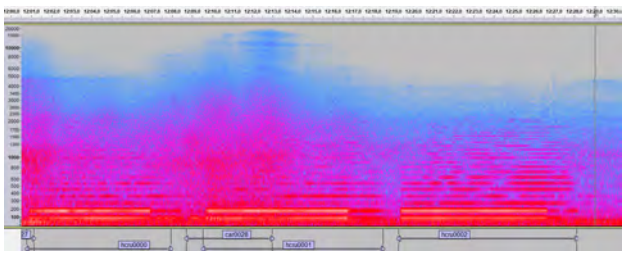
(b) Bike noise.



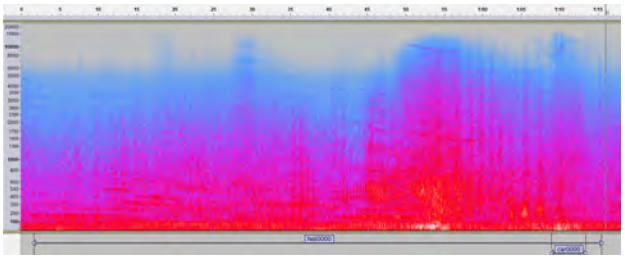
(c) Truck noise.



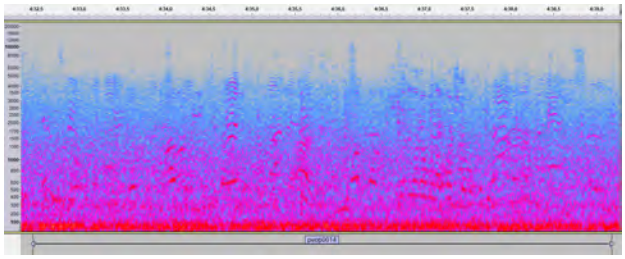
(d) Ferry noise.



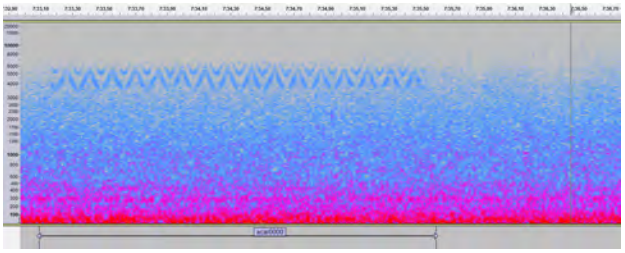
(e) Cruise horn noise.



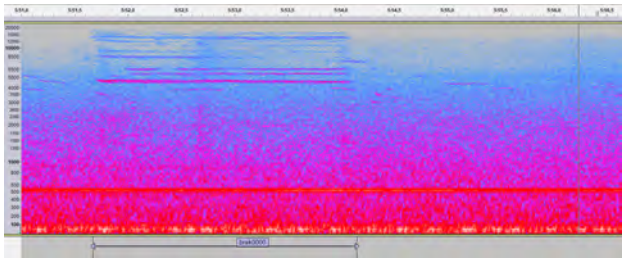
(f) Helicopter noise.



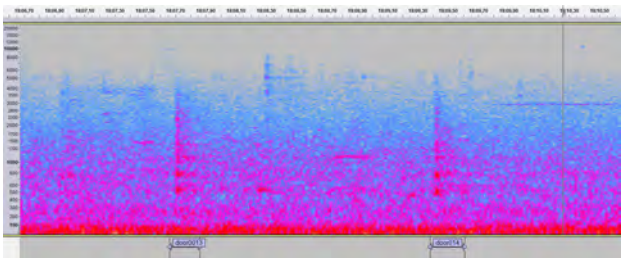
(g) People talking noise.



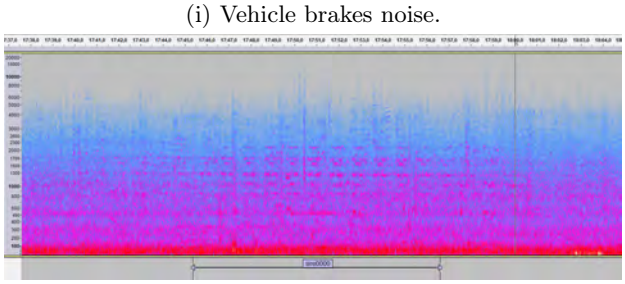
(h) Car alarm noise.



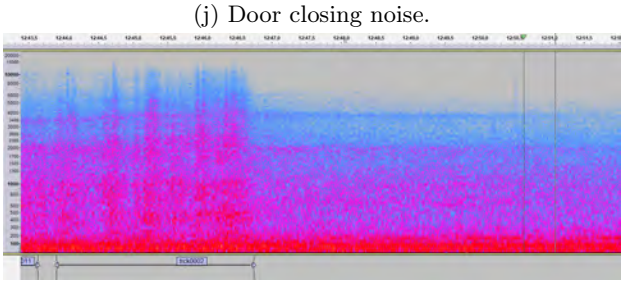
(i) Vehicle brakes noise.



(j) Door closing noise.



(k) Vehicle siren noise.



(l) Truck running over a bump noise.

Figure 18. Spectrogram detail of several sound events recorded in the Port of Barcelona.