UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR TÉCNICO

Waterfront Urban Areas Soundscape

Aline Souza Lopes Ventura Nardi

Supervisor: Doctor José Luis Bento Coelho
Co-Supervisor: Doctor Teresa Frederica Tojal de Valsassina Heitor

Thesis approved in public session to obtain the PHD Degree in Architecture
Jury final classification: Pass with Distinction

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Abstract

Waterfront cities are places that have their own identity, with uses, visual elements, and sound particularities, derived from the combination of the urban context with water. The complexity of their sound environments, with important information from its reference sources, such as the sounds of water, seagulls, and boats, and from the sources arising from the essentially urban use of these areas, such as human, traffic and operational sounds, require that a new or rehabilitation project for these areas includes a careful analysis of its soundscape and a soundscape design that considers the aspects that may influence its appraisal.

Nevertheless, the soundscape approach has not been contemplated by the urban designers in waterfront areas, where other criteria such as functionality, aesthetics, lighting, landscaping, connectivity, and sustainability, has still been considered more important.

The present research was developed with two main goals: to propose objective criteria which can support the urban planner on the soundscape analysis of a waterfront area; and to develop practical guidelines for the soundscape design of a waterfront public space.

A case-study line of action with an empirical survey on the urban waterfront of the Tejo River, in the city of Lisbon (Portugal), was carried out, making use of a variety of assessment techniques which included a questionnaire application, a non-participatory in situ survey and a laboratory listening panel. The information collected were combined and compared, to identify potential relationships with the sound environment evaluations.

Based on the significant correlations found, objective criteria and good practices for soundscape analysis were established, and practical guidelines for soundscape design of a waterfront public space were described, so that the professional practice of urban planners and designers succeed to include the soundscape approach in the analysis, planning, and design of urban waterfront public spaces, to better preserve, improve, or design it.

Keywords: soundscape; sound environment perception; public space; urban waterfront areas; waterfront design.

Resumo

As cidades ribeirinhas são lugares que possuem identidade própria, com usos, elementos visuais e particularidades sonoras, derivadas da combinação do contexto urbano com a água. A complexidade dos seus ambientes sonoros, com informações importantes das suas fontes de referência, como os sons de água, gaivotas e barcos, e das fontes decorrentes do uso essencialmente urbano destas áreas, como os sons humanos, de tráfego e operacionais, exigem que um projeto novo ou de reabilitação destas áreas inclua uma análise criteriosa da sua paisagem sonora e um projeto de paisagem sonora que considere os aspetos que podem influenciar sua avaliação.

No entanto, a abordagem da paisagem sonora não tem sido contemplada pelos urbanistas em áreas ribeirinhas, onde outros critérios como funcionalidade, estética, iluminação, paisagismo, conectividade e sustentabilidade, ainda são considerados mais importantes.

A presente pesquisa foi desenvolvida com dois objetivos principais: propor critérios objetivos que possam subsidiar o urbanista na análise da paisagem sonora de uma orla; e desenvolver diretrizes práticas para o design de paisagem sonora de um espaço público de frente de água.

Um estudo de caso foi realizado na orla urbana do rio Tejo, na cidade de Lisboa (Portugal), recorrendo a diversas técnicas de avaliação que incluíram a aplicação de um questionário, levantamento de dados não participativo e um painel de ouvintes laboratorial. As informações coletadas foram combinadas e comparadas, para identificar possíveis relações com as avaliações do ambiente sonoro.

Com base nas correlações significativas encontradas, foram estabelecidos critérios objetivos e boas práticas para a análise da paisagem sonora, e descritas diretrizes práticas para o projeto de paisagem sonora de um espaço público à beira-mar, de modo que a prática profissional de urbanistas consiga incluir a abordagem da paisagem sonora na análise, planejamento e projeto de espaços públicos urbanos de frente de água, para melhor preservá-los, melhorá-los ou projetá-los.

Palavras-chave: paisagem sonora; percepção do ambiente sonoro; espaço público; áreas urbanas de frente de água

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Abbreviations and key definitions

ANN	artificial neural network
ISO	International Organization for Standardization
L_{10}	A-weighted statistical sound level - sound level that has been exceeded by 10% of the measurement time.
L_{50}	A-weighted statistical sound level - sound level that has been exceeded by 50% of the measurement time.
L_{90}	A-weighted statistical sound level - sound level that has been exceeded by 90% of the measurement time.
L_{Aeq}	A-weighted energy equivalent sound pressure level [dB(A)]
L_d	continuous equivalent level for the daytime;
L_{den}	A-weighted day-evening-night equivalent level [dB(A)]
L_e	continuous equivalent level for the evening period;
L_{eq}	equivalent continuous sound pressure level,
L_n	continuous equivalent level for the night period;
MLR	multiple linear regression
RQ	Research Question
SPL	Sound pressure levels
t_d	day integration time - in Portugal, defined between 7:00 –20:00 = 13 hours;
t_e	evening integration time - in Portugal, defined between 20:00 –23:00 = 3 hours;
t_n	evening integration time - in Portugal, defined between 23:00 –7:00 = 8 hours
UN	United Nations
WHO	World Health Organisation

Appropriateness	Soundscape Descriptor that has been used to measure users' evaluation about how appropriate the soundscape with the place is as well as with the activity performed. The higher scores of appropriateness correspond to higher likeliness of visiting the place again (Aletta et al., 2019).
Perceive affective quality	model defined by two orthogonal dimensions "Pleasantness" and "Eventfulness", which are located at a 45 degrees rotation from the second set of orthogonal factors "Calmness" and "Excitement". (Aletta & Kang, 2018).
Sound pressure levels	A critical parameter in discussions on sound and particularly used in environmental noise management, where it can be calculated or measured. SPL are described on a logarithmic scale, decibels (dB), usually A-weighted (dBA) to account for the relative hearing sensitivity of the human ear in different frequency bands. Moreover, SPL often refer to an average (equivalent) value accumulated over a certain period of time.
Soundscape	A broad concept that can have different meanings in different contexts (Schafer, 1994 [1977]), e.g. to describe musical compositions, field recordings and art. In this thesis, the concept refers to the everyday experience of the sonic environment. It is defined by the International Organisation for Standardisation (ISO) as the "acoustic environment as perceived or experienced and/or understood by a person or people, in context" (ISO, 2014).
Soundscape Planning	Design process in which the, according to Bento Coelho (2016), the user characteristics and his sonic interests and preferences shall be priority, in line with the context: place, activities, sound composition and environmental features. It will bring to solutions that meet people's expectations, rising up the acceptability and identification with the place, together with feelings of comfort, satisfaction, appreciation, and well-being.

Waterfront Sounds	Sound source category established by the research autor in line with the research objectives. In addition to the classification in the ISO, the "waterfront sounds", the category was devised, since it is important for the research purposes to know how much these sounds, that usually characterize waterfront areas, are perceived. Therefore, the sounds of boats and pier, which are classified as sounds of technology, and the sounds of seagulls and water, regarded as sounds of nature, were then classified as "waterfront sounds".

1. INTRODUCTION

The understanding of the outside world is a complex cognitive process. Outdoor spaces carry their own characteristics, which includes their natural and man-made landscapes, with their own seasonal, clime and sound variations. In addition, they also offer a wide variety of experiences for their user's different senses, that depends as much on themselves (their socio-cultural factors and personal aspects), as their expectations, behaviour and motivations.

The landscapes that build up the public spaces, their territorial occupation, infrastructures and urban context are inherent associated to the sound. All these environmental characteristics bring direct and broad consequences to their sound environment which, in turn, affect their uses, users, experiences, and even the health and people well-being.

Due to the pioneering researches of Southwort (1969) and Schafer (1994), who significantly contributed to the urban environment questions, the concept of soundscape began to gain progressively importance. As an interdisciplinary field, the soundscape studies are attracting worldwide interest, and changing the historical view of "sounds", that focus on the human perception of acoustic environments, with an alternative approach on managing sound in the urban environments (J. Y. Hong & Jeon, 2015). This is the reason for which the environment researchers and professionals started to question how modern cities should "sound like", instead of just "look like" (Aletta & Xiao, 2018).

Auditory information is one of the main inputs to the human being mental appraisal process and its space construction. It will contribute to the image that each person will have about the global space (Kang & Zhang, 2010). The sound environment, as it is perceived, understood and experienced by the user of a space, forms the perceptual construction, a dynamic and personal concept.

Cities at the water's edge are places that have their own identity, with uses, visual elements and also sound particularities, that are derived from the combination of the urban context with the water (urban and maritime culture). The sound environment of these areas carries important dynamic information from its reference sources, such as the sounds of water, winds, birds or boats, which give meaning to this landscape, allowing an identity relationship of their users. However, the current and essentially urban use of these areas usually produces distinctive peculiarities to this characteristic sound environment, due to the insertion of other sound sources with its own features, such as human, traffic and operational sounds.

Due to these urban waterfront areas complexity, a new or a rehabilitation project to all the area, for a public space or for a single building should include a careful analysis of the original situation about the changes that will occur on the sound atmosphere (how the sounds are and will behaviour in these spaces). And not only that, but also one must consider the entire process of the sound perception in the space, its existing and future soundscape. (Bento Coelho, 2016).

Nevertheless, especially in these waterfront areas, the soundscape approach has not been contemplated by architects, engineers, environmental specialists, technicians and urban planners. The criteria study such as functionality, aesthetics, lighting, landscaping, connectivity and sustainability, still have been regarded as more important.

This research will focus on a soundscape empirical study of waterfront urban spaces from the urban designer perspective. The interpretation of the correlation between physical and functional elements, soundscape elements and users' behaviour and preferences, can define new paths to establish analysis and planning criteria which will include the "soundscape" as one of the objective determinants to the project concept to be considered by the urban planners in their design process.

1.1. SCOPE

This research analyses the urban waterfront spaces and their soundscape on the urban context of the Tejo River, in the city of Lisbon (Portugal).

It relies on the premise that the soundscape should be analysed, with appropriate tools, techniques and strategies, since the first design steps. This is even more imperative on already formalized urban environments, where the current and future activities will affect the user expectation and perception.

The waterfront areas can provide broad possibilities of restorative places implementation that may improve the people life quality, where the sound behaviour study should not be leave out and must be consider with all other constraints.

1.2. GOALS

The research explores an enhanced transdisciplinary exchange of knowledge, in order to understand "what it is" and "how to" obtain a quality soundscape for the waterfronts' public spaces, on the users' perspective, and how this knowledge can contribute to the analysis and design processes of the practitioners involved in the creation of urban space.

The aim is two-fold: 1) to propose objective criteria which can support the urban planner on the soundscape analysis of a waterfront area; and 2) to establish practical guidelines for the soundscape design of a waterfront public space that allows urban designers to compile soundscape information in the waterfronts urban spaces revitalization in order to achieve better integration levels within hosting cities by improving urban vitality while preserving their uniqueness, sensorial and spatial identity.

The research follows an evidence-based approach. It correlates the subjective and objective data concerning sound perception analysis criteria, on a waterfront urban space, in order to provide sensible information for urban designers - Why does this place sound different? What is unique? Are there sounds or sound components which interfere or support users' expectations? Are there other sensory factors which interact with the sounds in a supporting or distorting way? What leads users choose to use these areas? -, with the goal of implementing, improving and preserving quality soundscapes in sustainable and pleasing urban environments.

Assuming the urban waterfronts' role within the cities' economy context, the research aims to understand how the soundscape acts as a decision factor for the use of urban waterfronts, considering how soundscape impacts the users and interferes in the space performance. This includes the understanding of significant relationships between physical and functional elements (e.g., built environment, urban facilities and furniture, natural features, infrastructures, land uses) and soundscape elements (e.g., sounds composition, sounds heard, sound environment quality), which may influence the users' preferences and behaviour.

1.3. CONTEXT AND JUSTIFICATION

The acoustic environmental studies, before constructing or remodelling an urban space, tends to focus mainly on compliance with existing legislation, its criteria and limit values, or, on the previously existing conditions conservation.

The classical acoustic procedures, usually based on the noise mapping results, effort to attenuate the noise, reducing the sound energy, regardless of the content or context of the sound. High amounts are spent only to fulfil the guidelines established without be able to fully predict the actual impacts on the sound environment quality (Bento Coelho, 2016). Even less, take into account the human perception and the sounds of preference, which in the vast majority of cases are desired, expected and can contribute to relaxation and psychological restoration, essential for well-being and health (Schulte-Fortkamp & Lercher, 2003). It means that the sound pressure levels reduction does not necessarily lead to a quality-of-life improvement to the affected populations, mainly on urban areas, with landscapes and built environment constituted by a great number of sound sources with large variations.

In this context, soundscape research took on a new significance in sound related research field, since it involves not only physical parameters, and it considers environmental sounds as a 'resource' rather than a 'waste'. Research into soundscapes encompass more qualitative cognitive approaches focusing on meanings attributed to sounds in relation to human preference, behaviour and activities, in certain context.

Port cities, such as Lisbon (Portugal), witnessed in the post-industrial period, the abandonment of their old port structures, due to the port's reallocation to other open and large spaces determined by industrialization and mechanization of their processes. These old ports and its surrounding areas gradually are being transformed with interventions that have change the waterfront experience and image.

The cities are building a regeneration or revitalization mentality of their port fronts, with intervention processes that occur at different levels, studies, design and execution of plans. It varies from city to city according to their needs, conditions and motivations (Guimarães, 2006, p.12).

From the urban planners' point of view, urban areas or public spaces must always first undergo to an evaluation process so as to be transformed or revitalized. Due to the variety of contexts and the diversity of roles of public spaces, a systemic reading of their character is required. This process should not be different for the waterfront areas, where the diversity and complexity of producing public spaces claims interdisciplinary and collaborative approaches that include physical, perceptive and relational elements to achieve a successful future project in all aspects (Brandão & Brandão, 2019).

Accordingly, understanding the needs to proceed with a public space holistic analysis, and, also considering the need to be considered the human perception, is understood that these spaces acoustic assessment must be realized through the soundscape approach. Therefore, the soundscape also must be well organized, analysed and planned, using appropriate tools, during the design stages (Kang & Zhang, 2010).

Consequently, the sound perception assessment criteria require to be well known by urban designers, as well as the other that already are well-established in their evaluation processes. It is not only understand the human acoustic preference, but an intentional management or design process of the acoustic environment, which results in improve the urban public space overall sound quality, ensuring acoustic comfort and the most pleasant sound experience (A. L. Brown, 2014).

1.4. KNOWLEDGE GAPS

1.4.1. Water sounds studies

Water sounds are complex and difficult to predict, a reason why, over the last decade, both perceptual and its acoustic aspects have been explored on experimental research.

Although in the last decade, the number of researches on water sounds have increased significantly, it is important to highlight some gaps regarding aspects that can be better e xplored taking into account the soundscape concepts (ISO 12913-1, 2014). About these research limitations, mainly about to their practical application in soundscape research, it can be mentioned:

(i) Most of the water sounds research are developed in the laboratory

Studies comparing the effects of water sounds are typically indoors conducted by using recordings in listening laboratory settings. The surveys performed in this environment is easy to control many conditions comparatively the in situ researches, but their ecological validity may be considered limited (Trudeau, Steele, & Guastavino, 2020), due to some aspects:

- *Stimuli water sounds are not from a real environment*

Most research aims to explore the effects of the water sounds acoustical characteristics (e.g., sound level, spectral, and temporal features), through subjective preferences, to suggest desirable acoustic design factors. The sounds stimuli to this kind of experiment are usually obtained by recordings from just one sound source, produced in the laboratory or in recording studios, which do not get characterize a real situation or an urban environment with all the existing sounds combinations.

- *Stimuli water sounds are not from natural sources.*

From the few surveys in which the stimuli sounds were captured in an urban environment, scarce were conducted based on water sound from natural sources (Jeon, Lee, You, & Kang, 2012; Ren & Kang, 2015). Besides, there is no record of scientific research, carried out in laboratory environment, that explores the water sounds from waterfronts.

- *Acoustical preferences without visual interaction.*

The visual information will affect how the acoustic aspects are assessed and strongly influences the overall perception of urban environmental qualities. The results from the Ren & Kang (2015) audio-visual experimental research, for instance, revealed that the ecological waterscape landscape objects well match natural sounds, leading in higher acoustic comfort scores.

However, the approaches and methodologies used on water sounds studies have largely focused on the effects of these sounds and on acoustical preferences, whereas the audio-visual interactions have rarely been considered (Galbrun & Calarco, 2014; J. Y. Hong & Jeon, 2013; Jeon et al., 2012; Watts, Pheasant, Horoshenkov, & Ragonesi, 2009).

- *Visual stimuli without urban environment*

Even important, mainly related to the perceptive results, the visual effect may be considered as still little explored by laboratory research. Most of the studies exploited computer simulation images assessment from a certain outdoor environment (garden, yard or streetscapes) with different surroundings and water sources (Galbrun & Calarco, 2014; J. Y. Hong & Jeon, 2013; Watts et al., 2009). Few survey presents the water source photograph, same used on the experiment's sound stimulus, however with little surrounding environment visual information (Jeon et al., 2012; Ren & Kang, 2015).

The lasts water sounds laboratory research, however, have advanced the audio-visual interaction by the virtual reality tools (J. Y. Hong, Lam, et al., 2020; Lugten, Karacaoglu, White, Kang, & Steemers, 2018; Puyana Romero, Maffei, Brambilla, & Nuñez-Solano, 2021). From this resource it becomes possible to reproduce in laboratory the urban environments as a whole, with their sound sources, to get higher assertive soundscape assessments, more compatible with the reality.

- *Listeners do not represent the survey true target audience preferences*

The soundscape researches prove that not only the user demographical factor, but also sociocultural and behaviour aspects affect the environment appreciation (Jeon et al., 2018; Soares & Bento Coelho, 2016; Yang & Kang, 2005b). Therefore, as highlighted by Nilsson et al. (2010), the laboratory water sound researches listeners, are not representative of the typical users from the urban environment to where the research correlations are done. It would involve a wide range of participants, aiming to be representative and assertive, as much as possible, in the subjective evaluations carried out.

- *Experiments with restricted ecological validity*

The laboratory settings, besides the use of headphones or other equipment, can cause the participant to focus on the sound source or on the sound environment in a way that would not be possible in multimodal environments. In an urban public space context, the respondent's attention is more scattered, which could modify the perception not only from visual water feature but also from its acoustical properties and the soundscape assessment. Moreover, the users may be engaged in an activity and the water features may produce effect even if cannot be heard.

On in situ water sounds researches, Axelsson et al. (2014) and Trudeau et al. (2020) found that the water feature did not significantly affect the soundscape ratings, which contradicts with the laboratory-based studies whereby significant effects were achieved (Galbrun & Ali, 2013; J. Y. Hong, Ong, et al., 2020; Jeon et al., 2012; Rådsten-Ekman, Lundén, & Nilsson, 2015). These perceptual differences suggest that the mechanism by which the water affect soundscape ratings in the context of the urban public space is not straightforward and needs to be better understood. In addition, the water might provide visual and experiential appeal even without the auditory component, which affects respondents' expectations of the space. Therefore, especially for the soundscape studies whereby the context is inherent, the laboratories findings need to be validated in authentic environments.

(ii) In situ surveys do not explore natural water sounds features

Because of their practical implications for urban planning and design, the recent available research proves how central it is to study the water sound into its urban environment. However, the results of in-situ research show that there is no simple and direct relationship between the water sound, the acoustic environment and how people perceive it (Axelsson et al., 2014; Trudeau et al., 2020).

Due to the difficulty of creating control conditions, these studies are still rare and do not explore natural water sounds, focusing on the effects and on the soundscape ratings of water sounds produced by manmade sources (Axelsson et al., 2014; J. Y. Hong, Lam, et al., 2020; Trudeau et al., 2020).

(iii) Few research aiming results about the soundscape perception

Moreover, there is a clear evidence that introducing water sounds can potentially improve the overall soundscape quality (Axelsson et al., 2014; De Coensel, Vanwetswinkel, & Botteldooren, 2011; J. Y. Hong & Jeon, 2013, 2017b; J. Y. Hong, Lam, et al., 2020; J. Y. Hong, Ong, et al., 2020; Jeon, Lee, You, & Kang, 2010; Jeon et al., 2012; Lee & Lee, 2020; Lugten et al., 2018; Trudeau et al., 2020; You, Lee, & Jeon, 2010).

Even so, the data obtained from the water sounds research refer little and in isolated way about the soundscape perception. Some studies were limited to question about the overall soundscape quality (Axelsson et al., 2014; J. Y. Hong & Jeon, 2013; J. Y. Hong, Lam, et al., 2020; J. Y. Hong, Ong, et al., 2020; Lugten et al., 2018) and others about the emotional responses, such as pleasantness and eventfulness (De Coensel et al., 2011; Lugten et al., 2018; Rådsten-Ekman, Axelsson, & Nilsson, 2013).

1.4.2. Soundscape studies

According to Aletta & Xiao (2018), while the publication rate of soundscape studies is considerably increasing, the urban soundscape research is undergoing a harmonization and standardization process. There is an effort supported by the international research community, in order to address both general frameworks and definition issues (ISO 12913-1, 2014), as well as more practices and related methodological aspects (ISO 12913-2, 2017; ISO 12913-3, 2019).

Standardization can be seen as a significant step towards soundscape recognition as a legitimate approach to managing and designing urban sound environments. However, despite the soundscape area scientific studies confirm the importance of considering human sound perceptions on the evaluation or building of new urban spaces, little has been achieved on attracting stakeholders in practical situations.

The urban space soundscape study is broader than the research about specific sound sources, their characteristics and interactions with other sound sources. However, it does not mean that these surveys are not important for the other studies that follow, even to better understand how the appreciation and perception of the sound source in its environment takes place.

In Aletta & Xiao (2018) research, it was found that the biggest challenge faced by the soundscape community is the gap between academic research and urban planning and project practice. In addition, there is no scientific research in the area that establishes clear and objective methods for this, what makes difficult to include the soundscape as one of the objective determinants to the project concept.

1.4.3. Waterfront soundscape studies

Despite the growing scientific recognition that water sound has, in general, important features that can significantly contribute to a good soundscape appreciation, it must be considered that it will never be independently in an external environment. In the same way, it happens when aiming to study the soundscape of urban spaces located in waterfront areas. Even knowing about the water importance in these spaces composition and that it can contribute to a positive sound appreciation by its users, there are many other aspects, which go beyond this specific sound source, that collaborate to these places' overall appreciation soundscape process.

On a case study on the Naples waterfront, Puyana Romero, Maffei, Brambilla, & Ciaburro (2016b) developed a model of the waterfront's soundscape based on objective variables by a combination between two methods: artificial neural network (ANN) and multiple linear regression (MLR). The research aimed to evaluate the influence of acoustic parameters (sound levels and psychoacoustic descriptors) and visual parameters (percentages of different landscape elements from aerial photographs and panoramic photos) on the subjective soundscape quality appraisal (obtained from on-site interview). The research had unexpected results on the ANN method whereby the behaviour of some variables to the conformation of the model was not as expected. The researchers assigned that could be due to the study large area.

On another research Puyana Romero, Maffei, Brambilla, & Ciaburro (2016a) divided the Naples waterfront area according to three specific characteristics: pedestrian areas, limited traffic area and road traffic area. The objective and subjective data input was the same from the first research. However, it was applied a method to select the variables - mRMR ("minimum redundancy and maximum relevance features selection") - before the ANN method use. The research resulted in a very good performance of the models and outlined some tendencies, such as the positive association of the soundscape appraisal: with the percentage of the sea and green areas and the statistical levels L_{A50} - on road traffic areas, with the percentage of the sea and contiguity pedestrian areas - on limited traffic areas, and, with the percentage of the singular building - on pedestrian areas. However, according to the authors, it is not wise to extend the results to other areas, even with similar characteristics, mainly because the variables selected in one area can be different to those variables of the other one.

On a comparative study case, between Naples and Brighton waterfront (Puyana Romero, Ciaburro, & Maffei, 2016), the degree of match between a waterfront users' expectations and how different factors affect them was investigated. Artificial neural networks (ANN) were applied and almost the same variables have been chosen in both waterfronts. In general, the outcomes show the city where the users are more satisfied, as of the better results obtained on each variable, including about the soundscape quality. The models were very well performed, but it is not clear how each variable determines the results of the artificial neural networks.

As noted, there is few scientific research carried out about the waterfront soundscapes. Despite this, the results achieved point to some important advances for the development of other research in the area, such as the positive association of the soundscape appraisal with the percentages from sea area and green area.

The developed model, on the studies presented, can be considered a new approach to interpret the sound environment in order to characterize existing scenarios. However, regarding the application of the artificial neural network (ANN) method, its results cannot replicate to other similar locations, due to the likely differences between the variables selection. Besides, considering the soundscape definition, regarding the input subjective data used on the developed model, the research lack from more information about the user approach, who will perceive, experience and understand the sound environment.

1.4.4. Public space assessment methods and the soundscape approach

With regard to existing and well-explored methods and techniques of urban spaces analysis, it was noted that there is a gap concerning the study of sound behaviour. In addition, the works, studies or projects that refer to both the revitalization and the regeneration of urban waterfronts do not mention the sound aspect as a determinant to be met or that was respected at some stage of the assessment or design process.

On the assessment process for both architects and planners, key determinants aspects, such as dimensions, natural constraints, and constructed constraints are inherently accomplished. Within the natural conditions that should be considered to a design process, studying aspects like solar trajectory and wind direction, for example, is a natural and usual practice. These professionals are used to and required to think about this since the beginning of their academic careers, both in the technical and specific disciplines, such as the project and urbanism ones, which are part of a student's entire curriculum. However, the study related to the urban sound and its behaviour is little considered in the curricular transversality of these professionals.

It is necessary to develop more specific tools, techniques and strategies that can be used with the goal of constructing, improving or preserving the quality soundscapes providing sustainable, pleasing urban environments. The information and criteria on the degree of sounds acceptance by users should be considered by urban designers and incorporated into the design of urban spaces so as to attract citizens and bring them together.

Therefore, it is in the gap demonstrated from the few studies related to the aspects summarized below, that this research intends to position itself:

- Assessment of the water sound ecologically validated, from the perspective of its user: produced by a natural source, in waterfront environment, considering all variations and context of an outdoor space;
- Evaluation of the waterfront soundscape, from the perspective of its user: in a real environment, considering the possible correlations with the quality of the urban space as a whole, the perceived sound sources and the characteristics and behaviour of users;
- Urban spaces analyses and / or revitalization and regeneration design of waterfronts urban areas, which consider the soundscape approach as a determinant of their processes.

1.5. RESEARCH QUESTIONS

As stated before, scientific research about soundscape of the urban waterfront lacks information and criteria about the acceptance degree of sound environment by the public spaces users and what may be used for a positive appreciation. Based on this reason, it is difficult to include this concept as a conditioning factor to be considered on the assessment and in the design steps by the urban designers.

The present exploratory study, addresses the research gaps by focusing on three research questions:

RQ1 — To what extent the qualities and characteristics of the public spaces themselves affects the urban waterfront public space soundscape quality, by the user perspective?

RQ2 — What is the influence degree that the motivations, activities and socio-demographic data of the users of the waterfront urban public spaces have on the overall soundscape quality appraisal?

RQ3 — Which are the perceived sound sources and the sound environment evaluations that are associated to the better soundscape appraisals of the waterfront urban public spaces?

1.6. HYPOTHESIS

The hypothesis underlying this study is that by establishing a coherent correlation between the aspects presented above, it would be possible to obtain objective soundscape information, that may be useful for the urban designers on a waterfront revitalization, aiming to implement, improve or preserve soundscapes.

With a methodological framework for qualitative and quantitative analysis required for a soundscape study and the results of the comparisons to be conducted it is expected that it will be possible to identify potential relationships to propose objective criteria for the soundscape analysis and establish practical guidelines for the soundscape design of the urban waterfront spaces.

Therewith, it is expected that the results obtained can support the professional practice of urban planners and designers to include the soundscape approach in the analysis, planning and design of urban waterfront public spaces.

1.7. THESIS STRUCTURE

This thesis is organized in three parts. The <u>first one,</u> with four chapters, presents its introduction and the bibliographic review carried out.

The **Chapter 1** presents the research object of the case study, the objectives and questions surrounding its development, and the hypothesis raised.

On the next three chapters, the bibliographic review is presented, in which were held a broad analysis of publications on the correlated areas from the waterfront soundscapes studies on an urban designer perspective.

The **Chapter 2** is divided into two parts, which firstly the history of the transformations occurred in the urban port waterfronts is shown, and the Lisbon port waterfront historical evolution is briefly presented. In the second part of the chapter, contemporary public spaces and their characteristics are described, methodologies, consolidated methods and techniques commonly applied by urban planners in the analysis of public spaces are exposed, and some important quality criteria used in the evaluation of these spaces are presented.

The **Chapter 3** presents the concepts that encompass the soundscape. First, the general factors that influence the sound environment perception, experimentation and / or understanding process are shown. The following, the main descriptors used to investigate wider or narrower soundscape aspects are exposed. Finally, the most recognized and used methods to carry out the urban environments analysis, including those referenced in the soundscape standardization, are presented.

On the **Chapter 4** the most important acoustic concepts, used to describe or characterize the urban space sound environment, are presented. The main sound properties and sound sources classification are shown in addition to the main sound descriptors used to characterize the sound in outdoor spaces. Finally, some acoustic descriptors related to the perceptual aspects of human hearing are presented.

The following chapters, and the <u>thesis second part</u> presents the case study evolution, its results, analysis, and discussions.

Chapter 5 provides the general methodology adopted on the case study and a more detailed presentation of the area. The Lisbon waterfront public spaces and a brief description of their main characteristics is presented. As annex documents, the preliminary assessments carried out in each public space studied are presented, as well as the survey forms created to the data collection process.

Chapter 6 describes the used methods and the results obtained from the sound environment assessment carried out in the study area. It relates with the research quantitative data obtained on each waterfront public space selected, which includes the sound pressure level and the user's behavior on these locations.

In the **Chapter 7** the methods adopted, and the results obtained from the soundscapes assessment are presented. It relates with the research qualitative data obtained on the Lisbon waterfront public spaces, which includes the recordings of the existing sound environment and a questionnaire application. As annex document, the results obtained from the application of the inquiry, in each public space, are presented.

In **chapter 8,** the first analyzes are carried out based on the sound environment quantitative and qualitative data, collected in the public spaces, and presented in the previous chapters. The results obtained are compared with each other and analysed to identify potential relationships, and the correlations found are discussed.

The **chapter 9,** objective criteria and good practices for soundscape analysis were established, and practical guidelines for soundscape design of a waterfront public space were described, based on the significant correlations found in chapter 8. As annex document, suggestions of a questionnaire and data collection form that can be used for a soundscape analysis are presented.

Finally, the second part of the research ends with its conclusion, in **chapter 10**, in which a logical relationship of the results obtained with the research questions, its objectives and the literature review is presented.

The <u>third and last part</u> of this dissertation includes all the analysis sheets developed for the case study, as well as the support elements produced to facilitate the analysis process.

2. WATERFRONT URBAN PUBLIC SPACES

This thesis originates from an interdisciplinary understanding, which demands a collaborative approach between the various knowledge spheres. It is based, however, from the urban designer perspective, who must have a holistic view of the public spaces regarding analysis and planning, to obtain successful projects in all areas.

This chapter, therefore, on an urban designer perspective, aims at: (1) presenting a comprehensive overview of waterfront port cities in order to highlight the importance of considering the soundscape approach in their revitalization or reorganization planning processes (2) presenting methodologies, methods, techniques and criteria, experienced by urban planners and researchers in the analysis and evaluation of urban public spaces, which can be explored and integrated to the assessment of the soundscape of public waterfront spaces.

This chapter is organized in two parts. The first one reviews the waterfront urban spaces, presenting an overview of the changes occurred in the port city throughout the history, its main features and its connectivity, and how their regeneration and revitalization processes usually occur. Furthermore, in this part, the regeneration process of the Lisbon city riverside area is presented - the very object of the present research - in order to better understand it development and the way in which its spaces are organized.

The second part begins by presenting the contemporary public spaces and its characteristics that show an increasing concern with the 'human senses', including the sound perception. Then, the delay in addressing the sound aspects in the methods of analysis and planning regarding the public space was highlighted, since the urban planner lacks objective criteria which can assist him. Finally, the methodologies, as well as the consolidated methods and techniques commonly applied by urban planners in the analysis of the public spaces are presented; and also, some important quality criteria used in the evaluation of these spaces were pointed out, essentially highlighting those which take the sound aspect into account. It is intended to know the main practices of the urban planner during the characterization of the public spaces and their users, to provide the integration of the soundscape approach to his/her process of analysis and planning regarding the public space.

2.1. WATERFRONTS IN SEAPORT CITIES

2.1.1. Worldwide history

The port and the city have always had intense relationship of exchanges and movements that brought consequences for the waterfront, the city, and the region. The water that delimited and defended an urban expansion, was a driving element that led to the port fronts mutations, making it possible to visualize the city transformations. The port growth has been marked by historical periods, influenced by geographical and topographic circumstances, giving rise to different cities with distinct relationships with their ports (Guimarães, 2006).

Prior to the industrial revolution, ports were the central elements of trade negotiations as a link between the empire and its colonies. This period is marked by the emergence of large warehouses and roads that impacted the city's urban fabrics. For centuries, the port front was opened to the city, as a transitional element between water and the city (Guimarães, 2006).

Meanwhile, in the same century, the industry transformation speeded up its production capacity and needed to settle near the port areas, transforming their characteristics. New mechanical systems were implemented, and the docks, storage and outflow capacities were expanded. Combined with this, the civil aviation advent in the 1950s led to a reduction in passenger transport by sea. So, the port starts to work only to its activities and becomes a physical barrier between the water and the city, excluding the city inhabitant. This division becomes more evident with the need and then the construction of new infrastructures, such as buildings, highways, and railways.

However, over time, the traditional ports were progressively being vacated, because even trying to adapt, they could no longer meet the need for new infrastructures and larger territories for containers storage and move.

The transition period between the industrial and post-industrial eras brought functional, spatial, formal and structural changes to the city. The port authorities and the industry looked for large and empty building areas. This resulted in the devolution of extensive waterfronts territories to the city, with infrastructures that were part the port facility, but dissociated from urban life.

In most cities, urban waterfront territories become one of the few city areas with large urbanizable spaces, very close to their centres, and with great attraction potential for the services, equipment and housing implementation. (Guimarães, 2006). Therefore, they have again acquired spatial significance as a resource of urban design with huge strategic importance for their cities (Niemann & Werner, 2016).

Hence, since the 1960s, waterfront sites around the world spawned a series of large urban redevelopment projects with the intervention of their old port fronts (Marshall, 2001). The demographic pressure and the activities concentrated on these areas demanded the need to structure, order and qualify their uses and activities, leading to new projects that can be included in major urban remodelling. The regeneration of these areas is not only associated with an urban improvement of vacant, disabled or abandoned places, but also with the meeting of numerous demands, such social, political, environmental, or legislative requests. Besides refurbishing former port buildings, they have also developed an intense event program, including diverse cultural events.

Gradually, during the second half of the 20th century, the water, rivers and seas, gained a new role in the city´s urban structure, a phenomenon taking place worldwide. There was a new perception, and therefore economic use of water, as an identity and landscape element that could increase the property´s value (Ward, 2011).

Waterfronts became associated with ways to recreate the image of a city, not only by changing the face of its run-down quarters, but in more strategic terms by changing its character and creating new or alternative ‘city destinations' (Jones, 2017; Marshall, 2001).

New waterfront projects were created worldwide and seen as strong development concept, and as an asset to increase the profitability of the real estate operations.

Today the concept of ‘waterfront regeneration’ remains an important agenda for city planners and all urban stakeholders (Jones, 2017), considered as one of the most significant and comprehensive tasks of contemporary urban design (Niemann & Werner, 2016).

In that regard, therefore, it is to be expected that interventions on waterfronts become effective and successful when improving the city and composing something with continuity, not just momentarily; also with a strong environmental sense, without denying and overlapping the historical city and its memories, neither obstructing and depriving its relationship with the water (Jesus, 2018).

A creative port city must be capable of reactivating new urban metabolism, where the success strategies will be increasingly tied to a paradigm which reflects development criteria that encourages inclusivity, mixed and innovative projects that seek enforce the existent urban tissue and to promote sustainable planning, creativity, cultural sensitivity, cultural capacity, community resilience, connectivity, entrepreneurship, innovation, integration and an appropriate development scale (Carta & Ronsivalle, 2016; Jones, 2017).

From that perspective, it can be understood the importance of thinking design concepts that can incorporate, sustainably, beyond all the aforementioned aspects, the study and, if necessary, the strategies to improve the soundscape of the waterfronts, in a way so that the users can better contemplate them, in a more holistic way, considering all aspects related the human sensations beyond visual realms.

2.1.2. Lisbon waterfront: a brief history

Lisbon, like most port cities around the world, has been affected by the transformation processes of global reach that have substantially changed its urban spaces and the ways its urbanites relate to them (Pereira, 2013). The port is an important element of the city identity, with a significant historical role.

Historically, Lisbon always stood out in terms of occupation of its territory. Its excellent geographic position - strategic in relation to all continents - and the natural characteristics of its estuary (River Tejo), with depth and dimensions safe enough for vessels, made the port of Lisbon become a point of attraction for peoples of all civilizations and cultures, favouring the commerce and providing the conditions for Portugal to expand as an empire through its conquests and discoveries (Jesus, 2018; Marques, 2016).

The territorial occupation of Lisbon dates back to the Phoenicians (XII to VI B.C.), then the Greeks and Carthaginians. They all used the city as an important centre of commercial trade with the eastern Mediterranean. Based on Lisbon, the Romans also built a civilization with a strong relation with the river, making its port an important point of commercial control and monopoly of the Mediterranean (Jesus, 2018).

In the sixteenth century, in Dom Manuel I kingdom, the port of Lisbon became the biggest and the most important port of the world, following the discoveries and the conquests of the main world routes (by the Portuguese Empire). The transfer of the royal court, from the hillside to downtown, led to the installation of new public buildings and warehouses near the waterfront, thus contributing to set a direct relation with the port and the commercial trade.

The city and the port became one, as the city depended on the river and the port for its subsistence and its growth. The repercussions on the urban evolution of Lisbon are significant (Jesus, 2018), they are determined also by the installation of the court and the nobility by the river and the expansion of the city along its shore line, redefining the waterfront from the centre of the city to its outskirts.

With all these changes, the eighteenth century would require better infrastructures for the port, in order to make it more fluid and capable. However, the earthquake and the fire that occurred in Lisbon in 1755 and devastated most of the city and its waterfront, resulted in the fact that only by the end of the nineteenth century that occasional changes were implemented. The small industry on the outskirts of the city wasn't strong enough to break the stagnation brought by the interruption of commercial trades as much as the political and institutional instability (Jesus, 2018).

The intervention of the Boa Vista landfill on the waterfront of Lisbon during the decade of 1850, shown in Figure 2.1, represented a first step to reinsert the city in the route of the intense intercontinental maritime traffic and to meet the demand for a large industrial port for the country. (Marques, 2016). In the landfill area, warehouses and silos were being built to support the river-related and sea-related activities as much as the first small industries, linked to the metallurgical and mechanical sector, which made it difficult for people to access the river.

Since the mid-1840s, the debate over the creation of a new port was intensified by the growth of industrial facilities, which outgrew existing port facilities and required a larger port to meet their logistical interests (Pages Sanchez, 2017).

Based on this need, some plans for the reconstruction of the port area were drawn up with alternatives for the port and its waterfront, which only resulted in a definitive plan in 1886, after a competition in which six different plans were presented. The final project was developed by the engineers João Joaquim de Matos and Adolfo Loureiro, and its construction process began in 1887, after a few changes to the plan made by engineer Pierre Hildernet Hersent at the contractor's decision (Pages Sanchez, 2017).

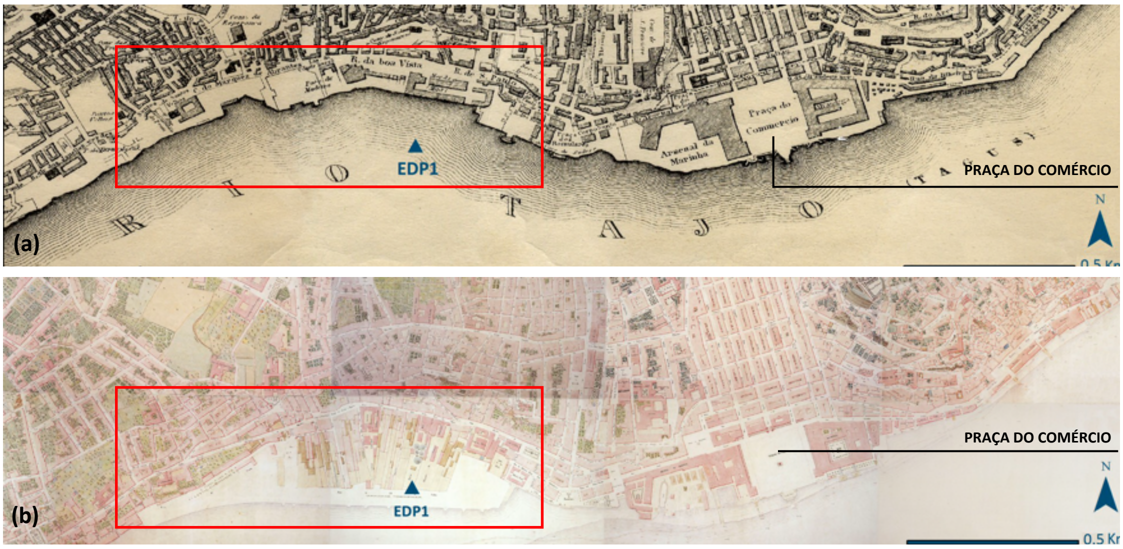


Figure 2.1: Tejo waterfront map with the demarcation of the Boa Vista landfill area (a) 1844 before the landfill - unknown author (b) 1856-58 - after the landfill - Filipe Folque topographic map. Source: Collection of Augusto Vieira da Silva. Georeferenced map courtesy of Câmara Municipal de Lisboa – author adapted.

Therefore, the improvement program for the port of Lisbon is only completed in the twentieth century, by the occupation of the entire waterfront of the city, distancing citizens from their experience, increased by urban expansion towards the interior of the territory, by the administrative autonomy of the port which blocked the public access to all of the area, and by the construction of the railway line that connects Lisbon to Cascais that created a physical barrier to access the water, as shown in Figure 2.2 (Jesus, 2018; Lavado, 2017).

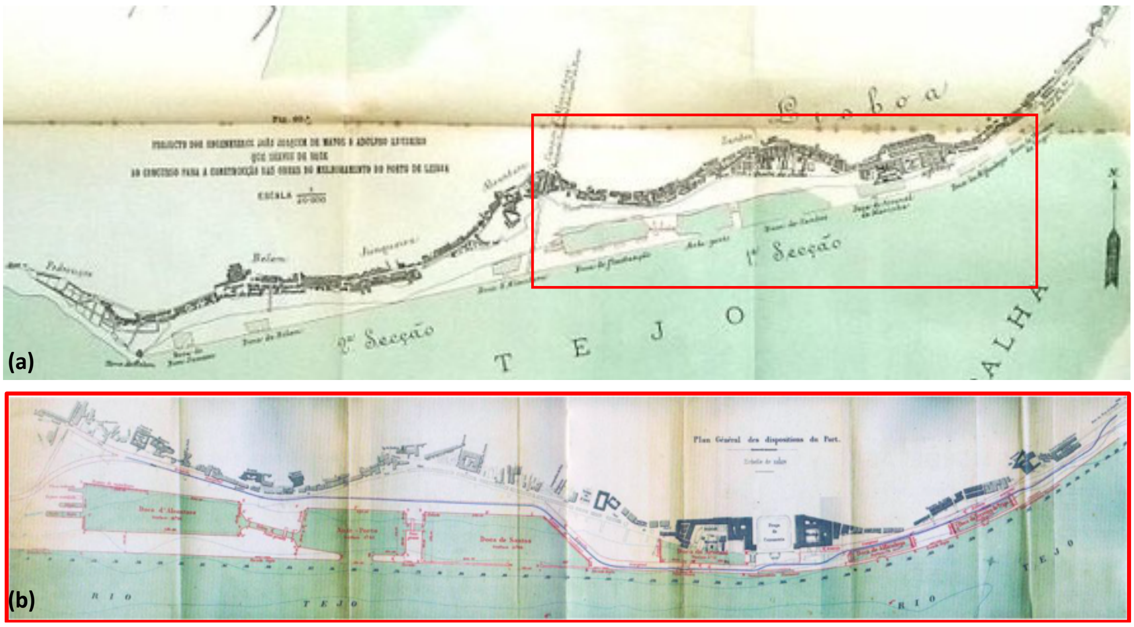


Figure 2.2: (a) Port plan developed by Loureiro and Matos in 1886 (b) Central section of the final plan developed by Hersent in 1887. Source: Pages Sanchez (2017) – author adapted.

Between the decades of 1970 and 1980, the port operations and services lost its competitiveness which contributed, significantly, for the deactivation and abandonment of some areas and facilities and consequently for the urban and environmental degradation of those places (Sousa & Fernandes, 2012). The changes taking place on a global scale in the maritime sector also affected the port and industrial development in Lisbon. The introduction of new technologies changed many port dynamics and the space the port required.

The port and industrial activities of large conglomerates diminished drastically. These industrial settlements, located on the eastern section of the city and the south side of the Tejo, developed during previous decades, originated large urban voids and brownfields affecting the general image of the waterfront as well as the public wellbeing.

As in other port-cities there was a process of socio-economical decay in the waterfront areas linked with port and industrial activities. The port activity was then concentrated in discontinuous platforms of container terminals, with a few areas for nautical recreation and public use. Although disconnected from the city these areas were seen as an opportunity to bring people back to the water's edge while creating new and more attractive urban environments in response to the public demand for access to the waterfront.

In 1940, the Exhibition "Exposição do Mundo Português", in honor of historical achievements such as the Discoveries, made it possible to revitalize the waterfront area of Belém, creating landmark spaces and buildings such as "Praça do Império" and "Padrão dos Descobrimentos", and other important works were also completed as the fluvial stations of Alcântara and Rocha Conde de Óbidos and the Cascais Motorway.

During the late 1980s and early 1990s the attention towards the use of the waterfront for public areas and facilities started to rise. The economic and technological changes along with the increasing social pressure to get a free river accessibility, motivated a set of planning initiatives, led by different stakeholders, that changed the port-city-river relationship.

Since then, following the trend of big European ports, there have been several interventions on the waterfront of Lisbon, continuing a process that started and was strongly potentiated by the advent of the EXPO'98 which, through an operation of urban and environmental requalification, made way for a new and large neighbourhood in the eastern part of the city, making a large area previously characterized by port and industrial activities public and attractive.

The urban and social reintegration of the waterfront became a priority in the Lisbon Master Plan, (CÂMARA MUNICIPAL DE LISBOA, 2012) which aims to redefine, revitalize, articulate and integrate its degraded and functionally obsolete urban spaces, considering an integration with the urban areas of equipment and services complementary to the port activities and with urban transportation interfaces (Jesus, 2018; Marques, 2016; Sousa & Fernandes, 2012).

The riverside zone, object of study of this research, presents favourable conditions for the process to be carried out progressively, through successive and chained interventions, similarly to what happened in the case of Praça do Comércio, in Ribeira das Naus, in Cais do Sodré, Campo das Cebolas and next to the Santa Apolônia train station (Marques, 2016).

The idea behind these redevelopment projects were not just only to improve the physical environment, but also to change the image of the waterfront from a derelict wasteland to an interesting and inviting place in line with renewal experiences based on a mix used of space as a key factor for success (Tunbridge & Ashworth, 1992). These projects envisaged the construction of green areas, promenades, museums and other outdoor facilities. The presence of historically and architecturally important buildings was also contemplated, thus contributing to the creation of an improved image of these sites through the symbiosis of heritage assets and new recreation facilities planned.

2.2. PUBLIC SPACES ANALYSIS AND PLANNING

2.2.1. Contemporary urban public spaces

Public space is defined as all places of public use, accessible by all (UN-Habitat, 2018). It forms the setting for a panoply of activities - the ceremonial festivities of the multi-cultural city, trade for the commercial city, the movement of goods and people, provision of infrastructure, or the setting for community life.

Public space can be seen as a system that serves the urban environment common activities, as well has the potential to influence a wide range of benefits: as to encourage social cohesion and interaction, as element in determining economic competitiveness and investment decisions; as an environmental resource; and as an important contributor to the liveability or urban places (Carmona, Magalhães, & Hammond, 2008).

On the last decades, the public space has become a central topic in the debate of urban policies, as urban value and also as a catalyser and speeder up of other processes. The typologies, scales and investments on these spaces' transformation were growing and diversifying (Brandão & Brandão, 2019).

The contemporary public space has no longer conventional urban typologies or contexts, they are hybrid spaces in forms, functions and uses (Carmona et al., 2008). They incorporate leisure, consumer, media and marketing trends and must be understood within urban changes, such as mobility, social and economic connectivity (Brandão & Brandão, 2019).

Simultaneously, there is a growing conscience that the contemporary public spaces play an increasing role in quality-of-life expectations. This awareness brings to theses spaces a diversity of public in the same place, with different needs, interests and expectations, each one with their own interpretations, appropriating them in various ways according to the relationships that are established (Brandão & Brandão, 2019).

In face on this perspective, it became important to know how people perceive and experience the urban places, with more attention to the subjective, emotional, and symbolic meanings they ascribe to the place (Cogger, 2016). Urban planners, therefore, now strive to create public spaces characterized by distinctiveness, planned on micro-level, with a greater focus on the 'needs' and 'expectations' of each individual who use them (Gehl, 2010).

That is to say, there is a growing concern with the 'human senses' and a strong demand for 'better urban quality', as stated by Gehl on his book 'Cities for People': "there are direct connections between improvements for people in city space and visions for achieving lively, safe, sustainable and healthy cities." (Gehl, 2010 p.7).

2.2.1.1. Appreciation of the sound perception on public spaces quality

According to Carmona et al. (2003), 'human senses' will influence, together and directly, on the way that the 'quality of urban space' is perceived, interpreted and experienced by individuals. Therefore and also considering the needs of the contemporary public spaces, it is important to take into account, both in the analysis and in the planning of a public space, all the senses of its users, including the hearing, in order to better appreciate it and use it from a holistic experience, as it has been highlighted and referred to by urban planners, since the "pioneer" studies on the city and its urban spaces.

Lynch (1960 p.2), when presenting the legibility of the urban landscape as a fundamental visual quality in the configuration of the city, included the "sound sensation" as a factor that influences the way the cities are perceived by its inhabitants. For the author, the sounds also may reinforce visual 'landmarks´, may be a singular quality which marks a key line, a 'path', and even a 'node', it may emit characteristic sound, which echoes some quality of the node itself.

Gehl (1971) in turn, approached the human senses, and the hearing ones, as an important prerequisite for designing and dimensioning all forms of outdoor spaces. "A knowledge of the senses is a necessary prerequisite also in relation to understanding all other forms of direct communication and the human perception of spatial conditions and dimensions" (Gehl, 1971 p.63).

Even before the popularization of the concept of soundscape, with Schafer (1977), the urban planners and designers have highlighted the importance to consider the sound perception, knowing that it influences directly on the way people perceive and relate to public spaces, as described by Gehl (1971 p.167) about the walking experience in Copenhagen: "the ability to hear music, song, shouts, and speech, that contribute to making the walk interesting and enriching" (..) "opportunities for talking with other people greatly influence the quality of outdoor spaces" (Gehl, 1971 p.168).

Since 1970s, therefore, urban planners and designers have been increasing appreciation of the sounds on urban spaces in a way to provide positive qualities to them, as stated by Lang (1994 p.227): "the concern for the 'sonic environment' should focus on increasing the positive, e.g. birdsong, children's voices, the crunching of autumn leaves". Carmona et al. (2008) pointed out that a 'stimulating sound' gives a positive and identifiable character for a public space, namely a 'distinctive' quality, which is identified by the author as one 'universal positive quality' for public space. Porteous (1996 p.35) highlights also that despite sound perception is information-poor, it is exceptionally emotion-rich since people are strongly aroused by screams, music, thunder and they are soothed by the sounds of water, leaves, wind in the grass.

Along with all, in recent years, there has been a resurgence in sensory studies that re-enforced even more the significance to be concerned with the pleasurableness of the sensations one receives from the environment, from the sounds, colours, textures, and smells, such as the concept of sensory aesthetics presented by Porteous (1996 p.22).

According to Llewelyn Davies (2000 p.100), a thriving public realm must be detailed in order to stimulate other senses besides the sight one, such as the sound, that can enhance the atmosphere of a place, shape its identity and influence its users.

Therefore, it is straightforward for urban planners the need to planning the public space considering all 'human senses', which involves the hearing ones, since they directly influence the perception of people. For this, consequently, it is understood the need for an adequate analysis, that may comprehend the gathering, the organizing and the making sense of information about the environment and its users (Carmona et al., 2003).

2.2.1.2. Sound perception on public spaces analysis

Public space planning and design models have been slow in recognizing the influence the sensory stimulation have on the urban experience and on promote health and well-being to individuals.

Most models for analysis or evaluation of public spaces performance fail to expose how users perceive these spaces. Although there is a common understanding that "when a person experiences an urban space will not be based on evaluations or measurements but on the interdependent interaction between multiple components: climate, orientation, materials, spatial order, other people, sounds, smells, etc" (Kasprisin, 2020 p. 17), in practice, there is a still tend to place a disproportionate focus on visual aesthetics, rather than take into account a full sensory experience, the way in which the senses interact one with other, and their impacts on the relationship between people and place (Cogger, 2016 p.121; Spence, 2020).

In addition, the models for analysis or evaluation usually have their results expressed in numbers, what frequently reduce the reality and don't mirror perfectly whatever the public space represents nor its peculiarities, as affirmed by Varna (2014) when she criticizes her own model of evaluation.

Particularly with regard to the theoretical, methodological, and technological approaches to understand the relationship between users of public spaces and their sound environment, Bild, Coler, Pfeffer, & Bertolini (2016) contend that they are insufficiently known and developed, and therefore, insufficiently integrated in the early stages of urban planning and design practice, and the sound remains mostly an afterthought.

The sound has peculiar features that make the analysis of its perception in the urban space a challenging and complex activity, considering that urban planners are used to deal with more objective aspects such as visual aesthetics, for example. Differently from the visual aspects that are sectored and emphasize objects in space, the sound aspects are omni-directional and they emphasize the space itself. Porteous (1996 p.33) expose that "sounds, compared with things seen, are more transitory, more fluid, more unfocused, more lacking in context, less precise in terms of orientation and localization, and less capturable". Furthermore, according to Pallasmaa (2012 p.53) "we are not normally aware of the significance of hearing in spatial experience, although sound often provides the temporal continuum in which visual impressions are embedded".

In the same way, this complexity of dealing with the sound aspects in the urban environment favours the adoption of practices of project and planning that can reach the improvement of the quality in the sound environment by the means of applying more objective parameters, such as the noise reduction case, for example. Hence, traditionally and usually, researchers and urban planners work the sound-as-noise, ignoring users' auditory environments multiplicity of meanings (Bild et al., 2016).

Therefore, although the sound has been pointed as a substantive aspect to be considered on the analysis of the urban space (Lynch, 1960; Rapoport, 1990); although in the 1970s Gehl (1971) has highlighted hearing is related to the most of outdoor social activities and, therefore, know how it is function is a fundamental planning factor; although the theoreticians urbanists considered the perceptual dimension, which includes the sound perception, one substantive dimension of urban design (Carmona et al., 2003; Cogger, 2016; Llewelyn Davies, 2000; Porteous, 1996), the methods of analysis of the public space, and, consequently, the planning and the design of it has been slow to address the role that sound plays in the experience of an urban environment, once the urban planners in this process lack helpful objective criteria.

"It is not about the lowering of sound levels. It is about the preservation of wanted and valued sounds, thereby enabling and fostering acoustic diversity and richness. It is about enhancing the acoustic experience of place, to ensure that not all places become homogenized, indistinctive, and sound the same (...)" (Cogger, 2016 p. 134).

Given that, it is understood that a planning which considers the sound experience of the people - in order to make it contribute to a better appreciation and a better use of a public space - it is supposed that this space and its sound environment have an appropriate characterization, fully integrated with the perception of its users. That is, it is expected that the urban planners can integrate the analysis of their soundscape to their process of public space analysis.

As for the characterization of the public space, what really matters is that it is complete, which includes information about the space itself: its physical elements, its functions and its environmental conditions, and information on its users: the individual and Group features, their dynamics of use and patterns of activities, their needs, and expectations. All these characteristics can alter, directly or indirectly, the human behaviour patterns (Askarizad & Safari, 2020), as much as have an influence on the perception that individuals might have of the public urban space and its sound Environment (Bild et al., 2016).

2.2.2. Methodologies, methods and techniques for public spaces analysis

Over time, the challenge of creating attractive cities, as much as the need to find solutions for demographic, environmental, social, health and security adversities, has made the urban planners more interested in understanding the interaction between people and public spaces (Gehl & Svarre, 2013). Therefore, since the 1960s, many authors have been developed theories, methods and techniques for public spaces analysis, interpretation and performance evaluation, which are very useful for the diagnosis and definition of planning strategies to improve urban spaces or design new ones.

The classic references regarding urban spaces studies have important insights on how to study and interpret the public spaces, mainly on the perspective of the interaction between the people and the constructed environment (Gehl, 1971; Lynch, 1960; Whyte, 1980). In the following decades, many authors developed important studies, moving forward to improve the techniques and tools when analysing the space, more systematic ways of investigation and also integrating the process of planning (Carmona et al., 2008; Carmona & Tiesdell, 2007; Gehl & Svarre, 2013).

Of all the methods of studying the urban space, the 'Spaceshaper' tool kit created by the Commission for Architecture and the Built Environment (CABE) in the UK (2007), stands out as a practical and an objective material, when measuring the quality of the public space throughout the recording of individual perception of the public space. The tool allows the public space analysis regarding its characteristics, through a questionnaire which records individual perceptions of the space, grouped into the eight sections (specified in Table 2.1):

'access', 'use', 'other people', 'maintenance', 'environment', 'design and appearance', 'community' and 'you', from a simplified process structured to be applied by anyone, as shown in Figure 2.3

Table 2.1: Characteristics to be analysed on the public space. Source: Commission for Architecture and the Built Environment (2007) – author adapted.

access	paths and movements on the space
use	what activities and opportunities the space has to offer
other people	how the space caters for different needs
maintenance	how clean and cared for the space is
environment	how safe and comfortable the space is
design and appearance	what the space looks like and what it's made from
community	how important the space is to local people
you	how the space makes you feel

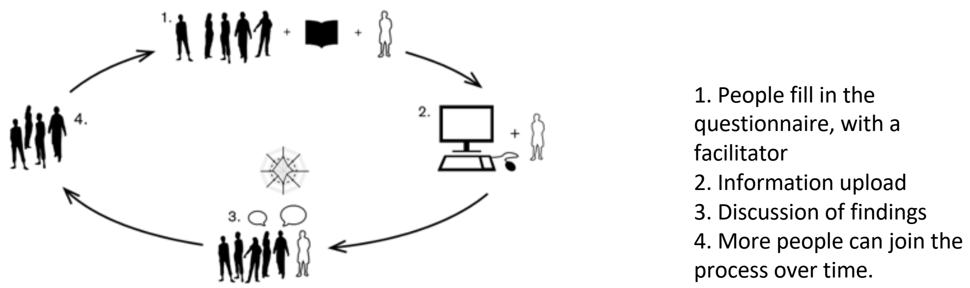


Figure 2.3: The spaceshaper process. Source: Commission for Architecture and the Built Environment (2007) – author adapted.

The methodology of deconstruction of the public space, from a user's perspective, applied by Carmona et al. (2008) in London and New York, on the other hand, is more comprehensive, but also systematized, aiming to characterize the public space, both physically and symbolically, and to describe the way they are used. The authors organized the study in two parts. Firstly, the public space is analysed as a whole with its key elements and constituent parts, in which they explore the experience of the place, its legibility (according to Lynch's concept), land uses, signage and advertising. Secondly, the approach proposes a microanalysis on the scale of the individual user, in which the human movements, the activities and the behaviour are observed closely and all the events occurred in the public spaces are described, as the example in Table 2.2, in order to understand how the individual relates to the area and is elements.

Practically, in all of the studies carried out, the direct observation technique at eye level turned out to be the main tool to interpret the public space, to study the interaction with the public life and to register or verify what is expected. (Gehl & Svarre, 2013; Oliveira, 2018). From the accumulated knowledge acquired in fifty years of public space Studies, Gehl & Svarre (2013), suggest to observe the space and its users focusing in key issues such as: ‘how many’, 'who', ‘where’, ‘what’, ‘how long’, as specified in Table 2.3, in order to obtain general knowledge about the users, their behaviour, patterns of activities, social interaction and interactions with the public space itself.

Table 2.2: Study area sample activity/behaviour table - Times Square. Source: Carmona et al. (2008) – author adapted.

TIMES SQUARE	
event/behaviour	People eating lunch and talking on grass. Indian group party with large picnic. ‘Others’ passed out on grass. Variety of users and ‘others’ drinking.
when/frequency	During every day. Much busier when good weather
place/position	Space 1, Gardens Space
connection to Design	Three out of the four grass areas of the gardens can be used to sit on with no fence or attempt at defensible space
connection to management	Gardens kept clean by private firm. Drinking is not allowed in the gardens, but wardens have no powers to remove alcohol from users
connection to ‘the other’ and systemic space	‘The other’ increases in early morning and just before closing at dusk. ‘The other’ is from a variety of cultural
connection to place marketing	NA
photograph	

Table 2.3: Elementary questions that can be used in practice for research purposes. Source: Gehl and Svarre (2013) – author adapted.

How Many	how many people do something - quantitative assessment
Who	who uses various public spaces - general categories such as gender or age
Where	where people move and stay
What	what happens - knowledge of the types of activities
How Long	how long it takes people to cover a certain distance, how long they stay in a certain place, and how long the activity lasts.

Gehl and Svarre (2013) propose that the observations must occur during long periods, in order to have a detailed understanding of the interactions and behaviours in the public space, and they also reinforce the need for the records to be precise, so that the data can be compared with the data from other places and other studies. The authors present some kinds of tools for the collection and registration of the observations: counting’, ‘mapping’, ‘tracing’, ‘tracking’, ‘looking for traces’, ‘photographing’, ‘keeping a diary’ and ‘test walks’, as specified in Table 2.4, which can be selected according with the objects, the budget, the time and the conditions of the place to be analysed.

The tools, the techniques and the methodologies presented in this work illustrate how some planners and urban scholars, propose, or characterize the public spaces, essentially about the physical space, its users and their interactions. Despite some differences, it is seen that the proposals are similar in essence, because they are all structured and simplified based on the collection and the recording of the data, and they have evolved from developing studies on public spaces that are being made throughout the years. Nonetheless, it is important to highlight that, from within what is aimed at the complete characterization of the public space, what matters most is that the users can be defined as to their needs and expectations regarding the quality of the spaces.

Table 2.4: Tools to collect and record the observations. Source: Gehl and Svarre (2013) – author adapted.

counting	provides numbers for comparisons
mapping	activities, people, places for staying
tracing	people's movements inside or crossing the space
tracking	observe people movements over a large area or for a longer time by following them
looking for traces	counting, photographing, or mapping traces from human activities
photographing	document situations
keeping a diary	register details and nuances about the interaction between public life and space
test walks	walk while observing to notice problems and potentials

2.2.3. Quality criteria for public space planning

Throughout the years, the analysis, the interpretation, and the evaluation of the public space performance and quality have provided the urban planners with a practical knowledge on the human needs, which go beyond aesthetic qualities. According to Carr, Francis, Rivlin, & Stome (2018), examining the needs not only explains the use of the places, but it is also important for the success of both old and new public spaces. Places that do not meet people's needs or do not meet important functions to people can be underutilized and unsuccessful.

Regarding that, it is important to understand that the needs can be as objective as the physical features of the space itself, for example, as the ones observed by Whyte (1980) in the public squares of New York, such as good location, spaces level with the floor, places to sit, movable seats and streets that form part of the social space. But also the needs can be more subjective, as the one identified by Carr et al. (2018), such as comfort, relaxation, discovery, passive and active involvements with the environment.

However, to meet the needs of the individuals itself might not be enough to make people use the public spaces. There are other qualities that can constrain or facilitate the users' experiences (Mehta, 2014) and directly related to the use of these spaces. Therefore, along the process of planning public spaces, it matters to establish which what quality criteria are standardized to form a better experience for their users (Lynch, 1960).

It has been a long time that scholars of urbanism are concerned with the quality of the public space and that they make compilations and empirical studies that bring together a vast variety of criteria that can directly influence the perceptions and experiences of users of these spaces.

Carmona et al (2008) explain that certain qualities emerge repeatedly as key priorities to the users of the public space, such as security, accessibility, comfort, cleaning and sense of belonging. On the other hand, there are studies that define more specific aspects regarding the quality of the public space according to its characteristics and its users, which must be considered.

It is important to present the studies by Carmona et al.(2008) and Mehta (2014), that mention, among the qualities considered to be important for the evaluation and the planning of public spaces, criteria which are closely related with the sound aspect. That is, to these authors, the sounds must be considered because they can directly influence the perceived quality of the public spaces.

Carmona et al. (2008) identified a group of 'universal positive qualities' for the public space that reflect the social, economic and environmental characteristics, all complex and overlapped. To these authors, a public space with quality is: 'Clean and tidy', 'Accessible', 'Attractive', 'Comfortable', 'Inclusive', 'Vital and viable', 'Functional', 'Distinctive', 'Safe and secure', 'Robust, 'Green and unpolluted' and 'Fulfilling. The authors expose that stimulating sound, touch and smell provides an identifiable character to the public space, which in turn provide to it the 'Distinctive' positive quality.

Mehta (2014), in his turn, outlined a method to empirically evaluate the open and public urban space, from five different criteria: 'inclusiveness', 'meaningful activities', 'safety', 'comfort' and 'pleasurability'. The 'pleasurability' criterion was built aiming to measure the pleasantness of the public space, classifying how much they are imaginable, and how they have spatial quality, attractiveness, and sensory complexity. The pleasure derived from sensorial experience, on the other hand, will depend on many stimuli perceived in the environment, such as lights, smells, touches, colours, shapes, patterns, textures, and also sound stimuli.

Cogger (2016) corroborates with the two quality criteria related to sound which were established by Carmona et al.(2008) and Mehta (2014), when they exposed the places that provided a rich sensorial experience, evoke a positive emotional response from their user, and stimulate the people to stay and connect with each other, contribute to a greater sense of place and are also important to the health and the well-being of the urban society. On one hand, the places that provide a unique sensorial experience, increase spatial awareness, resonate good memories, develop affective bonds and, for that, users tend to value them. On the other hand, places that lack distinctive personality, such as those without sound characteristics qualities e full of noise, for example, don't provide a rich sound experience for the individual, transmit little meaning, lack personality, difficult opportunities for high quality experiences and thus can lead to a sense of disconnection between the people and the place.

Thus, it is understood that the 'pleasurability' and 'distinctiveness' criteria find a direct relation with the sensorial aspects of the individual, including the sound sensations and, therefore, when considered, somehow, by the urban planners, they can contribute for a good appreciation of the quality of public spaces.

3. URBAN SOUNDSCAPE

Soundscape studies have been increasing mainly in the last 20 years, due to its potential to promote public health and quality of life, while it can provide to places uniqueness and cultural diversity (Kang et al., 2016).

Considering the importance of the soundscape studies to understand how it can be better appreciated in urban spaces, this chapter aims to (1) introduce the general soundscape concept and present the factors that influences a sound environment process of perception, experimentation and/or understanding (2) presents the state of the art from the urban soundscape studies mainly those one about assessment models, methodologies or methods, and also researches that approach aspects that are sound perception related.

The chapter is organized in two parts. The first one reviews the general concepts about the soundscape and the main sound perceptive factors and descriptors used to investigate soundscape aspects. In addition, the most recognized and used methods to carry out the urban environments' soundscape analysis are presented.

The second part focuses on research studies review about soundscape planning and assessment, especially those one that approach about the user perceptive aspects and the factors that influence it.

3.1. URBAN PUBLIC SPACE SOUNDSCAPE ANALYSIS

The International Standard (ISO 12913-1, 2014) defines the Soundscape as an "acoustic environment perceived, experienced and / or understood by a person or persons in a given context". By analysing this concept, two issues are emphasized that led to a broadening and deepening of analysis, design and management of the acoustic environments' different aspects. According to Hermida Cadena, Lobo Soares, Pavón, & Bento Coelho (2017) on the one hand there is the human being positioned as the protagonist, whereby different subjective evaluation models have been literature proposed with significant perceptual attributes established. On the other hand, this concept emphasizes the context importance, where the subjective and objective aspects of the sound environment need to be evaluated in such a way that its properties characterization and the perceptions are performed according to their context.

This means that the Soundscape managing requires much more than just controlling noise. The sound content and the geographical environment are as important as the place objectives functions, human activities and user expectations which will contribute to the listener's appreciation (Bento Coelho, 2016).

The soundscape approach is a more comprehensive process, while more complex, however leads to more satisfactory results than classical noise engineering. The main distinction between the soundscape study and the environmental noise field is not the sound sources or levels but human results (L. Brown, Kang, & Gjestland, 2011). While environmental noise examines the acoustic environment in which sounds produce people adverse results, soundscape studies explore the acoustic environment where the sounds produce results that improve, enable or facilitate human pleasure, health, well-being or activity.

The soundscape research scope is broad and can be applied to any context. However, it is particularly important in urban environment because of the increasing people density grown, the activities related to urbanization and globalization and the many sustainability challenges facing modern cities around the world.

3.1.1. Soundscape description

Evaluation or new design of an urban open space soundscape involves interactions between various factors. However, it will always have four basic elements: sound, space, user and environment. Zhang & Kang (2007) proposed a system for the soundscape description in urban open spaces, according with Figure 3.1, where were considered the characteristics of each sound, acoustic effects of the space, social/demographic aspect of the users, and other aspects of the physical/environmental conditions.

Sounds	Space	User	Environment
Sound Pressure Level	Reverberation	Social characteristics	Visual Characteristics
Spectrum	General background sound	Demographic characteristics	Landscape Characteristics
Source Location/ Movement	Sounds around the space	Experience	Architectural Characteristics
Temporal Conditions	Reflection / Echogram pattern	Acoustic conditions at home/work	Temperature
Psychological Social characteristics			Humidity
			Lighting

Figure 3.1: A system for the soundscape description in urban open space. Source: Zhang & Kang (2007) – author adapted.

3.1.1.1. Sound

An initial step of the soundscape evaluation of an urban open space is to characterize the exiting sound environment, by a quantitative method.

The soundscape is evoked by the sonic environment, therefore, its physical characteristics as sound pressure levels, statistical sound pressure levels, spectrum and temporal conditions, should be considered (Kang, 2019).

Many research studies found good correlations between the sound levels measured or the percentile weighted sound levels calculated, and the soundscape dimensions, sounds perception or emotional states. (Cao, Meng, & Kang, 2020; Herranz-Pascual et al., 2019; X. Hong, Wang, Liu, & Lan, 2019; X. Zhang, Ba, Kang, & Meng, 2017). In the same way, according to Genuit & Fiebig (2016), the temporal and spectral patterns, influence the environmental sound quality evaluation and its expected impact on annoyance.

Through these sounds' characteristics, the sounds composition can be analysed in detail, however, they do not describe the place soundscape. These sound physical characteristics, are limited in their ability to fully represent the sound environment (Dubois, Guastavino, & Raimbault, 2006). As the soundscape is a multifaceted phenomenon, it cannot be measured, assessed and evaluated with single numbers, and more than this: it should consider the acoustic environment through the human perception (Kang et al., 2016).

In this sense, many authors (de la Prida, Pedrero, Navacerrada, & Díaz, 2019; Genuit & Fiebig, 2016; Liu & Kang, 2015; Rychtáriková & Vermeir, 2013) explored the use of psychoacoustic parameters that relate the physical phenomenon (acoustic environment) with their caused hearing sensations. The use of psychoacoustic parameters, like loudness, roughness, sharpness, fluctuation strength parameters, will improve perceptually the assessment of the environmental sound quality, mainly related its expected impact on annoyance, however, cover only basic auditory sensations.

Although the physical metrics and the psychoacoustic parameters are essential to characterize the acoustic environment, the soundscape correct interpretation depends on the human response about the place experiencing, their expectations, suitability, or acceptability.

When exposed to the mix of sounds, the sound psychological and social characteristics should be regarded, which includes its meaning. The listener can naturally hear the sound or select it according to what they will detect and think to recognizing (Kang, 2019). According to Botteldooren et al (2016), the role of audition is not mere information processing but recognition. The process of attaching meaning to the sonic environment depends on the associations a stimulus evokes and, also, the user current state of the mind.

On Filipan et al. (2017) research, the urban park visitors experienced the space by a different way depending on the meaning they assign to the tranquillity concept. The user whose reports hearing mechanical sounds a lot, rates the overall quality of the urban space as bad or very bad, however, associates the natural sounds with tranquillity.

Besides the sound meaning, it is important to distinguish natural and human-made sounds. People usually showed a very positive attitude and preference for natural sound, as the water sound and birdsong. On the other hand, the mechanical sounds, such as construction sounds and traffic sounds, are the least preferred sounds. (J. Y. Hong et al., 2017; Kang, 2019; Krzywicka & Byrka, 2017; Liu, Kang, Luo, Behm, & Coppack, 2013; Ma, Mak, & Wong, 2021; Yang & Kang, 2005a, 2005b).

It would also be important to identify the relationship of the sounds to the place users' activities. The results of the Steele, Steffens, & Guastavino (2015) study, for example, showed a strong effect of activity on appropriateness across varied urban soundscapes and, also, on the pleasantness, mood, attention, and effort. This research findings suggest that particular care must be taken in the design of spaces where the associated activities are conducted.

3.1.1.2. Space

Sound path will directly influence the assessment of the soundscape. Some relevant factors such as the shape of the space, the urban furniture, the construction elements and the materials of the surfaces, should be considered, since they can directly affect the sound propagation, its distribution and the reflection patterns. Among the possible effects, one can notice the change in the sound spectrum, which can change its sound level, and also the reverberation, echoes and focus effects.

The background sound and the special sounds around the space are also important to be described since it directly influences on the sound appreciation. Usually, the background sound may provide a sense of place and also characterize the overall environment properties (Andringa & Van Den Bosch, 2013). Lower backgrounds sound level, for example, can make people feel quieter (Kang, 2019).

3.1.1.3. User

Soundscape research studies are being largely increasingly directed to the knowledge about all the user subjective aspects. Findings prove that the user' social, demographical and behaviour factors influence other factors as his visit motivation and experience, the perception of individual sounds as well as his overall soundscape experience (Erfanian, Mitchell, Aletta, & Kang, 2020; Liu, Wang, Zimmer, Kang, & Yu, 2019; Liu, Xiong, Wang, & Luo, 2018; L. Yu & Kang, 2010). Overall, these social, demographical and behaviour factors include user data related the place length of stay, his visit frequency and his residential status, and also information about his age, education and occupation.

Besides the social, demographic, behaviour and psychological factors, the cultural aspects play an important role on the soundscape assessment. Cultural differences could lead to rather distinct perception related to the dominance of sound sources and the sound environment affective qualities as well as different acoustic comfort evaluation and sound preferences (Engel, Fels, & Pfaffenbach, 2020; Jeon et al., 2018; Soares & Bento Coelho, 2016; C. J. Yu & Kang, 2014). The Soares & Bento Coelho (2016) research results showed that features such as geography, climate, urban architecture, infrastructures and sound sources, in addition to the visitor's expectations and sensorial responses, affects urban parks soundscape evaluations. Therefore, their appraisal will be different in distinct sociocultural and environmental contexts.

3.1.1.4. Environment

To create a better soundscape on a design process, the visual aspect must be considered (Liu, Kang, Luo, & Behm, 2013). A coherent combination of sound and visual elements leads to higher environmental preference scores (Jeon & Hong, 2015).

The use of space and visual components influence the pattern of human behaviours and may also affect soundscape perceptions. The Gothenburg (Sweden) common spaces were evaluated on the Estévez-Mauriz, Forssén, & Dohmen (2018) in-situ research and the appropriateness of the visual quality and the sound environment were positively correlated with passive purposes to visit sites (reading, walking, experience tranquillity, experience nature). In addition, on Filipan et al (2017) and Brambilla, Gallo, & Zambon (2013) studies, it was observed that the visual features, such as a park almost completely covered by forest and green paths, contribute to the perception of tranquillity.

The places landscapes will also produce important effects to the soundscape experience. The visual landscape information and the acoustic profile have certain interactions, as an aesthetic comfort factor (Yang & Kang, 2005a), and, in turn, are highly correlated with the overall soundscape perception (Jeon, Hong, & Jik Lee, 2013; Liu, Kang, Luo, & Behm, 2013; Pérez-Martínez, Torija, & Ruiz, 2018; Yong Jeon, Jik Lee, Young Hong, & Cabrera, 2011). In addition, the visual landscape show significant effect on experienced occurrence of individual sounds, mainly on natural sounds. (Jeon & Hong, 2015; Liu, Kang, Luo, & Behm, 2013).

The correlations between the diversities of architectural and urban characteristics, and the varieties of sound environments should also be taken into consideration. The urban morphological factors, for example, could be useful indicators for better understanding soundscapes in urban environments, since significant correlations were found among acoustic and morphological factors (J. Y. Hong & Jeon, 2017b). As well, the different functions of a place differently affect the soundscape evaluation and quality (J. Y. Hong & Jeon, 2015).

Besides the place and surroundings visual, landscape and architectural characteristic, the description of other physical and environmental conditions, which include temperature, humidity, wind, sun and luminous, must take into account (Kang, 2019).

3.1.1.5. Interaction other physical conditions

Human beings live in an environment in which not only the acoustical factor, but other physical/environmental conditions interact. Therefore, it is necessary to study the effects of these factors on soundscape evaluations. (Jin, Jin, & Kang, 2020).

(i) Thermal perception

Jin, Jin, & Kang (2020) explored, under different conditions, the effects of the thermal-acoustic environment on subjective acoustic evaluations, and vice-versa. The thermal-acoustic evaluations results showed that higher traffic noise aggravates the sensation of heat in summer, and also, has a reduction effect of the thermal comfort, in all seasons. On the acoustic evaluations, in turn, the acoustic discomfort increases with low temperatures in winter as well as with high temperatures in summer.

(ii) Odour perception

Studies about the sound and odour evaluations show a high correlation coefficient as far as a positive sensory stimulus can improve the evaluation of other senses, while a negative one has the opposite effect.

Through a laboratory experiment, Ba & Kang (2019) investigated the interaction of sound and odour in urban environments. The results showed that, except for birdsong and low sound pressure levels, higher odour concentration resulted in a more positive sound evaluation. In contrast, the odour evaluation became more negative with the sound pressure levels increase.

3.1.2. Context

According to the ISO 12913-1 (2014) standard, the soundscape exists through human perception of the acoustic environment, in its context. In the perception, experimentation or understanding process of the sound environment, it is necessary to understand the relationships between the factors that can influence it directly or indirectly, as the Figure 3.2.

According to Brown, Gjestland, & Dubois (2016), most authors suggest the soundscape of a place is a person's perceptual construct of the acoustic environment of that place. The acoustic environment perceptual constructing will occur when the individual is presented to a given acoustic environment, will experience the auditory stimulation and will interprets his auditory sensations and respond differently based the contextual factor.

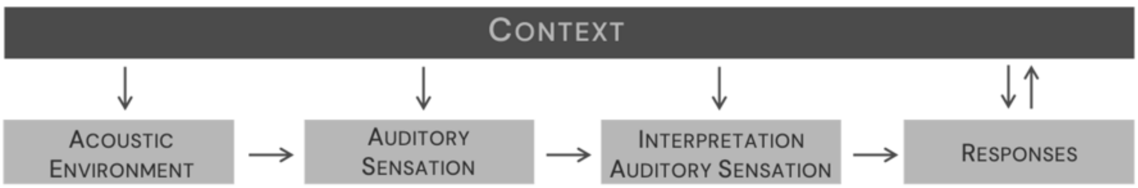


Figure 3.2: Elements in the perceptual construct of soundscape. Source: International Organization for Standardization (ISO 12913-1, 2014) – author adapted.

For Herranz-Pascual, Aspuru, & García (2010), the environmental experience to study the soundscape, includes four main elements, that are closely related: person, place, activity and person-place interaction (represented on Figure 3.3).

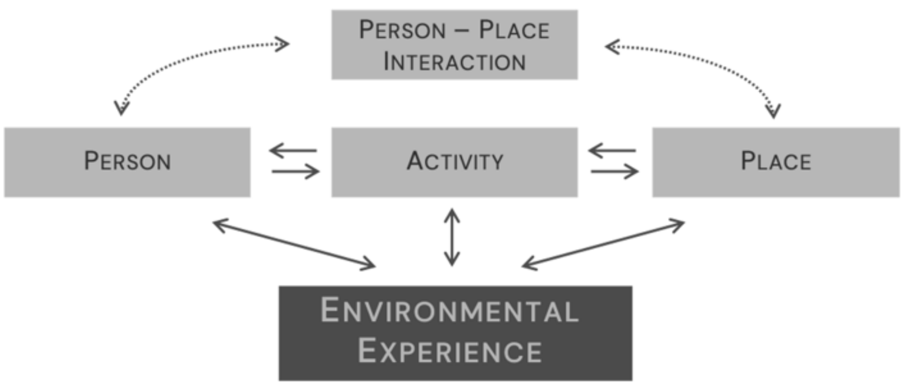


Figure 3.3: General conceptual model about environmental experience to study soundscape. Source: Herranz-Pascual, Aspuru, & García (2010) – author adapted.

The person has his own and others' motivations, preferences and purposes to be in a place and undertake an activity. His socio-demographics characteristics, perceptions, lifestyle, culture, networks and attitudes will be directly influencing them.

The place will be the space physical area, where the users will spend time, socialize and undertake active or passive activities, and also will interact with its environment, shaped by all sensory stimulations. The place is descripted by aesthetics, acoustics and other aspects, as well as by their interactions, determined by factors such as geography, topography, climate meteorology, urbanism, environmental quality and pollution, safety, humanization, presence of natural elements, etc., place type, and place functions. (Herranz-Pascual et al., 2010).

The person-place interaction is the prior environmental experience. It is defined by the previous experience, familiarity, expectations and identity of the user with the place, and also by the information about the place.

At last, the person will undertake activities on the place, on an active or passive form, alone or in social interaction, and will experience opportunities and needs.

Regardless the system or the model descripted, the elements and their interaction are similar. The most important to know is that a change in only one of these elements could significantly change the user's perceptual environmental experience of that place in that time, and, consequently, the perceptual construction of the soundscape (L. Brown et al., 2016).

The wide diversity of context which reflects, in turn, in a broad diversity of potential response and outcomes, highlight the importance of the role of context on any soundscape study (Kang et al., 2016).

3.1.3. Soundscape data collection

There is wide range of methods used to collect the soundscape data that aims a better soundscape description. Because is a multifaced phenomenon, the soundscape measurement is often used in a combined way, with the physical and perceptual data collecting, that have to be strongly related to the way humans perceive the acoustic environment. (Kang et al., 2016).

According to the ISO 12913-2 (2017) the soundscape approach can be implemented in planning and design, only through the proper integration of the techniques. In addition, the normative also highlights that a full-featured soundscape study must consider people, acoustic environment and context in a combination of several differing investigative methods.

The most typical methods and the corresponding operational tools to analyse the perception of the acoustic environment on site, that are described by the soundscape' normative (ISO 12913-2, 2017) as well as are widely used on soundscape studies, will presented on this item.

3.1.3.1. Soundwalks

Soundwalk is an empirical method, widely adopted on soundscape evaluations, to obtain human sensations, responses or outcomes of the places.

The method consists of sound and listening walks through the environment, following a predefined walking route, in which a participatory group make perceptual evaluations about the sound environment as well as collect context sensitive data. In general, the soundwalk is conducted by a group of local experts and members of relevant communities of interest (ISO 12913-2, 2017), but also can be done individually.

The data collection comprises a qualitative and quantitative data collection, ecologically validated, using a structured protocol, which procedures differ in many aspects (Engel, Fiebig, Pfaffenbach, & Fels, 2018), such as way of acoustical measurements, way of questioning, sampling of participants, sample size, soundwalk duration and instructions (Kang et al., 2016).

3.1.3.2. Interviews and questionnaires

Interviews and questionnaires are another common and empirical evaluation methods to assess the acoustic environment, its quality from a perceptual point of view (Kang et al., 2016). It is a method for gather individual responses against predetermined criteria, also used on the soundwalk method, adapted according to the purpose related to the soundscape.

There are different types of interviews that vary according with the study objectives. The interviews may be on a narrative way, mainly working with open questions. There are also the guideline interviews using closed questions and also may have open ones. Both cases, they try to explore associations, feelings, interpretations and emotions concerning the acoustic environment, and other environment aspects. These interviews must consider the location-specific as well as the interviewed personal specific aspects (social-demographic data, preferences, sensitivity) (Fiebig, 2018).

Questionnaires, in turn, shall capture the appreciation, preferences and behaviour without interfere the participants' experience, respecting the way people are experiencing their environment. In the same way as on the interviews, the questionnaire application must be an accurate representation of a specific location, with a holistic assessment, covering the auditory sensations, other context variables and personal expectations (ISO 12913-2, 2017).

3.1.3.3. Behaviour observations

The behaviour observation method aims the minimal interference with the test persons, assuring, this way, higher external validity. Usually, the participants are not aware to be part of a study hence might behave more naturally, preventing biased behaviour.

However, the soundscape non-participatory method needs a robust protocols to make them comparable for particular use cases (Fiebig, 2018).

3.1.3.4. Binaural measurements

The normative ISO 12913-2 (2017) recommends that the acoustic environment recording shall consider how the human beings perceive the acoustic environment, through a calibrated binaural measurement system.

The method consists of record the sound environment through a dual microphone installed on an artificial head that process the signal from both ears, as a human hearing. Later, it is possible to play back it in the same way as if the listener was in the original place, where is possible to distinguish different sounds as well as recognize their distinct directions, as close as possible, the human auditory sensation.

3.1.3.5. Laboratory experiments

The soundscape laboratory experiments aim to perform sounds evaluations under controlled conditions, removing certain factors which could influence the auditory perception, directly and indirectly (Engel et al., 2018).

In this sense, as the laboratory experiment usually explores evaluation through only some specific human senses, it is important a special consideration of the influence on participants' responses, mainly regarding the immersion in the sonic environment.

The listeners may be since listeners with no experience until experts in acoustics, according with the soundscape study. It is recommended before the experiment, however, test their hearing abilities.

3.1.4. Soundscape descriptors

The soundscape is a multifaceted phenomenon, in which the acoustic environment must be measured, assessed and evaluated through a human perception. According to Kang et al. (2016), this need raises proposals for soundscape descriptors in order to better define the sound environment quality from a perceptual point of view. The appropriate soundscape descriptor use, allow find similarities and better correlations between the sound environment perception and another factors.

Studies have been shown that the conventional decibel level approach does not well correlate with human perception. The perceived properties of the acoustic environment descript better the soundscape than the established acoustic as well as the psychoacoustic metrics (Kang, 2019).

In this sense, some studies propose to assess soundscape using a holistic descriptor, through a general classification for the soundscape quality, as the descriptors: pleasantness, tranquillity, music-likeness, restorativeness and appropriateness.

However, according to Aletta, Kang, & Axelsson (2016) the majority of available soundscape descriptors are inspired by emotion-denoting adjectives, through a 2-dimensional soundscape model. In addition, a third dimension, so called Appropriateness, have been lately used to complement the soundscape characterization.

(i) Perceive affective quality

Axelsson, Nilsson, & Berglund (2010) developed a model, based on a small number of basic dimensions, to perform a perceptual characterization of a soundscape.

Environmental psychologists demonstrated that the people respond affectively when are asked to freely describe how they perceived environments. In this sense, it was developed a model of perceived affective quality, summarized by the Figure 3.4, defined by two orthogonal dimensions “Pleasantness” and “Eventfulness”, which are located at a 45 degrees rotation from the second set of orthogonal factors “Calmness” and “Excitement”. (Aletta & Kang, 2018).

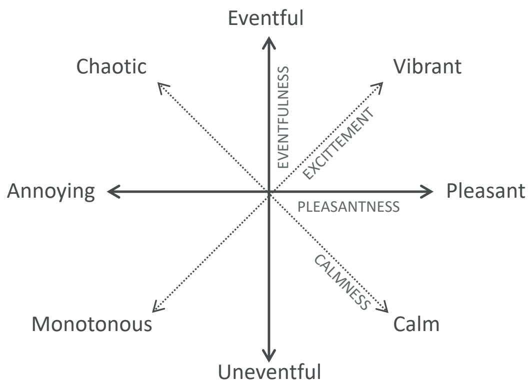


Figure 3.4: Perceive affective quality model. Source: ISO 12913-3 (2019) – author adapted.

According to the Figure 3.4, a soundscape that is both pleasant and eventful will be “vibrant”, whereas a pleasant and uneventful will be “calm”. Correspondingly, a soundscape that is both annoying and eventful will be “chaotic”, whereas an annoying and uneventful will be “monotonous”. In addition, a vibrant or a calm soundscape will be positive (pleasant). By contrast, a monotonous or a chaotic ones will be negative (annoying) (Aletta & Kang, 2018).

Studies where the perceive affective quality model was applied confirm the findings in which certain categories of sounds contribute to soundscape perception. For example, the soundscape excerpts dominated by technological sounds were found to be unpleasant, natural sounds were considered pleasant, and an environment busy with human activity were found to be eventful (Axelsson et al., 2010).

The perceive affective quality characterization, according to the example of data collection, specified on the "Method A" of the ISO 12913-2 (2017) is obtained through a level of agreement or disagreement of the listener (five-level Likert scale) with the eight soundscape attributes: pleasant, chaotic, vibrant, uneventful, calm, annoying, eventful and monotonous.

According with the “Annex A” of the ISO 12913-3 (2019), for each rating scale, shall be attributed specific scale values, started with 1, to the minimum level of agreement, until 5, to the maximum level of agreement. The mean values, therefore, must be calculated to derive the values on two dimensions (pleasantness and eventfulness) for each site. These results can be reported in a two-dimensional scatter plot with coordinates for the two dimensions 'pleasantness' and 'eventfulness'. On the X-axis are plotted the pleasantness coordinates, calculated by the equation (1), and, on the Y-axis are plotted the eventfulness coordinates, calculated by the equation (2).

$$P = \frac{(p - a) + \cos 45 * (ca - ch) + \cos 45 * (v - m)}{\left(4 + \sqrt{32}\right)} \tag{1}$$

$$E = \frac{(e - u) + \cos 45 * (ch - ca) + \cos 45 * (v - m)}{\left(4 + \sqrt{32}\right)} \tag{2}$$

Where:

a	*is annoying;*	*e*	*is eventful;*	*u*	*is uneventful;*
ca	*is calm;*	*m*	*is monotonous;*	*v*	*is vibrant;*
ch	*is chaotic;*	*p*	*is pleasant;*		

The range of the coordinates that results from the formulas is $\pm 9{,}66$. *To change the range to ±1, divide the coordinates* $\left(4 + \sqrt{32}\right)$.

(ii) Appropriateness

On a range of observations and suggestions aiming a soundscape standardization, Brown et al. (2011) highlights that a particular assessment approach is "appropriate" only for certain outcomes or places.

The term "appropriateness" has been used to measure users' evaluation about how appropriate the soundscape with the place is as well as with the activity performed. The higher scores of appropriateness correspond to higher likeliness of visiting the place again (Aletta et al., 2019).

For Astolfi et al. (2018), this perceptual dimension will describe, in an individual level, if a sound environment is 'expected' in a specific context.

According to Jo & Jeon (2020), the appropriateness has considerable importance on enhances an individual's experiences of presence and enjoyment in the space, when there is a congruency of landscapes and soundscapes, or of expectations regarding sound and soundscapes.

In general, on the soundscape studies, the appropriateness has been considered as a third dimension for the soundscape to a place, which provides complementary information beyond the perceived affective quality (Kang, 2019). However, Axelsson (2015) highlights that the appropriateness descriptor should not be used as the only information available, as this may lead to feeble conclusions.

The appropriateness, can be measured through the "Method A”, specified on the ISO 12913-2 (2017), which the listener assess the appropriateness of the surrounding sound environment through a five-point ordinal-category scale. According with the “Annex A” of the ISO 12913-3 (2019), for each rating scale, shall be attributed specific scale values, started with 1, to the “not at all appropriate” scale, until 5, to the “perfectly appropriate” scale.

Also, the appropriateness can be measured with a five-point unipolar continuous-category scale, through the "Method B” of the ISO 12913-2 (2017), which the listener assess how appropriate is the sound to the surrounding. In the same way, the “Annex B” of the ISO 12913-3 (2019), attribute specific scale values for each rating scale, started with 1, to the “not at all appropriate” scale, until 5, to the “extremely appropriate” scale.

3.2. URBAN SOUNDSCAPE PLANNING

The soundscape theory offers the possibility to integrate into intentional design process and management of urban public spaces, both to areas being redeveloped or in initial stages (Lex Brown, 2012).

According to Bento Coelho (2016), on the soundscape planning, the user characteristics and his sonic interests and preferences shall be priority on the design process, in line with the context: place, activities, sound composition and environmental features. Consequently, it will bring to solutions that meet people’s expectations, rising up the acceptability and identification with the place, together with feelings of comfort, satisfaction, appreciation, and well-being.

Some authors have been proposed a soundscape design or management procedure of outdoor space, which combines space planning principles and perceptual understanding.

Lex Brown (2012) suggests a concepts of soundscape that can be merged to a design process, through four steps, according to Figure 3.5.

On the Step 1, the place features and its users, the activities and the environmental characteristics, must be defined. The Step 2 shall be established the acoustic objectives for the place, the quality of the sound in accordance with other senses. On this stage it is important a community or focus group consensus.

1. Define: place, activity, context
2. Stablish: acoustic objectives
3. Specify : wanted/unwanted sounds
4. Acoustic management and design

Figure 3.5: Steps in an acoustic design process for outdoor space. Source: Lex Brown (2012) – author adapted.

According to the objectives set out, on the step 3, wanted and unwanted sounds, both existing and future, will be specified. In this sense, it is important a detail analyse of theses sounds, its energy, frequency ant time history, since it will allow its better management, that follows on the next stage.

The Step 4, all the existing skills and tools to the acoustic management and acoustic design shall be applied, aiming to eliminate, mask or reduce, as much as possible, the unwanted classified sounds, as well as maintain, enhance, or introduce the wanted sounds or components.

Bento Coelho (2016) developed the so called Soundscape Design Roadmap, a structured methodology for soundscape design purposes. On the drawing board, in Figure 3.6, three main steps were identified, each comprising various paths and criteria, and following different techniques. The process enables managing the soundscape at the initial stage of the project design in the line of common architectural or engineering processes.

STEPS	STABLISH: PLACE' ACCOUSTIC CHARACTER	PLAN	DESIGN AND OPTIMIZE
TECHNIQ.	• Purpose and activities • Acoustc objectives	Define: • Listening places and itineraries • Sound sources and sound componentes • Sound propagation paths • Preferred and unwanted sounds	Identify: • Manage sound componentes o Diminish unwanted sounds o Enhance preferred sounds • Identify wanted sound in context
CRITERIA / PATHS	Consider: • Project Objectives • Listener Expectations Involve: • Stakeholders	Perform: • Soundwalks • Sound measurements Identify • Topologies of sound components • Characteristics of sound components • Time and geographical variations Involve: • Stakeholders	Perform to unwanted sounds: • Reduce - noise control • Mask – psychoacoustics • Mind Mask - Divert attention Perform to preferred sounds: • Enhance or introduce in context Involve: • Groups of interest

Figure 3.6: Soundscape Design Roadmap. Source: Bento Coelho (2016) – author adapted.

On the first step, the acoustic character of the place shall be defined, according to the definition of the purpose, planned activities and the acoustical goals (defined from the activities).

On the planning stage, to identify, classify, and characterize existing and future sounds. Therefore, are necessary some procedures which starts with the identification of listen places and itineraries, followed by the determination of users' itineraries, sound sources, sound components, sonic interests, and context. Pursuing this, should be performed soundwalks and sound measurements at different times of the day, to identify the sound component topologies.

Also, each sound, existing and future, should be classified according to the character of the place and expectations. In this sense, it is important to distinguish them between the sounds of preference and the sounds of discomfort or unwanted ones, according with the place, users and context.

Finally, on the design stage, the soundscape management composition will realize, with the designing the distribution of sound and their audibility, the physical structure of the listening places and other details. The unwanted sounds shall be reduced or eliminated with noise control measures or masking techniques (mental or psychoacoustic masking).

This phase should be discussed with the stakeholders, where may be interesting consider distinct scenarios, with simulations and prediction, managing the soundscape to ensure an acoustic environment that are of high quality and are valued by people.

Both Lex Brown (2012) and Bento Coelho (2016) descripted methodologies are very similar in terms of soundscape planning strategies for a urban public space design. For both, as also highlighted by Siebein, Kwon, Smitthakorn, & Gold (2006) the place acoustical data will be used as the basis for determining design strategies: (1) reducing, masking and mitigating unwanted existing sounds, (2) preserving and enhancing wanted existing sounds, as well as, (3) designing new soundscape elements to enhance the "sonic experience that should be as good and enjoyable as possible" (Bento Coelho, 2016).

Echevarria Sanchez, Alves, & Botteldooren (2018) adds the importance of "respect the coherence between the soundscape and the urban space itself". In certain situations, for example, noisy places can receive an adequate activity or use, that supports noise soundscapes. Also, the authors highlight the importance of provide, at the same time, certain freedom to ensure diversity to the acoustic environment, that may be the element that enhances the soundscape and the urban environment.

4. FUNDAMENTALS OF SOUND

The sound is characterized by pressure fluctuations in a compressible medium. However, not all pressure fluctuations produce the hearing sensation when they reach the human ear. Vibrations perceived by the human hearing as a sound signal are characterized by a number of physical parameters.

This chapter aims to briefly present the fundamental concepts and phenomena related to the urban sound environment.

First, the physical properties of the sound wave are described, and the magnitude that acoustically characterizes the sound and the sound source are presented. Subsequently, the propagation of sound outdoors is explained, showing how the different shapes of sound sources, the atmospheric conditions and also the existing reflection surfaces can influence both the attenuation and amplification of the sound level. Finally, the chapter presents how the sound is characterized from objectives parameters, and how occurs the human's auditory perception.

4.1. SOUND BASIC PROPERTIES

4.1.1. Sound wave

The sound can be visualized physically as a wave movement, called a sound wave. A vibration is successively transmitted from particle to particle, through a medium - sound field - with inertia and elasticity, as shown in Figure 4.1.

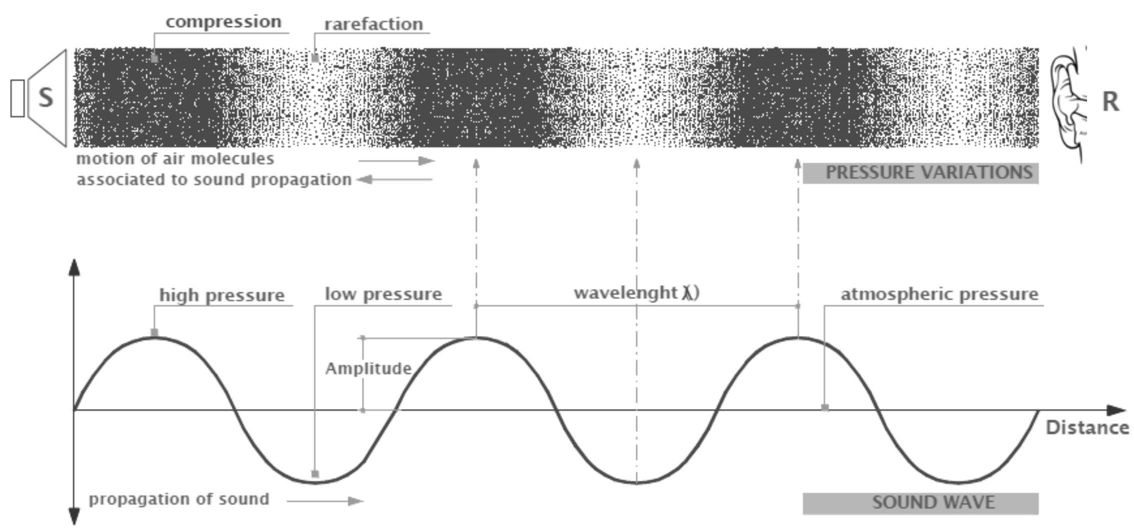


Figure 4.1: Particles Movement and Longitudinal Sound Wave, from the Sound Source (S) to the Receptor (R).

These particles movement alternates between compression and rarefaction from its original position, that causes the sound pressure (P) fluctuation, in the same direction as the sound wave transmission path, because of this, called the longitudinal wave.

The distance between the regions in which the particles are in identical pressure conditions, i.e., when they complete an entire vibration cycle, is called wavelength (λ) - unit *m*.

The time for a particle to complete a whole cicle is called a period (*T*), as shown in Figure 4.2., and, since it is repetitive, the oscillations amount that occur in 1 second determines its frequency (*f*), whose unit is Hertz (*Hz*).

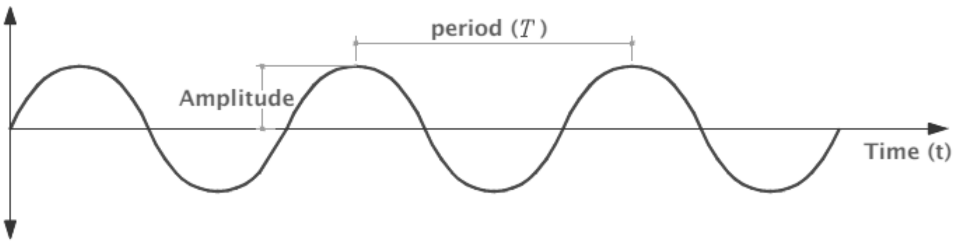


Figure 4.2: Longitudinal Sound Wave.

The frequency, period, speed and wavelength are related by the equation (3):

$$f = \frac{1}{T} = \frac{c}{\lambda} \qquad \text{Hz} \tag{3}$$

Where:
c is the sound speed;
λ is the wavelength;
T is the period: time for a particle to complete a whole cicle.

The sound travel speed through the air will directly depend on the atmospheric pressure (P_0) and inversely depend on the medium air density (ρ), as the equation (4).

$$c = \sqrt{\frac{\gamma P_0}{\rho}} \qquad \text{m/s} \tag{4}$$

Where:
γ = is the ratio of specific heats under conditions of constant pressure and constant volume.

Thus, at one atmospheric pressure (1 atm) and 20°C temperature, $\gamma = 1.41$, $P = 101300$ N/m^2, $\rho = 1.205$ kg/m^3, and the sound speed propagation will be approximately 343.5 m/s.

4.1.2. Sound pressure and sound pressure level

The sound pressure at one point will be the change in static pressure caused by the sound wave presence. The sound pressure unit is Pa.

The sound intensities range to which the human hearing is sensitive is very large - the most intense sound that the human hearing can detect without suffering physical damage is a million of million times more intense (10 W/m^2) from the lowest sound sufficient of being detected by the human ear, called the "hearing threshold" (10^{-12} W/m^2).

Because of this huge interval, the sound pressures and intensities are normally represented on the logarithmic scale, in which the unit is the decibel (dB). Thus, the logarithmic scale compresses the range of numbers to describe this wide range of intensities. Also, is consistent with the fact that humans judge the relative loudness of two sounds by the ratio of their intensities. The "hearing threshold" is assigned a value of zero decibels (0 dB). A sound 10 times louder than this threshold is assigned a value of 10 dB, 20 dB for a sound 100 times louder, 30 dB for a sound 1000 times louder, and so on. A magnitude on this logarithmic scale is often called a level.

The sound pressure level can be defined at any point from the sound source through the source sound power considering the medium characteristics in which it will propagate. A sound field is usually expressed by the sound pressure level equation (5) because its value is easier to be measured than the intensity.

$$L_P = 10 \log \frac{P^2}{P_0^2} \qquad \text{dB} \tag{5}$$

Where:
P_0 is the reference sound pressure which corresponds to the hearing threshold at a frequency of 1 kHz = $2x10^{-5}$ N/m^2 = 20 μPa.

4.1.3. Frequency band

The sound characterization must be complemented by the description how the emitted sound energy is distributed in the frequency domain, its spectrum. This analysis becomes important since most of urban space sounds constitutes a complex different frequencies mix, that are emitted by different sources.

In some cases, a high spectral resolution is needed to decompose time domain signals. It is wise to subdivide the frequency range into a small number of coarse intervals. Larger intervals do not express finer details. They contain a higher random error rate and cannot be reproduced very accurately.

Thus, a sound can be measured in a series of frequency intervals called frequency bands. The most important frequency band are the octave and third-octave band filters. The (coarser) octave band filters have a broader pass band than the (narrower) third-octave band filters, with a finer resolution, which let contributions of a higher frequency range pass. In each octave band the upper limiting frequency is exactly twice the lower limiting frequency. The third-octave band filters are named that way, because three adjacent filters form an octave band filter.

4.2. SOUND SOURCE

4.2.1. Sound power and sound intensity

The acoustic energy transferred from a vibrating source to a medium is called sound power, *W*, and it is measured in watts (W). This magnitude acoustically characterizes the source, when determine the sound energy amount generated by it, regardless of the environment.

When the energy from the vibrating source passes through a unitary cross section area, that is perpendicular to the sound propagation direction, the sound intensity, *I*, will be determined, by the unit W/m^2.

4.2.2. Sound power level and sound intensity level

As well as on the sound pressure level definition, due to the human ear does not respond linearly to sound intensity, it is more convenient to use the logarithmic unit, decibel (dB), to measure sound intensity level, L_I, and similarly, the sound power level of a source, L_W, expressed respectively by the equations (6) and (7):

$$L_I = 10 \log \frac{I}{I_0} \qquad \text{dB} \tag{6}$$

Where:
I_0 is the reference sound pressure which corresponds to the hearing threshold at a frequency of 1 kHz = 10W/m^2.

$$L_W = 10 \log \frac{W}{W} \qquad \text{dB} \tag{7}$$

Where:
W_0 is the reference sound pressure which corresponds to the hearing threshold at a frequency of 1 kHz =10W.

4.3. OUTDOOR SOUND PROPAGATION

In order to analyse the environmental acoustic field, one must consider: the source's sound power, the sound pressure level in the receiver and the sound propagation path.

On the propagation path the sound speed may change slightly due atmospheric conditions, the sound waves can be absorbed or reflected by the medium, which can result both in attenuation and amplification of sound pressure levels. It will depend by the sound physical characteristics, sound-receiver distance, the medium in which it will propagate and the surfaces or obstacles it will encounter along its propagation.

4.3.1. Basic equation

(i) Point source

For a point source in a free field, the sound power passes through a sphere surface area determined by $4\pi d^2$. Therefore, in a determined distance, the sound Intensity (I) is given by the equation (8):

$$I = \frac{W}{4\pi d^2} \qquad \text{W/m}^2 \tag{8}$$

Where:
d is the distance between the source and the receiver
W is the source power

Thus, the sound intensity is inversely proportional to the square of the distance. The sound power level at this distance, from a source with directivity in the direction towards the receiving point, can be expressed as the equation (9).

$$\begin{aligned} L_P &= L_W - 10\log 4\pi - 10\log d^2 + 10\log Q \\ L_P &= L_W - 11 - 20\log d + 10\log Q \qquad \text{dB} \end{aligned} \tag{9}$$

Where:
Q is the directivity factor. In a free field $Q = 1 \therefore 10logQ = 0$

Therefore, the relation between the L_{P1} (at distance d_1) and L_{P2} (at distance d_2) in the same direction is given by the equation (10).

$$L_{P2} = L_{P1} - 20\log\frac{d_2}{d_1} \qquad \text{dB} \tag{10}$$

Thus, for every doubling of distance, the sound pressure level is reduced by 6dB.

(ii) Infinite line source

The line source is small in one direction and large in the other, compared to the distance to the receiver. It can be a finite line source considered as lying continuously, such as a long pipe carrying a turbulent fluid. Or it can be an infinite line source, composed of several and incoherent point sources operating simultaneously on the line in random phases, such as vehicles flow on a street.

In a free field, the sound waves spread in a cylindrical form around a line source, which is the axis of the cylinder. For an infinite line source, the sound power is distributed over the cylinder surface $2\pi d$. Therefore, in a determined distance, the sound Intensity (I) is given by the equation (11).

$$I = \frac{W}{2\pi d} \qquad \text{W/m}^2 \tag{11}$$

Where:
d is the distance between the source and the receiver
W is the source power

Thus, the sound intensity is inversely proportional to the distance. The sound power level at this distance, can be expressed as the equation (12).

$$\begin{aligned} L_P &= L_W - 10\log 2\pi - 10\log d \\ L_P &= L_W - 8 - 10\log d \qquad \text{dB} \end{aligned} \tag{12}$$

Therefore, the ratio between the L_{P1} (at distance d_1) and L_{P2} (at distance d_2) in the same direction is given by the equation (15).

$$L_{P2} = L_{P1} - 10\log\frac{d_2}{d_1} \qquad \text{dB} \tag{13}$$

Therefore, for every doubling of distance, the sound pressure level is reduced by 3dB.

(iii) Finite line source

If the distance from the source to receiver (d) is in the near distance, where $d < l/\pi$ (considering "l" the source length), the sound pressure level reduces like an infinite line source: 3dB for every doubling of distance. In the far distance, where $d > l/\pi$, the sound pressure level reduces such as a point source: by 6dB for every doubling of distance.

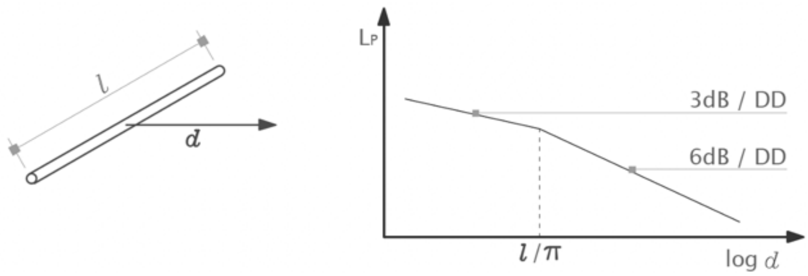


Figure 4.3: Distance attenuation from a line source.

(iv) Plane source

An ideal plane (area) source is an infinitely large flat surface that radiates sound, however, in practice, it occurs with the noise transmission through a surface, such as a door or wall. In this case, the acoustic variables are functions of only one spatial coordinate.

If the distance from the source to receiver (*d*) is in the near distance, where $d < a/\pi$ (considering "a" the source height), no attenuation will occur. In the range $a/\pi < d < b/\pi$, (considering "b" the source width), attenuation may be approximated by 3 dB for every doubling of distance. At last, in the range, $d > b/\pi$,), attenuation will be by 6 dB for every doubling of distance.

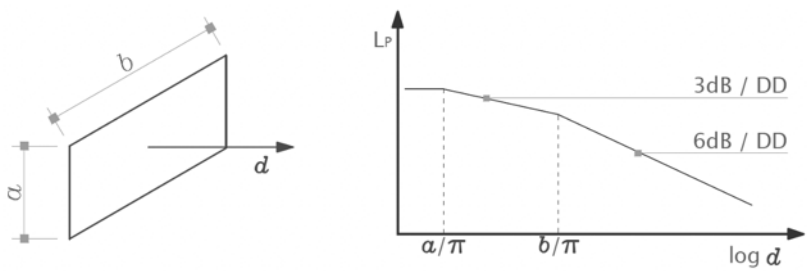


Figure 4.4: Distance attenuation from a plane source.

4.3.2. Atmospheric conditions

The propagation of sound in the open air is affected by attenuation along its transmission path and must be estimated through additive corrections for: air absorption, atmospheric conditions (relative humidity, temperature, and wind), ground reflection, obstacles (barriers, buildings, and vegetation), etc.

(i) Air

Sound waves attenuate during propagation in air because the energy is absorbed by the environment. There are two absorption processes in static and isotropic air. One is the classical absorption (macroscopic process), which is the energy extracted from the sound wave by the viscous friction between air molecules and by heat conduction during the pressure cycle. And the other, known as molecular relaxation (microscopic process), occurs from the energy dissipation during the molecules' vibratory relaxation process existing in polyatomic gas, composed by oxygen and molecular hydrogen, traces of other gases, including water vapor, and carbon dioxide.

The intensity (I) of a plane wave in a certain distance (d) is given by:

$$I_x = I_0 e^{-md} \qquad \text{dB} \tag{14}$$

Where:
m is the attenuation constant per meter, given in Figure 4.5.

The attenuation varies with the temperature and humidity, as shown in Figure 4.5. At low frequencies, the attenuation can be neglected, because is very low.

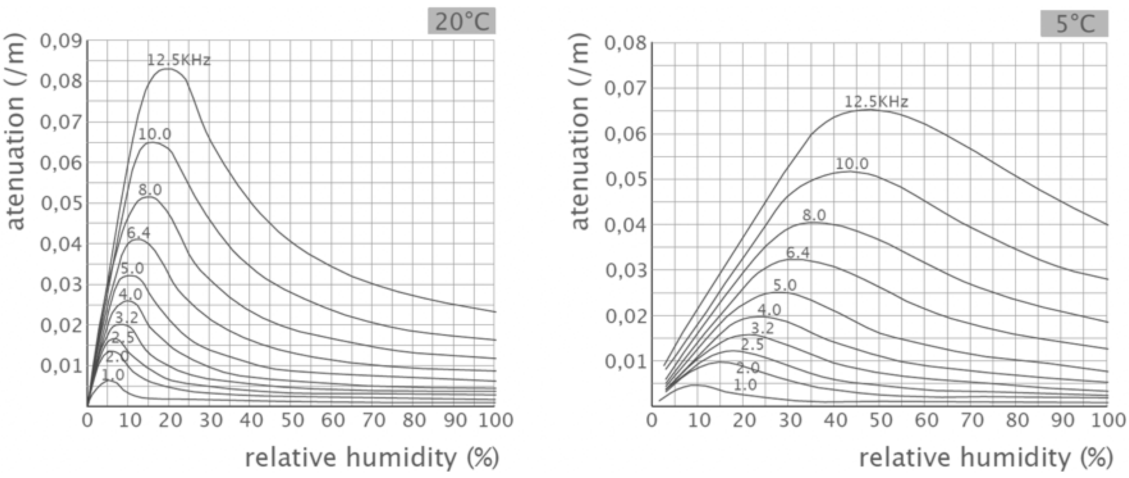


Figure 4.5: Attenuation Coefficient due to air absorption [Graph].

(ii) Humidity

For a certain temperature, the capability of the air to absorb the sound will depend on its relative humidity. The lower the air humidity is, the greater is the sound loss at a pre-fixed distance.

Water molecules act as gas molecular collisions inhibitors, as they reduce the transfer of translational and rotational kinetic energy to vibratory energy (and vice versa).

(iii) Temperature

When the air thermal level varies, its density and, consequently, the sound speed in its environment also change. This direct relationship occurs proportionally, so that as higher as the temperature is, the faster the sound will shift. Therefore, temperature gradients will produce speed gradients with the same characteristics. There are two main types of situations related to the temperature gradient, as can be seen in Figure 4.6.

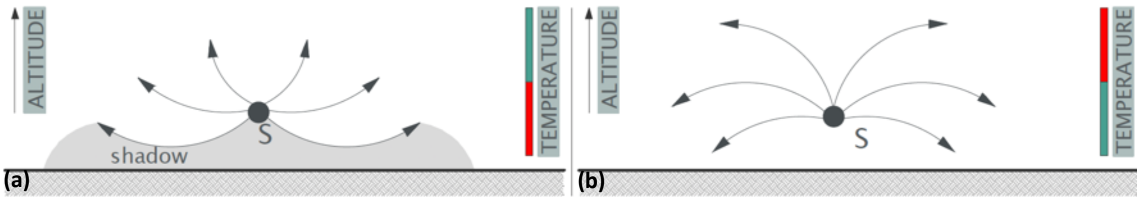


Figure 4.6: Temperature effects on sound rays (a) negative temperature gradient: altitude increase and temperature decrease (b) positive temperature gradient: altitude and temperature increase.

In situation (a) with a negative temperature gradient, when the altitude is increased and at the same time the temperature is decreased, the wavefront and the sound beam move away from the ground. It is a phenomenon that can be widely observed in cities during the day, accentuated even more in the evening. In this case, with the sound rays deviating upwards, a shadow region is formed close to the ground.

In situation (b), however, the opposite occurs, with the altitude increases, the temperature also increases, so there is a positive temperature gradient. In this case, both the wavefront and the sound beam are inclined towards the ground. This phenomenon occurs very commonly at night in cities, where there is the soil cooling, caused by the radiation heat loss.

(iv) Wind

The wind speed increases as it moves away from the ground. In the ground vicinity there are always obstacles that create a delayed roughness of the normal flow. Therefore, winds are characterized by positive velocity gradients close to the ground. When the sound propagation is downwind, the wavefront tilts towards the ground. In contrast, when the sound propagates against the wind, the sound front moves away from the ground, forming an acoustic shadow region, as shown in Figure 4.7.

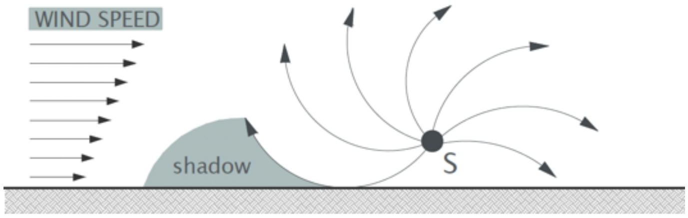


Figure 4.7: Wind effect on sound rays.

It should be noted that when sound propagates through the open air, there is a wide fluctuation in sound pressure levels due to varying meteorological conditions with time at the receiving point. Besides, the natural wind blows so erratically, thus leading to an absence of stable sound rays connecting source and receiver.

4.3.3. Reflections

When a sound wave concern on a smooth, hard, large surface there is a mirror-like reflection.

(i) Single reflecting surface

The reflected sound that is generated by the image source behind the reflecting surface, is added to the direct sound at the receiving point, as shown in Figure 4.8. In the general case of sounds, the energy densities need to be considered.

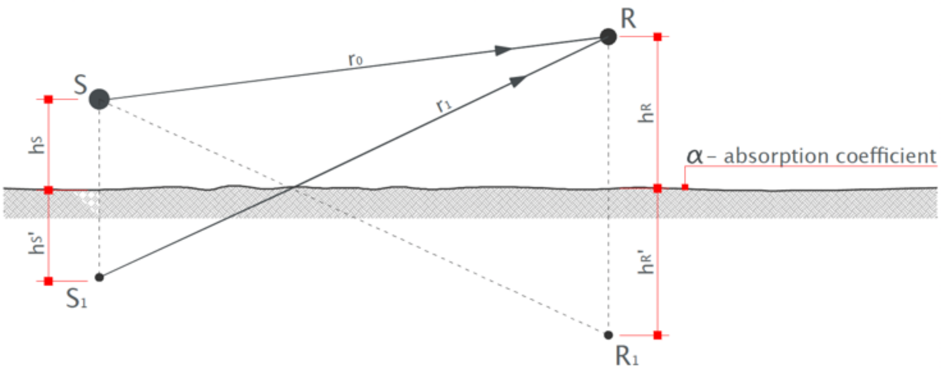


Figure 4.8: Sound reflection by a plane surface.

The direct sound energy density at the receiver (I_0) added with the reflected sound energy density (I_1) follows that:

$$I = I_0 + I_1 = I_0 \left\{ 1 + \left(\frac{r_0}{r_1} \right)^2 (1 + \alpha) \right\} \qquad \text{dB} \tag{15}$$

Where:
α is the surface absorption coefficient

When the reflecting surface is sufficiently large compared with the sound wavelength, after obtaining each Intensity value (I_0 and I_1), the energy summation can be carried out using Figure 4.9. However, the sum will only occur if the sources are not correlated (coherent), that is, if the waves they produce have time-varying phase differences.

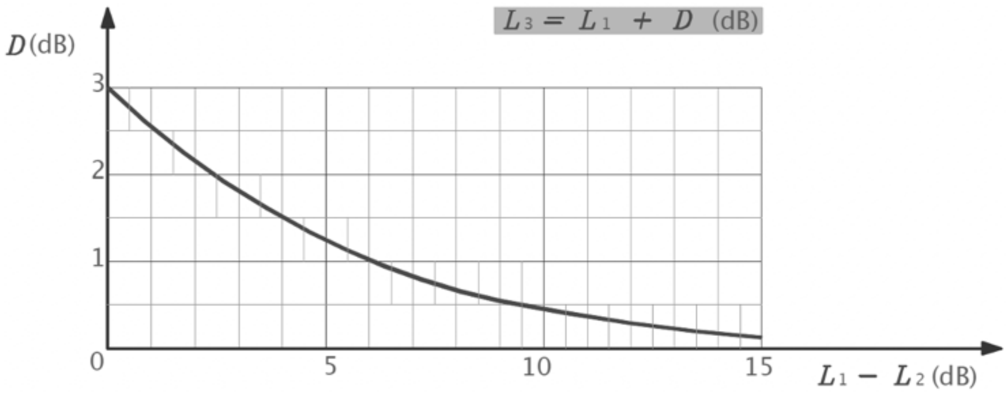


Figure 4.9: Summation of L_1 (dB) and L_2 (dB), $L_1 > L_2$ [Graph].

(ii) Many reflecting surfaces

When there are many reflecting surfaces, as shown in Figure 4.10, each one has not only an image source of first order but a second order image for a second order reflection, and also many higher order images corresponding to multiple reflections. The energy density at the receiving point is obtained using the same principle as in equation (15).

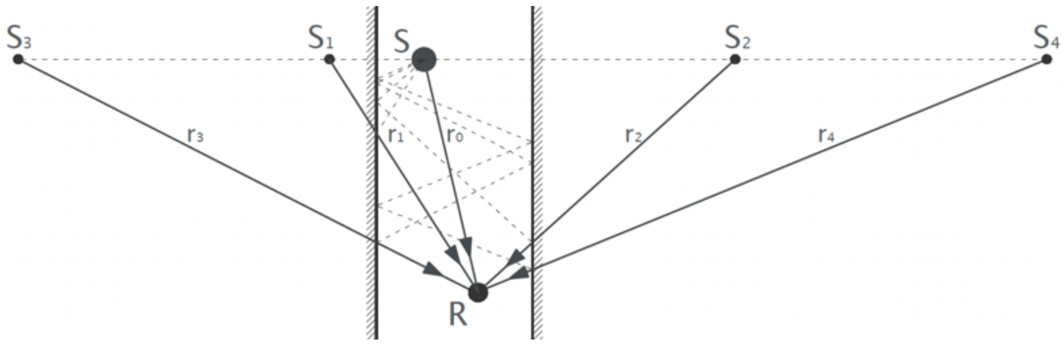
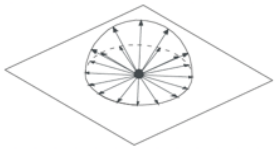
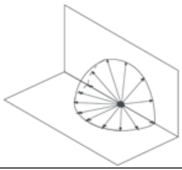


Figure 4.10: Multiple reflections between two parallel planes. Sound rays are shown from the 1st order image source at the left side, only.

When a point source located close to one or more large reflecting planes, the following simplified method can be used, as shown in Table 4.1.

Table 4.1: Q values for sources placed close to one or more large reflecting planes.

Source Position		**Area where the source energy passes**	***Q***
presence of an infinite rigid surface (semi-infinite space)		$2\pi r^2$	2
positioned on an edge (2 infinite intersecting surfaces)		πr^2	4
positioned at a vertex (3 intersecting infinite surfaces)		$\pi r^2/2$	8

(iii) Ground reflection

The ground reflection may result in both an attenuation and an amplification of the sound level, caused by the two waves phases interference that depends on the sound frequency. The reductions are caused by the destructive interference in frequencies, where the two rays are 180º out of phase. The amplifications, in turns, are caused by the doubling of the sound pressure in frequencies where the rays are in the same phase.

When the sounds are correlated, they create an interference field, and depending on the phase difference the total sound pressure amplitude at a given position will assume a value between the sum of the two amplitudes and the difference.

On acoustically hard soils, with non-shallow propagations, the directivity index for a source in an infinite rigid surface is considered, mentioned in the Figure 4.8. That is, there is an approximately 3dB average amplification in relation to the direct sound, caused by the sound energy reflection.

On the other hand, in acoustically soft soils (such as soils with vegetation, plowed land, snow, etc.), there is, in reflection, a wave phase inversion, with a broadband attenuation in the sound spectrum (except at very low frequencies).

In this context, it can be said that the coating materials used in urban areas, in general, have reflective characteristics, which can contribute to the sound pressure levels amplification.

(iv) Obstacle: barriers

Sound barriers are considered as any obstacles that prevent the receiver from seeing the source. When they are long, and the diffraction at the lateral edges does not affect the sound level at the receiver, the sound that reaches him (the receiver) will be the one that will cross the height of the barrier and by diffraction it will curve downwards, generating acoustic shadow behind the obstacle.

Therefore, the attenuation will depend on the barrier height or position, and the acoustic wavelength generated by the source.

If there is a barrier on the ground, the ground attenuation must be considered. In soft soils, the existence of an acoustic barrier destroys the attenuation of the soil, as there is an increase in the angle of incidence in the soil, also occurring a reduction in the path of the beam that reaches the receiver directly from the barrier top.

In addition, it is also important to consider the refraction phenomenon, in which the sound ray has its propagation altered by variations in the medium characteristics, according to the Figure 4.11and Figure 4.12. When the temperature gradient is negative or when the sound propagates against the wind, there is an increase in the attenuation of the barrier. Otherwise, there is a reduction in its attenuation.

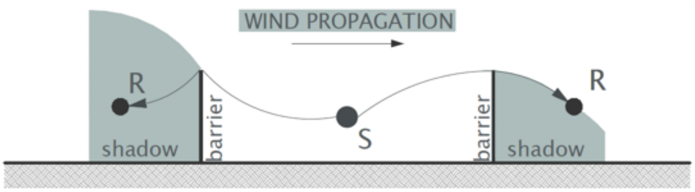


Figure 4.11: Barrier and wind propagation effect on sound rays.

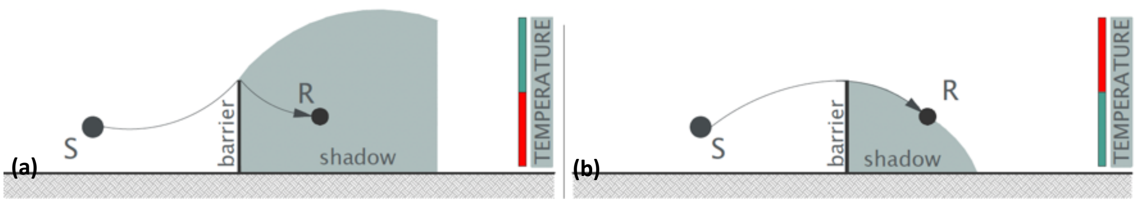


Figure 4.12: Barrier and temperature gradient effect on sound rays (a) negative temperature gradient (b) positive temperature gradient.

(v) Obstacle: vegetation

A green belt between the source and the receiver will act as a hollow sound barrier, that it can either absorb (due to the foliage properties, small branches, and shrubs), or spread the incident sound, through the trunks of trees, large branches, and dense foliage.

In this case, the sound attenuation capacity will highly depend on the vegetation density, width, and height than on possible differences between shapes, leaf types and existing branches. That is, to determine the noise attenuation potential, the spreading the sound property will be more important than absorption. This will only be significant in incident sounds with high frequencies.

In occupied areas with dense vegetation, characterized essentially by trees, the sound at medium frequencies, will be attenuated by scattering in the trunks and trees' branches parts; at high frequencies, it will be absorbed by the foliage, and at low frequencies it will be attenuated by undergrowth, roots, and shrubs.

Although vegetation provides little noise attenuation, it serves as a good visual receiver insulator, providing a favorable psychological effect.

4.4. SOUND DESCRIPTORS

The sound categories characterization and perception, as well as the way that each one affects the human being, is a multidimensional order complex phenomenon, which depends on several factors' combination.

The physical characteristic of the sound is one of these factors. It is important to be characterized with objectives parameters, through physical descriptors.

4.4.1. Equivalent continuous sound pressure level (L_{Aeq})

The equivalent continuous sound pressure level, L_{eq}, constitutes the level of a steady sound which, over the same interval of time as the fluctuating sound of interest, has the same mean square sound pressure. It is more common, however, for L_{eq} to be expressed as L_{Aeq}, which uses A-frequency weighting, that filters audible frequencies intended to reproduce the response of the human ear to sound. The interval of time must be stated.

This quantity is highly specified by various standards and legislation as a scale for the measurement of long-term noise exposure and is defined, by ISO 1996-1 (2016), by equation (16).

$$L_{Aeq,T} = 10\log\frac{\frac{1}{T}\int_{t_1}^{t_2} P_A^2(t)dt}{P_0^2} \qquad \text{dB} \tag{16}$$

Where:
$T = t_2 - t_1$,
P_A (t) is the A-weighted instantaneous sound pressure.
P_0 is the reference sound pressure (20µPa).

4.4.2. Statistical sound level

Sound generally fluctuates over time and its effect is highly dependent on its time-varying pattern. An intermittent or impact sound is considered more annoying than a continuous sound.

The statistical quantities better and more concisely characterize a sound pressure level record as a time function, because they calculate the percentage that a certain noise was exceeded during the measurement period.

Statistical levels are widely used to assess the transport systems noise such as vehicle traffic, aircraft flyovers and railway lines. Despite can range from L_1 to L_{99}, those that are most widely used are the L_{90}, L_{50} and L_{10}, defined by:

- L_{90} is the sound level that has been exceeded by 90% of the measurement time. Widely used to define the residual noise level.

- L_{50} is the sound level that has been exceeded by 50% of the measurement time. It is the measurement period median noise level, which is not necessarily equal to the average noise level (L_{Aeq}).

- L_{10} is the sound level that has been exceeded by 10% of the measurement time.

The further away the L_{10} from the L_{90}, the greater the noise discomfort, due to sudden variations in the sound pressure level.

4.4.3. Maximum sound pressure level

It is the highest environmental noise level, occurring in a position, over a period of time. It is used often in conjunction with other sound parameters (e.g., L_{Aeq}) to ensure that a single noise event has not exceeded a threshold.

4.4.4. Minimum sound pressure level

It is the lowest level of environmental noise that occurs in a position over a period of time.

4.4.5. Day-evening-night level (L_{den})

The L_{Aeq} energy index serves as the basis for the L_{den} indicator stipulated in the European Directive (European Parliament and Council, 2002) . This indicator is calculated over a period of 24 hours with a "penalty" of 5dB for the evening period and 10dB for the night period, since at these times the noises are considered more disturbing because these are considered as rest time for mostly people and also because of the lower background sound pressure levels.

In this way, the three ambient noise indicators, namely: L_d (L_{day}), L_e ($L_{evening}$) and L_n (L_{night}), are the long-term average sound pressure levels, weighted A, as defined in ISO 1996-2 (2017), determined during respectively day, afternoon and night periods.

From these three indicators, the value of the L_{den} indicator can be calculated according to equation (17).

$$L_{den} = 10\log\frac{1}{24}\left[t_d * (10)^{L_d/10} + t_e * (10)^{(L_e+5)/10} + t_n * (10)^{(L_n+10)/10}\right] \quad \text{dB} \qquad (17)$$

Where:
L_d is the continuous equivalent level for the daytime;
L_e is the continuous equivalent level for the evening period;
L_n is the continuous equivalent level for the night period;
t_d is the day integration time - in Portugal, defined between 7:00 –20:00 = 13 hours;
t_e is the evening integration time - in Portugal, defined between 20:00 –23:00 = 3 hours;
t_n is the evening integration time - in Portugal, defined between 23:00 –7:00 = 8 hours.

4.5. AUDITORY PERCEPTION

4.5.1. Binaural hearing

Humans can localize sound due to binaural hearing. The sound signal travelling with the plane wave is influenced by linear distortions. To a person in a free sound field, the plane wave is disturbed by reflection and diffraction at the head and torso. These distortions are dependent on direction and on distance.

The sound from a source located at the side of the head of a person, travels a longer time to the contralateral ear and suffers frequency-dependent damping due to diffraction and absorption. Both effects are noticeable as differences between the ear signals, as interaural time differences (ITD) and interaural level differences (ILD). Thus, at the two ears, the sound signals arrive with differences in time and amplitude.

Also, humans can distinguish between frontal, up, or back direction, due to evaluation of the monaural cues. Monaural cues are the spectral differences with reference to a free sound field or with reference to a specific direction, usually the frontal incidence.

4.5.2. Psychoacoustics

The term psychoacoustics involves the description and modelling of human hearing. Psychoacoustic model functions extract the characteristic data related to specific hearing dimensions from physical data, such as sound pressure time functions or spectra.

These dimensions, such as loudness, fluctuation, roughness, sharpness, and pitch strength, are physical descriptors which compose the "character" of sound.

(i) Loudness

The frequencies range to which a healthy human hearing is sensitive, referred to as the audio frequency spectrum, is approximately between 20 Hz and 20,000 Hz. However, it is important to considered that the human ear is not equally sensitive over this frequency range.

The loud or silent sounds are related to the sound physical intensity. However, the subjective sensation is not in simple proportion to the objective intensity, which requires a scale. The sensitivity of the human ear is strongly dependent on the tonal pitch.

The loudness level of a sound, measured in "phon" (F), is defined as the sound pressure level of a pure tone standard frequency, 1000 Hz, which is heard with equal loudness. The curves of perceived equal loudness are drawn in a sound pressure level versus frequency.

The array of curves obtained by varying the level of the 1 kHz tone is called hearing levels. The decibel value of a pure tone on 1 kHz is identical to the "phon" value.

The curves shown, according to Figure 4.13, for example, that a 50 Hz tone with an actual sound pressure level of 90dB is perceived with the same loudness as a 1 kHz tone with 60 dB.

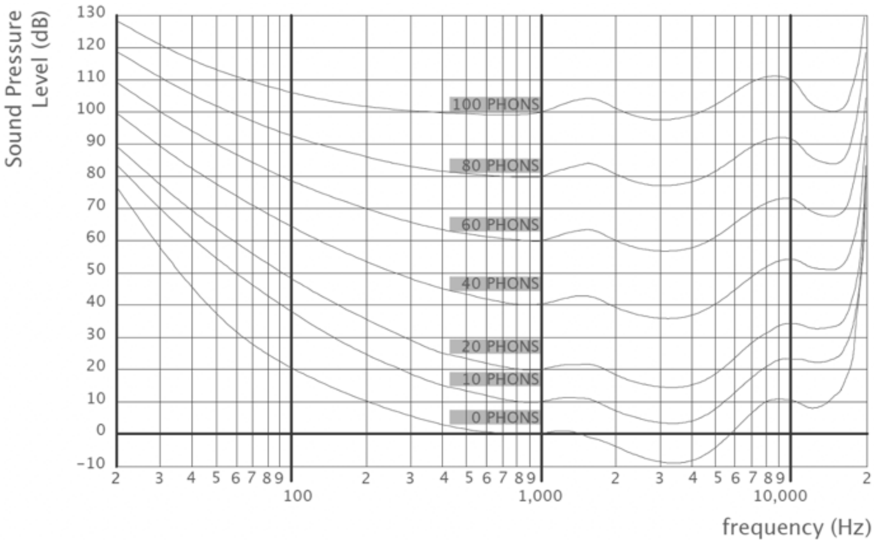


Figure 4.13: Equal Loudness Contours ISO data (ISO 226, 2003b) [Graph].

Although the minimum SPL (sound pressure level) audible to the average human ear is 0dB at 1kHz, generally speaking, for a constant sound, a level of 10–15dB is barely audible.

The ear is more sensitive in the middle frequency range than both at very high and very low frequencies. Below 500 Hz the auditory sensitivity is reduced with decreasing frequency, which means that is necessary much more sound energy. Maximum sensitivity exists between about 3000 or 4000Hz at the lower level.

In the median range of SPL, a change of 1dB is just perceptible, changes need to be around 3dB or more to be of any significance at all, and an increase of 10dB produces an approximate doubling of the strength of sensation.

4.5.3. Masking

The masking effect may change the overall perception of the acoustic environment. Both the auditory masking and the informational masking are the main two ways, through the addition of sounds, to achieve this end.

(i) Frequency masking / energetic masking

Frequency masking occurs when one sound decreases in audibility due to the presence of another sound. The masking sound makes a target sound (usually unwanted sounds) inaudible (complete masking) or less loud (partial masking) by decreasing the signal-to-noise ratios thresholds at specific frequency bands in the physical receptors of the inner ear (Moore, 2013).

This masking effect is not so easy to achieve, because of spectral differences between typical wanted and unwanted sounds. In a frequency range higher than the masker, the masking effect is stronger than in a frequency range lower than the masker.

The masking effect will be greater with the increase of the SPL of the masker. The amount of masking is measured by this threshold shift in dB.

Commonly, this masking concept refers to the case when the masker and the masked sound occur at the same time within the same critical band. However, there is other phenomena like partial masking, central masking, remote masking and no simultaneous.

(ii) Informational masking

The energetic masking will not be so efficient with the urban environment sounds, like the road traffic noises, for example, even if the masker produces relatively high sound levels.

However, some sounds feature in the urban environment may still reduce the loudness of the target noise due to informational masking effect. According to Moore (2013) this occurs (1) because the sound is confused with the masker (auditory similarity), it is difficult to perceptually segregate him from the masker or (2) because attention is not directed do the most appropriate aspect of the sound.

The informational masking is a result of neural functions at higher levels of auditory processing, involving several different mechanisms.

Some environment soundscapes studies have been explored the importance of the positive sounds to deflect or attract the attention of the listener, aiming to an overall quality of the acoustic environment, even if they do not reduce the audibility of unwanted sounds. So, the pleasant sounds, (e.g. natural sounds: birds, sparrows, water), would increase the overall pleasantness of the acoustic environment, thus decreasing the unpleasant sounds (e.g. traffic sounds) (Nilsson et al., 2010; Oldoni et al., 2013; Ong et al., 2017; Rådsten-Ekman et al., 2013; Van Renterghem et al., 2020).

5. METHOD

The present research aims to understand how the soundscape acts as a decision factor for the use of urban waterfronts, considering that a well appreciated, pleasant and appropriate sound environment is a key aspect in attracting people and bringing them together in an urban context in which it is integrated with all its complexity, meaning, and ambivalence.

This chapter aims to present the methodology adopted for the development of the research.

The chapter first presents the general methodology, with its different stages. Subsequently, the stages of the investigation are detailed, which begins with information on how the Tejo waterfront area and its public spaces were defined for the case study, followed by the description of how all the necessary assessments were performed. Finally, how the analyses were carried out to achieve the research objectives are described.

5.1. GENERAL METHODOLOGY

The urban waterfront area of the Tejo River was studied, so as to know how its sound environment is assessed and which aspects may influence this assessment. The research relies on data-based evidence, combining qualitative with quantitative methods and criteria, under three different approaches: the public space approach, the user approach, and the soundscape approach. It is essential to encompass all aspects that may influence the characterization and perception of the sound environment. The approaches of the public space and of its users were essentially based on empirical practices for characterizing the urban space which are used by planners and researchers in the analysis and evaluation of these spaces, as showed in chapter 2. Regarding the public space approach, the place's physical characteristics and surroundings were observed, as well as its functions and connections. As for the users' approach, their individual and collective characteristics, their dynamics of use and patterns of activities were observed, but mainly their subjective particularities composed of perceptive elements which denote their needs and expectations with the space. Finally, through the soundscape approach, the sound environment, the context and the user's perception were studied, observing the soundscape International Standard recommendations and the state of the art from the urban soundscape studies described in Chapter 3.

The research work followed a case-study line of action with an empirical survey on different public spaces of the Tejo's waterfront, which included *in-situ* observations, data collection, laboratory tests, and comprehensive cross analysis, making use of a variety of assessment techniques, hereinafter described in four different stages.

The case-study analysis combined all information collected and obtained in order to find the most significant correlations with the evaluations and perceptions of the sound environments of public spaces on the Tejo's waterfront, to be considered as the objective criteria pursued by the research objectives.

(i) Stage 1: study area definition and preliminary assessments

The first stage of the research aimed at defining and selecting the public spaces of the Tejo waterfront area of interest as case-studies. To this end, some criteria were established firstly, according to the research objectives.

Together with the definition of the public spaces, preliminary assessments were carried out mostly through local observations. During this stage, each public space was evaluated regarding its physical and functional features, its sound environment, and its users. In addition, it was further analysed regarding its location within the urban system, its connections and placement in a network of functional relations, and its morphological features, when considered relevant for soundscape characterization.

(ii) Stage 2: quantitative assessment

Following the preliminary assessment, a massive information collection programme was set up on the selected sites, where both quantitative and qualitative data were collected.

At the quantitative assessment stage, measurement campaigns of the existing sound levels were carried out. Together, information about the users’ behaviour were collected, through the classification of the users and the activities they performed on the sites.

(iii) Stage 3: qualitative assessment

The data collection for the qualitative evaluation of the sites was carried out through two different simultaneous procedures, one consisting of the application of questionnaires to the users of each site, and the other of sound recordings on the sites.

The application of the questionnaires made it possible to obtain objective and subjective information about the users, i.e., characteristics, behaviour, preferences, and perceptions. Users' data were then obtained, such as their social characteristics and relationship with the place they used, as well as their evaluations and perceptions regarding the site and its sound environment.

The sound signals recorded *in-situ* were organized and processed on a laboratory environment so as to be analysed later by a laboratory listening panel.

The listening panel composed by a group of non-acoustical experts aimed to reach subjective evaluations regarding the sound environment of the sites through listening to the recordings, in a laboratory environment, following appropriately set up guidelines.

(iv) Stage 4: soundscape analysis

The results obtained on the previous stages, i.e., the information regarding the measured acoustic data, the characteristics, behaviour, preferences, and perceptions of the users, and the laboratory panel listeners perceptions were compared for the purposes of soundscape analysis.

The comparisons aimed to identify potential relationships, mainly those with a greater and more straightforward relations with the best appreciations of the waterfront soundscape on the users' experience.

5.1.1. Data collection and the pandemic coronavirus disease

A note on the effects of the Coronavirus Disease (COVID-19) pandemic on the research seems important since a large portion of the research was planned to be carried out on outdoor public spaces.

Since March 2020 until September 2021, Portugal alternated between normal, alert, contingency, or emergency states, as imposed by the Government. Consequently, the unexpected alterations and restrictions led to changes on both city uses and citizens' behaviour, who had their routines seriously affected. The use of public spaces was also directly changed, going through a moment of almost abandonment during the emergency states.

Following periods of more extreme restrictions, people became resistant and unsafe about using these places again, which resulted in changes in the way they began to experience the public spaces. Some of their previous behaviour, such as meeting and socializing, changed, since people started to use this type of places mostly alone, mainly in order to prevent the risks of virus transmission.

Also, waterfront public spaces began to be used more often for the practice of physical exercises, both because outdoor spaces came to be considered safer in terms of the spread of the virus, as well as for the long period of time in which indoor gyms were forced to stay closed by the contingency state.

Therefore, the Tejo's waterfront public spaces became very different, with a change of their users, functions, uses, and, consequently, soundscape.

All these changes directly affected the data collection for the development of the research, since people were afraid of being approached and interviewed, due to the high sense of insecurity that remained. Furthermore, part of the research work that was planned to be carried out in a laboratory environment also needed to be adapted, as explained in detail further on, in subitem 0.

5.2. STAGE 1: STUDY AREA DEFINITION

5.2.1. Tejo's waterfront area delimitation and site selection

Initially, several places of the Tejo River waterfront area, at the city of Lisbon, Portugal, were considered for the case-study development. However, according to the research purposes, some criteria had to be established for a more objective and purposeful selection of the sites.

(i) Criteria for site selection

A public space to be considered as case-study for this work should have a strong connection with the adjacent water landscape, even if not too close or without a total view of the water. Therefore, considering this principle and supported by several *in-situ* observations on the area of interest, further criteria were established for the site selection, in which those with essentially temporary, private, or touristic uses, and those with the presence of some more specific sounds were disregarded.

- *Ephemeral use*

  Sites that are mostly used as a walkway, or other ephemeral use, were not included as areas of for the case-study, since places where people stay for longer time periods (even if short-term), performing activities such as reading, resting, appreciating the landscape, entertaining, or working, are preferred as study public spaces.

- *Restricted use*

Those waterfront' sites in which most of the area is constituted by delimited places and with restrict uses, essentially those ones appropriated by the terraces of bars, kiosks, and restaurants, were disregarded as interest area for the case study.

The users of these places have specific motivations to visit such sites, and most of all, perceptions, clearly different and outside the scope of the present research from those people who use the sites with essentially public use.

- *Touristic use*

Similarly, sites most frequented by tourists, were also left out of the selection, since this kind of users usually have very particular perceptions that may change the results to be obtained. The outcomes from research work with tourists has revealed many differences on the soundscape perception as compared to daily or resident users as reported in the literature (Puyana Romero, Brambilla, Gabriele, Gallo, & Maffei, 2015; Qiu, Zhang, Zhang, & Zheng, 2018).

Therefore, those sites with essentially tourist use at the Tejo River waterfront area, such as the Praça do Comércio Square and the vicinity of the Padrão dos Descobrimentos monument, were not considered for the case study.

- *Specific sounds*

Lastly, the sites marked with the presence of very specific sounds that seem not to be part of their common sound environment, such as warning signals, sounds from construction and machinery, were not considered since they can considerably affect their users' assessment and perception and mislead the research results.

(ii) Site definition

Following the principles and the criteria established, ten sites from the Tejo River waterfront were selected for study. They are distributed over two large areas named as Area I and Area II, as shown in Figure 2.1**.**

Area I is located between the Doca de Belém dock and the 25 de Abril Bridge, and comprises five selected public spaces, site 1 to site 5, as shown in Figure 5.2.

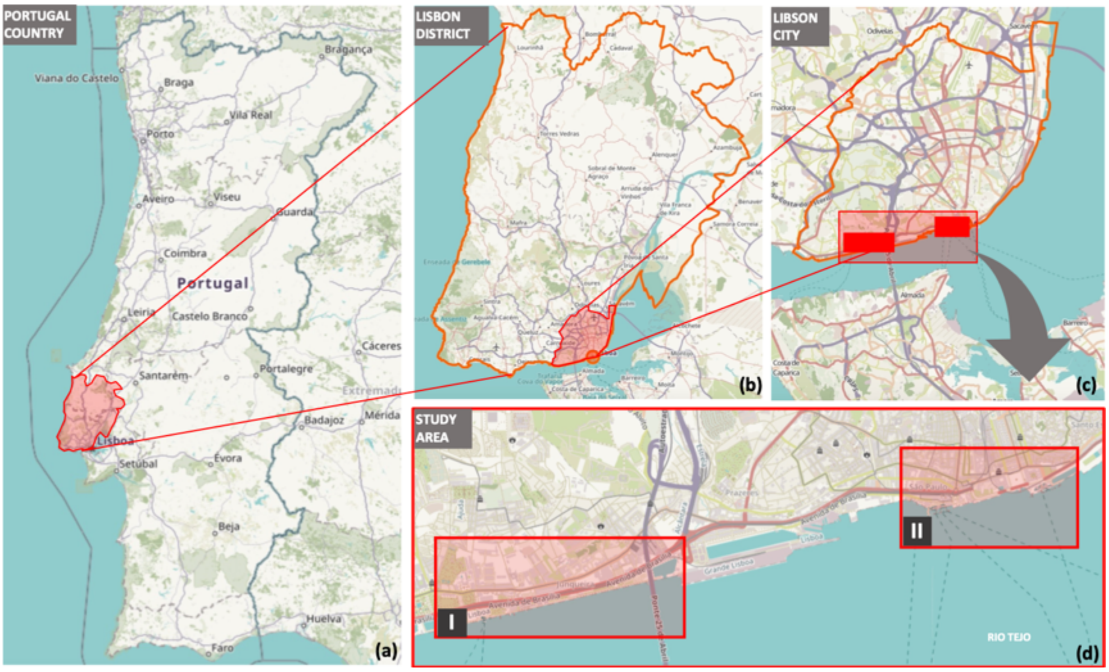


Figure 5.1: Waterfront area selected location: (a) Portugal, (b) Lisbon District, (c) Lisbon Municipality, (d) Tejo's River Waterfront with the Area I and Area II location: ©OpenStreetMap contributors, author adapted.

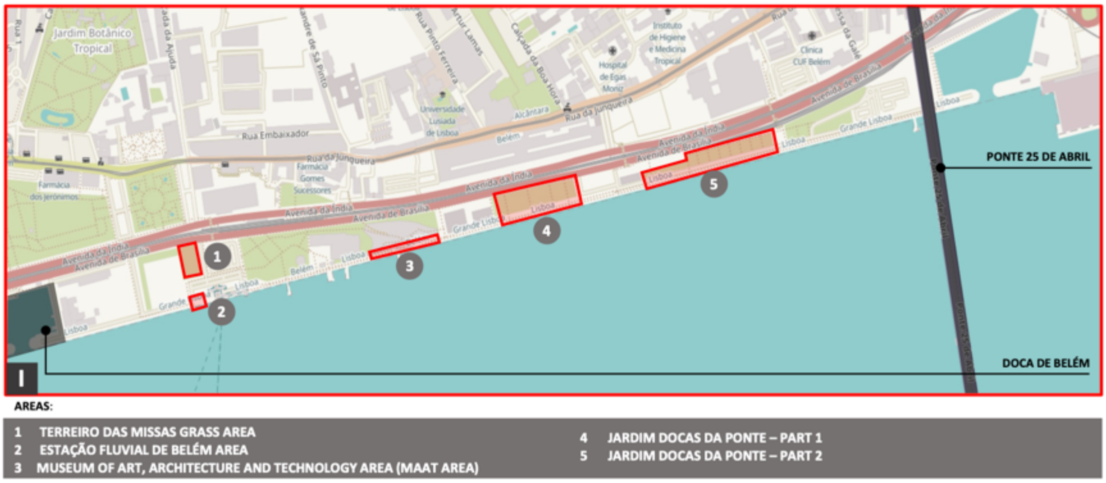


Figure 5.2: Area I with the location of sites 1 to 5. Source: ©OpenStreetMap contributors – author adapted

Figure 5.3: Area II with the location of sites 6 to 10. Source: ©OpenStreetMap contributors – author adapted.

Area II, located between the Cais do Sodré train station and the Praça do Comércio square, comprises also five public spaces, site 6 to site 10, as shown in Figure 5.3.

The proximity between some of the public spaces could make them to be considered as a single space, however, since they feature very different characteristics, all were evaluated separately. Therefore, the sites were considered independently due to their distinct characteristics, uses and functions. A more detailed description is presented next for all the sites considered.

- *Sites 1 and 2*

Sites 1 and 2 are close (less than 100 meters away) to each other, as shown in Figure 5.4, however, the only similarity they bear is the same Tejo River view. Besides the visual and organizational differences, the sites are also physically disconnected by a car park between them which cause a rupture on the space continuity.

Figure 5.4: Identification of Site 1 and Site 2. Source: ©OpenStreetMap contributors – author adapted.

Site 1 – "Terreiro das Missas area" is a place shaded by trees, with grass and some benches (Figure 5.5 and Figure 5.6). The place is close (less than 50 meters away) to the Av. de Brasilia Avenue, with heavy traffic of cars and trucks, and has a limited view of the river landscape.

Figure 5.5: Site 1 – Terreiro das Missas area – East and South View., by Nardi, 2020.

Figure 5.6: Site 1 – Terreiro das Missas area – West and North View, by Nardi, 2020.

Site 2 – "Estação Fluvial de Belém area" is a space built beyond the river Tejo edge, which makes it physically bordered by the water, and can be accessed only through one of the sides (Figure 5.7 and Figure 5.8). The space is made up of longitudinal benches around it, with unrestricted view of the water, but without inner natural elements.

Figure 5.7: Site 2 – Estação Fluvial de Belém Area– East and South View, by Nardi, 2020.

Figure 5.8: Site 2 – Estação Fluvial de Belém Area– West and North View, by Nardi, 2020.

- *Site 3*

Site 3 – "Museum of Art, Architecture and Technology area" is surrounded by the building of the museum and bordered by the Tejo River on the south, as shown in Figure 5.9.

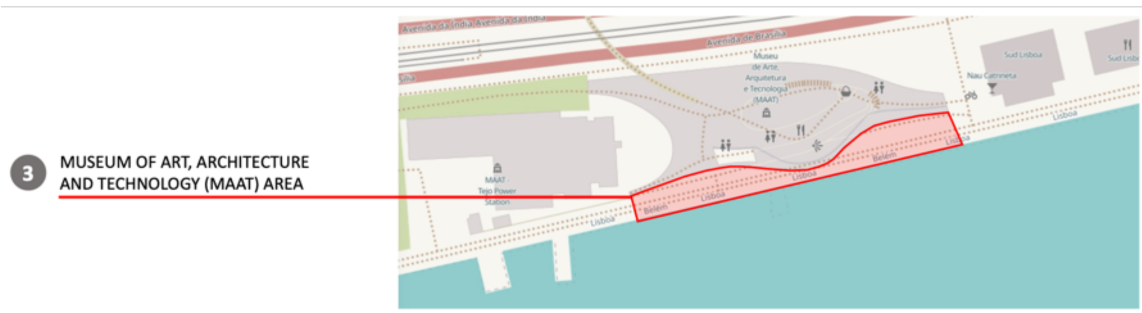


Figure 5.9: Identification of the Site 3. Source: ©OpenStreetMap contributors – author adapted.

It is a longitudinal area parallel to the river, with concrete steps along all the water edge, usually used as benches. The site has an unlimited view of the river and does not feature any natural element (Figure 5.10).

Figure 5.10: Site 3 - Museum of Art, Architecture and Technology (MAAT) Area – East and South View, by Nardi, 2020.

- *Site 4 and Site 5*

The Jardim Docas da Ponte is a linear public space between the Museum of Art, Architecture and Technology (MAAT) and the 25 de Abril Bridge, which is visually and physically separated in two areas - “Site 4" and "Site 5", by a building and a parking lot, as shown in Figure 5.11.

Figure 5.11: Identification of the Site 4 and Site 5. Source: ©OpenStreetMap contributors – author adapted.

Both sites present very similar physical characteristics, since they are Tejo Riverbanks longitudinal grassy areas with trees that provide shade, bordered at the north by the Av. de Brasilia Avenue, with heavy traffic of cars and trucks.

However, the sites are very different regarding their infrastructures, mainly their urban equipment.

Site 4 - “Jardim Docas da Ponte – part 1” features a number of urban equipment such as benches, a playground, and outdoor fitness equipment, as shown in Figure 5.12 and Figure 5.13.


Figure 5.12: Site 4 – Jardim Docas da Ponte – Part 1– East and North View, by Nardi, 2020.


Figure 5.13: Site 4 – Jardim Docas da Ponte – Part 1– South View, by Nardi, 2020.

Site 5 - "Jardim Docas da Ponte – part 2" has only a few benches spaced along the bank of the river as existing infrastructure, as shown in Figure 5.14 and Figure 5.15. The site is very close (less than 350 meters away) to the 25 de Abril Bridge, which is visually and acoustically imposing on the place, due to the noise produced by the road and railway traffic on the bridge.


Figure 5.14: Site 5 – Jardim Docas da Ponte – Part 2– East View, by Nardi, 2020.


Figure 5.15: Site 5 – Jardim Docas da Ponte – Part 2– South View, by Nardi, 2020.

- *Site 6 and Site 7*

The Jardim de Roque Gameiro is a public space located at the Lisbon downtown area. It is bordered on its west side by the Cais do Sodré terminal, which is one of the most important public transportation terminals in the city, where trains, underground, buses, trams, and boats converge. The area is divided into two different sites, "Site 6" and "Site 7", as shown in Figure 5.16, given their very distinct characteristics, in terms of both uses and users.

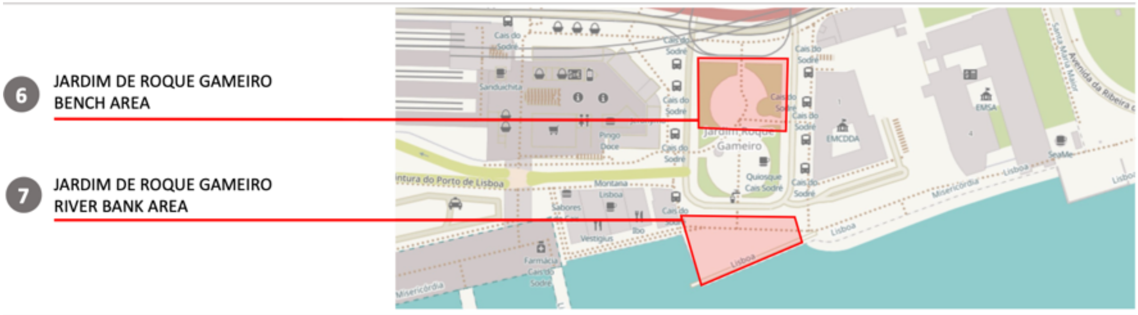


Figure 5.16: Identification of the Site 6 and Site 7. Source: ©OpenStreetMap contributors – author adapted.

Site 6 – "Bench area", shown in Figure 5.17 and Figure 5.18, is located inside the Jardim de Roque Gameiro square, bordered by three streets, that had an informal bus terminal, and by the Av. 24 de Julho Avenue, with heavy traffic of cars, trams, and buses. The space is a wooded site, with 20 benches located under a large tree and has a limited view of the Tejo River.

Figure 5.17: Site 6 - Jardim de Roque Gameiro – Bench Area – East View, by Nardi, 2020.

Figure 5.18: Site 6 - Jardim de Roque Gameiro – Bench Area – West View, by Nardi, 2020.

Site 7 – "Riverbank area", shown in Figure 5.19 and Figure 5.20, is disconnected from the square by the bus terminal street. This is an area with specially designed benches, and unlimited view to the Tejo River, without shade areas. Explicitly, it is an urban space used mainly for water landscape contemplation.

Figure 5.19: Site 7 - Jardim de Roque Gameiro – Riverbank Area – West View, by Nardi, 2020.

Figure 5.20: Site 7 - Jardim de Roque Gameiro – Riverbank Area – East View, by Nardi, 2020.

- *Site 8, Site 9, and Site 10*

The Ribeira das Naus public space is also located at the Lisbon downtown area and situated west of the Praça do Comércio, a very visited tourist site of the city. It is a linear area adjacent to the Tejo River, that is used mainly for circulation of people and for water landscape appreciation and it is longitudinally sectioned by the Av. Ribeira das Naus, an intense traffic avenue.

This large area, which is already physically separated into two parts by the avenue, was divided into three sites for the purpose of this research, also due to their distinct characteristics, uses, and users, “Site 8”, “Site 9”, and “Site 10”, as shown in Figure 5.21.

Figure 5.21: Identification of Site 8, Site 9 and Site 10. Source: ©OpenStreetMap contributors – author adapted.

The side of the avenue which is furthest the water edge was divided in two sites mainly due to distinct physical characteristics.

Site 8 - "Tree Area" is a flat large covered grass space with random spaced out trees that provide partially shaded areas, but with limited view of the water, as shown in Figure 5.22 and Figure 5.23.

Figure 5.22: Site 8 - Ribeira das Naus - tree area – North View, by Nardi, 2020.

Figure 5.23: Site 8 - Ribeira das Naus - tree area – South View, by Nardi, 2020.

Site 9 – "Grass Area" is constituted by two grassy ramps without trees, which slopes towards the river providing an unrestricted view of the water landscape, as shown in Figure 5.24 and Figure 5.25.

Figure 5.24: Site 9 - Ribeira das Naus - grass area – West View, by Nardi, 2020.

Figure 5.25: Site 9 - Ribeira das Naus - grass area – East View, by Nardi, 2020.

Site 10 – "Centre Area" is located at the edge of the Tejo river and is constituted of a stepped concrete ramp that reaches the water and works as a linear and longitudinal bench, with a unlimited view of the water landscape, as shown in Figure 5.26 and Figure 5.27. Despite the newly planted trees, no shade is yet provided in the place.

Figure 5.26: Site 10 - Ribeira das Naus - centre area – South View, by Nardi, 2020.

Figure 5.27: Site 10 - Ribeira das Naus - centre area – North View, by Nardi, 2020.

5.2.2. Preliminary assessment

Together with the delimitation of the waterfront area and its public spaces, a first data collection programme was set up and carried out to understand and better identify the selected sites. Data were collected strictly through observation and listening, which comprised information regarding the site and its physical and urban features, and the characterization of its sound environment and users, considering the methodologies, methods and techniques addressed in chapter 2.

Data was collected in different periods of the day (morning or afternoon), in distinct days of the week (weekdays and weekends), in two different seasons of the year (Summer and Winter) to track possible changes in routines, activities, users and uses on the area, as also followed by Gehl & Svarre (2013).

In the items hereinafter, it is described how all the information about the sites was collected and organized on the preliminary assessment, through the example of the data collected on the site 6 - Jardim de Roque Gameiro, bench area. All the data collected at all sites are presented in Annex A.

5.2.2.1. Public space information

On the first visits to the Tejo waterfront area, the characteristics of the public spaces and its surroundings, as well as its urban context were registered, as shown in Table 5.1 example. The data collected comprised information about the [1] physical and [2] urban characteristics of every site, and [3] the points of interest and the consumer goods establishments existent on the place.

Table 5.1: Example of public space data, collected from the "Site 6" - Jardim de Roque Gameiro – bench area.

PHYSICAL FEATURES		
[1]	**Built Environment**	East and West: buildings are away from the area because of Cais do Sodré street.
		North: buildings are away from the area because of 24 de Julho Avenue.
		South: Roque Gameiro Garden without building, only the kiosk.
	Constructive Characteristics	Recently redefined area, with stones floor covering (like the historical Portuguese's sidewalks). There is some raised beds and a historical kiosk where bus tickets are sold.
	Natural Elements	Raised beds with grass and some large trees that provide shadow to the local.
		Some newly planted trees that are still in small size.
[2]	**Urban Facilities**	There is nothing.
	Urban Furniture	Wood benches.
	Means of Transportation	Close (less than 500 meters away): 24 de Julho Avenue – heavy traffic: cars, buses,
		Close (less than 500 meters away): bus stop on the Garden surrounding
		Local: pedestrians.
[3]	**Consumer goods establishments**	Kiosk near the site, within the public space.
	Points of interest	Partial view of the Tejo River.

The data collected about the "physical characteristics" of the site were divided into the description of its 'built environment', which comprise the nearby buildings, their proximity, their historical importance, and other characteristics considered relevant; its 'constructive characteristics', such as the presence of buildings or inner built elements, the floors and surfaces coverings materials; and the existing 'natural elements', such as trees, grass area, or similar features.

For the "urban characterization", information was collected regarding the existence, on the site or its surroundings, of 'urban facilities', such as public transportation stations, parking facilities and playgrounds; of 'urban furniture', such as benches, litter beans, and bike racks; and of 'means of transportation', which include the existing infrastructures, such as roads, avenues, train line, and their use, and how people move at the sites.

Lastly, the 'consumer goods establishments' and the 'points of interest' of the sites were surveyed since they usually are strong attractive for people to go and use the places. At the 'consumer goods establishments' item, the existence of shops, bars, restaurants, and kiosks were annotated. At the 'points of interest' item, it was recorded, for instance, the existence of historical buildings, museums, playgrounds, touristic attractions, train stations, fluvial stations, bars, restaurants, kiosks, markets, and landscape.

5.2.2.2. Users' information

The data regarding the users of the sites was organized according to four criteria: 'age range', 'social interaction', 'category', and 'use', as shown in Table 5.2.

Table 5.2: Table used for the users' data annotation.

AGES	SOCIAL INTERACTION	CATEGORY	USES	USES
☐ 15-19	☐ SINGLE PERSON	☐ RESIDENTS	☐ CHILDREN´S PLAY	☐ TOURISM GROUP
☐ 20-29	☐ COUPLE	☐ TOURISTS	☐ LANDSCAPE APPRECI.	☐ INDIVIDUAL TURISM
☐ 30-64	☐ GROUP		☐ SHOPPING	☐ PASSER BY
☐ 65 +	☐ FAMILIES			☐ SPORT

It is important to note that since the 'preliminary assessment' was held essentially by observations at the sites, they might carry some assessment errors, mainly regarding the user characterization, which, nevertheless, can be considered adequate for this stage of the work.

For the 'age range', children and teenagers under the age of 15 were not considered since they do not usually visit public spaces on their own.

Regarding the 'social interaction' criteria, it was observed how users were accompanied on the places, whether they were alone, accompanied by one person, on a group or with their family.

The 'category' of the users aimed to distinguish the residents from the tourists, since both usually have very distinct uses, motivations, and space appreciation.

The 'uses' category relate to the main activities that people were performing on the waterfront site, whether they were passing through, contemplating its natural or built landscape, using its urban furniture, facilities, or establishments, practicing some sport activity or visiting the place as tourists.

The collected data were complemented with additional information considered relevant to data interpretation and the analyses stages, which it was noted as a 'diary' (Gehl & Svarre, 2013), as shown in Table 5.3 example.

Table 5.3: Example of users' additional information, collected from "Site 6".

USERS DATA	
Age	Majority adults and seniors.
Social interaction	The users are alone, couple and two people.
	Practically only residents are area users.
	Tourists' groups use the area only to passing through to go to another place.
Uses	The benches and the tree shades provide places to residents (essentially seniors) to get rest and looking at the built landscape. There are a few numbers of people that are passing by the local.

5.2.2.3. Perceived sounds

The first perceived sound analysis on the sites was carried out by listening to the acoustic environment so as to detect and catalogue the variety of sounds that can be heard on each site, to identify how they interact or overlap, and if different temporal sound compositions seemed relevant. The *in-situ* listening was carried out at different periods of the day and during distinct days of the week, where significant differences on the sound environment were noted, usually changing due to the different uses, users, and surroundings activities of the site.

A graphic scheme with icons was devised, as shown in Figure 5.28, to assist on the identification of all the sound sources perceived and of the predominant ones on the sound environment of each site.

Figure 5.28: Graphical scheme used for the annotation of the perceived sound sources.

The sound source icon meanings displayed in Figure 5.29 are divided into different categories: traffic sounds, natural sounds, human sounds, and operational sounds, based on the recommendations of the ISO 12913-2 (2017) standard.

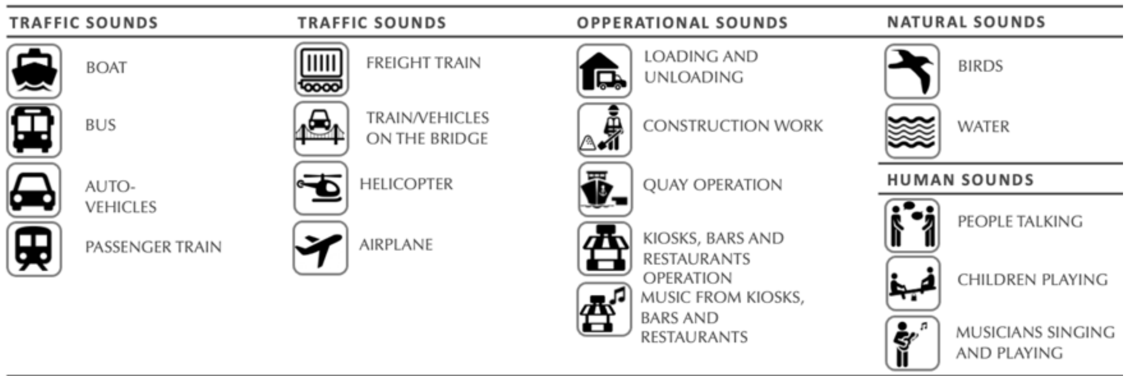


Figure 5.29: Sound source classification, sound source icons and meanings.

Additional information about the sounds, considered relevant for data interpretation, were also recorded, as shown in the Table 5.4 example, in a way to assist the next analyses stages.

Table 5.4: Example of sounds perceived additional information collected from "Site 6".

SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and buses – 24 de Julho Avenue.
Natural sounds	Heard: birds - when the traffic sound is low.
Human sounds	Sporadic: People chatting and Musicians playing on Kiosk area.
Operational sounds	There is nothing.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
Although the noise from the 24 de julho Avenue traffic, the area users are used to spent long time in there.	
The soundscape of the place has been changed when there were musicians playing on the kiosk area, because becomes the main sound heard.	

5.3. STAGE 2: QUANTITATIVE ASSESSMENT

Following the preliminary assessment, an extensive data collection was carried out, which comprised both quantitative and qualitative data, concomitantly, about the same reality for later comparison, essentially to better know the sounds and sound environment of the sites, their users, and their perceptions.

On the quantitative data collection, the sound environment physical characteristics of the sites were obtained through sound level measurements, as described next. Together, a survey was carried out on the number of people associated to the activities that are performed on each site.

A form was drawn (see Annex B) to assist and organize both the data collection process and the *in-situ* observations, and, at the same time, register the results.

One-year of data collection was carried out, to contemplate all possible seasonality, such as the variations in uses, users, behaviours, and activities, through the months and seasons. Besides, data collecting also occurred on different days of the week, in distinct hours, on its two periods of the day (morning and afternoon), to encompass and know all possible changes that might occur on the places of interest.

5.3.1. Sound pressure level measurements

Sound measurements were conducted according to the procedures described by the NP ISO 1996-1 (2019) and NP ISO 1996-2 (2019) standards.

In order to obtain acoustic data that reflected as much as possible the listening experience from the sites' users, the measurements were carried out always at fixed locations as close as possible to the places where most of users usually remain, thus, usually next to existing equipment or furniture.

The measuring equipment was a Brüel & Kjær 2270 Sound Level Meter Type 1, protected by a rainproof windscreen and mounted on a tripod at 1.5 m height from the ground, approximately the height of the users' ears. The values of the acoustic descriptors, the A-weighted continuous equivalent sound pressure level index (L_{Aeq}), as presented in subitem 4.4.1, and the statistical sound levels L_{A90}, L_{A50} and L_{A10}, as in subitem 4.4.2, were registered, with slow time response, and an integration period normalized to ten minutes. The "slow" time response, which corresponds to "1s", was considered more appropriate since the sound environments measured do not have impulsive characteristics that would require a "fast" time response. The integration period for each measurement was normalized to ten minutes since it was considered a reasonable period for detecting all changes that may occur in the sound environment of the sites.

Other information, essentially regarding unexpected events that occurred, and which could change the acoustic environment and thus contaminate the results, were also registered.

Together with the measurements, weather data, as temperature, real feel, cloudiness, wind, wind speed, UV index and humidity data were collected, from the AccuWeather application, which provides weather information by geographic location.

On windy or rainy days, data were not collected, since these weather characteristics can directly affect not only the measurements, due to sensitivity of the equipment and microphone, but also the uses and users of the site.

5.3.2. Users' activities

From a pre-determined list of activities that are usually performed by users of the Tejo waterfront, obtained on the preliminary assessments, a survey was held on the number of people who were performing each of them.

Data collection was carried out during about 10 minutes, since they were collected at the same time when the sound levels were measured, and it could also be regarded as a time interval appropriate to have a sample of the number of users.

Therefore, following the list of activities in Table 5.5, for every site, the number of users who: [1] remained for a long period on the site, either sitting or standing, [2] used, temporarily, the site for practicing some sports or use its equipment (as playground, gym equipment), [3] visited a tourist spot or a commercial establishment at the place or surrounding, [4] passed through the place strolling, or [5] passed by the place practicing some activity were registered.

Table 5.5: Classification of the users' activities performed on the waterfront sites.

Classification of data collected on user behavior				
[1]	[2]	[3]	[4]	[5]
Sitting: grass, benches	Sports: on site	Visiting local tourist spot	Strolling on foot: middle	Sports: running, walking
Sitting: restaurant	Using local equipment	Visiting local store	Strolling on foot: sides	Sports: cycling
Standing: + 3 '			Standing: 1 'to 3'	
			Strolling: bike, scooter.	

5.4. STAGE 3: QUALITATIVE ASSESSMENT

The qualitative assessment of the waterfront sites was mainly achieved through perceptual data collected from their users. Therefore, simultaneously with the quantitative data collection, inquiries were applied to the people that used the sites, and that regularly used some of their equipment, furniture, or other facilities.

The inquiry was set up to obtain objective and subjective responses regarding the users' characteristics, practices, preferences, and appreciations, mostly about the place itself, its sound environment and soundscape. It was designed based on recognised research about both the soundscape and the urban public spaces evaluation and considered the requirements and supporting information specified on soundscape standards (ISO 12913-2, 2017).

While the inquiries were applied, sound recordings were made on each site, and the existing sound sources and the moment they were perceived were registered, in a way to capture the temporal sound composition of its sound environment. The recordings together with the information gathered were analysed and organized on a laboratory environment, to be later listened by a laboratory listening panel, in which the sound environments were assessed subjectively, according to their perceptions.

5.4.1. Questionnaire

The questionnaire was conceived to obtain users' objective and subjective data, in such way to allow comparisons with other information collected, as well as with other soundscape studies, since most of the questionnaire followed the orientations in the ISO 12913-2 (2017) standard, which provides requirements and supporting information on data collection for soundscape studies.

Questionnaires were drafted in both English and Portuguese languages (Annex C) to allow answers by the largest possible number of the waterfront sites' users, due to the presence of people from different nationalities on the study areas.

The questionnaire was made of questions generally with five-point Likert scale answers to assist the respective assessment, to produce an accurate quality information and to reduce errors, as well as to be comparable with other evaluations.

The inquiry was structured in 4 parts: (i) Site Assessment and Influences; (ii) Soundscape Quality Measurement; (iii) User Behaviour; and (iv) User Personal Data.

(i) Public space quality assessment and its influences

Different to the more conventional soundscape questionnaires, the first part of the inquiry, which is depicted in Figure 5.30, was drafted to obtain information regarding the user assessment about the quality of the waterfront site itself.

On the first question, the respondent should set out his level of agreement with the eight quality criteria established, which were regarded as important for a public space assessment.

The selection of criteria was essentially based on the human needs and the quality criteria considered important for the evaluation and planning of urban public spaces. Therefore, the needs and the qualities repeatedly referred by urban planners, which was shown in subitem 2.4.1, were considered, such as comfort, safety, safe relationship between pedestrians and road traffic, appropriate infrastructures, delimitation between public and private spaces, and opportunity to socialize. In addition, the 'pleasant' criteria was also considered, defined by Mehta (2014) as important to evaluate public spaces.

Please rate this PUBLIC SPACE according to your experience.

Rate EVERY statement according to the scale presented.

	Strongly disagree	Disagree	Neither Agree, Nor Disagree	Agree	Strongly agree
It provides COMFORT to its users.	☐	☐	☐	☐	☐
It provides SAFETY to its users and their belongings.	☐	☐	☐	☐	☐
It provides a SAFE RELATIONSHIP between pedestrians and road traffic.	☐	☐	☐	☐	☐
Its INFRASTRUCTURES are well quantified and positioned.	☐	☐	☐	☐	☐
It has good INTEGRATION with its SURROUNDINGS: interconnection of paths and spaces.	☐	☐	☐	☐	☐
It presents an appropriate DELIMITATION between PUBLIC and PRIVATE spaces and between spaces with incompatible uses.	☐	☐	☐	☐	☐
It is organized: HARMONIOUS and PLEASANT place that creates unique experiences for its users.	☐	☐	☐	☐	☐
It creates an opportunity for people to know each other and SOCIALIZE, and promotes relationships between people different groups.	☐	☐	☐	☐	☐

Does the WATERFRONT proximity influences your decision to use this space?

Not at all	Slightly	Moderately	Very	Totally
1	2	3	4	5

Do the different SOUNDS you hear (eg wind, trees, water, birds, music, machines, boats, trains, traffic, etc.) influence your decision to use this space?

Not at all	Slightly	Moderately	Very	Totally
1	2	3	4	5

In the sound set you hear, how do you consider the sounds related to the waterfronts (eg water, seagulls, boats, piers):

Not Important	Slightly Important	Moderately Important	Very Important	Totally Important
1	2	3	4	5

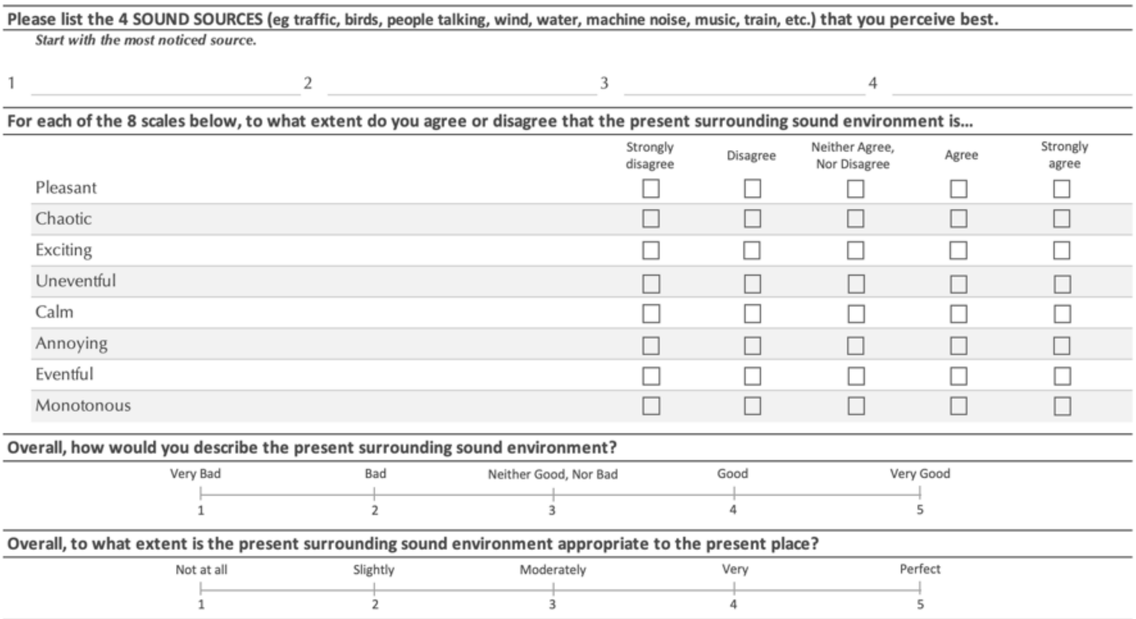
Figure 5.30: Inquiry first part: public space assessment, waterfront proximity and sound environment influence, and waterfront sounds importance.

Next, the second and third questions of the inquiry aimed to know the degree of influence that some features of the public space, namely its “waterfront proximity” and its "sound environment", on the decision of the user to visit and used the place.

Lastly, the fourth question was drafted based on the ´Distinctive’ quality, described in subitem 2.2.3, which was referred by Carmona et al. (2008) as a positive quality for the public spaces, in which a stimulating sound can provide an identifiable character to the public space. Therefore, the question seeks to get the respondent’s opinion regarding the degree of importance that he/she assigns to some specific sounds, that usually characterize an acoustic environment of a waterfront area, such as sounds of the water, seagulls, boats, and piers, independently of they were being perceived on the site.

(ii) Soundscape quality measurement

The inquiry’s second part, shown in Figure 5.31 was arranged especially focusing on the data collection regarding the user perception about the sounds and the sound environment of the sites, based mostly on the ISO 12913-2 (2017).



Please list the 4 SOUND SOURCES (eg traffic, birds, people talking, wind, water, machine noise, music, train, etc.) that you perceive best.

Start with the most noticed source.

1 ____ 2 ____ 3 ____ 4 ____

For each of the 8 scales below, to what extent do you agree or disagree that the present surrounding sound environment is...

	Strongly disagree	Disagree	Neither Agree, Nor Disagree	Agree	Strongly agree
Pleasant	☐	☐	☐	☐	☐
Chaotic	☐	☐	☐	☐	☐
Exciting	☐	☐	☐	☐	☐
Uneventful	☐	☐	☐	☐	☐
Calm	☐	☐	☐	☐	☐
Annoying	☐	☐	☐	☐	☐
Eventful	☐	☐	☐	☐	☐
Monotonous	☐	☐	☐	☐	☐

Overall, how would you describe the present surrounding sound environment?

Very Bad 1 — Bad 2 — Neither Good, Nor Bad 3 — Good 4 — Very Good 5

Overall, to what extent is the present surrounding sound environment appropriate to the present place?

Not at all 1 — Slightly 2 — Moderately 3 — Very 4 — Perfect 5

Figure 5.31: Inquiry second part: sounds perception and sound environment assessments.

Firstly, based on the standard recommendations, the acoustic environment of the site should be characterized with the identification of the sound sources that were heard. Therefore, on the first question, the user is requested to list those sounds that he/she perceived best, on a decreasing order, starting with the most noticeable ones.

On the sequence, the user should establish his/her level of agreement to each one of the eight presented qualities listed for the sound environment, '*pleasant*', '*annoying*', '*calm*, '*chaotic*', '*exciting*', '*eventful*', '*uneventful*' and '*monotonous*'.

The adjectives, named "perceived affective qualities", are considered as soundscape attributes which will compose the measurement system for soundscape quality, according to the ISO 12913-2 (2017) recommendation. The degrees of agreement can be represented in a two-dimensional space, with the "Pleasantness" and the "Eventfulness" components, defined by Axelsson, Nilsson, & Berglund (2010) as the basic components of the soundscape perception.

Besides, on the third question, the respondent should evaluate the overall sound environment according to a five-point ordinal-category scale, from "*very good*" to "*very bad*", to compose the measurement system for soundscape quality.

Lastly, the soundscape quality measurement recommended by the standard was completed with the establishment of the degree of "*appropriateness*" that the site's sound environment has with the place itself.

(iii) User practices

The third part of the questionnaire aimed at getting information about the user' practices regarding the use of the waterfront site (Figure 5.32), such as the frequency and time length he/she uses the site, his/her main motivation to visit it and his/her social interaction on it.

How often do you use this space?	How long do you STAY on average in this space?	What was the main reason that led you to CHOOSE this space?	Who do you use this space with?
☐ Daily	☐ Between 10 to 30 minutes	☐ Sport	☐ Alone
☐ 2-4 times a week	☐ Between 30 to 60 minutes	☐ Contemplate	☐ Accompanied + 1 person
☐ Once a week	☐ Between 1 to 2 hours	☐ Hang out	☐ Accompanied by 2 people or +
☐ 2-4 times a month	☐ More than 2 hours	☐ Recreation	☐ In family
☐ 1 time per month		☐ Rest / Relax	
☐ Rarely		☐ Pass trought	
☐ First Time			

Figure 5.32: Inquiry third part: User behaviour on Site.

(iv) User's profile

Lastly, the fourth and last part of the inquiry aimed at knowing data about the profile of the site' user such as his/her gender, age, education, and occupation (Figure 5.33).

GENDER	AGE RANGE	EDUCATION LEVEL	OCCUPATION
☐ F	☐ 15 - 19 years	☐ Basic education	☐ Student
☐ M	☐ 20 - 29 years	☐ High school	☐ Worker
☐ Other	☐ 30 - 49 years	☐ University education	☐ Retired
	☐ 50 - 64 years		☐ Unemployed
	☐ over 65 years		

Figure 5.33: Inquiry fourth part: User data.

5.4.1.1. Inquiry application

The questionnaire's application to the Tejo's waterfront site users was carried out during the same periods when the sound levels were measured, and the sound environment samples were recorded.

People were randomly selected to answer the questionnaire, regardless of their socio-demographical profile and of their activities on the site.

People with hearing issues or disabilities were not considered to be adequate to answer the questionnaire since most of its questions were related with auditory perceptions of the respondents. However, since the inquiry was applied on outdoor space, there was no proper way to test the participants hearing, so the users sorting was entrusted to the interviewer sensibility, when approaching the interviewees.

Questionnaires were personally handed to the site users to be answered preferably autonomously with a minimum of interference. The inquiries applied on this way were seen to provide more freedom and time for the respondent to think about each question and carry out the connections he/she assumed necessary. This is in line with the ISO 12913-2 (2017) standard recommendations: "When gathering data on human perception, the investigator should not interfere with the participants' experience. Such data collection shall capture the general mood, restoration, appreciation, preferences, and overt behaviour to create an accurate representation of a specific location. Moreover, this type of evaluation shall respect the way people are experiencing their environment. (...) The final assessment shall be holistic, covering all auditory sensations as well as all other context variables such as visual stimuli and personal expectations."

Due to the feeling of insecurity generated by the risk of contagion by the coronavirus during the period in which the surveys were applied (see section 5.1.1), alternatively to the printed questionnaires, an online form with the same questions was devised, that could be accessed through a Quick Response Code (QR code) and autonomously answered.

5.4.1.2. Inquiry data processing

(i) Five-point Linkert scale

For the analysis of the collected responses and subsequent comparisons, according with the ISO 12913-3 (2019), a score between 1 and 5 should be assigned to the response categories with a five-point Linkert scale. Therefore, different scale values were attributed according to the level of agreement with the specific item/attribute, in which the score "1" was assigned to the lowest level of agreement, and the score "5" was consequently assigned to the highest one, as the example in Table 5.6.

Table 5.6: Example of score adopted for each Likert Scale attribute.

Variable	Question	Score	Atribute
Sound Environment: Overall	Overall, how would you describe the present surrounding SOUND ENVIRONMENT?	1	Very Bad
		2	Bad
		3	Neither Good, Nor Bad
		4	Good
		5	Very Good
Sound Environment: Appropriateness	Overall, to what extent is the present surrounding sound environment APPROPRIATE to the present place?	1	Not at all
		2	Slightly
		3	Moderately
		4	Very
		5	Totally

(ii) Sound source perceived ranking

- *Sound sources - classification*

The sound sources perceived by the site's users were to be compared later with the answers obtained with the laboratory listening panel (see section 7.2).

However, to make the data obtained from both methods comparable, once the perceived sounds on the sites were listed by free-text answers, firstly, a classification of these responses considering the same categorization applied on the laboratory panel was necessary.

Therefore, a classification was established, following Table 5.7 criteria, mostly based on ISO 12913-2 (2017) orientation, but introducing the "waterfront sounds" category, in line with the research objectives.

Table 5.7: Classification of the sound sources

Waterfront Sound	Natural Sound	Human Sound	Traffic Sound	Other Sound
boat	birds	ball	airplane	alarm
boat whistle	cicada	palms	bus	ambulance
pier	dog barking	people	cars	bicycle
seagull	wind	sneeze	helicopter	construction
water		whistle	motorcycle	drag objects
			train / tram	kiosk operation
			truck	music
			tuktuk	scooter

On the sound source classification for an urban acoustic environment guided by the ISO 12913-2 (2017), there are the "sounds not generated by human activities", also named "sounds of nature" and, the "sounds generated by human activities", that can be distinguished between "sounds of human beings" and "sounds of technology", which, in turn, can be divided into "traffic sounds" - sounds from means of transport – and "other sounds" - sounds from industry.

In addition to the classification in the ISO, the "waterfront sounds" category was devised, since it is important for the research purposes to know how much these sounds, that usually characterize waterfront areas, are perceived. Therefore, the sounds of boats and pier, which are classified as sounds of technology, and the sounds of seagulls and water, regarded as sounds of nature, were then classified as "waterfront sounds".

- *Sound sources - perception order weighting*

In addition of the categorization, it was also found necessary to attribute more importance to the established ranking order of the sound sources, setting out more weight to those which were perceived best.

In this sense, a weighting criterion was conceived which consists of attributing different scores according to the perception order established, in which the highest score (100%) was assigned to the first best perceived sound source, a medium score (80% and 60%) to the second and third ones, and the lowest score (40%) to the fourth.

A practical example of the weighting is shown in Table 5.8, where the values from the second until the fifth column, group (i), represent the number of listeners who ranked the specific sound source respectively as the first, second, third, or fourth best perceived. For instance, the "waterfront sounds" were considered as the first sound source best perceived by 9 panel listeners, as the second by 2 listeners, as the third by 1 and as the fourth by 4.

Table 5.8: Tutorial to recoding the sound sources ranking established by listeners.

	Public Space 7									
	Sound Source Perceived Ranking				Ranking Order Recoded				Total Recoded each Sound Source	Percentual
	1st (*100%)	2nd (*80%)	3rd (*60%)	4th (*40%)	1st	2nd	3rd	4th		
Waterfront Sound	9	2	1	4	9,0	1,6	0,6	1,6	12,8	18,4%
Natural Sound	0	0	1	1	0,0	0,0	0,6	0,4	1	1,4%
Human Sound	0	16	7	3	0,0	12,8	4,2	1,2	18	26,2%
Traffic Sound	9	4	7	4	9,0	3,2	4,2	1,6	18	25,9%
Other Sound	8	4	9	7	8,0	3,2	5,4	2,8	19	28,0%
	(i)				(ii)				(iii)	(iv)

The values from the sixth to the nineth column, group (ii), represent the weighting applied, in which the numbers of listeners were multiplied by the factors 100%, 80%, 60% and 40% respectively according to the perceived order. Then, the tenth column (iii) shows a sum of the values weighted for each sound source category. Lastly, the eleventh column (iv) presents the percentages obtained which means the contribution of every sound source category on the acoustic environment, according to the user perception.

In this sense, in the example, it is possible to note that, despite "traffic sounds" and "waterfront sounds" being the first sound sources more perceived categories, through the weighting criteria, the “traffic sounds” have become more representative of the sound environment, together with the “human sounds” and the “other sound”.

5.4.2. Laboratory listening panel

The listening panel was devised in order to obtain a subjective assessment regarding the sound environments of the waterfront sites, in a laboratory environment. Essentially, it was aimed at knowing from the panel, composed by non-acoustic experts and not necessarily familiar with the waterfront sites, the sound sources they best perceived by listening to the sound recordings.

Initially, the panel was intended to be set up within a laboratory environment, with appropriate facilities and means, such as an anechoic chamber and loudspeakers, as to provide an insulated space and a realistic audio reproduction. However, due to the pandemic situation, the university laboratories were closed and even when they opened adequate health safety conditions could not be assured for a proper panel implementation.

Therefore, since this was considered an important stage of the research project, the listening panel was adapted for a safe environment for the participants. In this sense, (i) the sound environment of each site needed to be characterized and prepared, and (ii) an on-line form was structured and built, for an individual and autonomous assessment by the panel.

(i) Sound environment characterization

For the panel implementation, the various sound recordings needed to be summarized in a single audio sample for each site, that could represent its sound environment according to its temporal sound composition.

Firstly, at the IST Acoustics laboratory environment, each sound recording was analysed using the computer program “Audacity”, in order to characterize the sound environment of each site, by record the sound sources categories perceived and the time period they remained being noted. By using that software, as shown in Figure 5.34, (i) the changes on the sound time history of each recording could be observed through the visual information of its sound wave, and then (ii) each sound source perceived could be identified, aided by the annotations carried out *in-situ*, from the exact instant when it started to be noted until when no longer could be perceived.

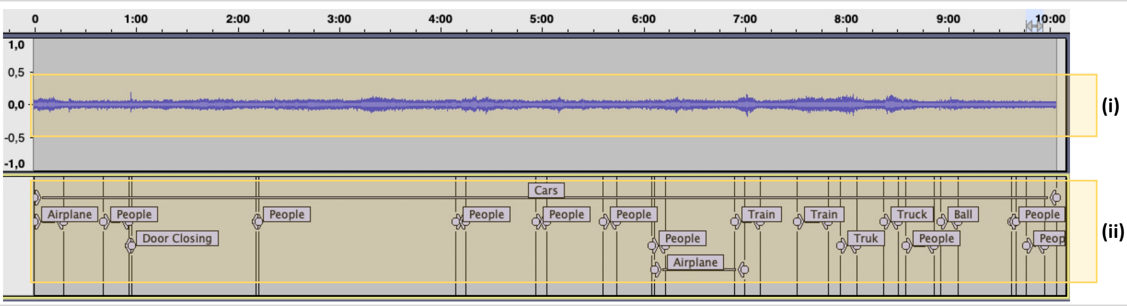


Figure 5.34: Sound recorded, and sounds labelled by Audacity Software.

Subsequently, the sounds identified by their sound sources name were classified among the five categories established for the research, following the same criteria of Table 5.7.

Hence, considering the sound sources categories and the time period each one was perceived on the recording, (i) the percentage of the recording time of every category was calculated, as shown by the example of Site 9 in Table 5.9, (ii) to then calculate an average of the percentages of the categories and obtain the temporal sound composition of the sound environment of each site.

Table 5.9: First step: sound environment characterization. Example of the mean calculation of each sound source perceived from the recordings - Site 9

Site 9						
Recordings	**Waterfront Sound**	**Natural Sound**	**Human Sound**	**Traffic Sound**	**Other Sound**	
1	100,0%	0,0%	100,0%	100,0%	0,0%	**(i)**
2	3,3%	0,0%	17,4%	100,0%	5,8%	
3	100,0%	0,4%	21,8%	100,0%	1,1%	
4	2,9%	0,5%	41,1%	100,0%	0,0%	
5	100,0%	1,6%	3,5%	100,0%	8,0%	
7	15,7%	0,3%	12,5%	100,0%	10,3%	
Mean	**53,6%**	**0,5%**	**32,7%**	**100,0%**	**4,2%**	**(ii)**

(ii) On-Line form

For the on-line form application, short videos were composed for each site, with an approximate duration of 1 minute and 45 seconds each, by combining the audio sample and a sequence of six representative photos of the place, as in the example of Figure 5.35. The photographs aimed to provide visual information of the site, such as its characteristics, its surrounding environment and, mainly, its relationship with the water.

Figure 5.35: Visual information about the Site 1, to complement the audio sample, showed by a video to the panel.

The videos were complemented by an online form to be filled by the listener sequentially after the presentation of each site. The form asks for the four sound sources categories which the respondent perceived best by watching the video with the sound environment recording composed, starting from the most relevant ones as shown in Figure 5.36.

Please select the 4 SOUND SOURCES that you perceive best. *

	WATERFRONT	NATURAL	TRAFFIC	OTHER	NENHUM
1st Sound Source	○	○	○	○	○
2nd Sound Source	○	○	○	○	○
3rd Sound Source	○	○	○	○	○
4th Sound Source	○	○	○	○	○

Figure 5.36: Question of the electronic form about the sound sources perceived on video of each site.

For an appropriate sound source categorization, the listener was previously introduced by an orientation regarding its classification, as shown in Figure 5.37, in line with the criteria previously established in Table 5.7.

Figure 5.37: Orientation for the sound source classification to answer the electronic form.

5.4.2.1. Listening panel application

The listening panel was composed by invited participants, non-acoustical experts, with different socio-demographical characteristics, such as gender, age, occupation, and education. The participants were sent an e-mail with the video, the link for the online form access and a tutorial which explained how to autonomously perform the assessment.

As participants were supposed to have a good hearing, since auditory accuracy was required, the listener's hearing ability was entrusted to a self-declaration at the moment when he/she agreed to participate in the panel.

For a proper evaluation with a minimum of interference, and to perceive the sound environment of the sites as clear as possible, the listener was asked to reproduce the video by a computer or a cell phone, and to use a headphone.

5.4.2.2. Listening panel data processing

Following the assessment of all sites, the online form filled by the listening panel was sent automatically.

The order of perception of the different sound sources for each site, in the same way as on the "inquiry data processing", must be weighted to attribute more importance to those categories perceived best. Therefore, different scores were established, since the first sound source category, with the highest one (100%), to the fourth category, with the lowest one (40%) using the same method illustrated by Table 5.8.

Hence, through the weighting, the results from the listening panel became comparable with the inquiry responses.

5.5. STAGE 4: SOUNDSCAPE ANALYSIS

At the soundscape analysis work stage, the Information collected on the previous stages were compared, analysed, and discussed, to identify potential relationships that may be significant to the establishment of objective criteria for the analysis, planning and design of urban waterfront soundscapes.

Therefore, at first, the results obtained from the data collected were analysed and compared, in order to find different relations and to contribute to the direction the subsequent comparisons.

The analyses have been carried out site by site, and in whole Tejo waterfront studied, so as to understand both the segmented results and the overall results obtained.

The comparisons were carried out in different ways, whether by using tables, graphs, or maps. The results were compared among the sites, to detect the differences in users, behaviours, evaluations, and perceptions, and among the different evaluations, to denote the preferences of the sites' users.

After firsts analyses, other comparisons were carried out in order to find the significant relationships between the sound environments evaluations and the other data collected through the inquiry, an also, to find differences between the data obtained through the inquiry applied and those ones obtained through the listening panel.

The comparisons followed essentially three different methods, according to the results and discussions presented: (1) through graphs and tables - so as to compare the different evaluations and perceptions, and to compare the evaluations obtained through the inquiry with those ones obtained through the panel (2) through maps of the study areas - so as to compare the sound sources best perceived, both by the users and by the panel, with the relationships the sites have with the water (3) through statistical analysis - so as to also compare the different evaluations and perceptions, and to compare other data that were being exposed along the analysis process.

The statistical analyses were carried out aiming to obtain empirical evidence of the relationships. The Spearman's rank correlation was used to measure the degree of association between two variables, following the ISO 12913-3 (2019) standard recommendations, in which the coefficient ($r_{spearman}$) was calculated and the statistical significance of the correlation was determined. In addition, Cross-tabulations, Chi-Squared

Independence Test and Cramer's V Test were also used to analyse some nominal data established along the analysis process.

The IBM SPSS Statistics base 26.0 software was used to set up a general database of all the subjective and objective information collected, and also, to proceed with the statistical analysis.

The 'overall sound environment assessments' and the 'sound environment appropriateness assessments' were the first evaluations of the sound environments compared, considering that they are the most important issues of the measurement system for soundscape quality, in which from them it is possible to understand directly how the sound environments are appreciated. Subsequently, both evaluations were compared with the other evaluations which are also related with the sounds and the sound environment.

Next, all these sound environment evaluations were than compared, in a sequence, with: (1) the quantitative data - essentially, the acoustic parameters measured (2) the qualitative data – the users' social demographical data and their practices, the "soundscape" and the "landscape" influence on people decision to visit the place, and the evaluations of the quality of the sites.

Lastly, a comparison between the result of the best perceived sound sources obtained through the inquiry applied and those ones obtained through the listening panel was carried out, in order understand and analyse the perceptive differences between both the users and the panel.

SITE 1 – TERREIRO DAS MISSAS AREA

Figure A.1: Site 1 - Terreiro das Missas area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

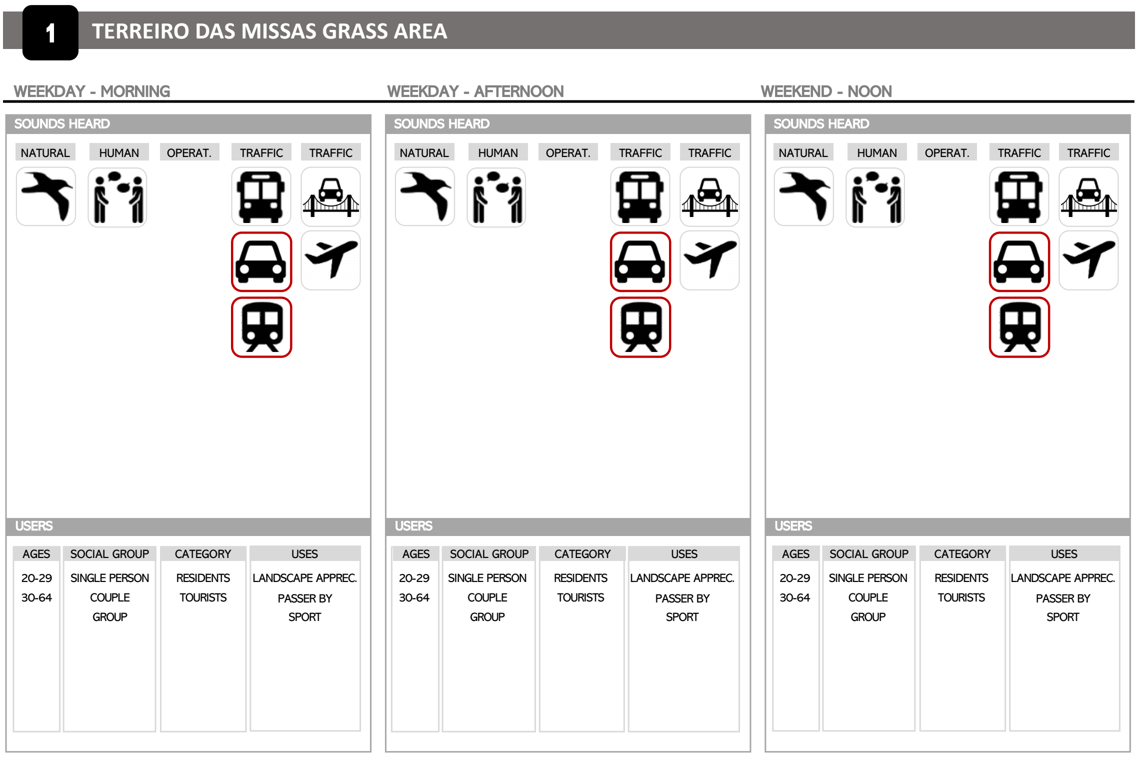


Figure A.2: Site 1 - Terreiro das Missas area – area characterization.

Table A.1: Site 1 - Data collect Terreiro das Missas area.

SITE 1 – TERREIRO DAS MISSAS AREA	
PHYSICAL FEATURES	
Built Environment:	There are no near buildings.
Urban Facilities:	There is nothing.
Urban Furniture:	Wood benches.
Points of interest:	Grass area with trees' shadows.
Characteristics Constructive:	There is nothing.
Natural Features:	Area coated with grass and some large trees that provide shadow to the local.
Means of Transportation:	Close (less than 500 meters away): Brasilia Avenue – heavy traffic: mainly cars and some buses.
	Close (less than 500 meters away): Belém train Station
	Local: pedestrians, scooters and bicycles.
	Close (less than 500 meters away): Fluvial Station
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and trains crossing the bridge. Heard: boat, airplane and train noise.
Natural sounds	Heard: birds.
Human sounds	Heard: people chatting.
Operational sounds	There is nothing.
USERS DATA	
Age:	Majority young people and adults.
Social Group:	Practically only residents are area users.
Uses:	The area is mostly used to rest on the grass, below the trees' shadows, and sports activities.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
Birds are better heard while there is less traffic movement, majority on the mornings and on weekends.	

SITE 2 - ESTAÇÃO FLUVIAL DE BELÉM AREA

Figure A.3: Site 2 - Estação Fluvial de Belém area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

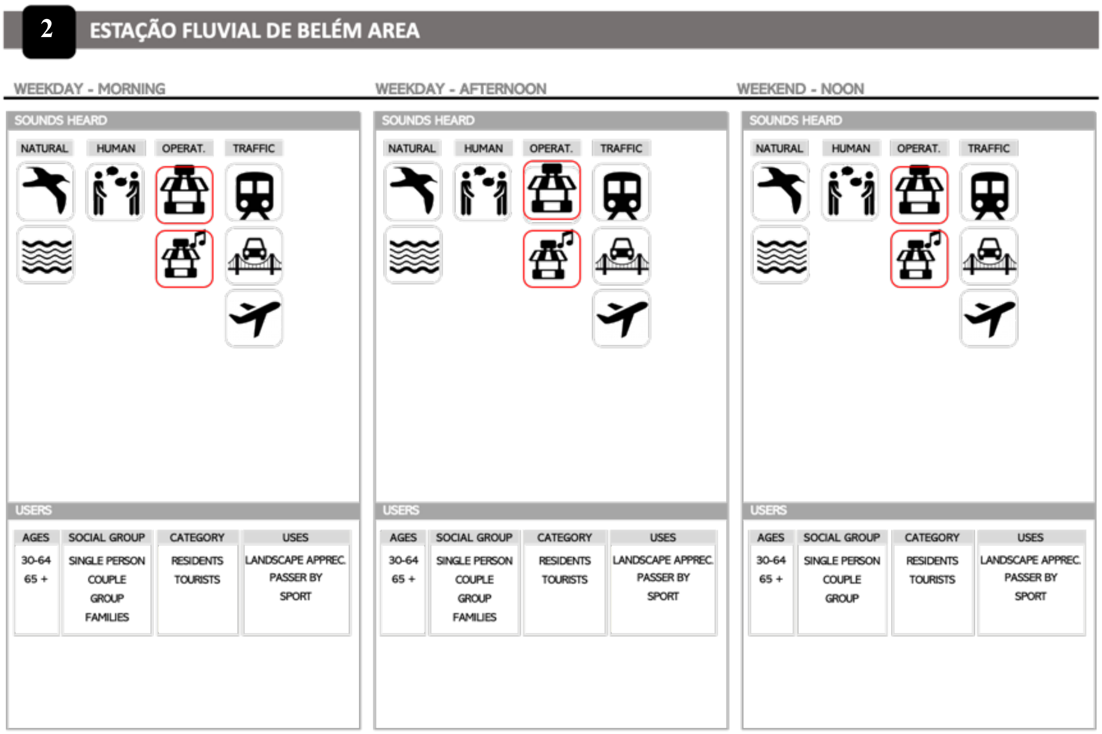


Figure A.4: Site 2 - Estação Fluvial de Belém area – area characterization.

Table A.2: Site 2 - Data collect Estação Fluvial de Belém area.

SITE 2 - ESTAÇÃO FLUVIAL DE BELÉM AREA	
PHYSICAL FEATURES	
Built Environment:	East: one floor building - Fluvial Station
	Other sides: There are no near buildings.
Urban Facilities:	Fluvial Station and Kiosk, terrace with chairs, tables and sunshades.
Urban Furniture:	There is nothing.
Points of interest:	Fluvial station and kiosk with view of river landscape
Characteristics Constructive:	Along the river, the pedestrian walkway is stones floor covering and on its side, there is an asphalt paving street for motor vehicles. Also, there is one building (the Fluvial Station with the kiosk) inside the area.
Natural Features:	Behind the Fluvial Station there is area coated with grass and some large trees. But this area is not often used and don´t have the river view.
Means of Transportation:	Close (less than 500 meters away): Brasilia Avenue – heavy traffic: mainly cars and some buses.
	Close (less than 500 meters away): Belém train Station
	Local: pedestrians, scooters and bicycles.
	Local: Fluvial Station
SOUNDS HEARD	
Traffic sounds	Heard (low): cars and trains crossing the bridge.
Natural sounds	Heard: birds and water sound.
Human sounds	Heard: people chatting.
Operational sounds	Heard (any weekday and daytime): kiosk operation and music.
USERS DATA	
Age:	Majority adults and seniors.
Social Group:	Every kind of social group uses the local. The families that frequent the place are not residents.
	Residents usually use the place practicing sports such as running and cycling Majority on the mornings.
	Tourists are the main users.
Uses:	The area is mostly used for water landscape appreciation through the bar. Also, the area is used for sports activities and riding with scooter and bicycles.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	

SITE 3 - MUSEUM OF ART, ARCHITECTURE AND TECHNOLOGY (MAAT) AREA

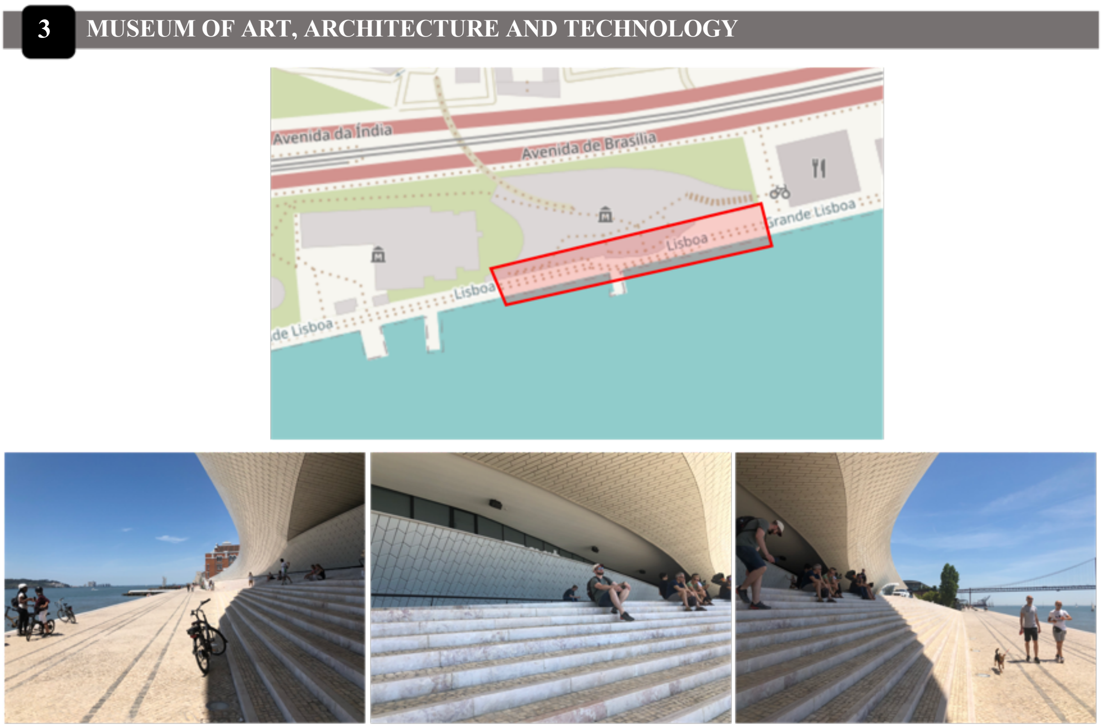


Figure A.5: Site 3 - Museum of Art, Architecture and Technology (MAAT) area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

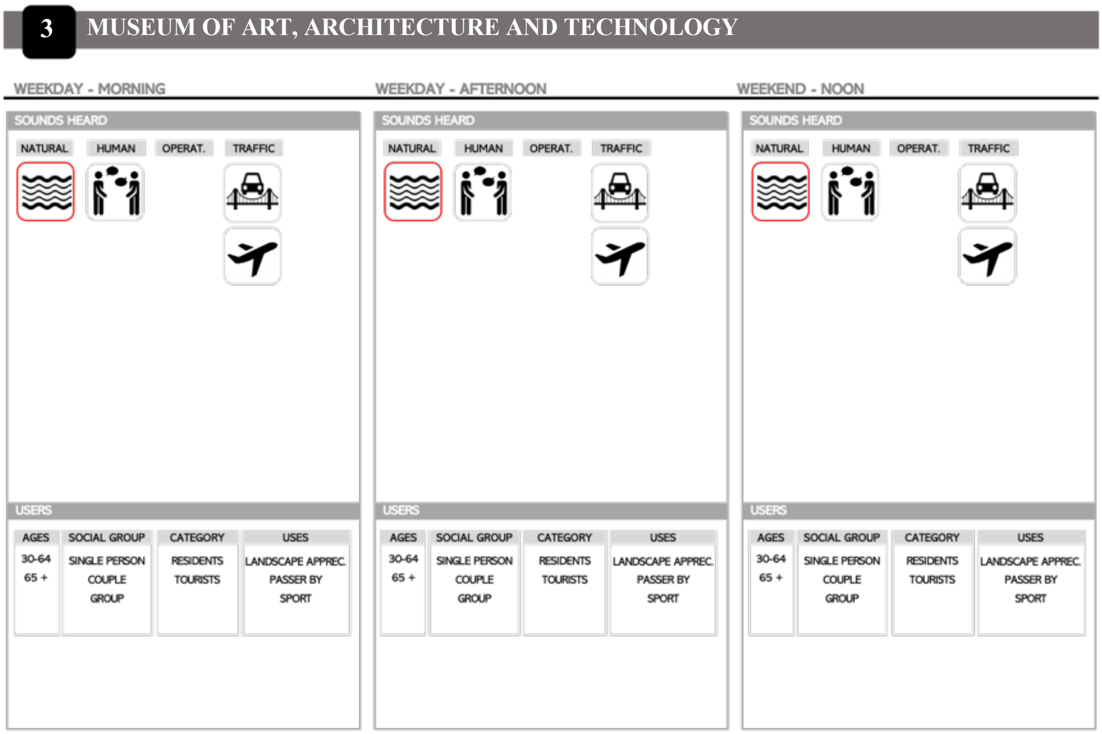


Figure A.6: Site 3 - Museum of Art, Architecture and Technology (MAAT) area – area characterization.

Table A.3: Site 3 - Data collect Museum of Art, Architecture and Technology (MAAT) area.

SITE 3 - MUSEUM OF ART, ARCHITECTURE AND TECHNOLOGY (MAAT) AREA	
PHYSICAL FEATURES	
Built Environment:	North: museum building.
	Other sides: There are no near buildings.
Urban Facilities:	Museum
Urban Furniture:	Longitudinal stone bench on the riverbank.
Points of interest:	Museum and Tejo River view.
Characteristics Constructive:	Recently redefined area, with stones floor covering (like the historical Portuguese's sidewalks), and a longitudinal stone bench on the Rio Tejo waterfront.
Natural Features:	There is nothing
Means of Transportation:	Close (less than 500 meters away): Brasilia Avenue – heavy traffic: mainly cars and some buses.
	Close (less than 500 meters away): Belém train Station
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and trains crossing the bridge. Heard: airplanes.
Natural sounds	Predominance (any weekday and daytime): water sound.
Human sounds	Heard: people chatting.
Operational sounds	There is nothing
USERS DATA	
Age:	Majority adults and seniors.
Social Group:	All types of social group use the place, with the exception of the families.
	Tourists and residents are area users.
	Residents usually use the place for practicing sports such as running and cycling.
Uses:	The area is mainly used to water landscape contemplation on the museum stairs and on the river's edge. In addition, the area is used for sports activities and ride with scooter and bicycles.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
The main sound heard is the natural sound of the water, in spite of constant noise of cars crossing the bridge.	

SITE 4 – JARDIM DOCAS DA PONTE – PART 1

4 JARDIM DOCAS DA PONTE – PART 1

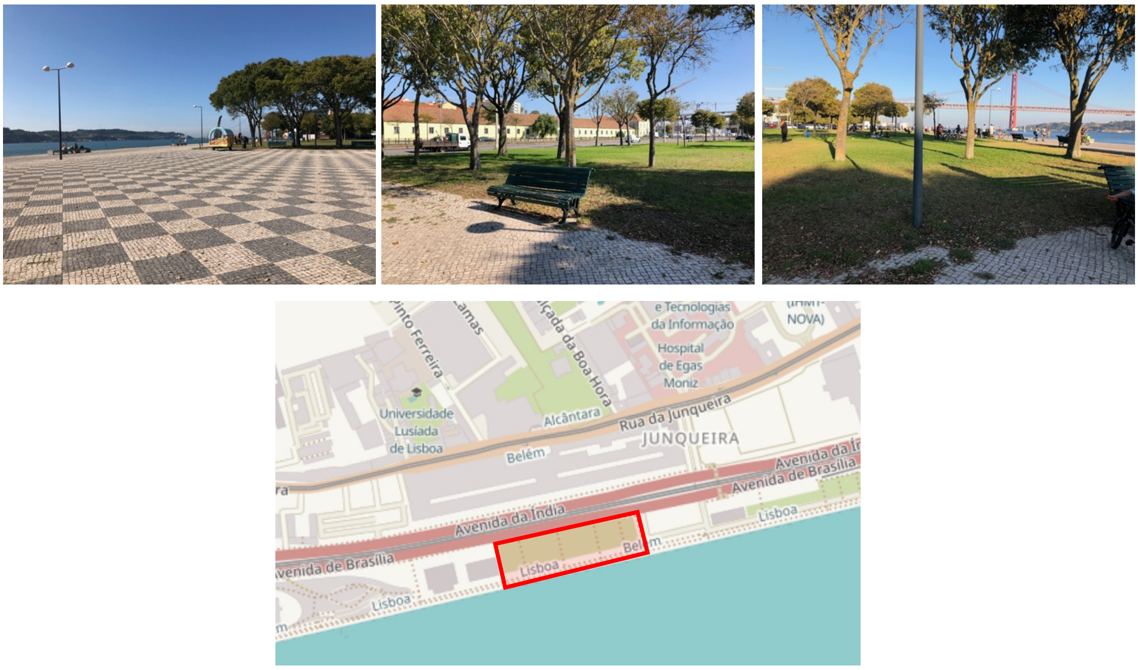


Figure A.7: Site 4 - Jardim Docas da Ponte – part 1 – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

4 JARDIM DOCAS DA PONTE – PART 1

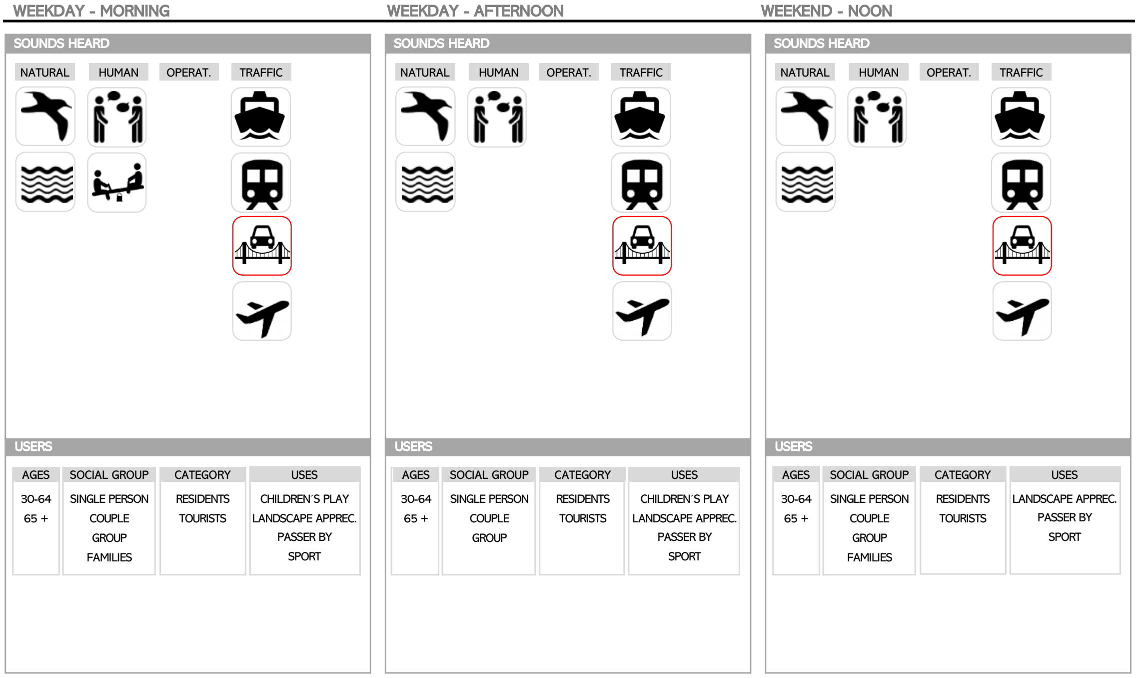


Figure A.8: Site 4 - Jardim Docas da Ponte – part 1 - area characterization.

Table A.4: Site 4 - Data collect Jardim Docas da Ponte – part 1.

SITE 4 - JARDIM DOCAS DA PONTE – PART 1	
PHYSICAL FEATURES	
Built Environment:	There are no buildings close from the area.
Urban Facilities:	Occasional: Mobile Kiosk
Urban Furniture:	Stainless steel benches, cement benches and wood
Points of interest:	Tejo River view
Characteristics Constructive:	Along the river, the walkway is a stone floor covering.
Natural Features:	There is a large area coated with grass and l large trees that provide shadow to the local.
Means of Transportation:	Close (less than 500 meters away): Brasilia Avenue – heavy traffic: mainly cars and some buses.
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and trains crossing the bridge. Heard: boat, airplane and train noise.
Natural sounds	Heard: birds and water sound.
Human sounds	Heard: people chatting and children playing on the grass.
Operational sounds	There is nothing.
USERS DATA	
Age:	Majority adults and seniors.
Social Group:	All types of social group use the place.
	Tourists and residents are area users.
Uses:	Residents use the area for running, cycling and sports activities on the existing grass. On the morning, children students use to play on the grass too. In addition, there are locals and tourists that use the local to appreciate the water landscape.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
The noise of the cars crossing the bridge also occurs all the time on the area, but it is possible more easily hear another transportation sounds like: airplane, train and boats. Besides, birds and water sounds can be heard.	

SITE 5 – JARDIM DOCAS DA PONTE – PART 2

Figure A.9: Site 5 - Jardim Docas da Ponte – part 2– area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author

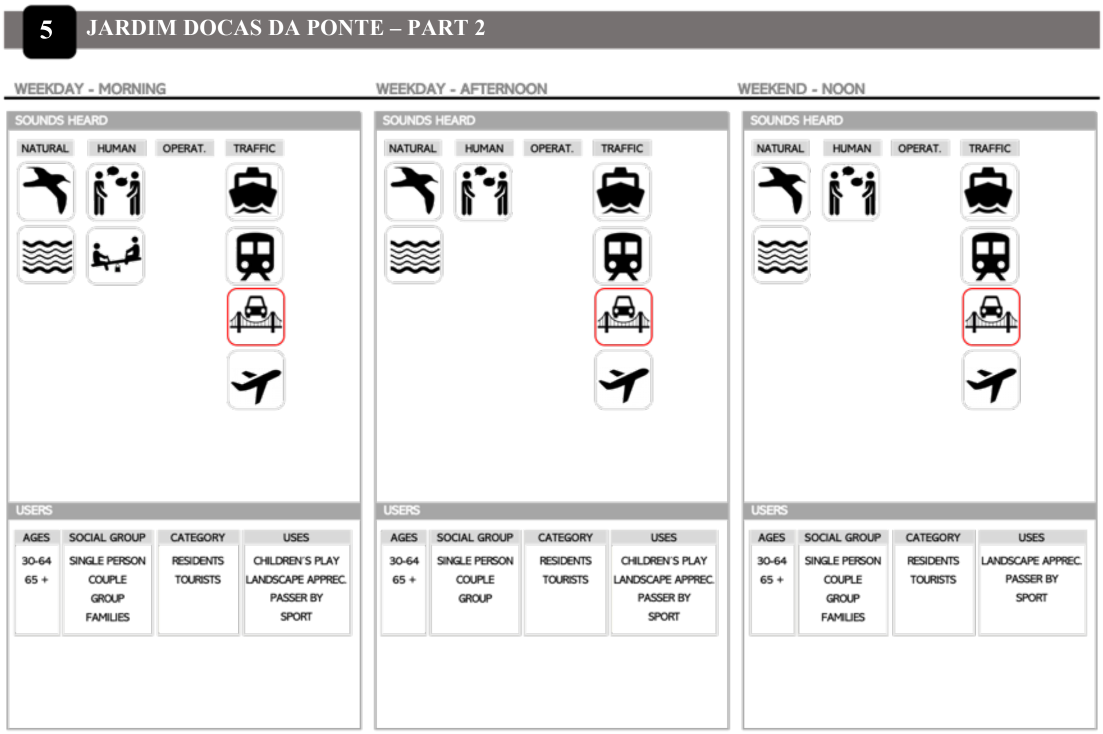


Figure A.10: Site 5 - Jardim Docas da Ponte – part 2– area characterization.

Table A.5: Site 5 - Data collect Jardim Docas da Ponte – part 2.

SITE 5 - JARDIM DOCAS DA PONTE – PART 2	
PHYSICAL FEATURES	
Built Environment:	There are no buildings close from the area.
Urban Facilities:	There is nothing.
Urban Furniture:	Stainless steel benches and cement benches
Points of interest:	Tejo River view
Characteristics Constructive:	Along the river, the walkway is a stone floor covering, and the bicycle trail floor is concrete covering. In part of the area, there is a paved street for motor vehicles. And in there is one building inside the area which is a restaurant.
Natural Features:	There is a large area coated with grass and l large trees that provide shadow to the local.
Means of Transportation:	Close (less than 500 meters away): Brasilia Avenue – heavy traffic: mainly cars and some buses.
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and trains crossing the bridge. Heard: boat, airplane and train noise.
Natural sounds	Heard: birds and water sound.
Human sounds	Heard: people chatting and children playing on the grass.
Operational sounds	There is nothing.
USERS DATA	
Age:	Majority adults and seniors.
Social Group:	All types of social group use the place.
	Tourists and residents are area users.
Uses:	Residents use the area for running, cycling and sports activities on the existing grass. In addition, there are locals and tourists that use the local to appreciate the water landscape.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
The noise of the cars crossing the bridge also occurs all the time on the area, but it is possible more easily hear another transportation sounds like: airplane, train and boats. Besides, birds and water sounds can be heard.	

SITE 6 - JARDIM DE ROQUE GAMEIRO – BENCH AREA

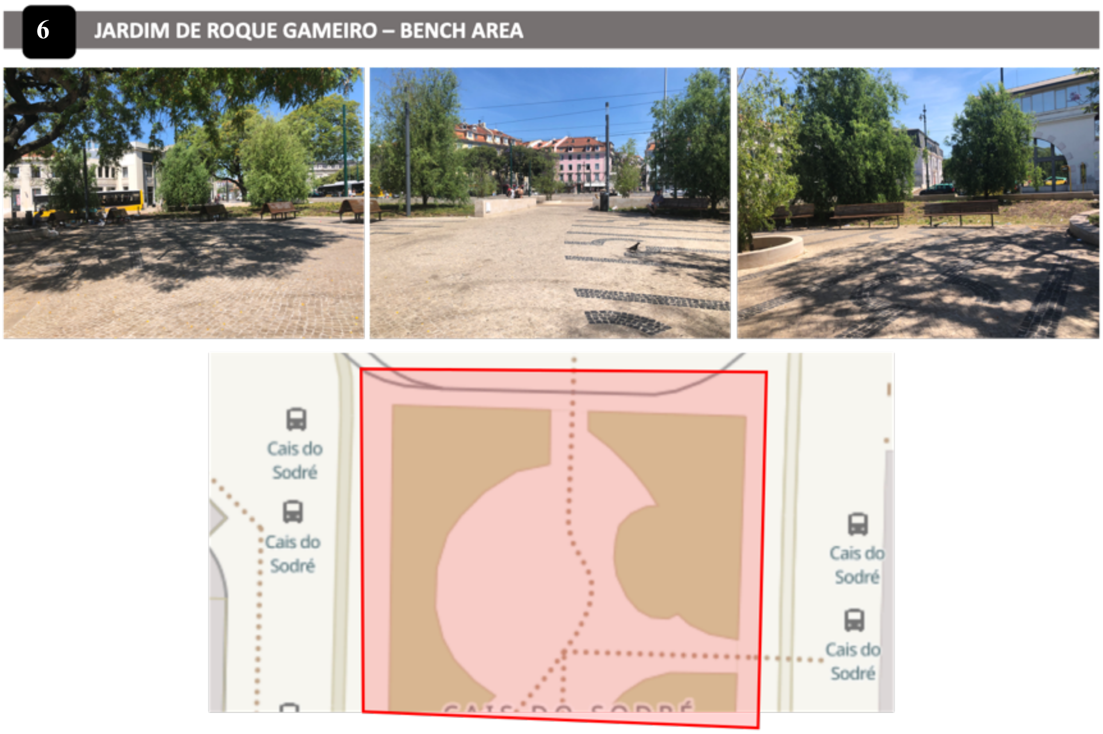


Figure A.11: Site 6 - Jardim de Roque Gameiro – bench area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

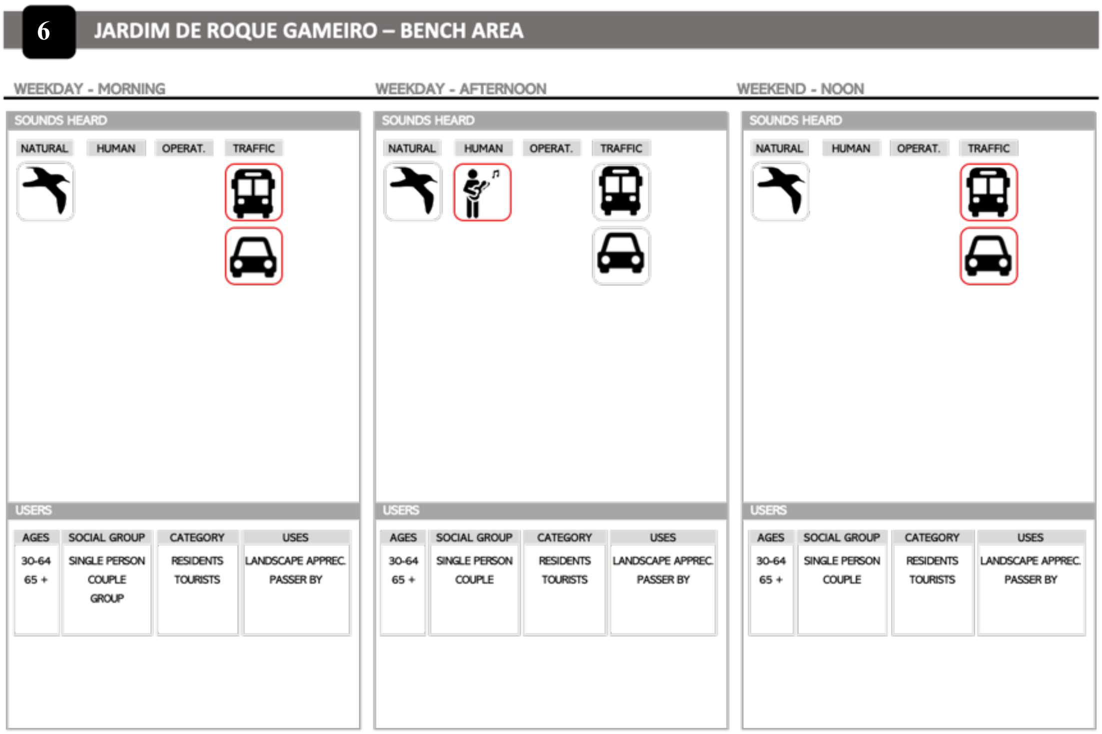


Figure A.12: Site 6 - Jardim de Roque Gameiro – bench area – area characterization.

Table A.6: Site 6 - Data collect Jardim de Roque Gameiro – bench area.

SITE 6 - JARDIM DE ROQUE GAMEIRO – BENCH AREA	
PHYSICAL FEATURES	
Built Environment:	East and West: buildings are not so close from the area because of Cais do Sodré street.
	North: buildings are not so close from the area because of 24 de Julho Avenue.
	South: Roque Gameiro Garden without building, only the kiosk.
Urban Facilities:	There is nothing.
Urban Furniture:	Wood benches.
Points of interest:	Partial view of the Tejo River.
Constructive Characteristics:	Recently redefined area, with stones floor covering (like the historical Portuguese's sidewalks). There is some raised beds and a historical kiosk where bus tickets are sold.
Natural Features:	Raised beds with grass and some large trees that provide shadow to the local.
	Some newly planted trees that are still in small size.
Means of Transportation:	Close (less than 500 meters away): 24 de Julho Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close (less than 500 meters away): bus stop on the Garden surrounding
	Local: pedestrians.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and buses – 24 de Julho avenue.
Natural sounds	Heard: birds - when the traffic sound is low.
Human sounds	Sporadic: People chatting and Musicians playing on Kiosk area.
Operational sounds	There is nothing.
USERS DATA	
Age:	Majority adults and seniors.
Social Group:	The users are alone, couple and two people.
	Practically only residents are area users.
	Tourists' groups uses the area only to passing through to go to another place.
Uses:	The benches and the tree shades provide places to residents (essentially seniors) to get rest and looking at the built landscape. There is a few numbers of people that are passing by the local.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
Although the noise from the 24 de julho Avenue traffic, the area users are used to spent long time in there.	
The soundscape of the place have been changed when there were musicians playing on the kiosk area, because becomes the main sound heard.	

SITE 7 – JARDIM DE ROQUE GAMEIRO – RIVERBANK AREA

Figure A.13: Site 7 - Jardim de Roque Gameiro – riverbank area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

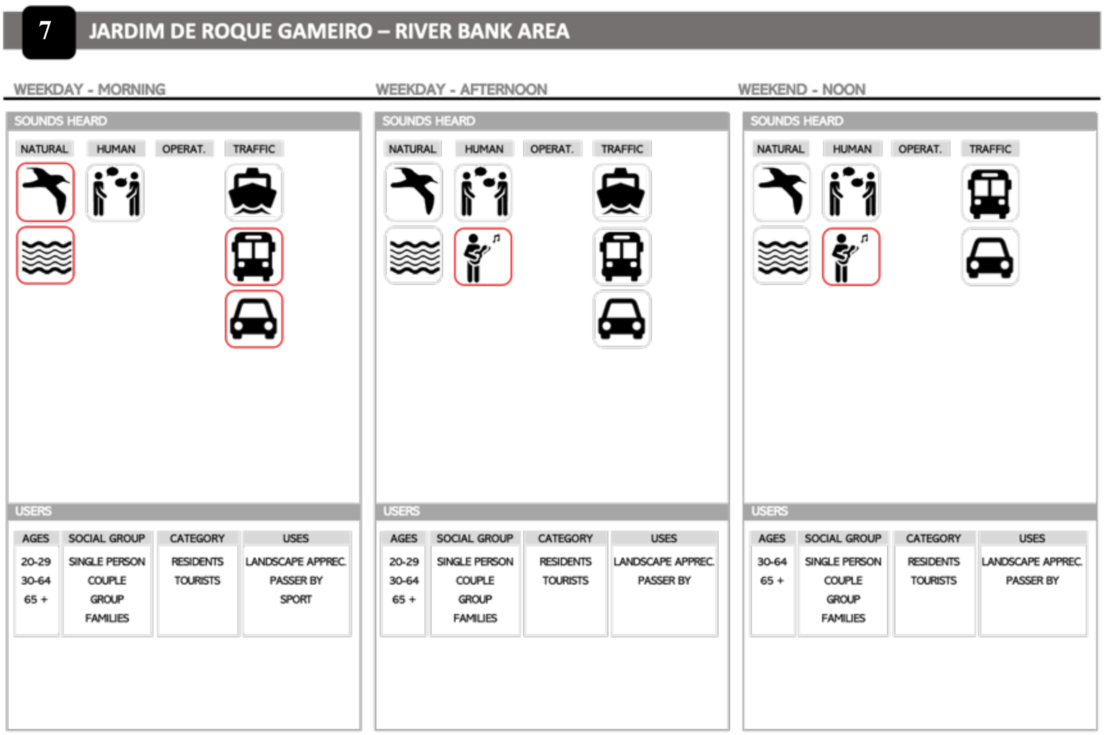


Figure A.14: Site 7 - Jardim de Roque Gameiro – riverbank area– area characterization.

Table A.7: Site 7 - Data collect Jardim de Roque Gameiro – riverbank area.

SITE 7 - JARDIM DE ROQUE GAMEIRO – RIVERBANK AREA	
PHYSICAL FEATURES	
Built Environment:	There are no near buildings.
Urban Facilities:	Occasional: Mobile Kiosk
Urban Furniture:	Wood benches and longitudinal stone benches
	bicycle stands
Points of interest:	Tejo River view
Constructive Characteristics:	Recently redefined area, with stones floor covering (like the historical Portuguese's sidewalks), and a longitudinal stone bench on the Rio Tejo waterfront.
Natural Features:	Some newly planted trees that are still in small size.
Means of Transportation:	Close (less than 500 meters away): 24 de Julho Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close (less than 500 meters away): bus stop on the Garden surrounding.
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): buses on streets garden surrounding. Heard: boat - when the traffic is lower.
Natural sounds	Heard (Majority on the mornings): birds and water - when there is no musicians performing's on the place.
Human sounds	Predominance (any weekday and daytime): people chatting. Sporadic (on some afternoons, and on weekends): musicians playing.
Operational sounds	There is nothing.
USERS DATA	
Age:	Majority young people, adults and seniors. The young people are more often on afternoons and weekends, contrary to the seniors.
Social Group:	All types of social group use the place.
	Tourists' families frequent the place in the morning, while residents' families use on the afternoon. Both are usually passing through the area.
Uses:	The use of the area for sporting activities, like running and cycling, are more often on the mornings, from Monday to Friday. In all time of the day the area is used for water landscape appreciation.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
Birds and water sounds are better heard while there is less bus movement, Majority on the mornings and on weekends.	
The bus noise and the nature sound is less heard while the musicians are playing.	

SITE 8 – RIBEIRA DAS NAUS – TREE AREA

8 RIBEIRA DAS NAUS - TREE AREA

Figure A.15: Site 8 - Ribeira das Naus – tree area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

8 RIBEIRA DAS NAUS - TREE AREA

WEEKDAY - MORNING

SOUNDS HEARD

NATURAL | HUMAN | OPERAT. | TRAFFIC | TRAFFIC

USERS

AGES	SOCIAL GROUP	CATEGORY	USES
15-19 20-29	COUPLE GROUP FAMILIES	RESIDENTS	LANDSCAPE APPREC. PASSER BY SPORT

WEEKDAY - AFTERNOON

SOUNDS HEARD

NATURAL | HUMAN | OPERAT. | TRAFFIC | TRAFFIC

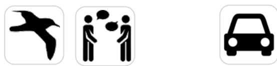
USERS

AGES	SOCIAL GROUP	CATEGORY	USES
15-19 20-29	COUPLE GROUP FAMILIES	RESIDENTS	LANDSCAPE APPREC. PASSER BY SPORT

WEEKEND - NOON

SOUNDS HEARD

NATURAL | HUMAN | OPERAT. | TRAFFIC | TRAFFIC



USERS

AGES	SOCIAL GROUP	CATEGORY	USES
15-19 20-29	COUPLE GROUP FAMILIES	RESIDENTS	LANDSCAPE APPREC. PASSER BY SPORT

Figure A.16: Site 8 - Ribeira das Naus – tree area - area characterization.

Table A.8: Site 8 - Data collect Ribeira das Naus – tree area.

SITE 8 – RIBEIRA DAS NAUS – TREE AREA	
PHYSICAL FEATURES	
Built Environment:	North: Marinha Portuguesa.
	Other sides: There are no near buildings.
Urban Facilities:	There is nothing.
Urban Furniture:	There is nothing.
Points of interest:	Grass area with trees' shadows.
Characteristics Constructive:	There is nothing.
Natural Features:	area coated with grass and some large trees.
Means of Transportation:	Local: pedestrians, scooters and bicycles.
	Local: Ribeira das Naus Avenue – local traffic: individual auto-vehicles, without public transportation.
	Near: boats and train station.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime, except on the weekend): cars - Ribeira das Naus Avenue. Heard: boat - when the traffic is lower.
Natural sounds	Heard (Majority on the mornings): birds - when the traffic sound is low.
Human sounds	Predominance (any weekday and daytime): people chatting.
Operational sounds	There is nothing.
USERS DATA	
Age:	Majority young people.
Social Group:	All types of social group use the place.
	Families are not usually users on any day and period, they are just passing through the area.
	The area is mostly used for water landscape appreciation or for people meetings.
Uses:	Majority young people.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
Birds and seagulls' sounds can be heard more often on the early mornings and on weekends, when the traffic on Ribeira das Naus Avenue is lower.	

SITE 9 – RIBEIRA DAS NAUS – GRASS AREA

Figure A.17: Site 9 - Ribeira das Naus – grass area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

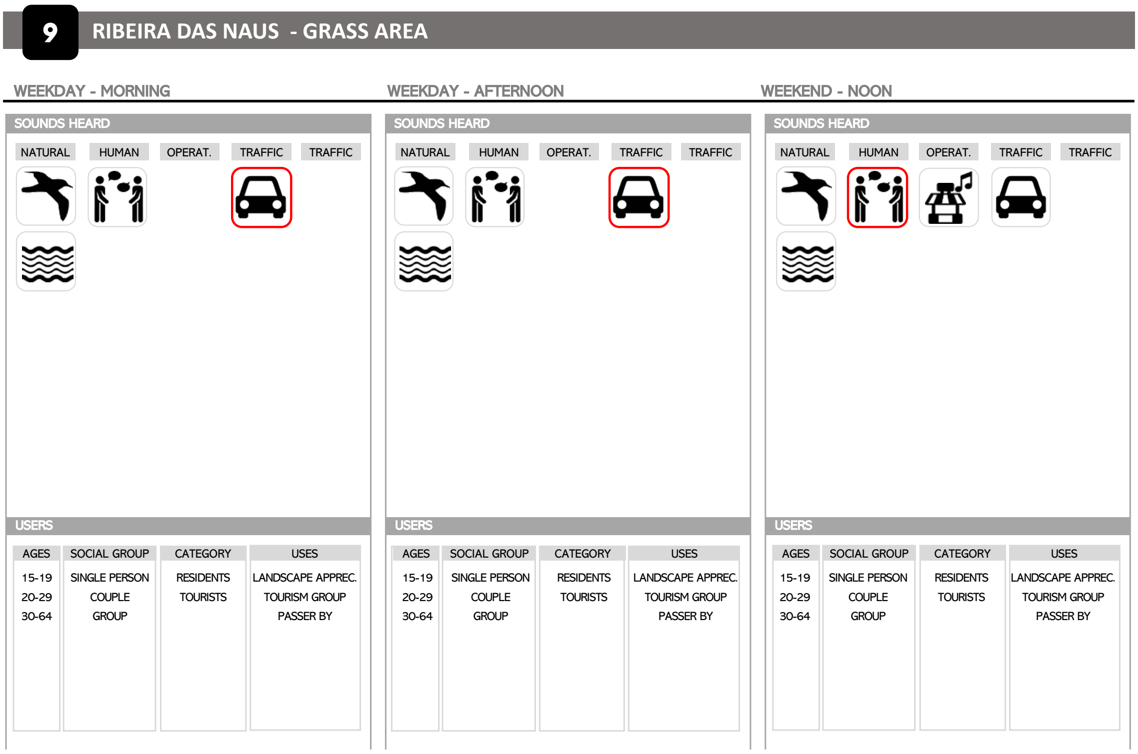


Figure A.18: Site 9 - Ribeira das Naus – grass area - area characterization.

Table A.9: Site 9 - Data collect Ribeira das Naus – grass area.

SITE 9 – RIBEIRA DAS NAUS – GRASS AREA	
PHYSICAL FEATURES	
Built Environment:	North: Marinha Portuguesa.
	Other sides: There are no near buildings.
Urban Facilities:	There is nothing.
Urban Furniture:	There is nothing.
Points of interest:	View of river landscape.
Characteristics Constructive:	two grassy ramps without trees, which slopes towards the river providing an unrestricted view of the water landscape.
Natural Features:	grass area.
Means of Transportation:	Local: pedestrians, scooters and bicycles.
	Local: Ribeira das Naus Avenue – local traffic: individual auto-vehicles, without public transportation.
	Near: boats and train station.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime, except on the weekend): cars - Ribeira das Naus Avenue. Heard: boat - when the traffic is lower.
Natural sounds	Heard (Majority on the mornings): birds - when the traffic sound is low.
Human sounds	Predominance (any weekday and daytime): people chatting.
Operational sounds	There is nothing.
USERS DATA	
Age:	Majority young people.
Social Group:	All types of social group use the place.
	Families are not usually users on any day and period, they are just passing through the area.
Uses:	The area is mostly used for water landscape appreciation or for people meetings.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
Birds and seagulls' sounds can be heard more often on the early mornings and on weekends, when the traffic on Ribeira das Naus Avenue is lower.	

Near: boats

SITE 10a - RIBEIRA DAS NAUS – CENTRE AREA – PART 1

Figure A.19: Site 10a - Ribeira das Naus – centre area – part 1 – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

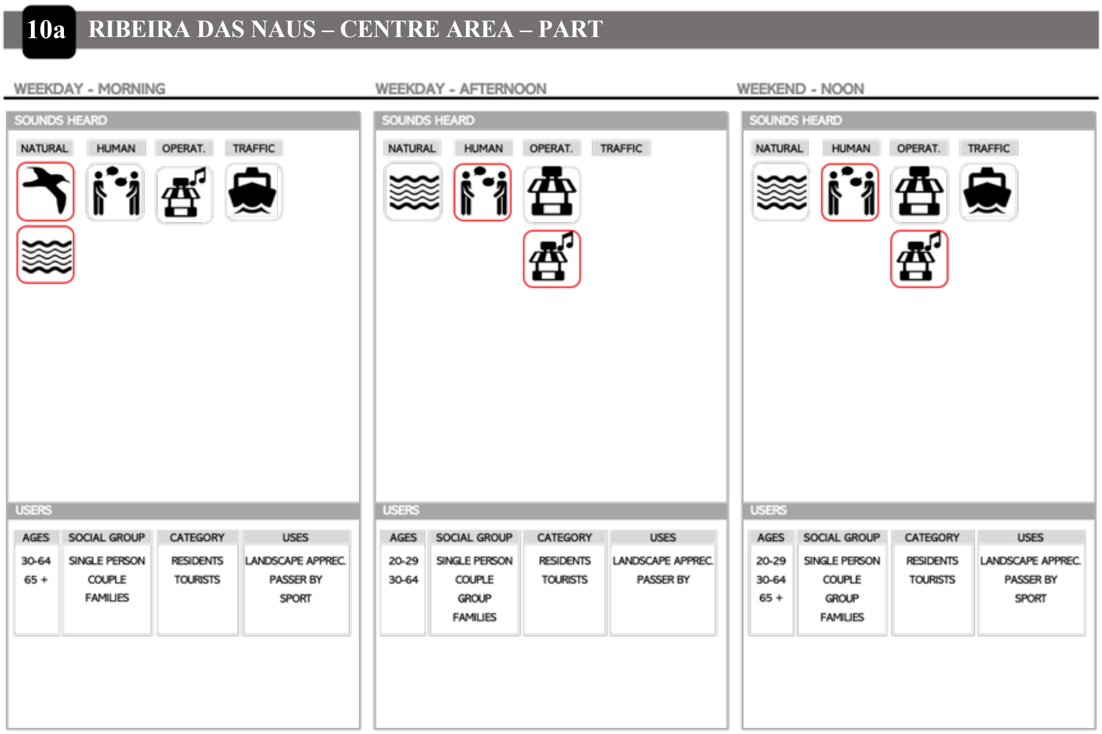


Figure A.20: Site 10a - Ribeira das Naus – centre area – part 1 – area characterization.

Table A.10: Site 10a - Data collect Ribeira das Naus – centre area – part 1.

SITE 10a - RIBEIRA DAS NAUS – CENTRE AREA – PART 1	
PHYSICAL FEATURES	
Built Environment:	West: hotel building with a slab that provides canopy to some kiosk´s chairs and tables.
	North: the existing buildings are not so close (more than 500 meters away).
	Other sides: there are no buildings.
Urban Facilities:	Kiosk and a terrace with chairs, tables and sunshades.
Urban Furniture:	Concrete bench.
Points of interest:	Rio Tejo landscape view and Kiosk area.
Constructive Characteristics:	Recently redefined area, with concrete floor coating and cobble stone (like a historical paving). On the kiosk area there is a wood deck.
Natural Features:	On the kiosk area there is some ornamental plants.
Means of Transportation:	Local: pedestrians, scooters and bicycles.
	Local: Ribeira das Naus Avenue – local traffic: individual auto-vehicles, without public transportation.
	Near: boats and train station.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime, except on the weekend): cars - Ribeira das Naus Avenue. Heard: boat - when the traffic is lower.
Natural sounds	Heard (Majority on the mornings): birds and water - when the traffic sound is low.
Human sounds	Predominance (any weekday and daytime): people chatting.
Operational sounds	There is nothing.
USERS DATA	
Age:	Majority adults, young people and seniors. The young people are more often on afternoons and weekends, contrary to the seniors.
Social Group:	All types of social group use the place.
	Families and residents are not usually users on any day and period, they are just passing through the area.
Uses:	The use of the area for sporting activities, like running and cycling, are more often on the mornings. On the remainder of the time the area is used for contemplation of the water landscape on the existing kiosk.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
Natural sounds of water and birds can be heard while kiosk music is lower and there is also less movement, mainly on the mornings.	

SITE 10b - RIBEIRA DAS NAUS – CENTRE AREA – PART 2

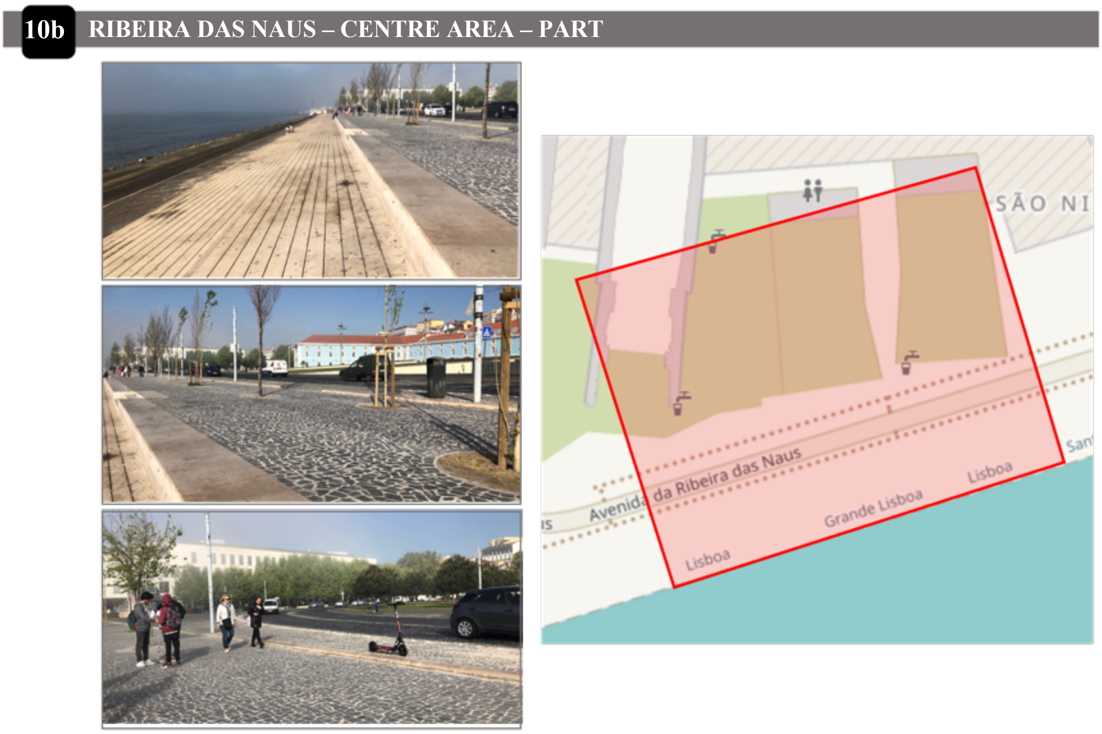


Figure A.21: Site 10b - Ribeira das Naus – centre area – part 2 – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

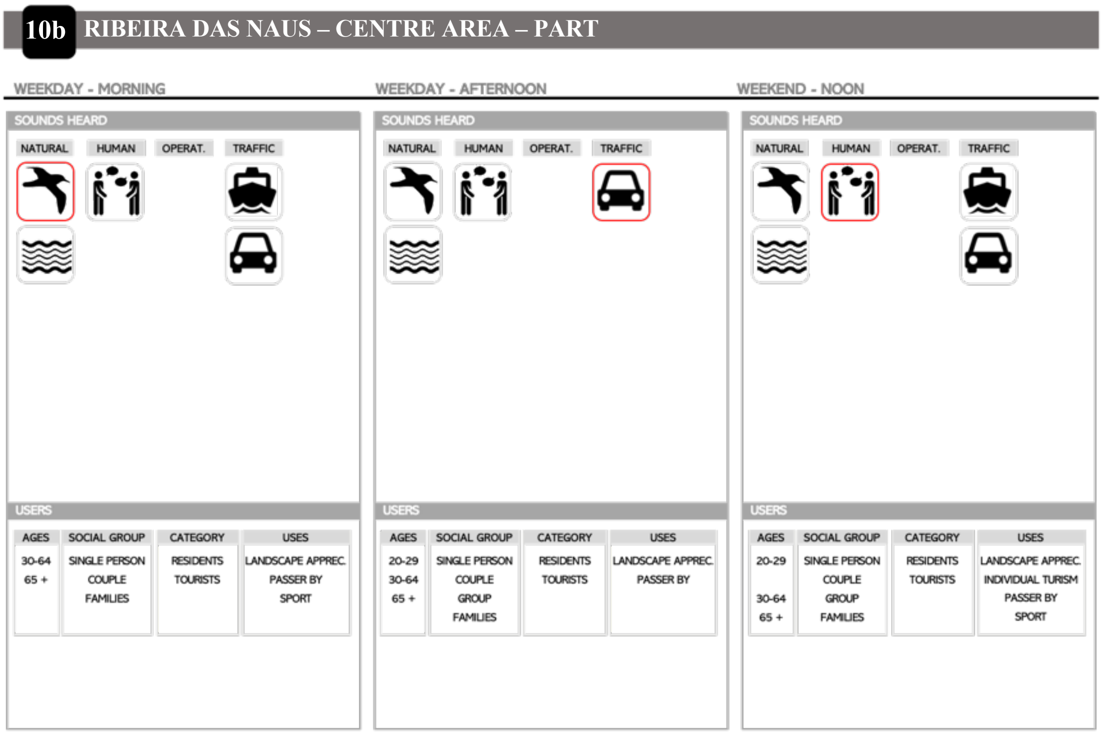


Figure A.22: Site 10b - Ribeira das Naus– centre area – part 2 - area characterization.

Table A.11: Site 10b - Data collect Ribeira das Naus – centre area – part 2.

SITE 10b - RIBEIRA DAS NAUS - CENTRE AREA – PART 2	
PHYSICAL FEATURES	
Built Environment:	North: the existing buildings are not so close (more than 500 meters away).
	Other sides: there are no buildings.
Urban Facilities:	There is nothing.
Urban Furniture:	Stairs with ramp that form a cement bench
Points of interest:	Rio Tejo landscape view.
Constructive Characteristics:	Recently redefined area, with concrete floor coating and cobble stone (like a historical paving).
Natural Features:	Much of the area is covered by grass.
	Some newly planted trees that are still in small size.
Means of Transportation:	Local: Ribeira das Naus Avenue – local traffic: individual auto-vehicles, without public transportation.
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime, except on the weekend): cars - Ribeira das Naus Avenue. Heard: boat - when the traffic is lower.
Natural sounds	Heard (Majority on the mornings): birds and water - when the traffic sound is low.
Human sounds	Predominance (any weekday and daytime): people chatting.
Operational sounds	There is nothing.
USERS DATA	
Age:	Majority adults and seniors.
	On the afternoons and weekends there is young people.
Social Group:	All types of social group use the place.
	Tourists' families frequent the place in the morning, while residents' families use on the afternoon. Both, usually, are passing through the area.
Uses:	The use of the area for sporting activities are more often on the mornings. The grass and the steps on ramps are mainly used for rest and for water landscape view on the afternoons and weekends.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
Birds, water and boat sounds can be heard more often on the early mornings and on weekends, when the traffic on Ribeira das Naus Avenue is lower. Also, on this period of the day, the area is used for residents sporting activities.	

SITE 10c - RIBEIRA DAS NAUS – CENTRE AREA – PART 3

Figure A.23: Site 10c - Ribeira das Naus– centre area – Part 3 – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

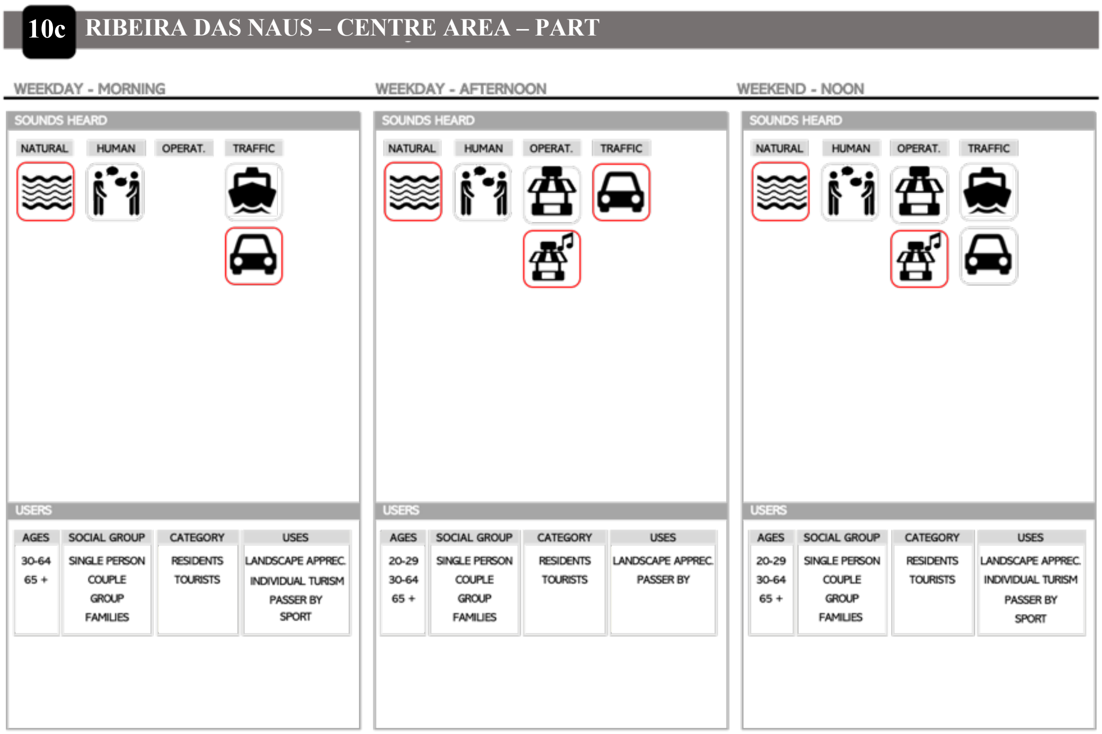


Figure A.24: Site 10c - Ribeira das Naus– centre area – Part 3 – area characterization.

Table A.12: Site 10c - Data collect Ribeira das Naus – centre area – part 3.

LOCAL 10c – RIBEIRA DAS NAUS – CENTRE AREA – PART	
PHYSICAL FEATURES	
Built Environment:	North: the existing buildings are not so close.
	Others sides: there are no buildings.
Urban Facilities:	Occasional: Mobile Kiosk
Urban Furniture:	Stairs with ramp that form a cement bench
Points of interest:	Praça do Comercio Square is nearby. Rio Tejo landscape view.
Constructive Characteristics:	Recently redefined area, with concrete floor coating and cobble stone (like a historical paving).
Natural Features:	Much of the area is covered by grass.
	Some newly planted trees that are still in small size.
Means of Transportation:	Local: Ribeira das Naus Avenue – local traffic: individual auto-vehicles, without public transportation .
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime, except on the weekend): cars - Ribeira das Naus Avenue. Heard: boat - when the traffic is lower.
Natural sounds	Heard (Majority on the mornings): Water - when the traffic sound is low.
Human sounds	Predominance (any weekday and daytime): people chatting
Operational sounds	Predominance (at afternoon and weekends): mobile kiosk operation and music.
USERS DATA	
Age:	Majority adults and seniors.
	On the afternoons and weekends there is young people.
Social Group:	All types of social group use the place.
	Tourists families frequent the place in the morning, while residents families use on the afternoon. Both, usually, are passing through the area.
Uses:	The use of the area for sporting activities are more often on the mornings. The steps on ramps are mainly used for rest and for water landscape view on the afternoons and weekends.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
Water and boat sound can be heard more often on the early mornings and on weekends, when the traffic on Ribeira das Naus Avenue is lower. Also on this period of the day, the area is used for residents sporting activities.	
The mobile kiosk music becomes predominant on the soundscape when they are operating.	

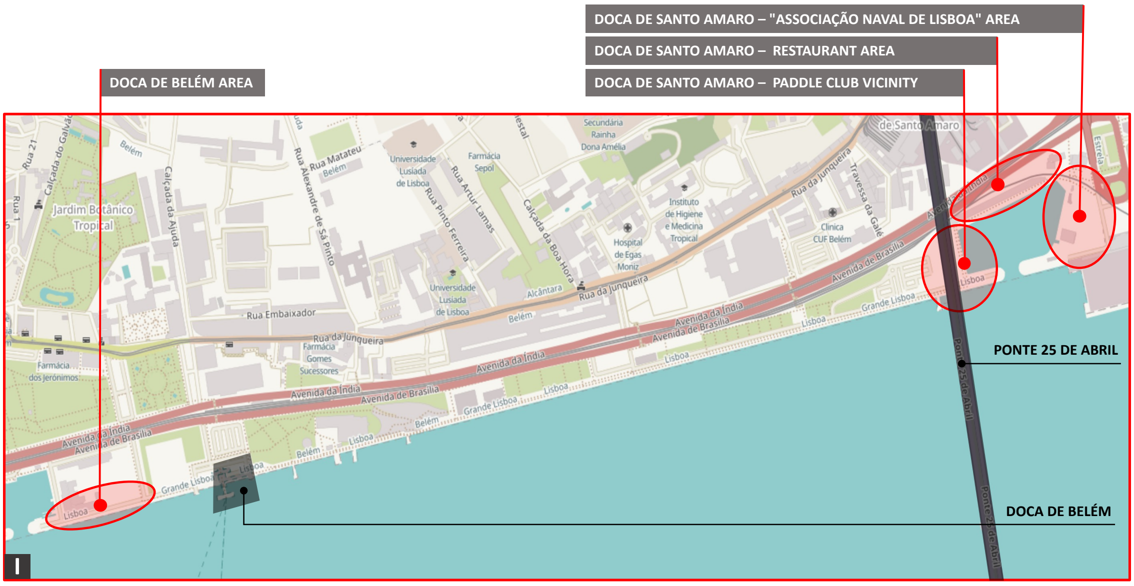


Figure A.25: Area I with the location of the other sites where it was carried out the Preliminary Assessment. Source: ©OpenStreetMap contributors – author adapted.

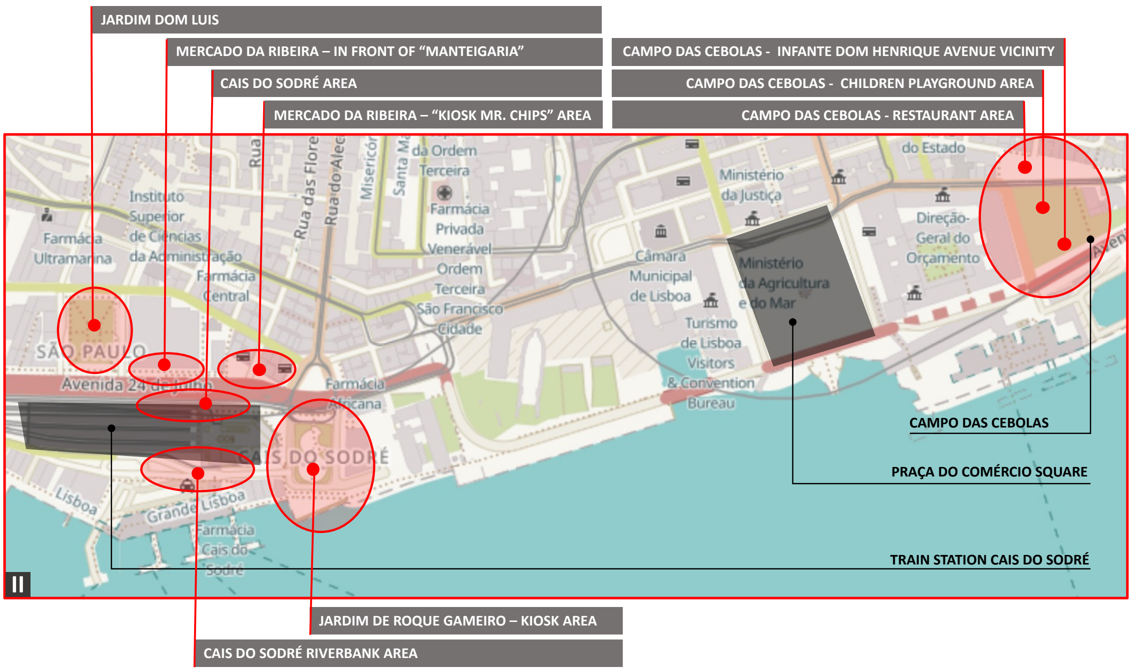


Figure A.26: Area II with the location of the other sites where it was carried out the Preliminary Assessment. Source: ©OpenStreetMap contributors – author adapted.

DOCA DE BELÉM AREA

Figure A.27: Other site - Doca de Belém area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

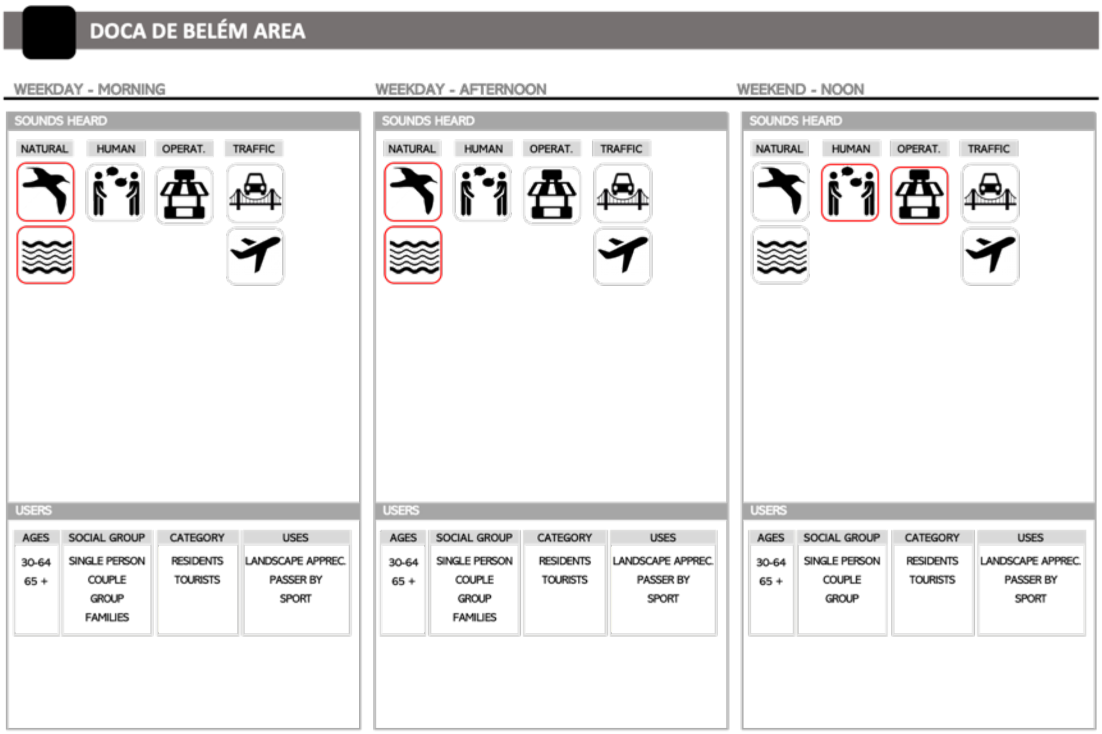


Figure A.28: Other site - Doca de Belém area – area characterization.

Table A.13: Other site - Data collect Doca de Belém.

DOCA DE BELÉM	
PHYSICAL FEATURES	
Built Environment:	North: two floor buildings twinned (bars and restaurants).
	Other sides: there are no buildings.
Urban Facilities:	Bars and restaurants with table service
Urban Furniture:	There is nothing.
Points of interest:	Bars and restaurants, view of river landscape, Doca de Belém, Federação Portuguesa de Vela, Clubes Náuticos: Associação Naval de Lisboa, Clube de Vela do Tejo, Sport Algés e Dafundo.
Characteristics Constructive:	Along the river, the pedestrian walkway is cover by asphalt paving.
Natural Features:	There is nothing.
Means of Transportation:	Close (less than 500 meters away): Brasilia Avenue – heavy traffic: mainly cars and some buses.
	Close (less than 500 meters away): train Station - Belém
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Heard (too low): cars and trains crossing the bridge.
Natural sounds	Predominance (Majority from Monday to Friday): birds and water sound.
Human sounds	Heard (Majority on weekends): people chatting.
Operational sounds	Heard (from Monday to Friday) and Predominance (on weekends): restaurants and bars operation.
USERS DATA	
Age:	Majority adults and seniors.
Social Group:	All types of social group use the place. The families that frequent the place are not residents.
	Residents are the main users.
	Tourists usually use the place as passers-by.
Uses:	The area is used mostly for water landscape appreciation through the exiting restaurants. Also, the area is used for sports activities and riding with scooter and bicycles.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
On weekends, the restaurants are more often used. So, the water and birds sounds heard from Monday to Friday are lower than the restaurant operational noise.	

DOCA DE SANTO AMARO – PADDLE CLUB VICINITY

Figure A.29: Other site - Doca de Santo Amaro – Paddle Club vicinity – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

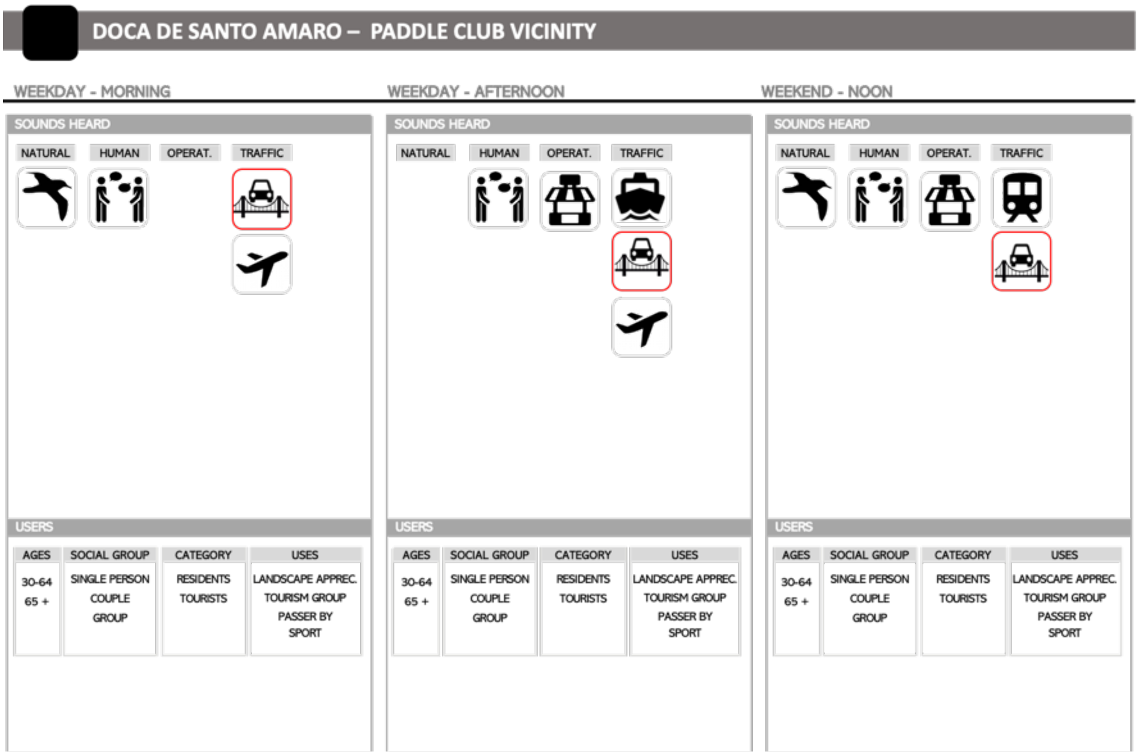


Figure A.30: Other site - Doca de Santo Amaro – Paddle Club vicinity – area characterization.

Table A.14: Other site - Data collect Doca de Santo Amaro – Paddle Club vicinity

DOCA DE SANTO AMARO – PADDLE CLUB VICINITY	
PHYSICAL FEATURES	
Built Environment:	East: paddle court
	Other sides: Riverbank without building.
Urban Facilities:	Bar (paddle club).
Urban Furniture:	There is nothing.
Points of interest:	Marina, paddle court and Tejo River view
Characteristics Constructive:	Area with cement floor coating
Natural Features:	There is nothing.
Means of Transportation:	Close (less than 500 meters away): Brasilia Avenue – heavy traffic: mainly cars and some buses.
	Close (less than 500 meters away): Alcantara Mar train Station.
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and trains crossing the bridge.
Natural sounds	Heard: birds.
Human sounds	Heard: people chatting (on noon and afternoon)
Operational sounds	Heard: docked boats on the Marina
USERS DATA	
Age:	Majority adults and seniors.
Social Group:	All types of social group use the place, with the exception of the families.
	Tourists and residents are area users.
Uses:	Residents usually are practicing sports like running and cycling on the place. Tourists are passing through the area or on a guided bicycle tour.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
The noise of the cars crossing the bridge is predominant all the time on the area. Even so, it´s possible to hear, in a low volume, the birds sounds, people chatting, and transportation noise from boats, train and airplane.	

DOCA DE SANTO AMARO – RESTAURANT AREA

Figure A.31: Other site - Doca de Santo Amaro – restaurant area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

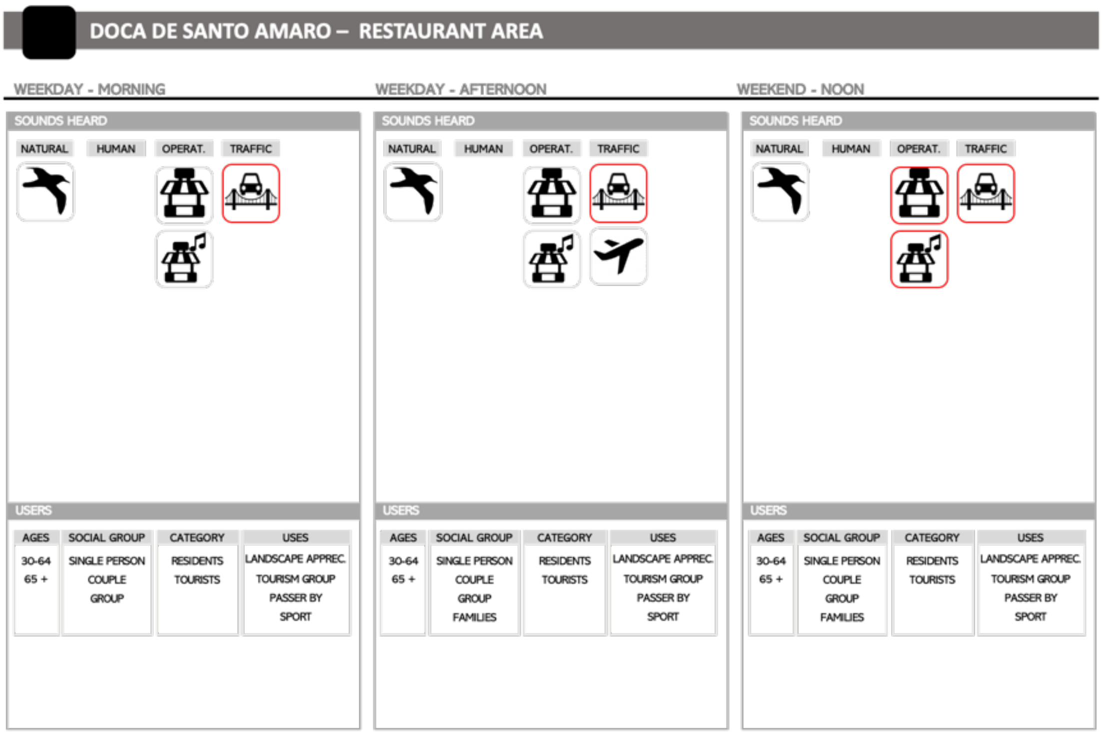


Figure A.32: Other site - Doca de Santo Amaro – restaurant area – area characterization.

Table A.15: Other site - Data collect Doca de Santo Amaro – restaurant area.

DOCA DE SANTO AMARO – RESTAURANT AREA	
PHYSICAL FEATURES	
Built Environment:	North: two floor historical buildings - restaurants
	South: Riverbank with some sunshades, tables and chairs from the restaurants.
	Other sides: There are no buildings.
Urban Facilities:	Bars and restaurants with table service
Urban Furniture:	There is nothing.
Points of interest:	Marina, bars and restaurants, and Tejo River view
Characteristics Constructive:	Area with cement floor coating
Natural Features:	There is nothing.
Means of Transportation:	Close (less than 500 meters away): Brasilia Avenue – heavy traffic: mainly cars and some buses.
	Close (less than 500 meters away): Alcantara Mar train Station
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and trains crossing the bridge.
Natural sounds	Heard: birds.
Human sounds	Heard: people chatting (on noon and afternoon)
Operational sounds	Heard (any weekday and daytime, Majority on weekends): restaurants and bars operation and music.
	Heard: boats there are docked on the Marina
USERS DATA	
Age:	Majority adults and seniors.
Social Group:	All types of social group use the place.
	From Monday to Friday the residents usually use the place to practice running and cycling. On weekends they usually stay more time in the area, on the bars and restaurants.
	Tourists are the main user.
Uses:	The area is mostly used for sporting activities and waterfront landscape appreciation with the bars and restaurants use. Also, it is very common to see tourists' groups on a guided tours with bicycles.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
The noise of the cars crossing the bridge is predominant all the time on the area. Even so, it´s possible to hear, in a low volume, the birds sounds, the music from bars and restaurants and its operation noises.	
On the weekends, the music from bars and restaurants and its operation noises is considerable.	

DOCA DE SANTO AMARO – "ASSOCIAÇÃO NAVAL DE LISBOA" AREA

Figure A.33: Other site - Doca de Santo Amaro – "Associação Naval de Lisboa" area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

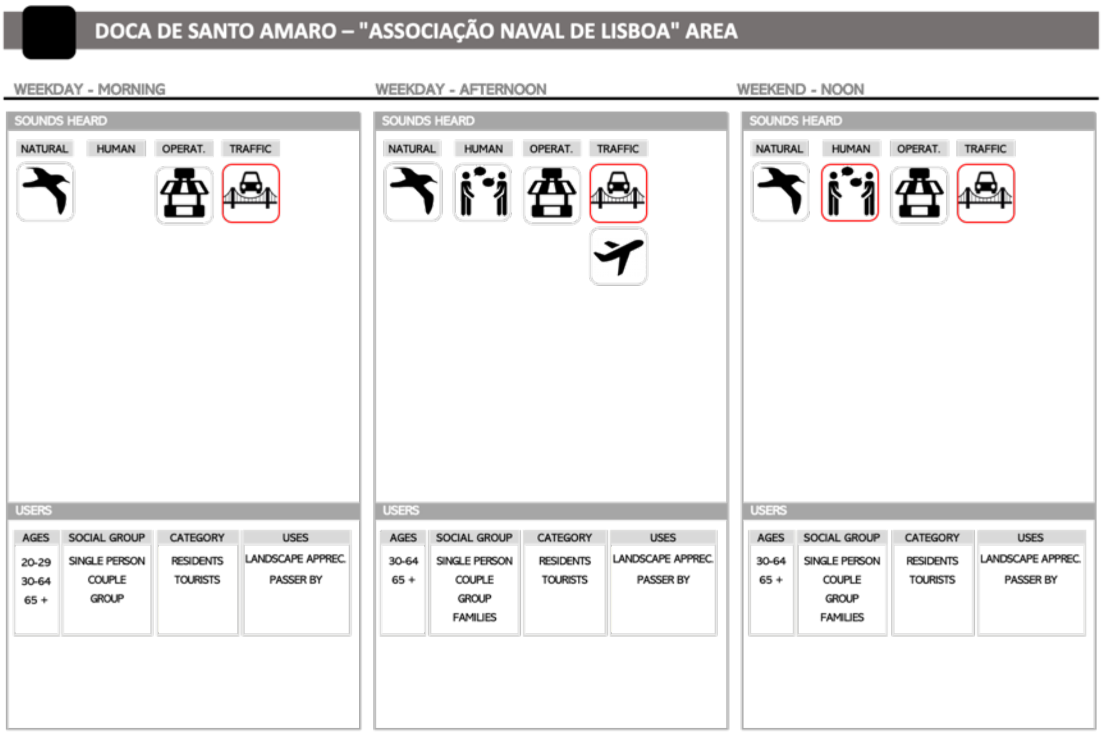


Figure A.34: Other site - Doca de Santo Amaro – "Associação Naval de Lisboa" area – area characterization.

Table A.16: Other site - Data collect Doca de Santo Amaro – "Associação Naval de Lisboa" area.

DOCA DE SANTO AMARO – "ASSOCIAÇÃO NAVAL DE LISBOA" AREA	
PHYSICAL FEATURES	
Built Environment:	East: one floor building - restaurant
	South: Riverbank without building.
	Other sides: There are no buildings.
Urban Facilities:	Bars and restaurants with table service
Urban Furniture:	There is nothing.
Points of interest:	Marina and Tejo River view
Characteristics Constructive:	Area with cement floor coating
Natural Features:	There is nothing.
Means of Transportation:	Close (less than 500 meters away): Brasilia Avenue – heavy traffic: mainly cars and some buses.
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and trains crossing the bridge.
Natural sounds	Heard: birds.
Human sounds	Heard (Majority on weekends): people chatting.
Operational sounds	Heard (any weekday and daytime): restaurant operation.
USERS DATA	
Age:	Majority adults and seniors.
Social Group:	All type of social group use the local.
	From Monday to Friday the residents usually use the place just passing through. On weekends they usually stay more time on the restaurant area.
	Tourists are the main users.
Uses:	The area is used mostly for waterfront landscape appreciation with the restaurant use.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
The noise of the cars crossing the bridge is predominant all the time on the area. Even so, it´s possible to hear, in a very low volume, the birds sounds and the restaurant operation sounds.	
On weekends, the sound of people chatting on the restaurant is considerable.	

JARDIM DOM LUIS

Figure A.35: Other site - Jardim Dom Luis – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

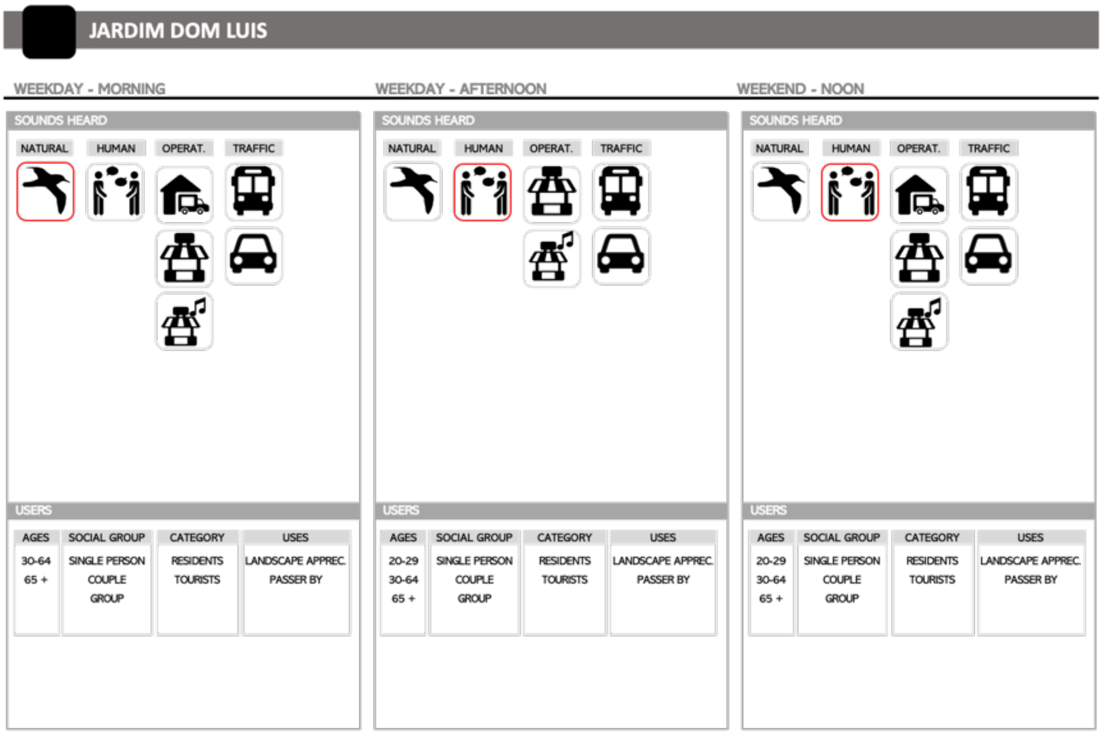


Figure A.36: Other site - Jardim Dom Luis – area characterization.

Table A.17: Other site - Data collect Jardim Dom Luis.

JARDIM DOM LUIS	
PHYSICAL FEATURES	
Built Environment:	Buildings are far from the area because of the streets that ring up Dom Luis Garden.
Urban Facilities:	Kiosk and a terrace with chairs, tables and sunshades.
Urban Furniture:	Wood benches
	bicycle stands
Points of interest:	Kiosk, nature and the Marquês Sá da Bandeira statue
Characteristics Constructive:	The walks are concrete floor coating and there is a metallic kiosk on the area
Natural Features:	Garden coated with grass and large trees that provide shadow to the local.
Means of Transportation:	Close (less than 500 meters away): 24 de Julho Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close (less than 500 meters away): train station, metro station, boat station, bus stop.
	Local: pedestrians and, sometimes, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and buses – 24 de Julho avenue.
Natural sounds	Heard: birds - when the traffic sound is low.
Human sounds	Predominance (any weekday and daytime): people chatting.
Operational sounds	Heard (any weekday, morning): loading and unloading of materials.
USERS DATA	
Age:	Majority adults and seniors. In the afternoons and weekends some young people can be observed.
Social Group:	All types of social group use the place, with the exception of the families.
	On the morning is more usual to see residents in the area.
	On the afternoon and on weekends, tourists are the main users of the place.
Uses:	The area is used for landscape appreciation with the Kiosk and bench use and to rest, on the grass, below the trees' shadows.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
The traffic noise is lower inside the garden, so it is possible to hear the birds sounds, on the mornings, and people chatting on the afternoons.	

MERCADO DA RIBEIRA – IN FRONT OF "MANTEIGARIA"

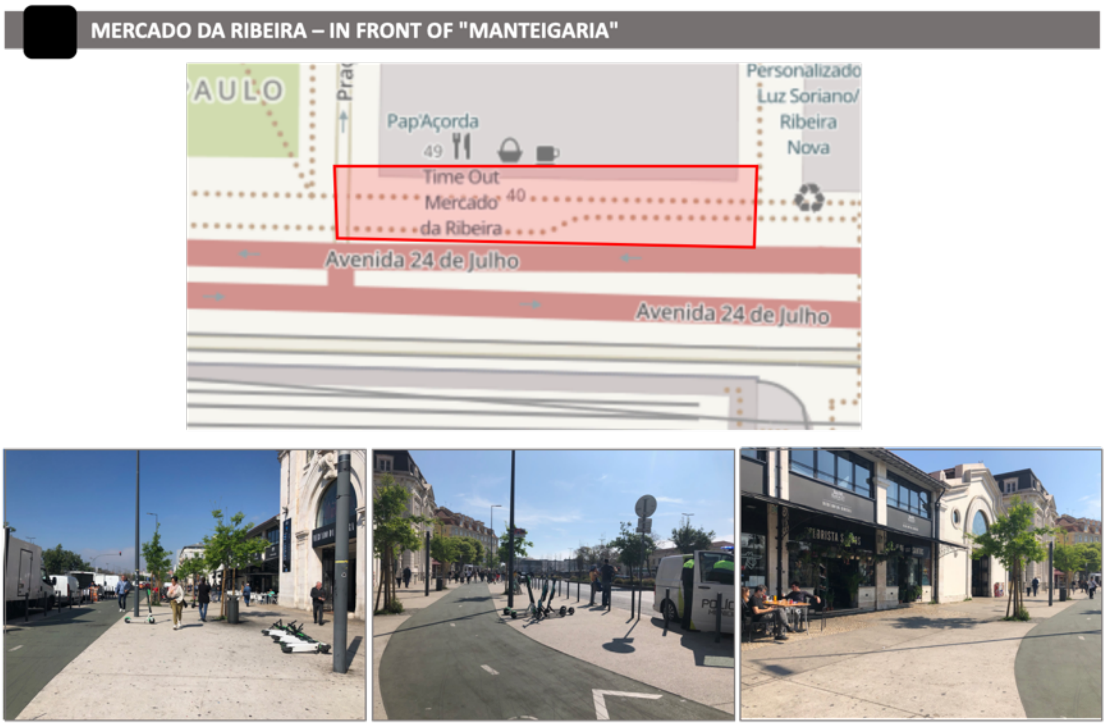


Figure A.37: Other site - Mercado da Ribeira – in front of "Manteigaria" – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

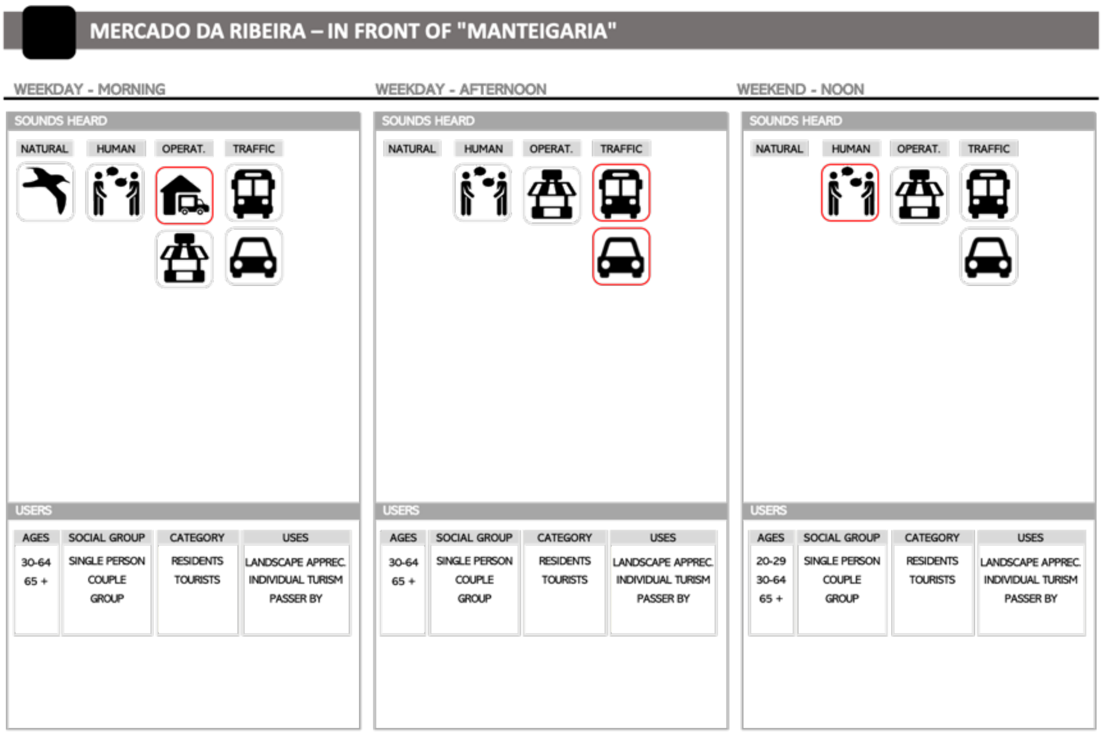


Figure A.38: Other site - Mercado da Ribeira – in front of "Manteigaria" – area characterization.

Table A.18: Other site - Data collect Mercado da Ribeira – in front of “Manteigaria”.

MERCADO DA RIBEIRA – IN FRONT OF "MANTEIGARIA"	
PHYSICAL FEATURES	
Built Environment:	North: three floors historic building - Ribeira Marketplace
	Other sides: there are no buildings.
Urban Facilities:	Restaurants and coffee houses with table service
Urban Furniture:	Longitudinal Cement Bench
	Bicycle stands
Points of interest:	Ribeira Marketplace
Characteristics Constructive:	Area with concrete and stones (like the historical Portuguese's sidewalks) floor coating
Natural Features:	Some newly planted trees that are still in small size.
Means of Transportation:	Close (less than 500 meters away): 24 de Julho Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close (less than 500 meters away): train station, metro station, boat station, bus stop.
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and buses – 24 de Julho avenue.
Natural sounds	Heard: birds - when the traffic sound is low.
Human sounds	Predominance (any weekday and daytime): people chatting.
Operational sounds	Predominance (any weekday, morning): loading and unloading of materials.
	Predominance (any weekday and daytime): restaurants, coffee house operation.
USERS DATA	
Age:	Majority adults and seniors. At weekends some young people can be observed.
Social Group:	All types of social group use the place.
	Tourists are the main user. Families and residents are not usually users on any day and period, they are just passing through the area.
Uses:	The area is used mainly by tourists for the coffee houses and restaurants consumption.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
On weekends, the traffic noise is lower than on weekdays, so it is possible to heard people chatting.	
On the mornings, the loading and unloading activity is the main noise that was heard.	

MERCADO DA RIBEIRA – "KIOSK MR. CHIPS" AREA

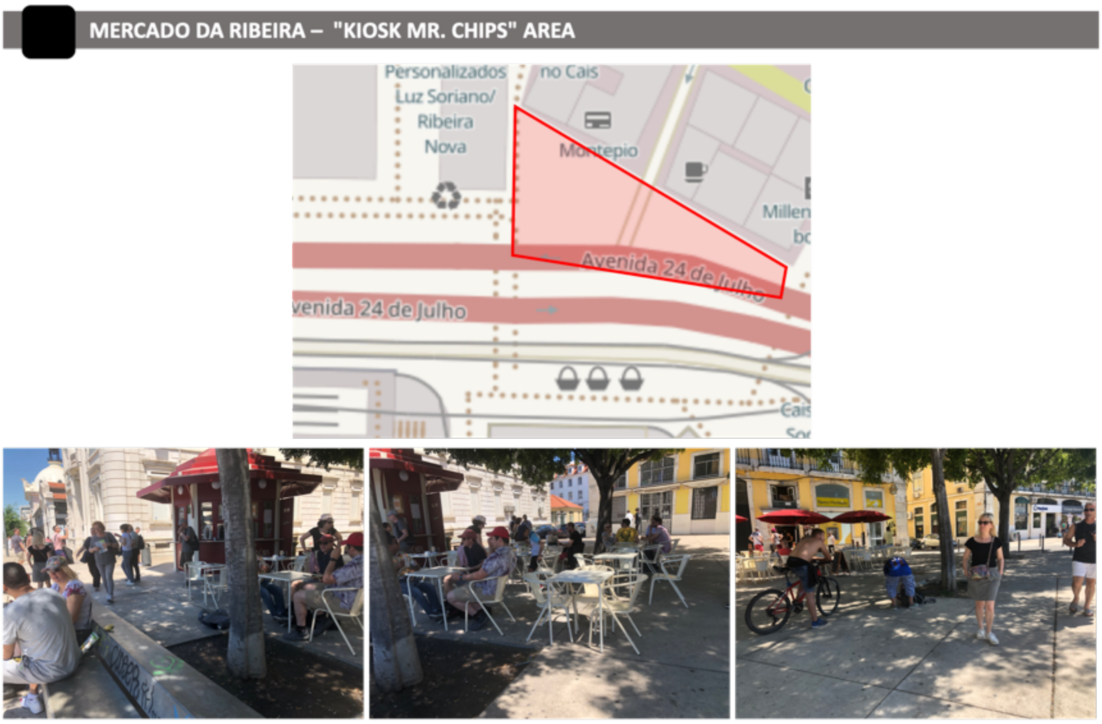


Figure A.39: Other site - Mercado da Ribeira – "Kiosk Mr. Chips" area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

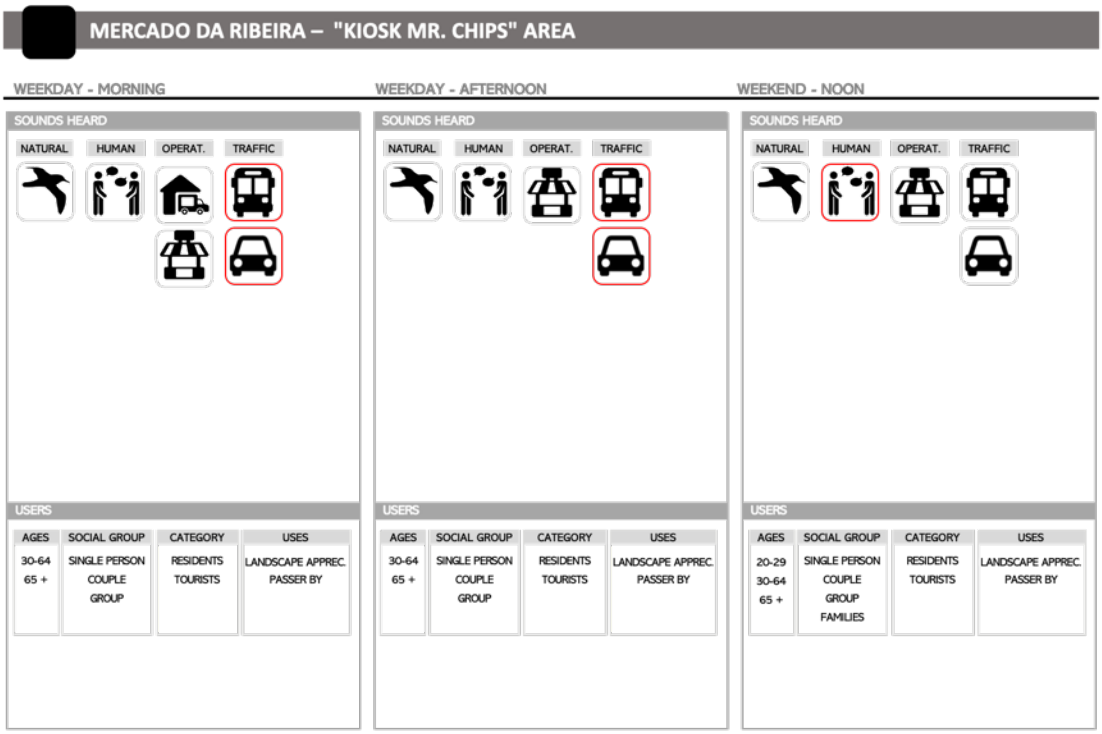


Figure A.40: Other site - Mercado da Ribeira – "Kiosk Mr. Chips" area – area characterization.

Table A.19: Other site - Data collect Mercado da Ribeira – "Kiosk Mr. Chips" area.

MERCADO DA RIBEIRA – "KIOSK MR. CHIPS" AREA	
PHYSICAL FEATURES	
Built Environment:	North: four floors historic building.
	East: two floors historic building.
	West and South: there are no buildings.
Urban Facilities:	Kiosk and a terrace with chairs, tables and sunshades.
Urban Furniture:	Cement benches
Points of interest:	Kiosk.
Characteristics Constructive:	Area with concrete floor coating with a metallic kiosk.
Natural Features:	Large trees that provide shadow to the local.
Means of Transportation:	Close (less than 500 meters away): 24 de Julho Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close (less than 500 meters away): train station, metro station, boat station, bus stop.
	Local: pedestrians and, sometimes, scooters.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and buses – 24 de Julho avenue
Natural sounds	Heard (any weekday and daytime): birds - when the traffic sound is low.
Human sounds	Heard (Majority on weekends): people chatting - when the traffic sound is low.
Operational sounds	Predominance (any weekday and daytime): kiosk operation.
USERS DATA	
Age:	Majority adults and seniors. At weekends some young people can be observed.
Social Group:	The users are alone, in two, couple or in a group. At weekends some families can be observed.
	From Monday to Friday the mainly users are resident, and tourists are just passing through the place. On weekends the scenery change, and the tourists becomes the mainly users.
Uses:	The area is used for contemplation of the landscape, and also for rest, because of the existing kiosk and the benches shaded by the trees.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
On weekends, more tourists were observed using the area, and the residents appear in lesser quantity. Besides, on these days, the traffic noise is lower, and it is possible to heard more clearly the birds sounds and chatting.	

CAIS DO SODRÉ AREA

Figure A.41: Other site - Cais do Sodré area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

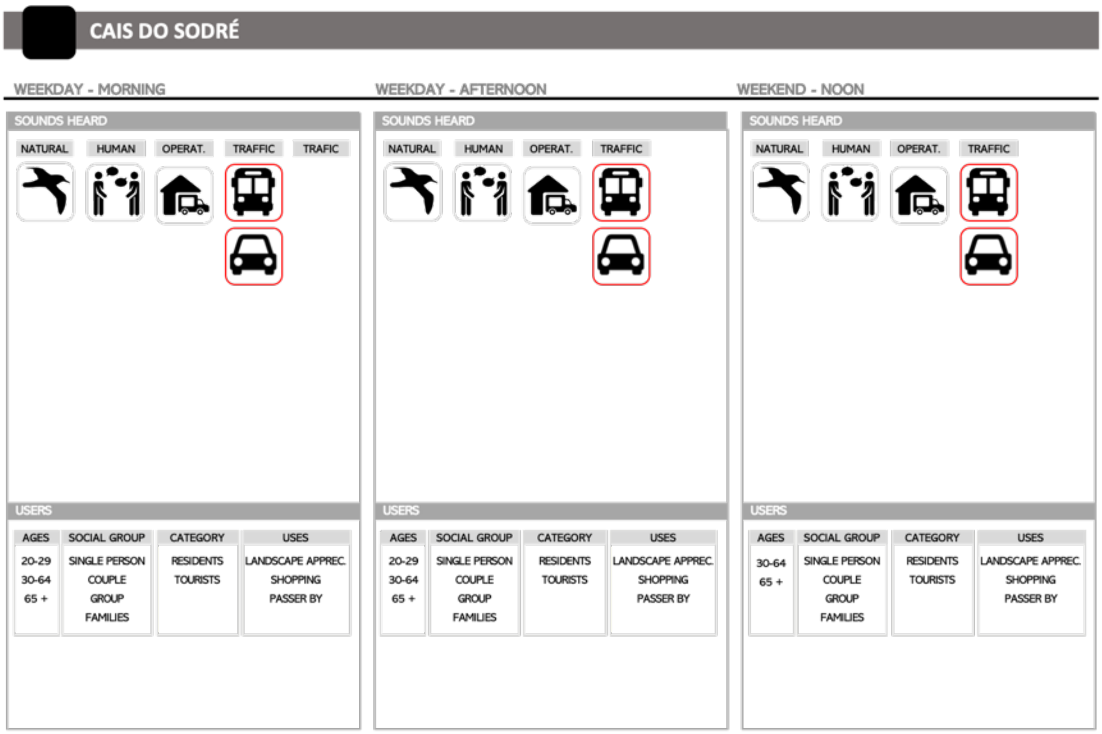


Figure A.42: Other site - Cais do Sodré area – area characterization.

Table A.20: Other site - Data collect Cais do Sodré area.

CAIS DO SODRÉ AREA	
PHYSICAL FEATURES	
Built Environment:	North: buildings are far from the area because of 24 de Julho Avenue.
	South: Cais do Sodré, metro station building.
	East and West: there are no buildings.
Urban Facilities:	Newsstands and Mobile Kiosks
Urban Furniture:	Wood benches
	bicycle stands
Points of interest:	Boat Station, metro Station, train Station.
Characteristics Constructive:	Area with concrete floor coating with three newsstands and some mobile kiosks.
Natural Features:	Some newly planted trees that are still in small size.
Means of Transportation:	Close (less than 500 meters away): 24 de Julho Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close (less than 500 meters away): train station, metro station, boat station, bus stop.
	Local: pedestrians and, sometimes, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): cars and buses – 24 de Julho avenue
Natural sounds	Heard: birds - when the traffic sound is low.
Human sounds	Predominance (any weekday and daytime): people chatting.
Operational sounds	Heard (any weekday, morning): loading and unloading of materials.
USERS DATA	
Age:	People of all ages.
Social Group:	All types of social group use the place.
Uses:	All kind of user usually use the area to passer through. People usually use the banks to get rest for a short time.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	

CAIS DO SODRÉ – RIVERBANK AREA

Figure A.43: Other site - Cais do Sodré – riverbank area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

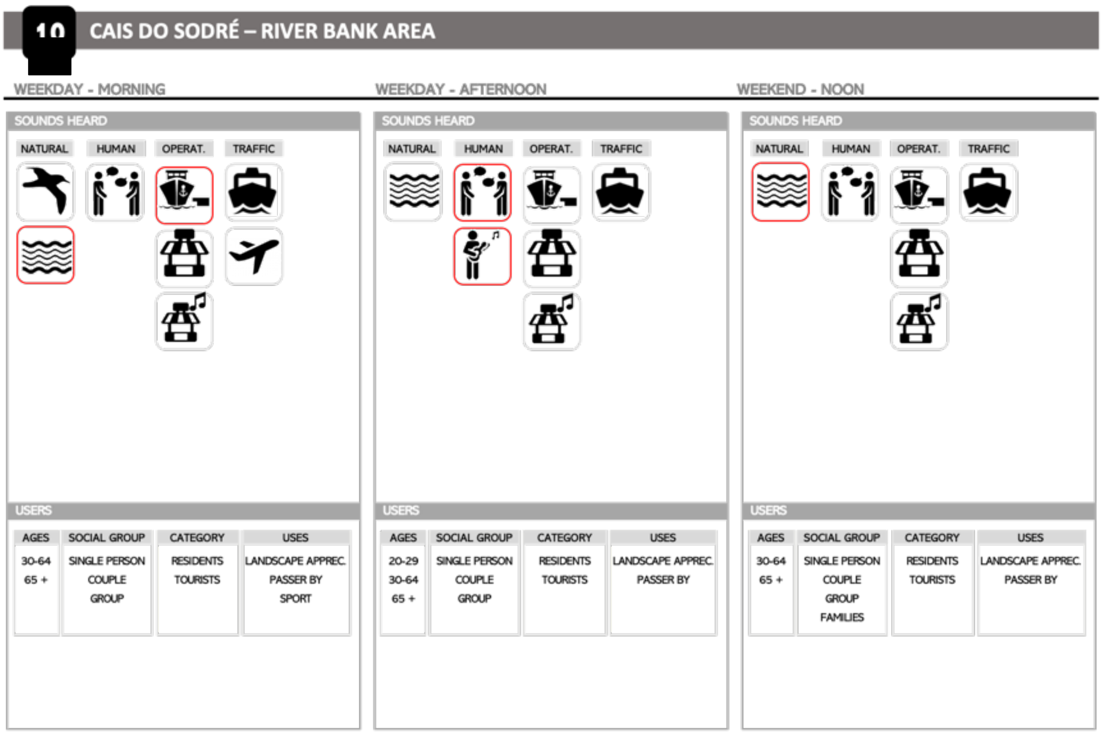


Figure A.44: Other site - Cais do Sodré – riverbank area – area characterization.

Table A.21: Other site - Data collect Cais do Sodré – riverbank area.

CAIS DO SODRÉ – RIVERBANK AREA	
PHYSICAL FEATURES	
Built Environment:	West: Cais do Sodré (loading and unloading boat area).
	North: one floor buildings (bars and restaurants).
	Other sides: there is no building.
Urban Facilities:	Bars and restaurants with table service
Urban Furniture:	There is nothing
Points of interest:	Bars and restaurants with Tejo River view
Characteristics Constructive:	There is a paved road to pedestrians, scooters and bicycle traffic. On the water´s edge there is stone ramp.
Natural Features:	There is nothing.
Means of Transportation:	Close (less than 500 meters away): 24 de Julho Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close (less than 500 meters away): bus stop on the Garden surrounding
	Local: pedestrians, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Heard (any weekday and daytime): boat motor.
Natural sounds	Predominance (any weekday and daytime): water. Heard (on mornings): birds.
Human sounds	Heard (any weekday and daytime): people chatting.
Operational sounds	Heard (any weekday and daytime): bars and restaurants operation and music.
	Predominance (any weekday and daytime): quay operation.
USERS DATA	
Age:	Majority adults.
Social Group:	The user's area alone, couple, in two or in a group.
	Tourists are the main user.
	Residents and families usually use the place to passer through.
Uses:	The use of the area for sporting activities, like running and cycling, are more often on the mornings, from Monday to Friday. On the remainder of the time the area is used for water landscape appreciation with the bars and restaurants use.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	

JARDIM DE ROQUE GAMEIRO – KIOSK AREA

Figure A.45: Other site - Jardim de Roque Gameiro – kiosk area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted. Photos – author.

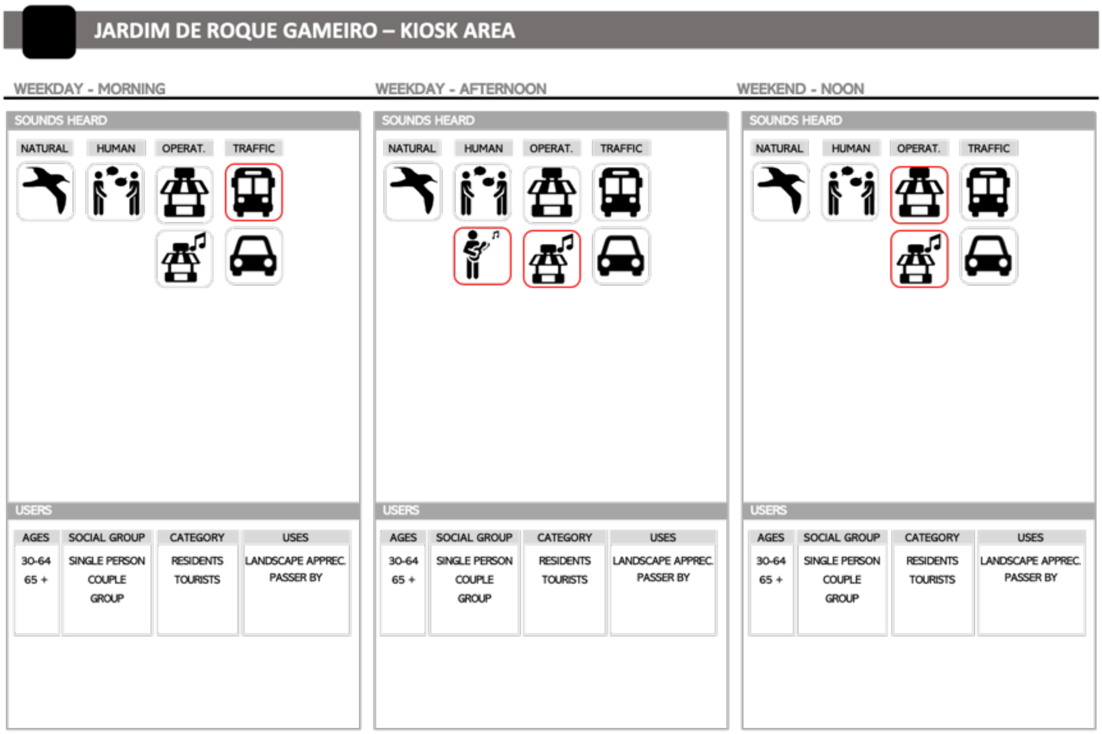


Figure A.46: Other site - Jardim de Roque Gameiro – kiosk area – area characterization.

Table A.22: Other site - Data collect Jardim de Roque Gameiro – kiosk area.

JARDIM DE ROQUE GAMEIRO – KIOSK AREA	
PHYSICAL FEATURES	
Built Environment:	Other sides: buildings are far from the area because of Cais do Sodré street.
	South: Riverbank without building.
	North: Roque Gameiro Garden without building.
Urban Facilities:	Kiosk and a terrace with chairs, tables and sunshades.
Urban Furniture:	Wood benches
Points of interest:	Kiosk with Tejo River view
Constructive Characteristics:	Recently redefined area, with stones floor covering (like the historical Portuguese's sidewalks). There is some raised beds.
Natural Features:	Raised beds with grass and some large trees that provide shadow to the local
	Some newly planted trees that are still in small size.
Means of Transportation:	Close (less than 500 meters away): 24 de Julho Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close (less than 500 meters away): bus stop on the Garden surrounding
	Local: pedestrians.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime): buses on streets garden surrounding. Heard: boat - when the traffic is lower.
Natural sounds	Heard: birds - when the kiosk music is lower
Human sounds	Predominance (any weekday and daytime): people chatting. Sporadic: Musicians playing.
Operational sounds	Predominance (any weekday and daytime): Kiosk operation and music.
USERS DATA	
Age:	Majority adult and seniors.
Social Group:	The users are alone, couple, in two or in a group.
	There are: tourists, residents and workers on the area.
	Families are not users on any day and period.
Uses:	There is two distinct places: a bench area and a kiosk area. Both of them are more often used to landscape appreciation (water and nature). Besides, there are same people that are passing by the local.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
Birds' sounds are better heard when kiosk music is on a lower volume and also when there is less bus movement, mainly on the mornings.	
The bus noise is less heard when the kiosk music is on a high volume.	

CAMPO DAS CEBOLAS - RESTAURANT AREA

Figure A.47: Other site - Campo das Cebolas - restaurant area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted.

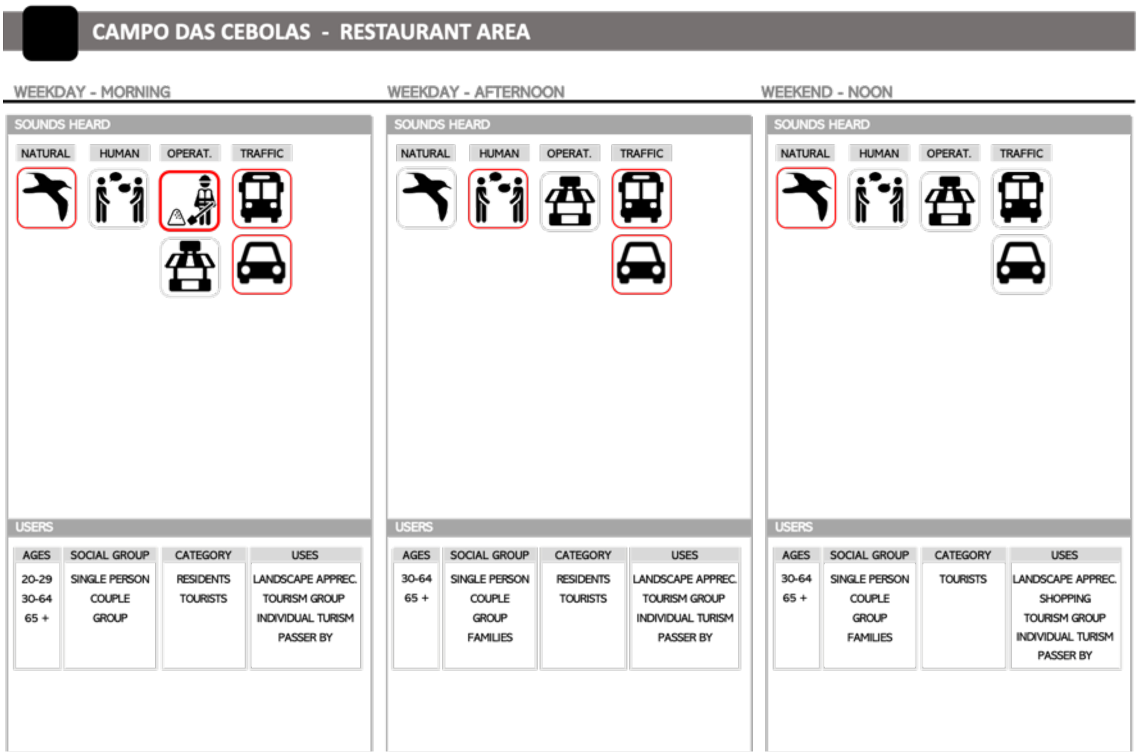


Figure A.48: Other site - Campo das Cebolas - restaurant area – area characterization. Source: author elaborate.

Table A.23: Other site - Data collect Campo das Cebolas - restaurant area.

CAMPO DAS CEBOLAS - RESTAURANT AREA	
PHYSICAL FEATURES	
Built Environment:	West, North e East: Old and historical buildings with commercial use mainly, such as shops, bars and restaurants.
	South: there are no buildings.
Urban Facilities:	Bars and restaurants with table service.
Urban Furniture:	Longitudinal cement bench.
	Bicycle stands
Points of interest:	Historic building: Casa dos Bicos House / Jose Saramago Foundation which presents substantial touristic visit.
Constructive Characteristics:	Large part of the area has cobble stone (like a historical paving).
Natural Features:	Some historical and large trees that provide shadow to certain places.
	Some newly planted trees that are still in small size.
Means of Transportation:	Close: Infante Dom Henrique Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close: bus stop on Infante Dom Henrique Avenue
	Local: Alfandega Street - local traffic: individual auto-vehicles.
	Local: pedestrians.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime, except on the weekend): cars and buses – Infante Dom Henrique avenue.
Natural sounds	Predominance (any weekday and daytime): birds.
Human sounds	Predominance (any weekday and daytime, except in the morning): people chatting.
Operational sounds	Sporadic (from Monday to Friday, at morning): construction work.
	Sporadic (any weekday, at afternoon): bars and restaurants operation.
USERS DATA	
Age:	Majority adults and seniors.
Social Group:	People in large groups - tourists (up to ten) because of to the existing tourist point.
	Residents, most of then, use the place to passer through.
Uses:	There is a considerable number of people who are just passing through the site. The benches and the tree shades provide some places to rest or read a book looking at the built landscape.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
During the mornings there was considerable noise from building working machines. Probably, this kind of noise tends to be common because this is a historical site with constant buildings restoration.	
On the afternoon, the sounds coming from the operation of bars and restaurants become more frequent and intense, and changes the local soundscape. Therefore the birds becomes less audibles.	
On the afternoon the area is used by families to access the existing playground in the adjacent area.	

CAMPO DAS CEBOLAS - CHILDREN PLAYGROUND AREA

Figure A.49: Other site - Campo das Cebolas - children playground area – area identification. Sources: Map - © OpenStreetMap contributors, author adapted.

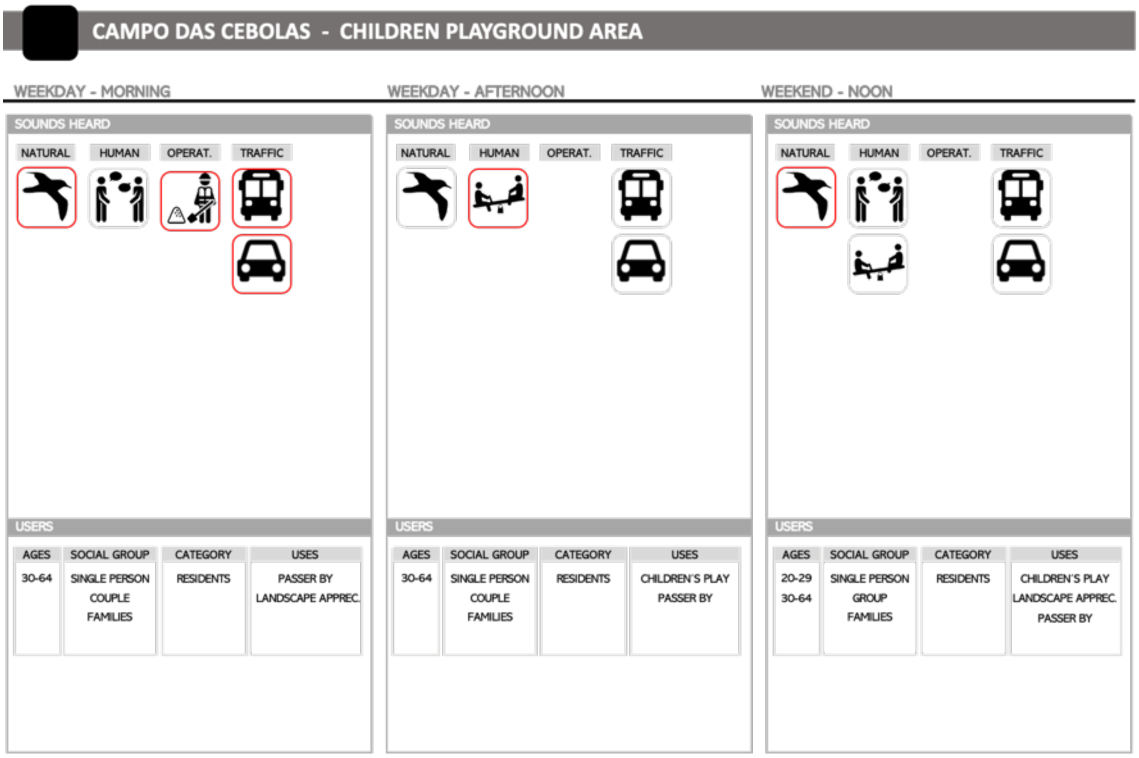


Figure A.50: Other site - Campo das Cebolas - children playground area – area characterization.

Table A.24: Other site - Data collect Campo das Cebolas - children playground.

CAMPO DAS CEBOLAS - CHILDREN PLAYGROUND AREA	
PHYSICAL FEATURES	
Built Environment:	West: buildings are not so close from the area because of Infante Dom Henrique Avenue.
	East: two historical buildings that are accessed by the area.
	Others sides: there is no buildings
Urban Facilities:	Playground.
Urban Furniture:	There is nothing.
Points of interest:	Playground: families widely use it during at certain parts of the day.
Constructive Characteristics:	Recently refurbished area, with pedestrians walk that crosses it, mainly used by the people who use the underground parking access.
Natural Features:	Major part of the area is covered by grass.
	Some newly planted trees that are still in small size.
Means of Transportation:	Close: Infante Dom Henrique Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close: bus stop on Infante Dom Henrique Avenue
	Local: pedestrians and some scooters.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime, except on the weekend): cars and buses – Infante Dom Henrique avenue.
Natural sounds	Heard (any weekday and daytime): birds - when the traffic sound is low.
Human sounds	Predominance (any weekday, Majority at afternoon): children playing.
Operational sounds	Sporadic (from Monday to Friday, at morning): construction work.
USERS DATA	
Age:	Majority adults and young people (more often on weekends).
Social Group:	The mainly users are residents. Groups (young people), couple and families are the users who spend more time on the place.
	Occurrence of tourists are in lesser amount, just passing through the place.
Uses:	Many people passing through the place to access the public underground parking. Grass is used by young people to picnic and rest. The playground is used by children and their families.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
In the morning there was considerable noise from building working machines originating from restaurants area. Probably, this kind of noise tends to be common because this is a historical site with a constant building restoration.	
On the afternoon periods and on weekends, the sounds from the playground use becomes dominant.	

CAMPO DAS CEBOLAS - INFANTE DOM HENRIQUE AVENUE VICINITY

Figure A.51: Other site - Campo das Cebolas - Infante Dom Henrique avenue vicinity – area identification. Sources: Map - © OpenStreetMap contributors, author adapted.

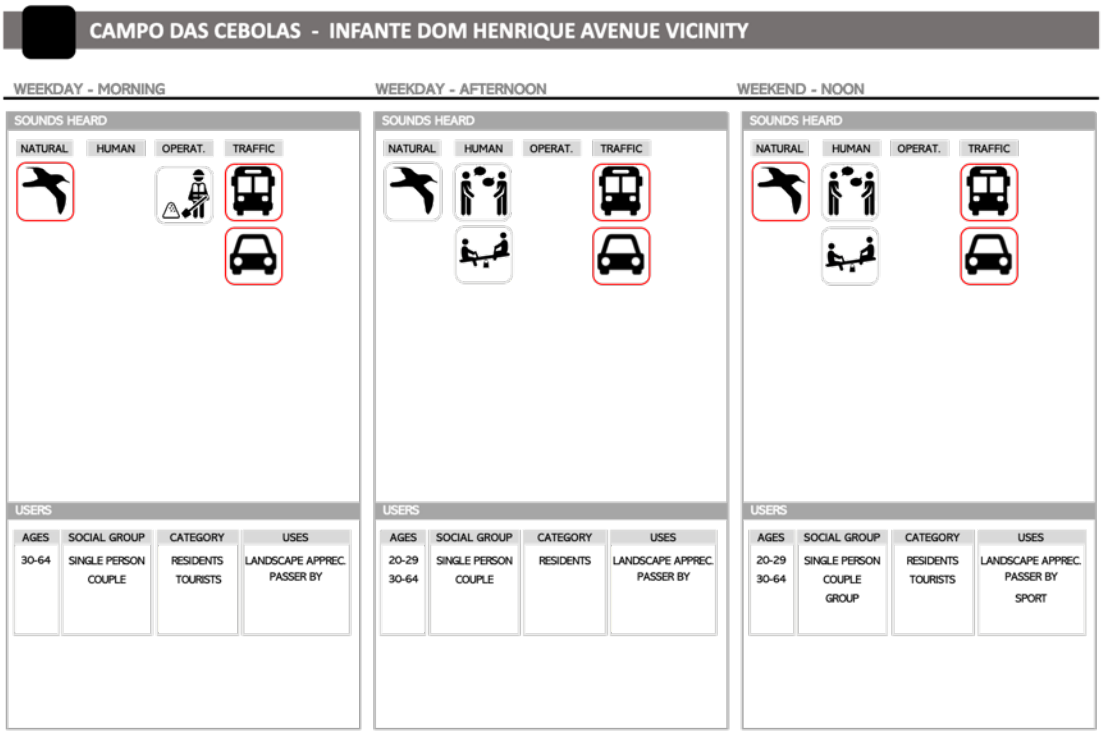


Figure A.52: Other site - Campo das Cebolas - Infante Dom Henrique avenue vicinity – area characterization.

Table A.25: Other site - Data collect Campo das Cebolas - Infante Dom Henrique avenue.

CAMPO DAS CEBOLAS - INFANTE DOM HENRIQUE AVENUE VICINITY	
PHYSICAL FEATURES	
Built Environment:	West: buildings are not so close from the area because of Infante Dom Henrique Avenue.
	Others sides: there is no buildings.
Urban Facilities:	There is nothing.
Urban Furniture:	Longitudinal cement bench where it is possible to see Tejo River partial view.
Points of interest:	Partial view of the Tejo River.
Constructive Characteristics:	Recently redefined area, with concrete floor coating.
Natural Features:	There is nothing.
Means of Transportation:	Close: Infante Dom Henrique Avenue – heavy traffic: cars, buses and electric public vehicles.
	Close: bus stop on Infante Dom Henrique Avenue.
	Local: pedestrians and, sometimes, scooters and bicycles.
SOUNDS HEARD	
Traffic sounds	Predominance (any weekday and daytime, except on the weekend): cars and buses – Infante Dom Henrique avenue.
Natural sounds	Heard (any weekday and daytime): birds - when the traffic sound is low.
Human sounds	Heard (on weekend): children playing.
Operational sounds	There is nothing.
USERS DATA	
Age:	Majority adults.
Social Group:	The users are alone or at most two people.
	The majority users are residents.
	Occurrence of tourists are in lesser amount, just passing through the place.
Uses:	The area has few users and normally they are just passing by the local. However, it was observed the practice of skates by a group, on the weekend. People stay in the place only to rest in the existing bench.
DIFFERENCES / SIMILARITIES AUTHOR'S COMMENTS	
The local is the only part of all the Campo das Cebolas area with Tejo River view. However, the most users are only passing through the area, even with longitudinal bench that provides this appreciation.	

DATA SURVEY	Local	Data	Time		

Weather Data						
Temperature	Real Feel	Cloudiness	Wind	Wind Speed	UV Index	Humidity

User Data													
Period													

Acoustic Data			
Period	File Name	Laeq	Comments

Sounds Data		
Period	File Name	Main Sounds

Sounds	Periods									

Figure B. 1 Survey Form – Sound Environment

TÉCNICO LISBOA

This questionnaire is part of an Architecture PhD research, at the Instituto Superior Técnico (University of Lisbon), about the acoustic / sound conditions of the urban spaces on Rio Tejo waterfront (Lisbon). It is intended to collect information about your SOUND EXPERIENCE to assess your perception of the pleasantness and the acoustic quality by these spaces.

According to the new General Data Protection Regulation (Regulation (EU) 2016/679), all respondents are guaranteed the security and anonymity of their responses. The information provided is intended exclusively for statistical purposes of this academic research and will be presented in an aggregated form, guaranteeing the confidentiality of individual responses.

We appreciate your participation in this study. ***It takes about 10 minutes to complete this questionnaire.***

1

Please rate this PUBLIC SPACE according to your experience.

Rate EVERY statement according to the scale presented.

	Strongly disagree	Disagree	Neither Agree, Nor Disagree	Agree	Strongly agree
It provides COMFORT to its users.	☐	☐	☐	☐	☐
It provides SAFETY to its users and their belongings.	☐	☐	☐	☐	☐
It provides a safe relationship between pedestrians and road traffic.	☐	☐	☐	☐	☐
Its INFRASTRUCTURES are well quantified and positioned.	☐	☐	☐	☐	☐
It has GOOD INTEGRATION with its surroundings: interconnection of paths and spaces.	☐	☐	☐	☐	☐
It presents an APPROPRIATE DELIMITATION between public and private spaces and between spaces with incompatible uses.	☐	☐	☐	☐	☐
It is ORGANIZED: harmonious and pleasant place that creates unique experiences for its users.	☐	☐	☐	☐	☐
It creates an opportunity for people to know each other and socialize, and promotes relationships between people different groups.	☐	☐	☐	☐	☐

Does the WATERFRONT proximity influences your decision to use this space?

Not at all	Slightly	Moderately	Very	Totally
1	2	3	4	5

Do the different SOUNDS you hear (eg wind, trees, water, birds, music, machines, boats, trains, traffic, etc.) influence your decision to use this space?

Not at all	Slightly	Moderately	Very	Totally
1	2	3	4	5

In the sound set you hear, how do you consider the sounds related to the waterfronts (eg water, seagulls, boats, piers):

Not Important	Slightly Important	Moderately Important	Very Important	Totally Important
1	2	3	4	5

2

Please list the 4 SOUND SOURCES (eg traffic, birds, people talking, wind, water, machine noise, music, train, etc.) that you perceive best.

Start with the most noticed source.

1 ____________ 2 ____________ 3 ____________ 4 ____________

For each of the 8 scales below, to what extent do you agree or disagree that the present surrounding sound environment is…

	Strongly disagree	Disagree	Neither Agree, Nor Disagree	Agree	Strongly agree
Pleasant	☐	☐	☐	☐	☐
Chaotic	☐	☐	☐	☐	☐
Vibrant	☐	☐	☐	☐	☐
Uneventful	☐	☐	☐	☐	☐
Calm	☐	☐	☐	☐	☐
Annoying	☐	☐	☐	☐	☐
Eventful	☐	☐	☐	☐	☐
Monotonous	☐	☐	☐	☐	☐

Overall, how would you describe the present surrounding sound environment?

Very Bad	Bad	Neither Good, Nor Bad	Good	Very Good
1	2	3	4	5

Overall, to what extent is the present surrounding sound environment appropriate to the present place?

Not at all	Slightly	Moderately	Very	Perfect
1	2	3	4	5

3

How often do you use this space?	How long do you STAY on average in this space?	What was the main reason that led you to CHOOSE this space?	Who do you use this space with?
☐ Daily	☐ Between 10 to 30 minutes	☐ Sport	☐ Alone
☐ 2-4 times a week	☐ Between 30 to 60 minutes	☐ Contemplate	☐ Accompanied + 1 person
☐ Once a week	☐ Between 1 to 2 hours	☐ Hang out	☐ Accompanied by 2 people or +
☐ 2-4 times a month	☐ More than 2 hours	☐ Recreation	☐ In family
☐ 1 time per month		☐ Rest / Relax	
☐ Rarely ____		☐ Pass trought	
☐ First Time ____		☐ Other: ____	

4

SEX	AGE RANGE	EDUCATION LEVEL	OCCUPATION
☐ F	☐ 15 - 19 years	☐ Basic education	☐ Student
☐ M	☐ 20 - 29 years	☐ High school	☐ Worker
☐ Other	☐ 30 - 49 years	☐ University education	☐ Retired
	☐ 50 - 64 years		☐ Unemployed
	☐ over 65 years		

Figure C. 1: Survey Form – Public Space, Sound Environment and Soundscape Assessment

6. QUANTITATIVE ASSESSMENT

The sound levels are a measure of the sound environment and thus directly relate to the sound appreciation of the place. Therefore, they are important data and must necessarily be considered in a soundscape study for a baseline characterization.

Hence, considering that on a soundscape study, all the possible comparisons between the physical acoustic parameters of a site and the subjective perceptions of its users must be explored, this chapter presents and discuss the L_{Aeq} index and the statistical Indexes which were measured on the Tejo waterfront public spaces.

Furthermore, since the information on how people experience each site, associated with its characterization and the perceptions of its users, can favour the analysis of its soundscape, the chapter also presents the quantitative data regarding all the activities people perform at the Tejo waterfront sites.

The data presented in this chapter are intended to be later compared with the qualitative data collected and presented in chapter 7.

6.1. ACOUSTIC PARAMETERS OF THE SOUND ENVIRONMENT

The overall sound levels were measured and analysed at each site of the Tejo waterfront. Sound measurements were conducted between August 2020 and May 2021, at different moments of the day, on fixed points previously established for each site. Several measurements were carried out at each location and the results obtained were averaged to provide mean sound level values for the sound indexes, the A-weighted continuous equivalent sound pressure level (L_{Aeq}) and the A-weighted statistical sound levels L_{A90}, L_{A50} and L_{A10}.

6.1.1. L_{Aeq} index

Table 6.1 show the mean values of the L_{Aeq} index at each waterfront site, in which a colour scale was adopted, to better distinguish the lower from the higher levels.

Table 6.1: Continuous equivalent sound pressure level index calculated from the acoustic recordings [dB].

	L_{Aeq} [dB]										
	1	2	3	4	5	6	7	8	9	10	MEAN
Mean	58,0	56,2	60,5	62,7	63,9	60,9	59,8	59,1	64,0	64,8	60,9
SD	1,6	2,0	2,4	1,2	1,0	2,6	1,2	2,9	3,0	4,6	3,6
Minimun	55,9	51,8	57,6	61,0	62,4	57,7	57,5	56,4	60,6	55,3	51,8
Maximum	60,6	59,5	64,4	65,0	65,6	65,2	61,4	62,8	66,1	69,1	69,1

Across the sound environment measurements at the ten waterfront sites, the A-weighted continuous equivalent sound pressure level index ranged from the lowest value of 51.8 dB, at “Site 2” up to 69.1 dB at “Site 10”.

Comparatively, the measured levels varied more on the site 10 (SD = 4.6 dB), while they were more constant on the sites 4 (SD = 1.2 dB), 5 (SD = 1.0 dB) and 7 (SD = 1.2 dB).

With regard to the mean values calculated for every site, it can be noted that all of them exceed 55 dB, ranging from 56,2 to 64,8 dB, and also are very close to the limit of noise exposure of 65 dB (A) - expressed by the long-term average sound pressure level (L_{den}) - established by the Portuguese Noise Act (Republica Portuguesa, 2007) for a “mixed zone”. However, it must be considered that the mean values were obtained from measurements which were carried out only during daytime periods, which may mean that the limit values may be exceeded when calculating the L_{den} or the L_n indicators.

The “Land Use Plan of Lisbon” (Município de Lisboa, 2020) delimited all the Tejo River waterfront area as a “mixed zone”, in line with the uses and spaces existing on the area, as opposed to a “sensitive zone”, of residential use, schools, hospitals or similar, or leisure spaces, and may contain commerce and services small unit to serve the local population, without night functioning.

Despite the limits established by the Portuguese Noise Act not being exceeded, it must be considered that the mean values of all sites are high and exceed other thresholds, such as those established by the World Health Organization (WHO Regional Office for Europe, 2018), which recommends levels below 53 dB L_{den}, in order to protect human health from exposure to environmental noise on areas exposed by the road traffic noise, such as the Tejo's waterfront.

In addition to comparisons with limits and recommendations, it should be noted that the average values calculated at sites 4, 5, 9 and 10, which are the highest and also close to 65 dB, can contribute to a more unpleasant evaluation of their sound environments, as opposed to the average value calculated on site 2, which is the lowest and closest to 55 dB, and which, in turn, can contribute to a more pleasant evaluation of its sound environment.

The mean values of the continuous equivalent sound pressure level (L_{Aeq}) calculated for each site were introduced on the two maps, shown in Figure 6.1, which represent the Area

I and the Area II of the Tejo's River waterfront, with the identification of the researched sites.

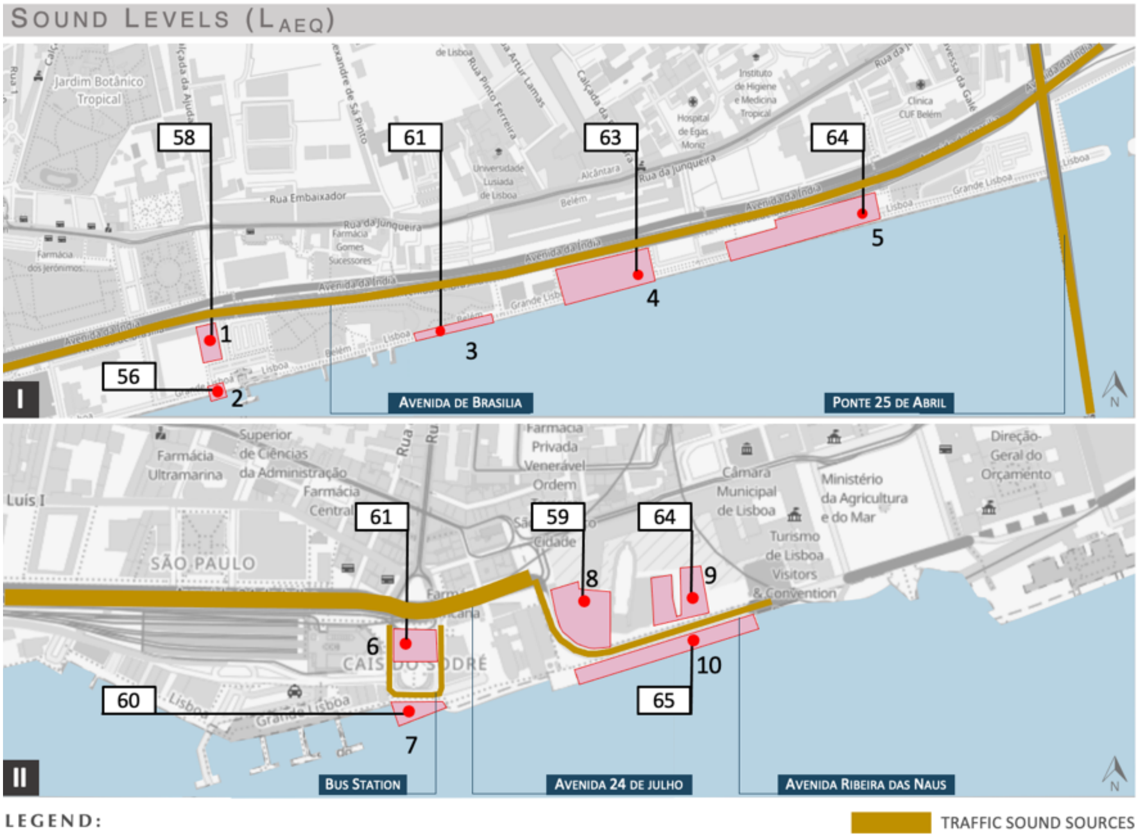


Figure 6.1: Sound Levels (L_{Aeq}) [dB] plotted on each site. Source: ©OpenStreetMap contributors – author adapted.

The values introduced on each site validate the influence of the traffic noise, which is very characteristic of the urban environment in which the sites are inserted, on the sound levels measured, since the sites closest to the avenues and the 25 de abril Bridge presented the highest sound levels.

For instance, the measured sound levels in the sites 1 and 2 were very much determined by the traffic noise from the Av. de Brasília Avenue, evidenced by the mean value from the site 2, which was lower since it is furthest from the avenue whilst closest to the water limits.

At sites 3, 4 and 5, in turn, the sound levels are considerably determined by the noise from the 25 de Abril Bridge, proven by the higher mean values when closer to it, due not only the high traffic on it, but also the friction of the vehicles tires with its floor surface of metallic grid.

As for sites 6 and 7, despite being very close, the sound levels contributions are determined by different sound sources, while on the site 6 they are set specially by the high traffic flow from the Av. 24 de julho Avenue, on the site 7, they are determined by the noise produced by the bus station which border the place, with buses movement all day long.

Lastly, the sound levels measured on sites 8, 9 and 10 are determined essentially by the noise from the Av. Ribeira das Naus Avenue, due not only the high road traffic density, but also the friction of the vehicles' tires with its stone surface. Sound levels of the site 8 are lower, since the measurement's position, close where its users usually stay, was further away from the avenue, differently to the sites 9 and 10, where their users usually stay closest to the waterfront which, in turn, are closest to the avenue.

It should be noted that the influence of the traffic on the sound levels measured on the sites can also contribute to a low quality evaluation of their sound environments, since the traffic is a sound source category usually associated to more unpleasant soundscapes (Axelsson et al., 2010; Nilsson & Berglund, 2006).

However, it is also important to consider that, in the sites closer to the water limits, the sound levels measured may also be influenced by the sounds coming from the water against the riverbank, mainly from places 3 and 10, once the measurements points were very close to this sound source.

6.1.2. Statistical Indexes

The mean values of the A-weighted statistical sound levels calculated for each site are presented in Table 6.2. The small differences found between the descriptors L_{A10} and L_{A90}, indicate that the sound levels of the sites were mostly caused by background sounds, which, on the Tejo waterfront, as highlighted on section 6.1, is essentially determined by the traffic noise predominance.

Table 6.2: Means values of the Statistical Sound Levels calculated for each site [dB].

	Sound Level mean values									
	1	2	3	4	5	6	7	8	9	10
L_{A10}	60,1	58,5	61,8	64,1	65,1	62,4	62,2	61,6	66,5	67,4
L_{A50}	56,9	54,7	59,0	60,6	62,9	59,3	58,1	58,5	63,2	63,3
L_{A90}	54,3	52,4	57,4	58,4	61,2	56,5	55,1	54,3	59,0	58,7
L_{A10} - L_{A90}	5,8	6,1	4,4	5,6	3,9	6,0	7,2	7,3	7,6	8,7

When a sound is continuous and steady such as the background sound, it can easily be unnoticed, as may occur on the sites 3 and 5, which presented the lowest differences between the descriptors L_{A10} and L_{A90}. Therefore, despite that these sites presented high mean L_{Aeq} values, 60.5 dB and 63.9 dB respectively, their sound environments may not be qualified as so annoying by their users.

In contrast, on sites 9 and 10, besides their acoustic environments presenting the higher mean L_{Aeq} values, 64.0 and 64.8 dB respectively, the differences between the values of their indexes L_{A10} and L_{A90} were also the highest ones. That is, their sound environments are characterized by featuring more sound events compared to the other, which can be considered as annoying or not by their users, depending on how much these events are noted, as well as how much they are desirable and perceived as pleasant.

In other words, not only average sound levels but also sound events matter. For instance, if, on the one hand, undesired sounds can be more annoying to people and characterize a sound environment as less pleasant, on the other hand, the desired sounds can perceptually mask unwanted sounds and even reduce its perceived loudness.

DISCUSSION

As stated, objective data from the sound environments of the sites are not enough to evaluate their quality since this may be affected by many parameters.

Therefore, the high sound levels measured at sites 4, 5, 9 and 10, and the sound environments with more variations of sites 9 and 10, represent parameters that can contribute to an evaluation of a worse quality of their soundscape.

While the low sound levels of site 2, the sound environments with less variations of the sites 3 and 5, and even the sound environments with more variations of sites 9 and 10, represent parameters that can contribute to a better quality of their soundscape.

From these considerations, it can be noted that, at the same time, the sound environment physical characteristics of sites 5, 9 and 10 can contribute either to a worse evaluation or to a better evaluation of their sound environment. Therefore, it must be considered that there are many other parameters regarding the sound environments of the sites that need to be analysed together with the physical data, mainly the perceptive ones, so that they can represent significance for the evaluation of the quality of their soundscapes.

To better understand how much the descriptors calculated may mean on the perception and evaluation of the soundscape of the sites, it is important to observe the subjective data from their users presented on Chapter 7, and therefore to analyse their correlation on Chapter 8.

6.2. USERS' ACTIVITIES

In the application of the questionnaires for the collection of qualitative data, carried out in stage 3 of the research, the users of the sites answered about the reasons that led them to use the sites, from which it is possible to know the activities they were performing at that moment. However, this information does not represent all the activities performed at the sites, since a considerable number of users who were passing through were not available to answer the questionnaires.

Therefore, a more comprehensive and quantitative data regarding all the activities carried out at the sites was considered important to obtain, by quantifying the number of users who were performing each of them, in order to know the activities which were most and least performed, in addition to compare data collected among the waterfront sites.

From the information collected, it is possible to understand how the user interacts with the environment, which can lead to a relationship of consequence or cause of how people appreciate the sound environment of the place. That is, it is understood that in addition to the urban characteristics of the site, its soundscape can directly influence the uses and the activities performed on the waterfront areas, or vice versa, the activities can influence the evaluation of the soundscape, as already found in previously published research (Dohmen, 2017; Nielbo, Steele, & Guastavino, 2013; Steele et al., 2015).

Table 6.3 represents the percentage of users who perform each type of activity, at each site. Generically, the activities were divided on those in which the user remains at the site - by using some equipment, furniture or infrastructure, visiting some establishment, or practicing a sport activity – and on those ones where the user just passes through the site - by walking or practicing a sport activity.

Comparatively, one can observe that the activities performed do not differ substantially among the waterfront sites.

Overall, the percentage of users who remain on sites is very lower compared to the other activities. This percentage is even lower on sites 2 and 10, representing only 3% of users, while it is particularly higher on site 8, representing 24% of users, most of them seated appreciating the landscape, resting and relaxing or interacting with other users.

Table 6.3: Percentual of different types of activities performed by users on each site [number of users/hours].

	Percentage of users on each site [number of users/hour]									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
User: sitting or standing	3%	3%	4%	4%	5%	9%	7%	24%	6%	3%
User: sports practice User: local equipment	4%	0%	0%	2%	2%	0%	0%	2%	0%	0%
Visitor: Tourist Spot Visitor: Store	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%
Users that remain on the site	**7%**	**3%**	**8%**	**6%**	**7%**	**9%**	**7%**	**26%**	**6%**	**3%**
Strolling: through the site	74%	54%	48%	51%	46%	86%	70%	66%	77%	87%
Sports: through the site	18%	43%	44%	43%	47%	5%	22%	8%	18%	10%
Users that just pass through the site	**93%**	**97%**	**92%**	**94%**	**93%**	**91%**	**93%**	**74%**	**94%**	**97%**

Most users usually use the sites just to pass through, mainly strolling, although, on sites 2, 3, 4 and 5, there is a significant number of users which pass through practicing some physical activity, as running, walking, or cycling. These particular uses should be motivated by the physical characteristics of these sites, endowed with extensive linear area along the water edge.

Figure 6.2 shows the maps where the percentage of the users are introduced on each site, according to the different activities performed, distinguished by gradual change of the yellow colour scale. The darker colours correspond the activities which users remain at the sites, while the lighter ones identify the activities which users pass through the sites.

It can be observed that the percentage of users who pass through the sites by developing some physical activities are higher at the sites closer to the water limits, mainly at the sites 2, 3, 4 and 5. In contrast, the percentage of users who remain more time on the places are higher at those sites farther to the water limits, mainly at the sites 6 and 8.

Although it was found some relations between the activities performed and the water limits proximity, the percentage variations between the sites is small. Therefore, several other aspects need to be considered to understand these differences, such as the surroundings and context in which the sites are placed, their typologies, their constructive and natural physical characteristics and, certainly, the perceptive aspects of their users.

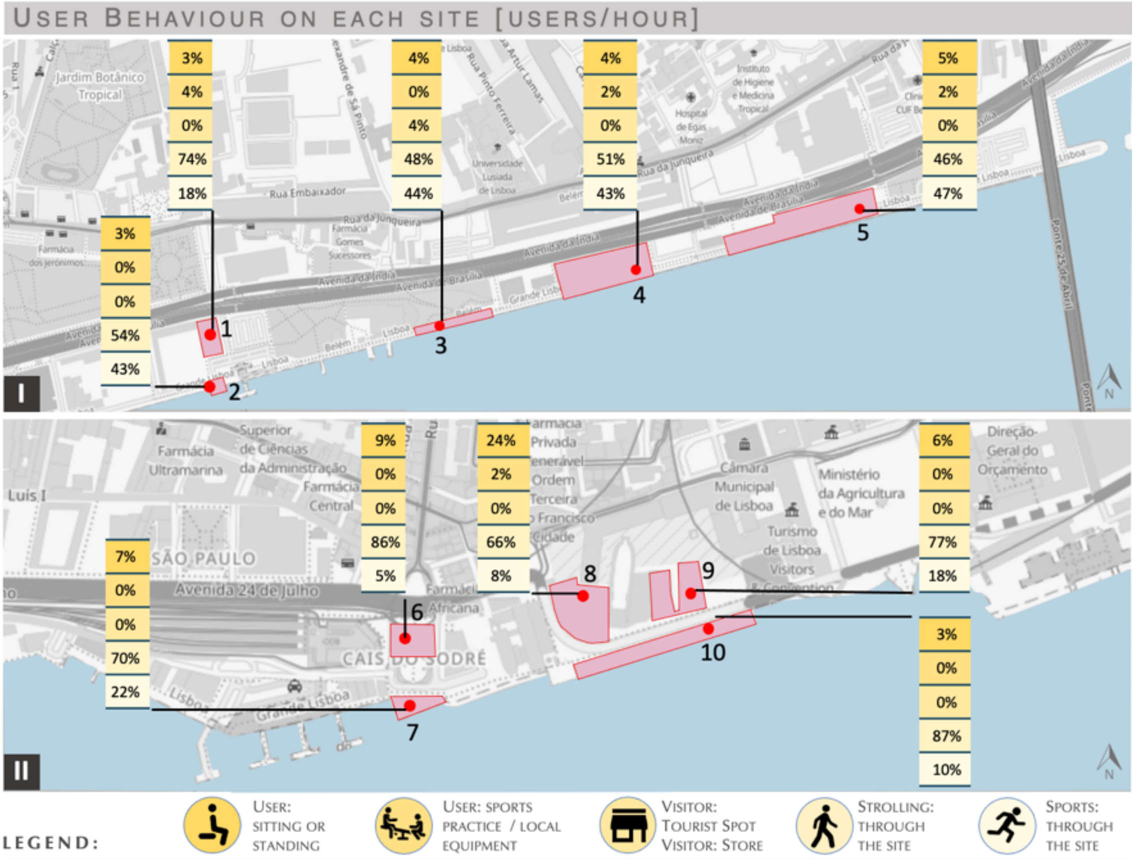


Figure 6.2: Percentual of different types of activities performed by users plotted on each site. Source: ©OpenStreetMap contributors – author adapted.

7. SOUNDSCAPE ASSESSMENT

According to the ISO 12913-2 (2017), "human sensations, responses and outcomes cannot be easily reduced to singular values of physical units. The response to sound depends on the listener's mental, social and geographical relation with the sound source".

Soundscape studies in urban spaces show that the physical acoustic parameters of a sound environment, have limitations or are not enough in accurately representing how users perceive the sound environment (Aumond et al., 2017; J. Y. Hong & Jeon, 2015, 2017a; Nilsson & Berglund, 2006; X. Zhang et al., 2017).

Therefore, although the quantitative data about the sound environment are very important to the research development, they are not sufficient for an integral and reliable soundscape study of a place. A more holistic approach is required, where perceptual data are the most important information to be collected, with users assessing the sound environment according to their preferences and experiences.

At the soundscape assessment chapter, results obtained from the collection of perceptual data regarding the waterfront sites of the Tejo River were organized and analysed. Data collection took place in two ways: through the application of a structured inquiry directly to users of each site (subitem 5.4.1) and through an on-line form answered by a listening panel (subitem 5.4.2).

Users' perceptions regarding the site, its sound sources, and sound environment were evaluated through questionnaires (all the results obtained from the application of the questionnaire, site by site, are shown in Annex D). Through the on-line form, in turn, the listening panel assessed the sound signals recordings from the same waterfront sites, by establishing the best perceived sound sources.

The evaluation of the same sound environments from two different contexts, one *in-situ* and the other on a laboratory, since they can be compared, allows to better exploit, and understand how much the surroundings, the sensations, the visual aspects, and other conditioning factors can impact on users' sound perception.

7.1. INQUIRY RESULTS

The inquiry was applied to 642 users, as described in Table 7.1, aged between 15 to 71 years, with 411 being women and 231 men (M age = 28,5 years). 95%s were Portuguese and the remaining 5% were foreigners who preferred to answer the questionnaires in English language. The questionnaires covered different days of the week, periods of the day and seasons of the year.

Table 7.1: Number of questionnaires applied.

		Number of questionnaires applied on each site										
		1	2	3	4	5	6	7	8	9	10	TOTAL
Days of the Week	Week	41	27	80	50	91	42	69	63	64	60	587
	Weekend	3	1	10	16	0	4	6	5	6	4	55
Day Shift	Morning	17	18	25	30	49	22	48	9	5	12	235
	Afternoon	27	10	65	36	42	24	27	59	65	52	407
Season	Winter	2	7	43	12	29	2	13	22	45	27	128
	Summer	42	21	47	54	62	44	62	46	25	37	117
TOTAL		44	28	90	66	91	46	75	68	70	64	642

The fewer questionnaires applied on some sites can be explained by the smaller number of their users who develop some activity, as shown in Table 7.2. Users who are just passing through usually are not willing to stop to answer the questionnaire and anyway may not be real users, with the site just being in their path.

Table 7.2: Number of users on each site.

	Number of users on each site [users/hour]									
	1	2	3	4	5	6	7	8	9	10
User: sitting or standing	3	5	10	11	12	11	27	21	9	11
User: sports practice User: local equipment	3	0	0	5	5	0	0	2	0	0
Visitor: Tourist Spot Visitor: Store	0	0	9	0	0	0	1	0	0	0
Users: remain on the site	6	5	19	16	17	11	27	23	9	11
Strolling: through the site	59	89	112	141	107	107	270	59	123	302
Sports: through the site	15	70	103	119	109	6	86	7	28	35
Users: pass through the site	74	159	215	261	216	113	356	66	151	337

7.1.1. User profile

The socio-demographic data of the users of the Tejo's waterfront area are herein presented both for the whole waterfront area and for each site separately.

Figure 7.1 shows data collected from the whole waterfront area where it can be noted that (a) women represented 63,2% of the users and (b) most of them are young users, with more than 67% being aged between 15 and 29 years.

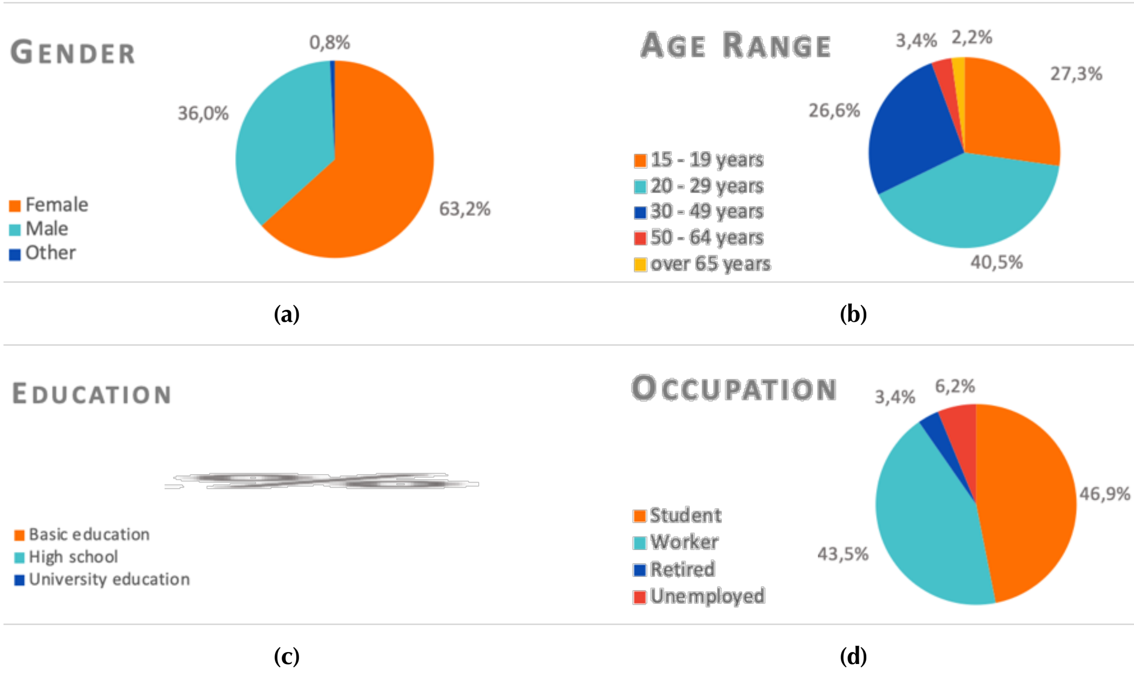


Figure 7.1: Profile of the user of the Tejo's waterfront site: (a) Gender (b) Age range (c) Education level (d) Occupation.

Regarding the users' education level (c), they are essentially divided into those that have concluded high school (41,1%) and those that have completed a university education (56,4%). Regarding their occupation (d), most of the users are students (46,9%) or working users (43,5%).

Figure 7.2. confirms that "women" are much more representative on most of the sites, except on sites 3, 4, 5 and 6, where the differences were lower.

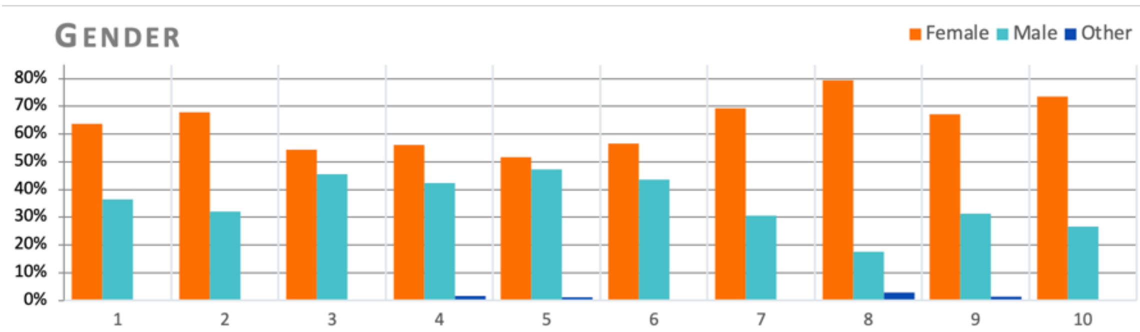


Figure 7.2: Gender of the user of each site.

Figure 7.3 also confirms that young users (aged between 15 and 29 years) represent most of the users on all the sites, mainly on those located on Area II of the waterfront.

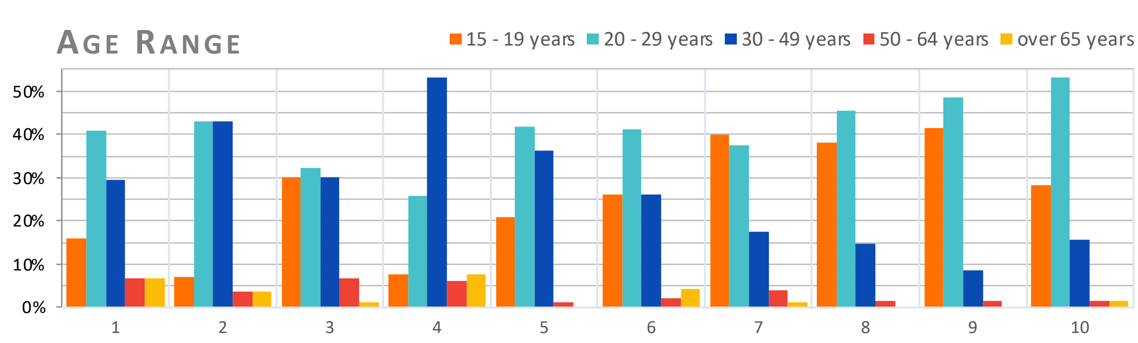


Figure 7.3: Age range of the user on each site.

However, Figure 7.4 shows that, regarding the users' education, there are differences between users of Area I and users of Area II, since on Area I, users have mostly completed a university education, while on Area II, users have mostly concluded high school.

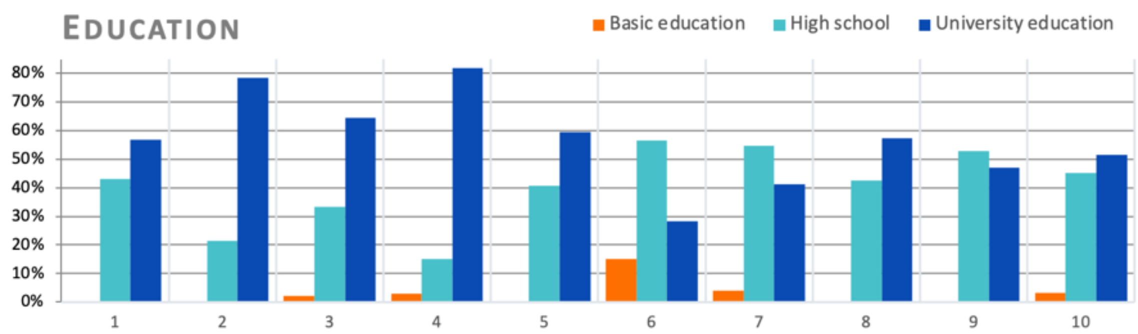


Figure 7.4: Education level of the user of each site.

Lastly, Figure 7.5 shows that similarly there are differences on the users' occupation between Area I and Area II, since on Area I, there are more working users, except on site 3, and, on Area II, there are more students, except on site 6. In general, there are more significant differences on site 4, with a large majority of workers, and on sites 8 and 9, mostly frequented by students.

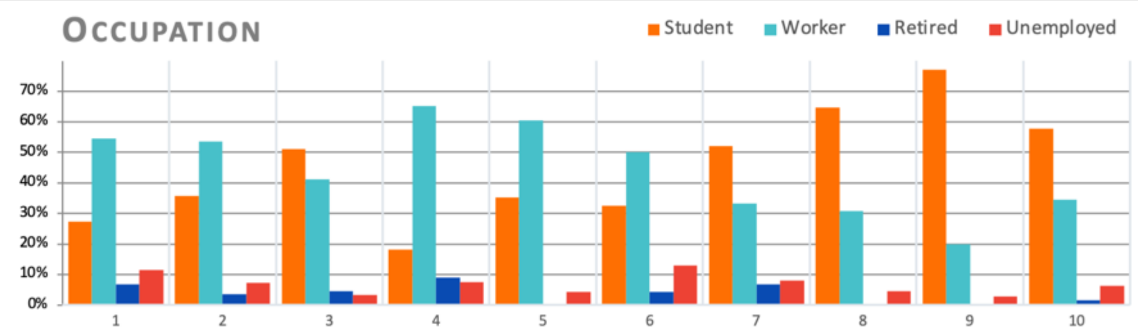


Figure 7.5: Occupation of the user of each site.

7.1.2. User practices

The practices of the users on the Tejo's waterfront area are herein presented both for the whole waterfront area and for each site separately.

Data from the whole waterfront area presented in Figure 7.6 shows that the user' frequency of visit (a) is very balanced. The percentage of users that are on the sites periodically, from once a week to daily, is almost same of users that are on the sites less often, from 2 to 4 times a month. Besides, there are also a significant number of users reported using the sites rarely or for the first time.

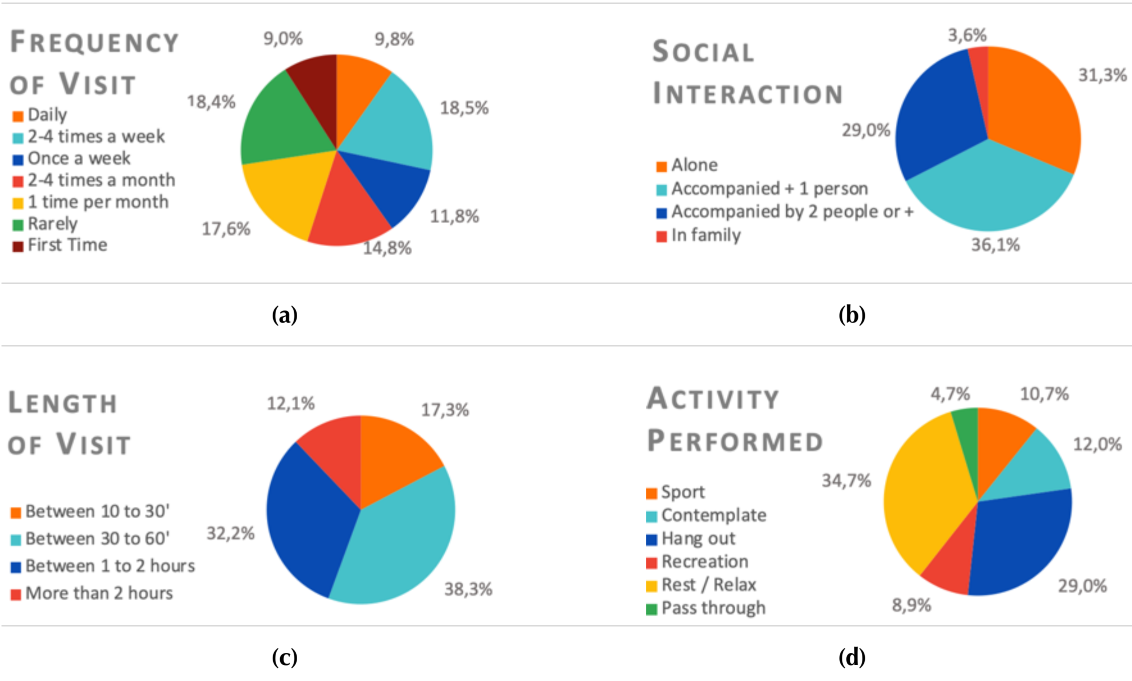


Figure 7.6: Practices of the users Tejo's waterfront sites (a) frequency of visits, (b) social interaction, (c) length of visit, and (d) activity performed.

The way users interact socially (b) on the sites are also balanced, since the percentage of users alone, accompanied by one person and accompanied by two or more person is almost the same, while "users with family" do not usually visit the area.

Regarding users' length of visit (c), it can be noted that users remain on sites between 30 and 60 minutes or between 1 and 2 hours, while users that remains less than 30 minutes or more than two hours are in small numbers.

Lastly, "rest and relax" or to "hang out" are the main activities performed (d) on the waterfront area, by more than 63% of users.

Figure 7.7 shows that users' frequency of visits on the waterfront sites are also variable, since while users of sites 1, 2, 4, 5 and 6 usually visit them periodically, users of sites 8, 9 and 10 visit them less often. Besides, on sites 1, 3, 7, 9 and 10 there are also a significant number of users that use them rarely or for the first time.

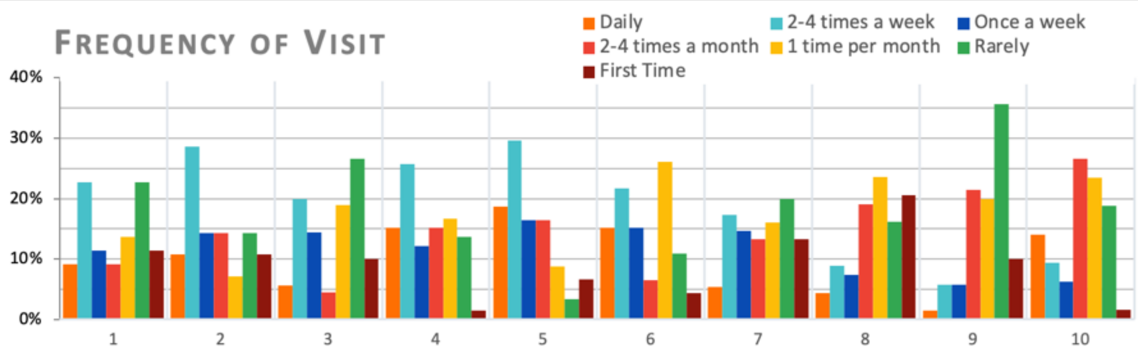


Figure 7.7: Visit frequency of each site.

The social interaction between users is also variable among the sites, as shown in Figure 7.8. There are higher differences on sites 4 and 6, mostly visit by alone users, on sites 1 and 10, mostly visit by users accompanied with one person, and on sites 8 and 9, mostly visit by users accompanied with more users. Users with family are more present only on site 4.

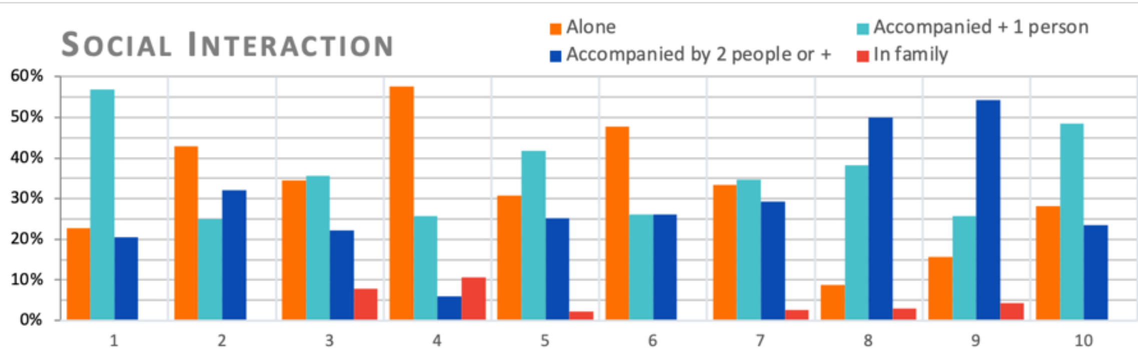


Figure 7.8: The way user interacts socially on each waterfront site.

Figure 7.9 shows that on most sites the length of visit is well distributed, except on sites 3, 6, 7 and 10 that users usually remain until 1 hour on the place, and on site 8, that they usually remain even more than 2 hours.

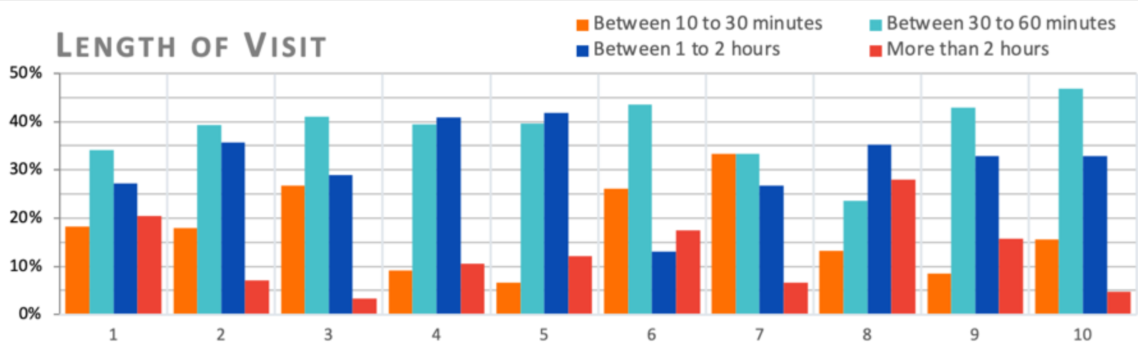


Figure 7.9: User' length of visit on each site.

Regarding the activities performed by users on the sites, Figure 7.10 shows that users of most sites use to visit them to "rest and relax", except on sites 8, 9 and 10 most visited to “users hang out", and on site 5 most visited to “sport practice”.

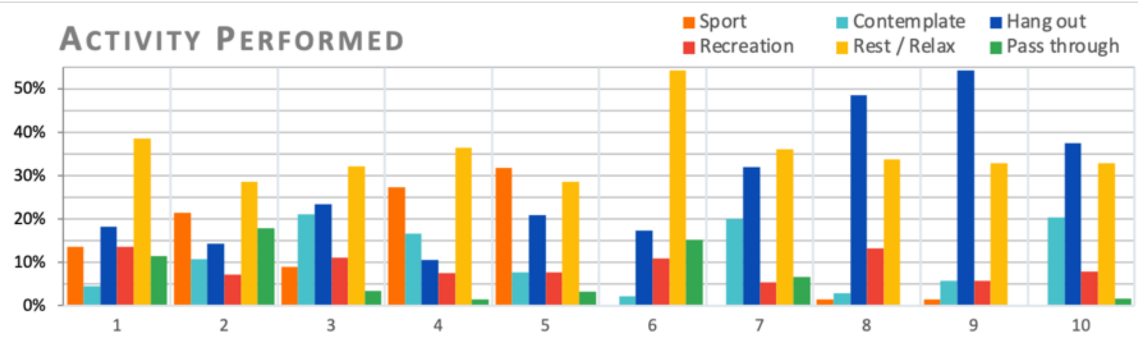


Figure 7.10: Activity performed by the user on each site.

Besides, it can be noted that on some sites particular activities are performed, with sites 2, 4 and 5 very used to “sport practice” and sites 3, 7 and 10 very used to “contemplate the water landscape” and “hang out with users".

7.1.3. Public space quality evaluation and its influences

In the first part of the inquiry, users assessed subjectively, according to their perceptions, (i) the public space itself, from quality criteria established (ii) the influence which both “the waterfront proximity” and the “sound environment” had on their decision to visit the site, and (iii) the importance they assign to waterfront sounds.

7.1.3.1. Public space quality evaluation

Users assessed the quality of the space, according to some predetermined criteria considered important for the research, based on referenced surveys on public spaces evaluation.

The general evaluation of all the quality criteria predetermined are shown in Figure 7.11, where the mean scores obtained from the different degrees of agreement attributed to each one of them are presented.

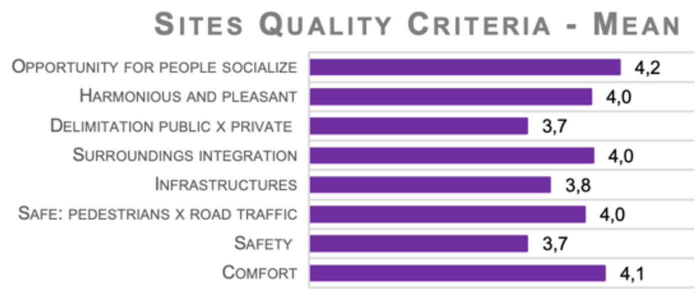


Figure 7.11: Sites Quality Criteria - Mean Score – higher score implies higher public space quality.

The quality criteria mean scores were from 3.7 to 4.2, which means that most users of the Tejo waterfront evaluated positively all the quality criteria established.

Even so, despite the minimum differences, one can observe that comparatively and in general, users agreed slightly less with the qualities: "appropriate delimitation between public and private spaces and between spaces with incompatible uses", “safety to the users and their belongings” and “appropriate quantity and position of infrastructures”. While users agree slightly more with the qualities: "opportunity for users socialize" and “comfort for its users”.

The mean scores obtained from the assessment of each quality criterion for every site are shown in Figure 7.12.

The evaluation of certain criteria varied more than others among the sites, as the qualities (ii) “safety”, (iv) “infrastructures” and (viii) “socialize opportunity”, while certain criteria were evaluated very similar among the sites, as the qualities (i) “comfort”, (iii) “safe relationship between pedestrians and traffic” and (vi) “appropriated delimitation between public and private spaces”.

In detail, even with little variations, it is important to highlight the evaluation of some qualities on some sites. For instance, the lower evaluations of the qualities (ii) “safety” on sites 7 and 8, (iv) “infrastructures” on site 8, and (viii) “opportunity for users socialize” on site 6, as well as the higher evaluations of the quality “opportunity for users socialize” on site 7.

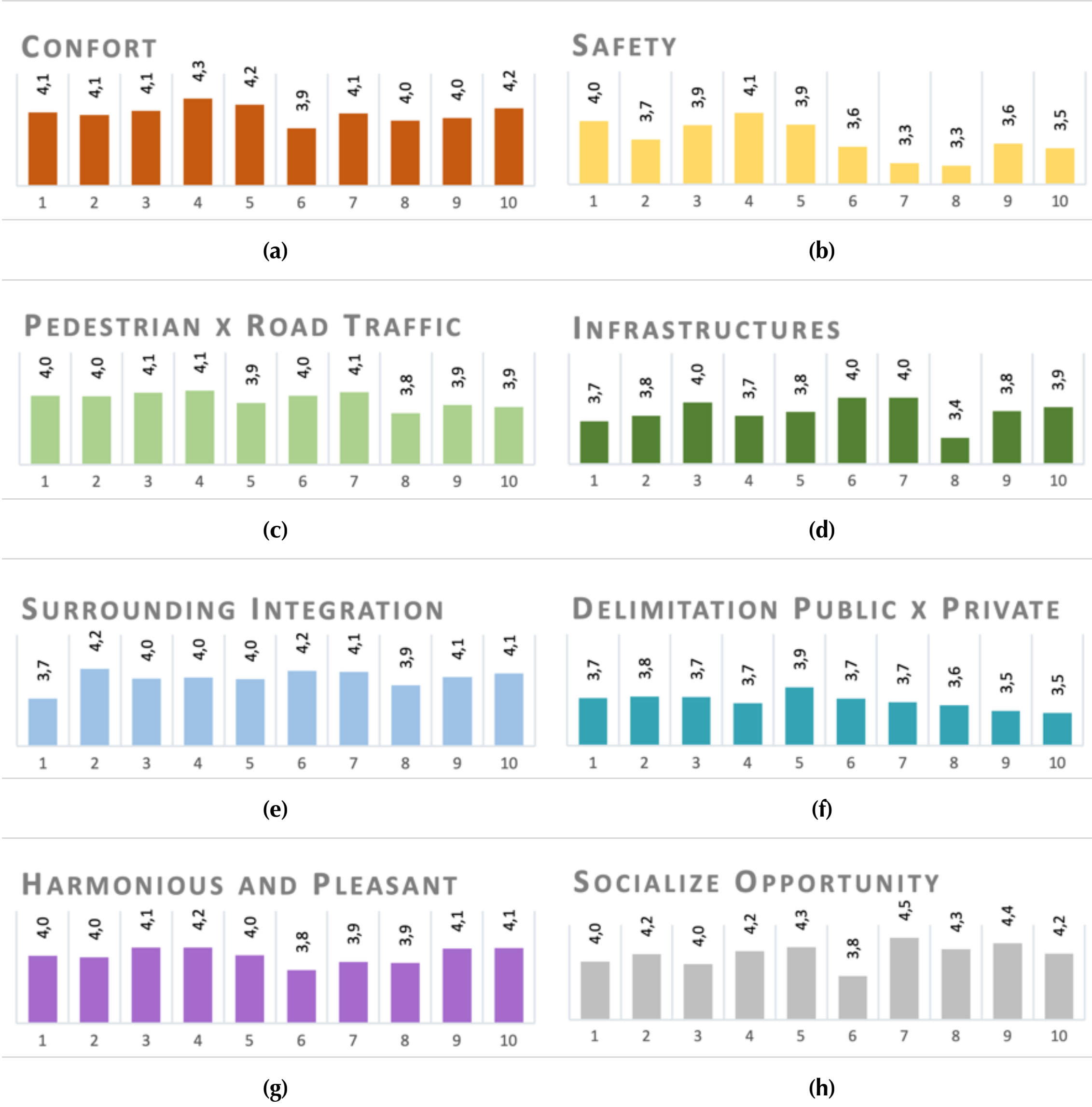


Figure 7.12: Sites evaluation – (a) provides comfort to its users; (b) provides safety to its users and their belongings; (c) provides a safe relationship between pedestrians and road traffic; (d) has infrastructures well quantified and positioned; (e) has good integration with its surroundings; (f) presents an appropriate delimitation between public and private spaces; (g) it is organized: harmonious and pleasant; (h) creates opportunity for users socialize.

Lastly, it was also noticeable that, in general, the evaluation of all the quality criteria of sites 3, 4 and 5 was superior compared to the other sites, while, in sites 8 and 6, it was lower.

The slightly lower-quality evaluation of site 8, at the "Ribeira das Naus - Tree Area", can be also observed with the evaluation average of the eight qualities which were calculated for each site, shown in Figure 7.13.

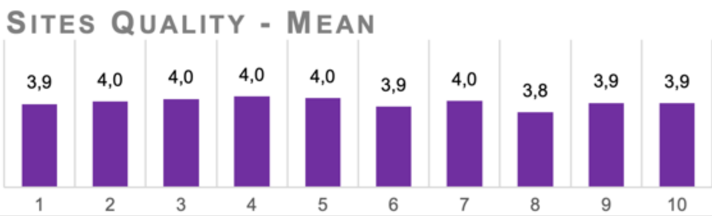


Figure 7.13: Site Quality Average for each Site.

7.1.3.2. The "Landscape" and the "Soundscape" influence to visit the sites

The second and third questions of the questionnaire aimed to know how much the "proximity to the water" and the "sound environment" influence the users' decision to visit the site.

However, the "proximity to water" characteristic can be interpreted in different ways, since it involves a multisensory perception, through different senses: vision, hearing, smell, touch, and even taste. The "sound environment" characteristic is more directly related to the user's auditory perception.

Therefore, in order to decrease the extent of the "proximity to water" characteristic and considering, above all, that the visual component represents the most dominant sense of the human being (Gan, Luo, Breitung, Kang, & Zhang, 2014; Spence, 2020), the term "landscape" was used, which appropriates to a more physical dimension directly related to visual perceptive aspects.

Accordingly, the assessment, was mainly intended to understand how much each characteristic, the "landscape" and the "soundscape", influences the users' decision to visit the site.

The mean scores obtained, from the different degrees of influence attributed to both characteristics are shown side by side, for each site, in Figure 7.14.

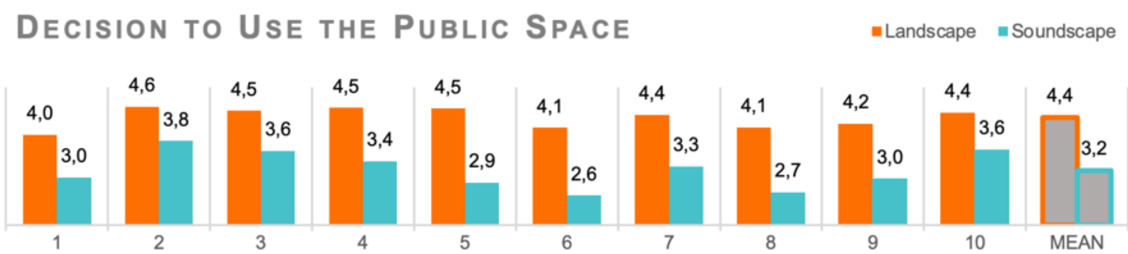


Figure 7.14: Parameters that influence on the decision to site use: waterfront environment x sound environment – higher score imply higher influence on decision to use the site.

For all the sites surveyed, the “landscape” characteristic influenced from "very" to "totally" their users on the decision to visit the place. While the “soundscape” influenced less, usually "slightly" or "moderately” the decision, except sites 2, 3 and 10, in which their soundscapes were "very" influencing.

The mean scores introduced on the maps in Figure 7.15 demonstrate that both sites’ characteristics, the “landscape” and the “soundscape”, comparatively influenced more the users of those sites who were placed indeed in front of the water limits.

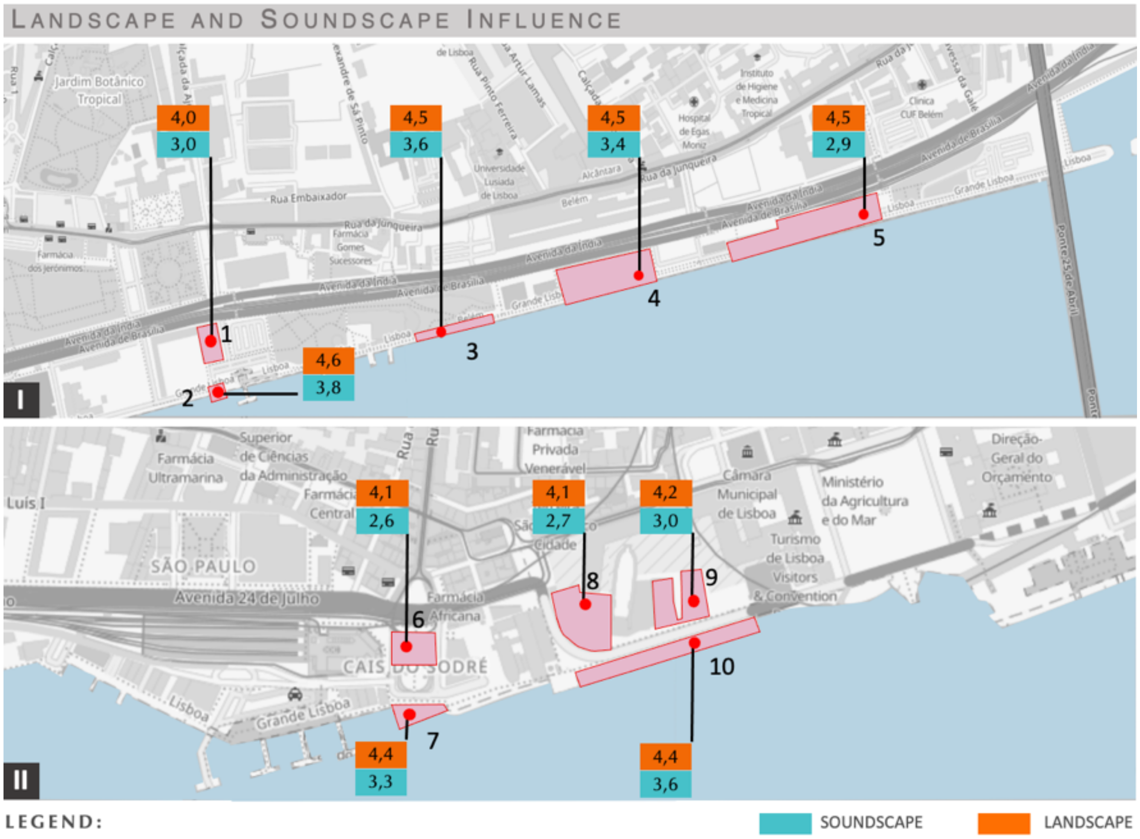


Figure 7.15: Sound environment influence on the sites use, located on each site of the waterfront maps – Area I and Area II. Source: ©OpenStreetMap contributors – author adapted.

It is understood, therefore, that the position of the sites somehow may affect how much their characteristics influenced the users visit. Except for site 5, where its “soundscape” less influenced their users to visit when compared to the other ones in a similar position, in front of the water, such as sites 2, 3, 4, 7 and 10.

7.1.3.3. Waterfront sounds importance

Since a waterfront site can feature very specific sounds which contribute to a better characterization of this typology of space, such as the sounds of water, pier, seagulls, and boats, it was relevant to understand the importance the users attribute to these sounds, regardless of they were being perceived.

The mean scores obtained from the different degrees of importance established to the waterfront sounds on each site are shown in Figure 7.16.

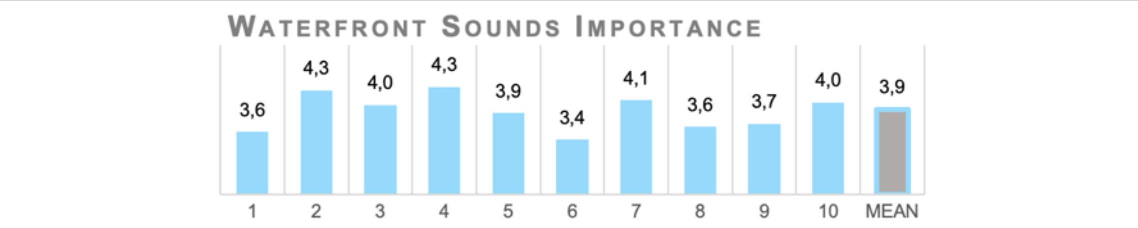


Figure 7.16: Importance of sounds waterfront related – higher score implies higher waterfront importance.

The waterfront sounds were considered “important” for most of sites’ users, except to the site 6 users which they were regarded "moderately important".

The mean scores introduced on the maps in Figure 7.17 show that comparatively users who were on the sites placed indeed in front of the water limits valued more the "waterfront sounds", which means that the users’ position may also influence this evaluation.

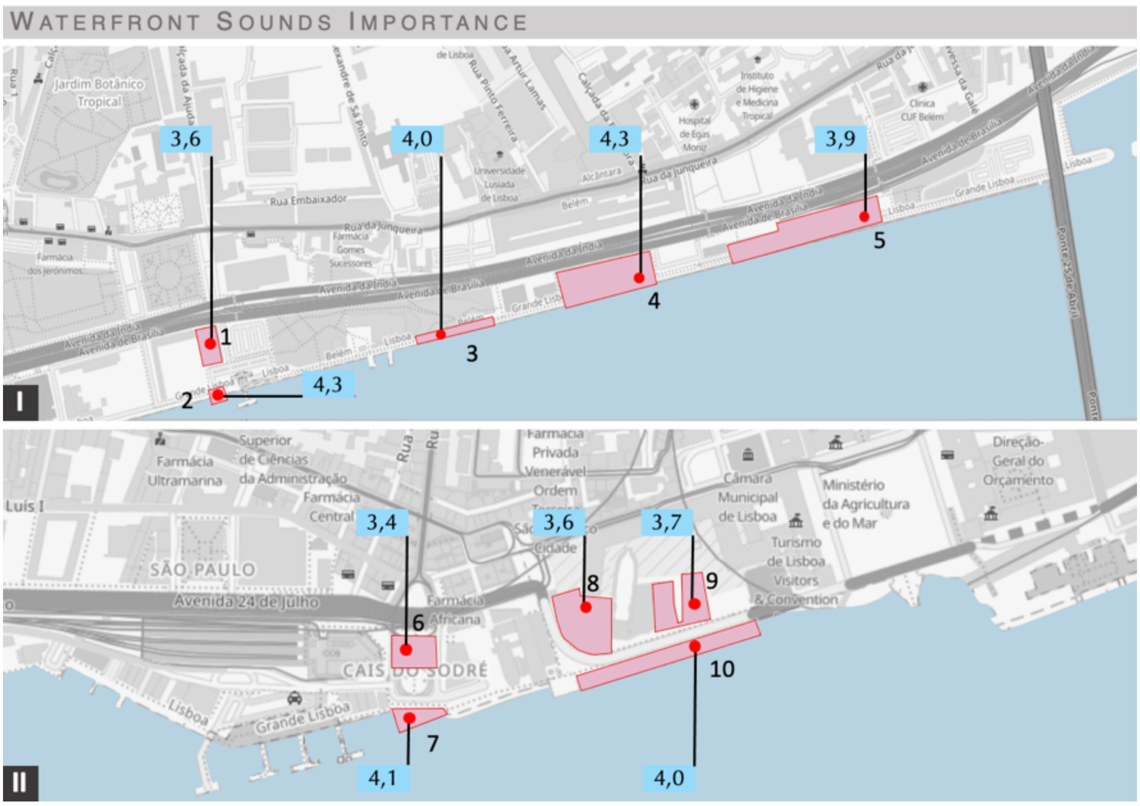


Figure 7.17: Waterfront sounds importance, located on each site of the waterfront maps – Area I and Area II.
Source: ©OpenStreetMap contributors – author adapted.

7.1.4. Soundscape quality evaluation

The ISO 12913-2 (2017) standard establishes a set of relevant information to be collected from a given environment in order to assess the quality of its soundscape, which essentially comprises how users perceive, experience and understand the sound environment.

Considering that users at an external environment are stimulated by several factors and may experience the places in many different ways, that can directly interfere directly with their perception, including the auditory ones, it is important to know how they individually assess the sites' sound environment.

On the questionnaire application, the user of the Tejo's waterfront assessed a diversity of aspects regarding its sound environment, which comprehended: (i) the sound sources perceived, (ii) the sound environment affective qualifications (iii) the sound environment itself, and (iv) the sound environment appropriateness.

7.1.4.1. Perceived sound sources

On the first sound environment assessment, users established a ranking of the sound sources they perceived best, in a decreasing order.

From the free-text answers collected, firstly, it was necessary to carry out the sound sources classification according to the categories set out for the research and attribute the proper weighting to the perception order defined, to obtain the contribution of every sound source category on the acoustic environment (according to subsection 5.4.1.2(ii)), whose results for the Tejo’s waterfront are shown in Figure 7.18.

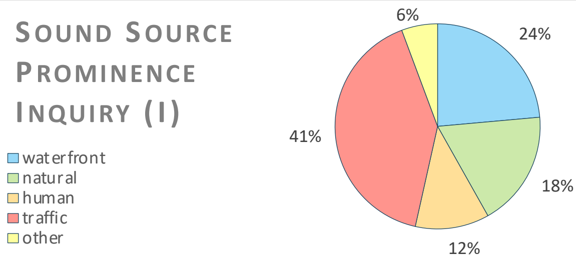


Figure 7.18: Inquiry Response (I): average perception percentual of each sound source [%].

From the users’ perception responses, the “traffic sounds” was the best perceived sound source category (41%) on the acoustic environment. Nevertheless, the categories “waterfront sounds” (24%) and “natural sounds” (18%) were also well perceived, whereas the “human sounds” (12%) and the "other sounds" (6%) were the less ones perceived.

The results demonstrate that, despite the sites being within a waterfront environment, in which their characteristic sounds could have been the best perceived, the "traffic sounds" were still the best perceived, perhaps due to the urban characteristics of the waterfront area.

However, the contribution of each sound source category on each site’s sound environment was different, as shown in Figure 7.19.

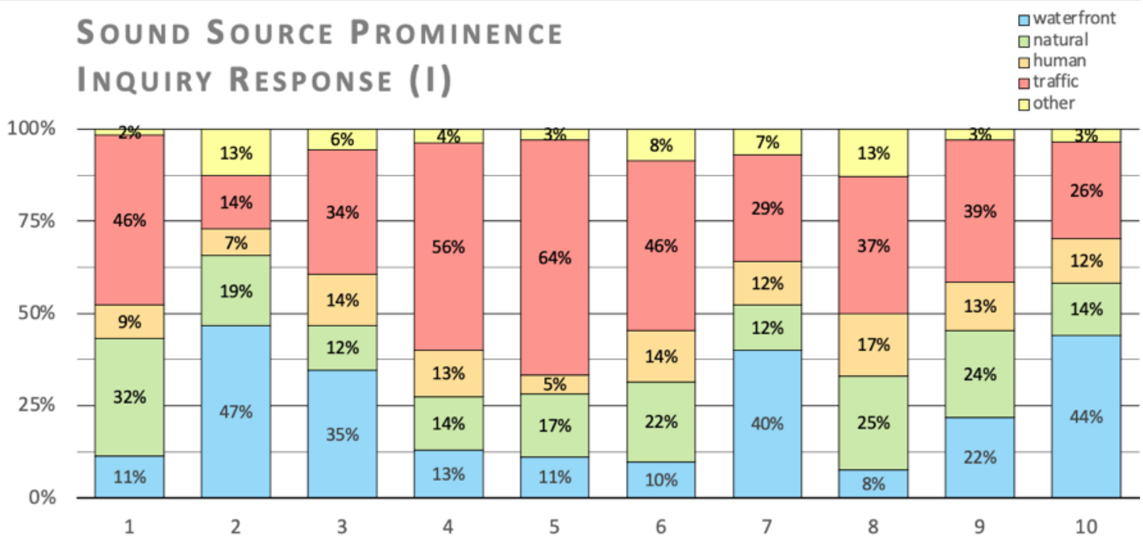


Figure 7.19: Inquiry Response (I): average perception percentual of each sound source on each site [%].

The “traffic sounds" were very well perceived at all sites (varying between 14% and 64%), except on site 2. "Waterfront sounds" were also notably perceived (8% - 47%), but mostly on sites 2, 3, 7, 9 and 10. Comparatively, "natural sounds" were less perceived (12% - 32%), but considerably noted on sites 1, 6, 8 and 9. Lastly, “human sounds” (5% - 17%), and "other sounds" (2% - 13%), were the sound sources least perceived by the users on all sites.

The prominence order in which the sound source categories were perceived at each site are presented in Table 7.3, where those that dominate the acoustic environment can be clearly noted.

The “traffic sounds” was the category considered as dominant on the sound environment at most sites, except at sites 2, 3, 7, and 10. Precisely at these sites, the “waterfront sounds” were regarded as the most dominant ones. The "natural sounds" category, in turn, shows up as the second most dominant sound source, except on sites 3, 7 and 10.

It is important to note the small perception of the "traffic sounds" at site 2, and of the "waterfront sounds" at sites 1, 4, 5, 6 and 8, which it was different than the perception of the other sites.

Table 7.3: Inquiry Response (I): Ranking of the sound source categories prominence on each site.

	Ranking of Sound Source Prominence on each site - Inquiry Response (I)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1st	46%	47%	35%	56%	64%	46%	40%	37%	39%	44%
2nd	32%	19%	34%	14%	17%	22%	29%	25%	24%	26%
3rd	11%	14%	14%	13%	11%	14%	12%	17%	22%	14%
4th	9%	13%	12%	13%	5%	10%	12%	13%	13%	12%
5th	2%	7%	6%	4%	3%	8%	7%	8%	3%	3%

The contribution of each sound source category on the sound environment of each site were introduced on the waterfront area maps in Figure 7.20.

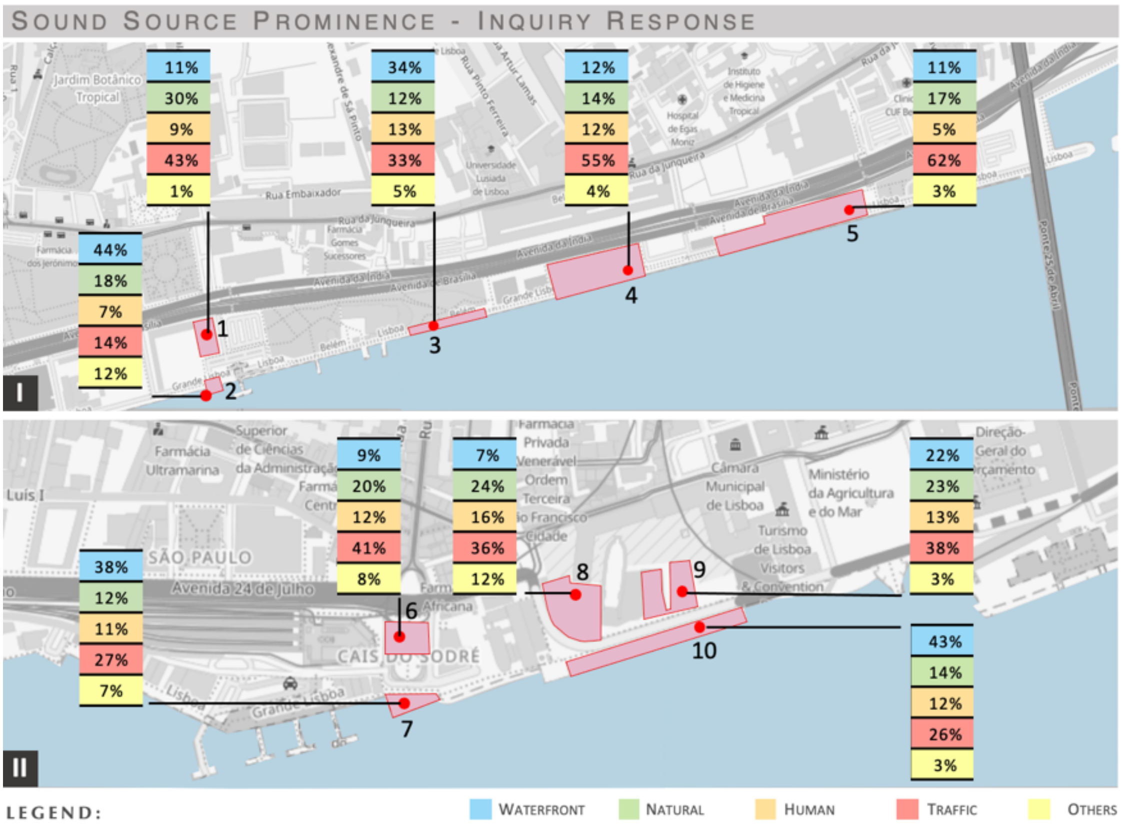


Figure 7.20: Inquiry Response (I): percentual of the perceived sound sources on each site, located on the waterfront maps – Area I and Area II. Source: ©OpenStreetMap contributors – author adapted.

The results in the maps show that the “waterfront sounds” category dominates the sound environment at those sites that are really facing the water, except at sites 4 and 5. Specifically at these sites, the "traffic sounds" was the sound source category perceived as predominant on the sound environment, which leads to understand that this dominance can be masking the “waterfront sounds” perception, which was noticed as common in the areas with this water relation.

7.1.4.2. Perceived affective quality

Eight perceived affective quality items are recommended by the ISO 12913-2 (2017), in order to understand how people perceive the soundscape of a place. Axelsson et al. (2010) suggest a measurement system for soundscape quality, where the eight attributes’ responses can be represented in a two-dimensional circumplex model with two main dimensions related to how much pleasant and eventful the environment was judged. And, at a rotation of 45° from the two main dimensions are two alternative dimensions representing environments that are chaotic versus calm, and environments that are monotonous versus exciting.

Therefore, the eight affective quality items were assessed for each site and, according with the circumplex model proposed by Axelsson et al. (2010), were introduced on the radar graph in Figure 7.21, where the affective quality items are identified on each corresponding axis and the mean scores from 0 to 4,5 are marked. Each colour line represents the evaluation from one site, which connects the mean scores obtained for each affective quality.

The graphic shows that apparently the affective qualities were very similarly evaluated at the ten sites, with sound environments that tend to be more “uneventful” and “exciting” and mainly “pleasant” and “calm”.

The evaluation of the “monotonous” and “uneventful” qualities varied less between the sites, while the qualities “eventful”, “pleasant”, and "annoying" are the ones who differed more.

Despite the slight differences, one can note that the users of some sites evaluate differently some affective qualities when compared to the other, such as site 6 which is more 'eventful', 'chaotic', and 'annoying', while less 'pleasant' than the other sites, almost the opposite that site 2 that is more 'exciting', 'pleasant' and 'calm', while less 'eventful', ‘chaotic’, and 'annoying’.

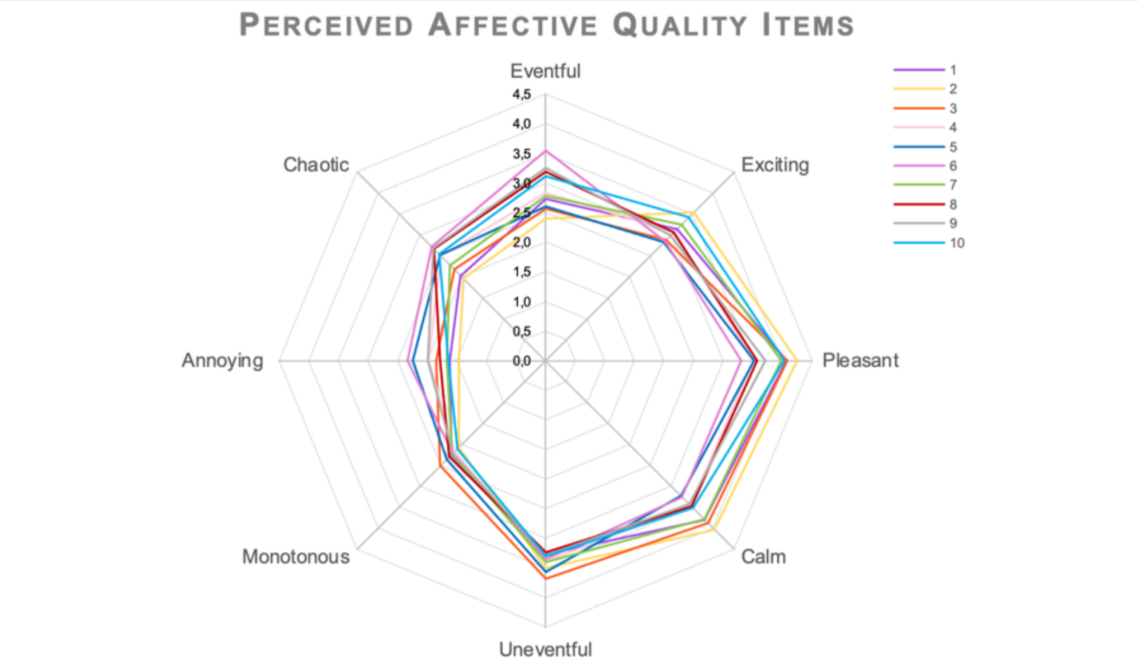


Figure 7.21: Mean scores of the perceived affective quality items on the ten sites – higher scores imply higher level of agreement with the specific attribute.

Therefore, although the quality evaluation seems to be very similar, the differences noted in sites 2 and 6 impose the need to examine the results in more detail and distinguish the evaluations of each site. In this sense, firstly, it was necessary to investigate the mean scores obtained for each affective quality of every site, shown in Table 7.4.

Table 7.4: Mean scores obtained from the sound environment affective qualities evaluations on each site.

	Mean Scores of the Sound Environment Affective Qualities of each Site											
	1	2	3	4	5	6	7	8	9	10	mín.	máx.
Eventful	2,7	2,4	2,6	2,8	2,6	3,5	2,8	3,2	3,3	3,1	2,4	3,5
Exciting	3,1	3,5	2,9	3,1	2,8	2,8	3,3	3,1	3,0	3,4	2,8	3,5
Pleasant	4,1	4,3	4,1	3,5	3,5	3,3	4,0	3,6	3,7	4,0	3,3	4,3
Calm	3,8	4,0	3,9	3,5	3,2	3,3	3,8	3,5	3,4	3,5	3,2	4,0
Uneventful	3,3	3,5	3,7	3,4	3,6	3,3	3,4	3,2	3,3	3,3	3,2	3,7
Monotonous	2,3	2,1	2,5	2,2	2,4	2,2	2,2	2,3	2,2	2,1	2,1	2,5
Annoying	1,6	1,5	1,8	2,0	2,2	2,3	1,7	1,8	2,0	1,6	1,5	2,3
Chaotic	2,0	2,0	2,2	2,5	2,5	2,7	2,3	2,7	2,7	2,5	2,0	2,7

From the data in the table, one can observe the importance of the 'pleasant' quality on the soundscape of the waterfront sites, since it was the best evaluated quality on all the sites. In this sense, a more detailed analysis on the mean scores on the 'pleasant' evaluation, aided by a colour scale usage, can help to better understand some evaluation differences or similarities between the sites.

As already evidenced in Figure 7.21, the more different evaluations were between sites 2 and 6, which can be defined, respectively, as the most and least pleasant sites of the waterfront. From the other sites results, it can be noted that comparatively the sites 1, 3, 7 and 10 rated the 'pleasant' quality better than sites 4, 5, 8 and 9.

Considering the evaluations differences on the ‘pleasant’ quality, a radar graphic of the affective qualities assessments of sites 1, 2, 3, 7 and 10 was prepared, which proves many evaluation similarities, mainly between sites 1 and 7, as shown in Figure 7.22. On site 10, there is a slightly higher evaluations for the qualities 'chaotic' and 'eventful' and lower for the 'calm' quality. At site 3, in turn, there is a slightly higher rating for the 'annoying', 'monotonous' and 'uneventful' qualities, and lower for the 'exciting' quality. Lastly, site 2 confirms to be the more 'exciting', 'pleasant' and 'calm', and the less 'eventful', 'chaotic', and 'annoying' than the other sites.

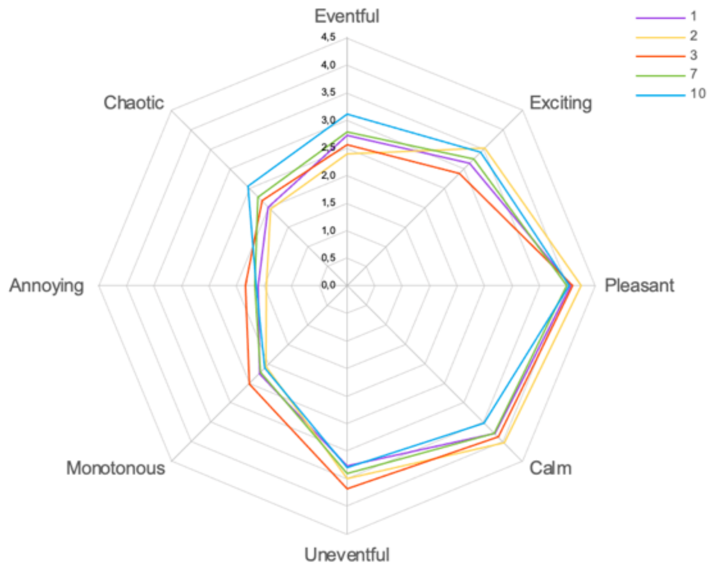


Figure 7.22: Mean scores of the perceived affective quality items on the sites 1, 2, 3, 7 and 10 – higher scores imply higher level of agreement with the specific attribute.

Figure 7.23 shows the affective qualities evaluations of sites 4, 5, 6, 8 and 9, which attributed lowest scores for the 'pleasant' quality. Likewise, there is considerable similarity on the evaluations of all the sites, mainly between sites 8 and 9. At site 5, there is a slightly higher evaluation for the qualities 'monotonous' and 'uneventful' and a lower evaluation for the 'eventful' quality. Site 6 confirms to be the more 'eventful', 'chaotic', and 'annoying', and the less 'pleasant' than the other sites.

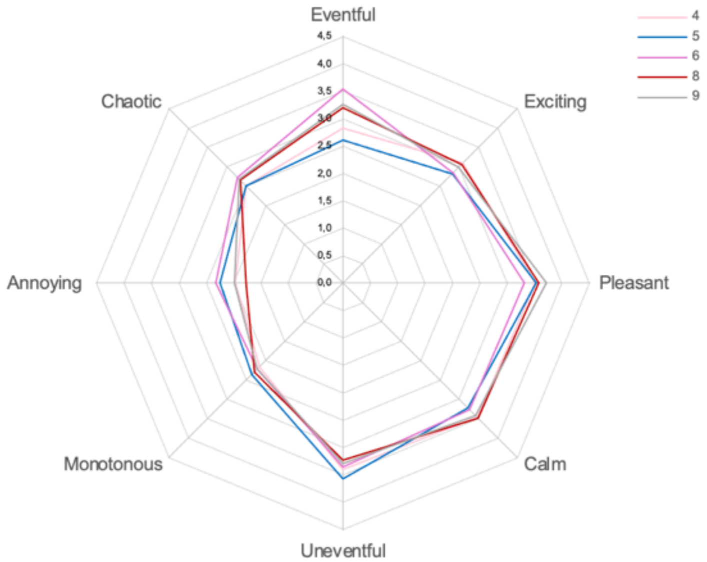


Figure 7.23: Mean scores of the perceived affective quality items on the sites 4, 5, 6, 8 and 9 – higher scores imply higher level of agreement with the specific attribute.

(i) Results processed to pleasantness and eventfulness dimensions

According to Axelsson et al. (2010) the "soundscapes may be represented by their position in a two-dimensional space defined by the two main components Pleasantness and Eventfulness". The 'Pleasantness' is a hedonic value of sound environment, represented by how pleasant or unpleasant the environment was judged, while 'Eventfulness' is concerned to a variety of sounds or temporal variations of sound environments, related to how eventful or uneventful the acoustic environment is perceived to be.

The Pleasantness and Eventfulness dimensions must be calculated, respectively, through equations (1) and (2), presented on subitem 3.1.4, as recommended in the "Annex A" of the ISO 12913-3 (2019), based on the results from the assessment of the eight affective.

Therefore, considering the mean scores of the affective quality items evaluations, the Pleasantness and the Eventfulness of each site were calculated, and the results were introduced on the bi-dimensional circumplex graph presented in Figure 7.24, where on the X-axis the coordinates for Pleasantness were plotted, and, on the Y-axis, the ones for Eventfulness, and, consequently, every point represents one site.

The Pleasantness results confirms the mean scores showed in Table 7.4., where sites 1, 2, 3, 7 and 10 can be considered more pleasant than sites 4, 5, 6, 8 and 9. However, the model makes more apparent the pleasantness order of the sites, in which site 2 confirms as the most pleasant one, then there are the sites 1, 7, 10 e 3, followed by sites 8, 4 and 9, and lastly sites 5 and 6 which are the less pleasant ones.

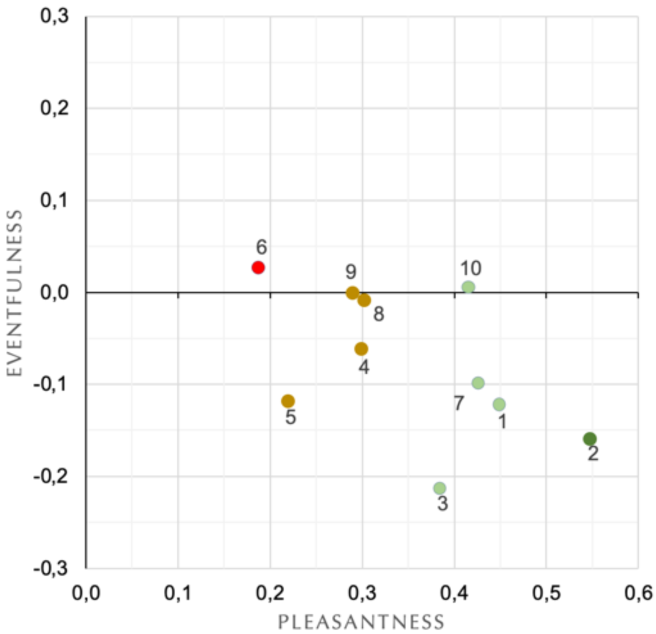


Figure 7.24: Bi-dimensional circumplex model: pleasantness and eventfulness components of each site.

The Eventfulness results demonstrates that, except for site 6, the sound environments are perceived as uneventful, despite the values obtained being low. However, an uneventful sound environment is described as completely devoid of human activity, by the ISO 12913-3 (2019), which does not match with the waterfront sites' characteristics once they are totally integrated in an urban mesh, busy with human activities.

This incompatibility between what the standard describes about an uneventful sound environment and the characteristics of the Tejo's waterfront, leads to the understanding that there may be other factors that are also influencing the uneventful characteristic of the sound environments obtained.

The graph also makes evident the similarity of the evaluations of sites 1 and 7 and sites 8 and 9, both on “pleasantness” and on “eventfulness” of the sound environment, as already observed by Figure 7.22 and Figure 7.23.

Pleasantness and eventfulness dimensions introduced on the circumplex model in Figure 7.25, shows that the soundscape of sites 5 and 3 is ‘calm’, because they are almost in the same proportion ‘uneventful’ and ‘pleasant’.

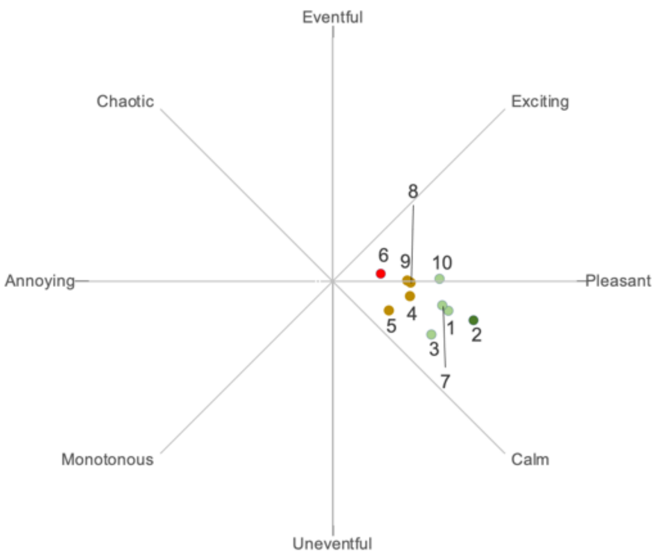


Figure 7.25: Sites pleasantness and eventfulness dimensions of each site plotted on a circumplex model.

7.1.4.3. Surrounding sound environment assessment

The assessment of surrounding sound environment and the assessment of the sound environment represent for the research the two most important issues since they measure the soundscape quality of the public spaces.

Since from both assessments it is possible to understand directly how the sound environments of the places are appreciated, it is from them that the other comparisons proposed for the research were carried out, to obtain significant relationships for the establishment of objective criteria for the analysis of a waterfront soundscape.

The mean scores obtained for the surrounding sound environment assessment of each site are shown in Figure 7.26, where a "good" evaluations from the users of sites 1, 2, 3, 7 and 10 can be observed, while sites 4, 5, 6, 8 and 9 were evaluated as "neither good, nor bad".

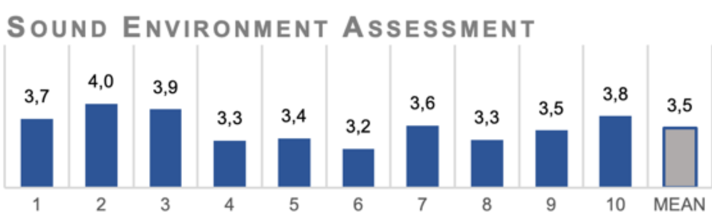


Figure 7.26: Sound environment evaluation mean on each site – higher scores imply higher level of appreciation of the sound environment.

The mean scores were also introduced on the maps of the waterfront area, as shown in Figure 7.27. The results demonstrate that the better evaluations of the sound environment were on the sites placed really in front of the water limits, except the sites 4 and 5, that, in turn, obtained among the worst evaluations.

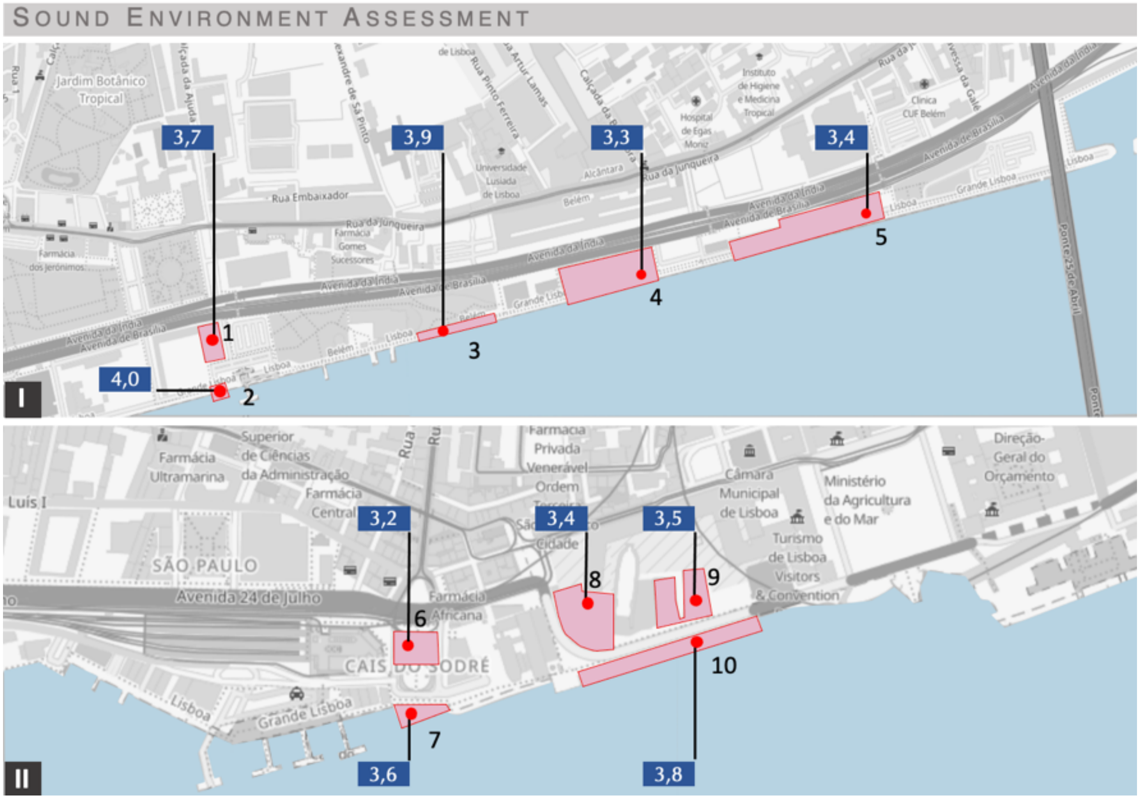


Figure 7.27: Overall sound environment evaluation, located on each site of the waterfront maps – Area I and Area II. Source: ©OpenStreetMap contributors – author adapted.

7.1.4.4. Appropriateness

Regarding the appropriateness of the sound environment with the place, the user establishes a more direct correlation between the space itself, within its context, relationships and characteristics, and its sound environment.

The mean scores obtained from the assessment of the appropriateness of the sound environment with the place are shown in Figure 7.28. From the results, it can be noted that on sites 1, 2, 3, 7 and 10 the sound environment was considered "very appropriate" to the place, whereas on sites 4, 5, 6, 8 and 9 it was regarded as "moderately appropriate".

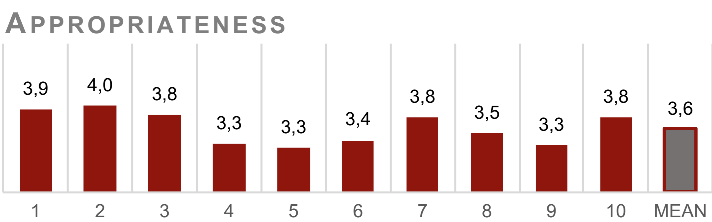


Figure 7.28: Appropriateness of the sound environment mean on each site – higher scores imply higher level of agreement with the adequacy of the sound environment, with the site and the user activity.

The appropriateness evaluations mean of each site when plotted on the maps in Figure 7.29, demonstrate that the sound environments considered "very appropriate" were from the sites located indeed in front of the water limits, except for the sites 4 and 5, in which their sound environments were regarded as "moderately appropriate".

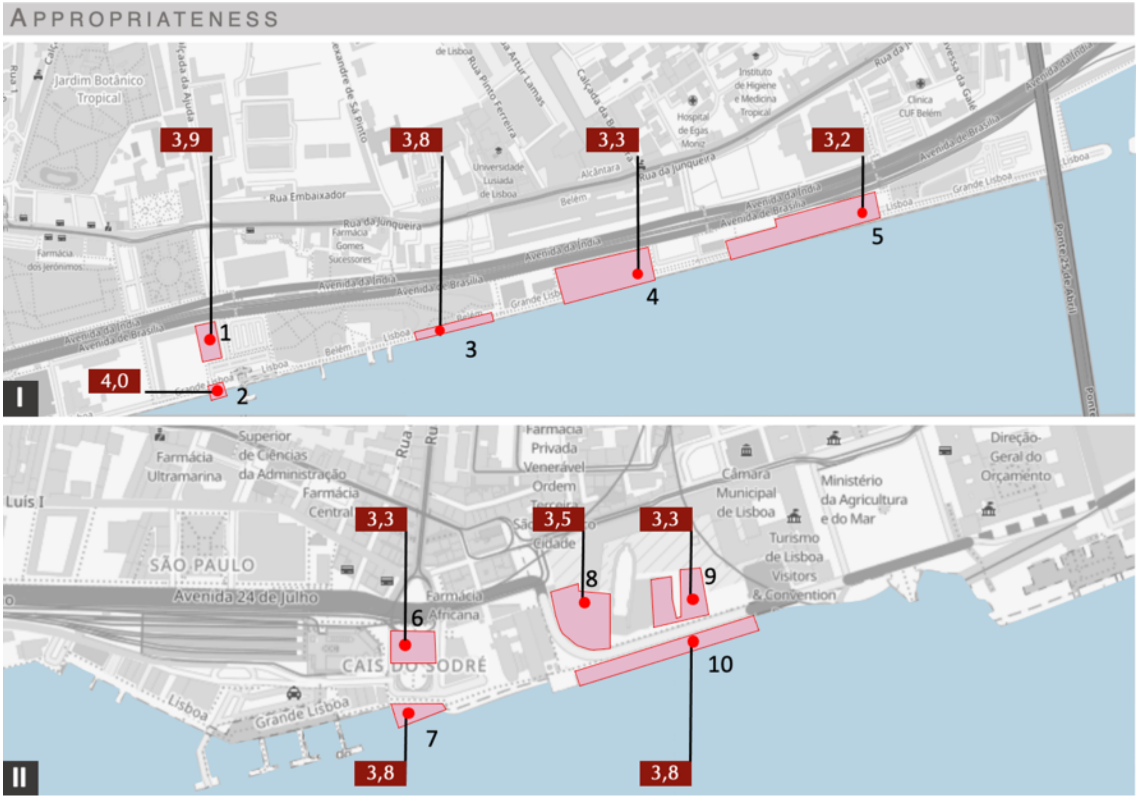


Figure 7.29: Appropriateness of the sound environment located on each site of the waterfront maps – Area I and Area II. Source: ©OpenStreetMap contributors – author adapted.

7.2. LABORATORY LISTENING PANEL RESULTS (L)

The laboratory listening panel was established in order to determine the sound sources perceived, by watching and listening to ten videos that represent each Tejo waterfront site, composed with an audio sample of its sound environment and illustrative photographs of the place.

In total, a sample of 26 listeners voluntarily participated on the laboratory panel experiment, whom 16 were women and 10 were men (M age = 42,5 years).

The panel listener identified and ranked the best perceived sound sources on each site, through an online procedure.

From their answers, in the same way as the inquiry, it was necessary to attribute the proper weighting to the perception order defined, to obtain the contribution of every sound source category on the acoustic environment (according to the subsection 5.4.1.2(ii)), whose results for the Tejo's waterfront are shown in Figure 7.30.

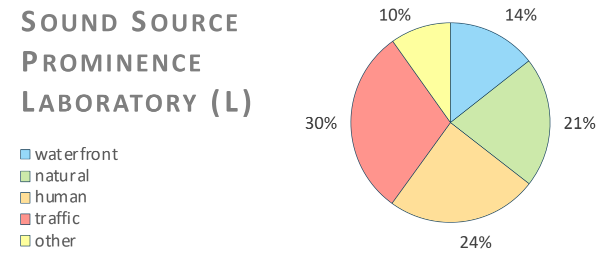


Figure 7.30: Laboratory Response (L): average perception percentual of each sound source category [%].

From the perception response of the panel, the "traffic sounds" was the best perceived sound source category (30%) on the acoustic environment. Nevertheless, the categories "human sounds" (24%) and "natural sounds" (21%) were also well perceived, while the "waterfront sounds" (14%) and the "other sounds" (10%) were the less perceived.

The general perception demonstrates that, despite the temporal sound composition of each waterfront site includes the "waterfront sound", it was a sound source category little perceived, even with the visual support of the photographs which show the relationships of the sites with the water.

The percentage of contribution of each sound source category on every site's sound environment listened are shown in Figure 7.31.

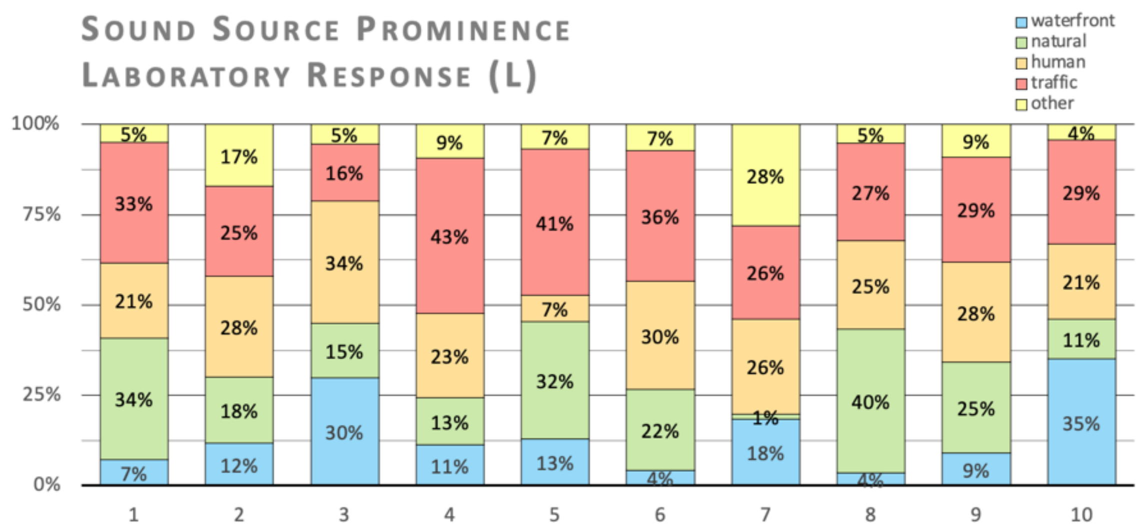


Figure 7.31: Laboratory Response (L): average perception percentual of each sound source on each site [%].

One can observe that the "traffic sounds" were the best perceived sound source category, except on site 3, and the "human sounds" were also well perceived on almost all sites, except on site 5. By contrast, the "waterfront sounds" category was more noted on the samples from sites 3, 7 and 10, while the "natural sounds", on the samples from sites 1, 2, 5, 6, 8 and 9. "Other sounds" was the category least noted, it was audible with more prevalence only on sites 2 and 7.

The prominence order in which the sound sources were perceived on each site are presented in Table 7.5.

Table 7.5: Laboratory Response (L): Ranking of the sound source categories prominence on each site.

	Ranking of Sound Source Prominence on each site - Laboratory Response (L)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1st	natural 34%	human 28%	human 34%	traffic 43%	traffic 41%	traffic 36%	other 28%	natural 40%	traffic 29%	waterfront 35%
2nd	traffic 33%	traffic 25%	waterfront 30%	human 23%	natural 32%	human 30%	human 26%	traffic 27%	human 28%	traffic 29%
3rd	human 21%	natural 18%	traffic 16%	natural 13%	waterfront 13%	natural 22%	traffic 26%	human 25%	natural 25%	human 21%
4th	waterfront 7%	other 17%	natural 15%	waterfront 11%	human 7%	other 7%	waterfront 18%	other 5%	waterfront 9%	natural 11%
5th	other 5%	waterfront 12%	other 5%	other 9%	other 7%	waterfront 4%	natural 1%	waterfront 4%	other 9%	other 4%

The “traffic sound” was the dominant category on the sound environment of sites 4, 5, 6 and 9, and it shows up as the second most dominant sound source on the other sites, 1, 2, 8 and 10. The other categories were dominant on specific sites, as the “natural sounds” on sites 1 and 8, the “human sounds” on sites 2 and 3, the “waterfront sounds” on site10, and the “other sounds” on site 7. “Human sounds” category also shows up as the second most dominant sound source on sites 4, 6, 7 and 9.

The percentage of contribution of each sound source category on the sound environment sample of each site were introduced on the waterfront area maps in Figure 7.32.

From the results in the map, it can be noted that the "waterfront sounds" category was more perceived on sites that are closest to the Tejo River, mainly on sites 3 and 10. However, regarding the other perceived sound source categories, no relations with the position of the sites on the waterfront were found.

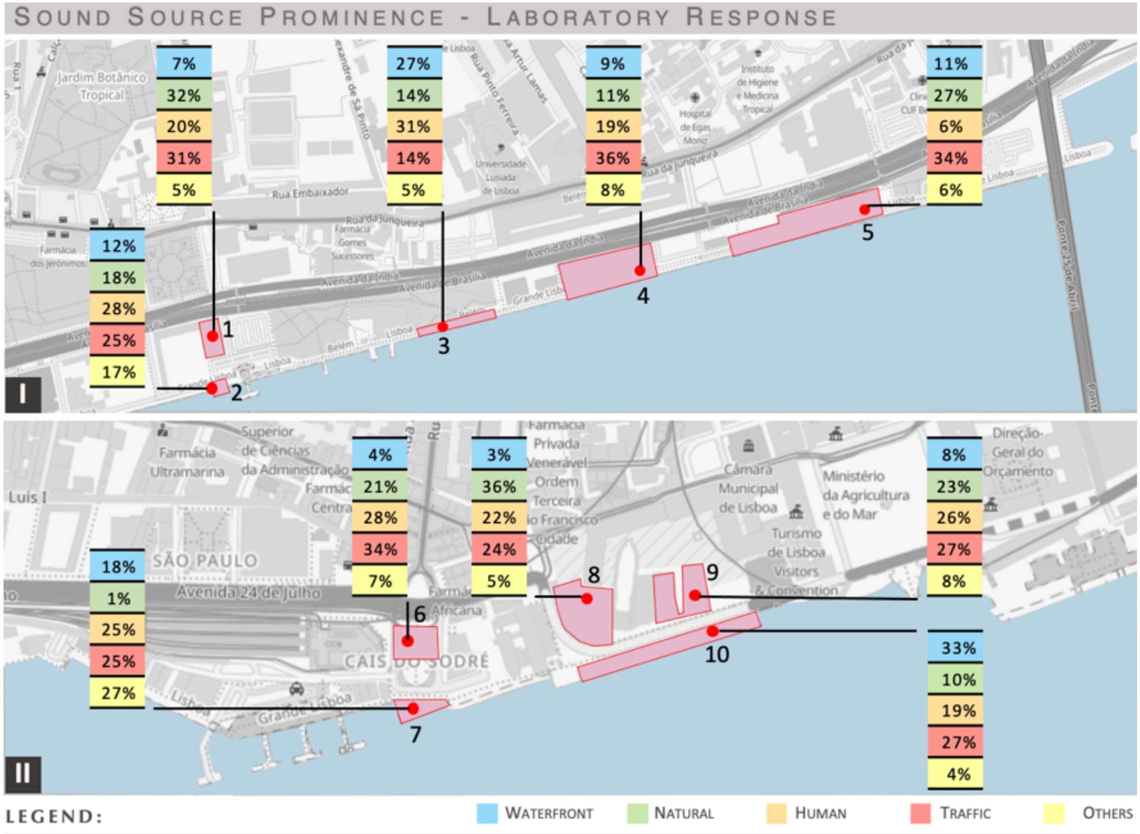


Figure 7.32: Laboratory Response (L): percentual of the perceived sound sources on each site, located on each site of the waterfront maps – Area I and Area II. Source: ©OpenStreetMap contributors – author adapted.

SITE 1 - Public Space and waterfront sound assessment

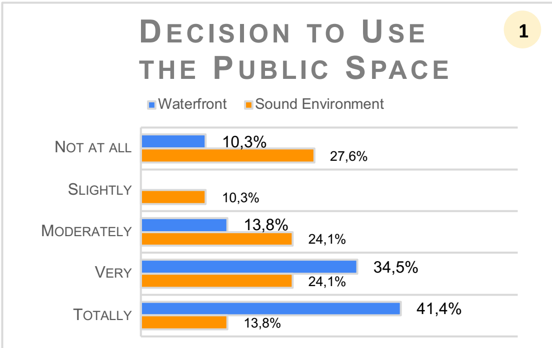


Figure D. 1: Site 1: Parameters that influence on the decision to public space use: Waterfront x Sound Environment [Graph].

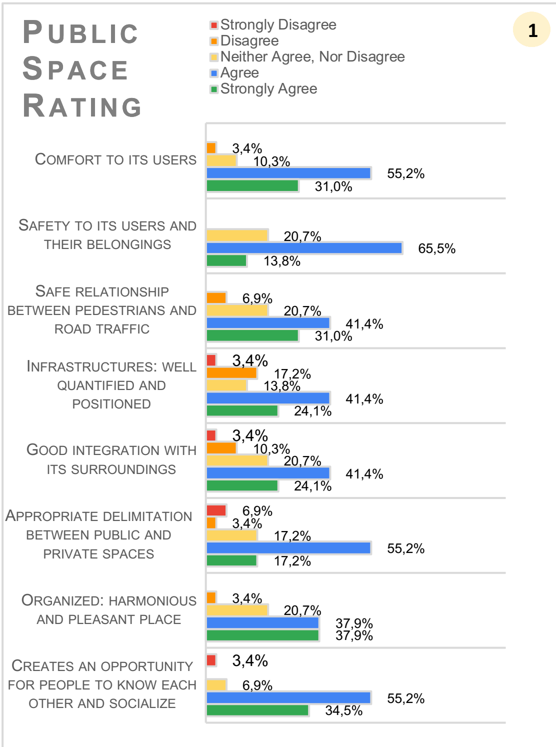


Figure D. 2: Site 1: Public Space Assessment [Graph].

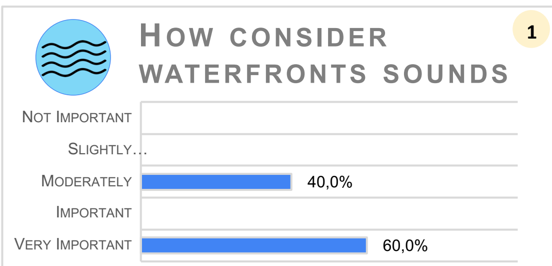


Figure D. 3: Site 1: Importance of sounds waterfront related [Graph].

SITE 1 - Environmental Sound and Soundscape assessment

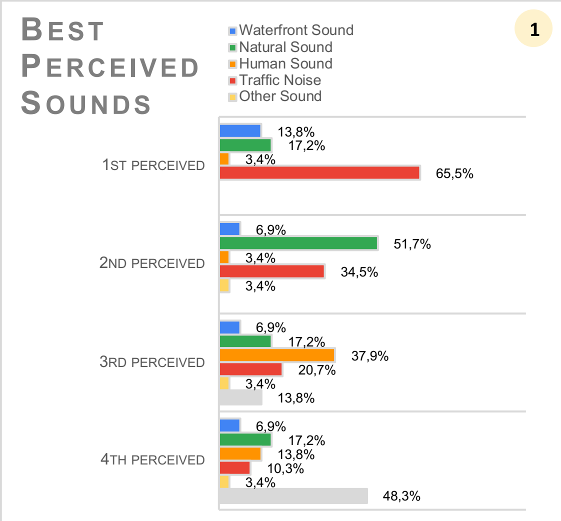


Figure D. 4: Site 1: Most perceived sound sources in the public space [Graph].

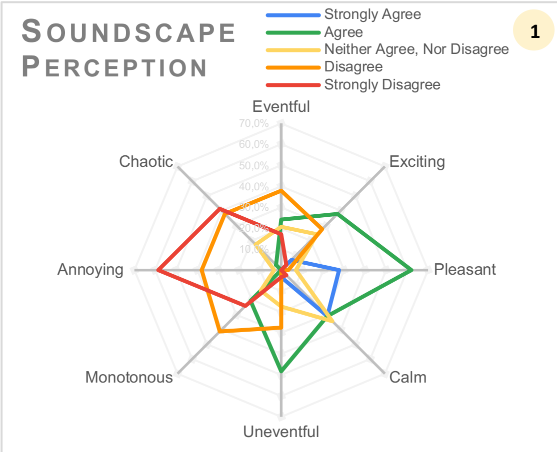


Figure D. 5: Site 1: Soundscape Assessment [Graph].

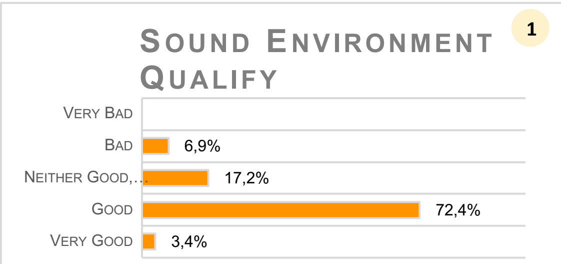


Figure D. 6: Site 1: Sound Environment Assessment [Graph].

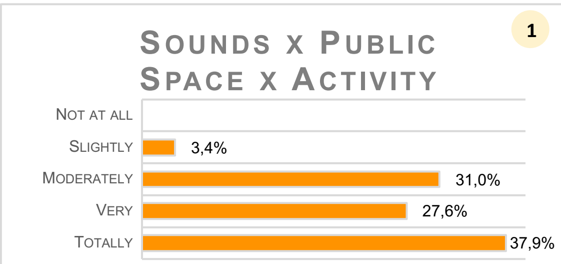


Figure D. 7: Site 1: Relationship between sounds, public space and user activity [Graph].

SITE 1 - User Behaviour

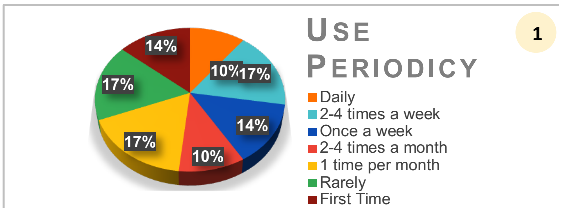


Figure D. 8: Site 1: Public space user periodicity of use [Graph].

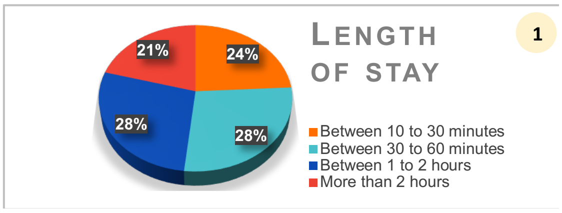


Figure D. 9: Site 1: Public space user length of stay [Graph].

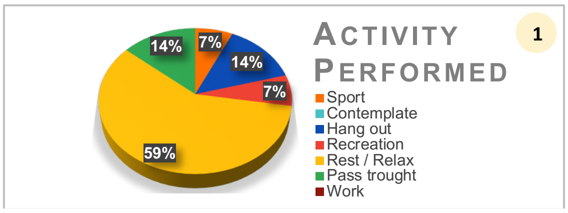


Figure D. 10: Site 1: Reason that led the user to choose the public space [Graph].

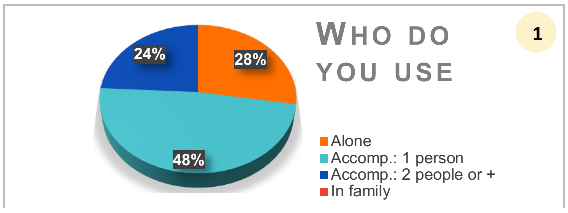


Figure D. 11: Site 1: Who the user usually stays in the public space [Graph].

SITE 1 - User Data

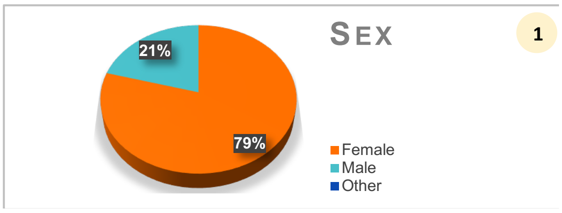


Figure D. 12: Site 1: User sex [Graph].

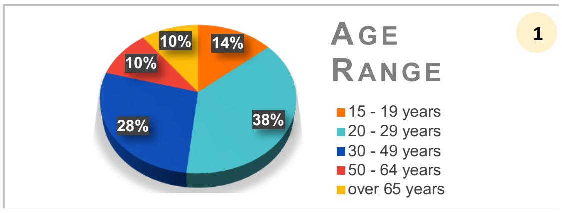


Figure D. 13: Site 1: User age range [Graph].

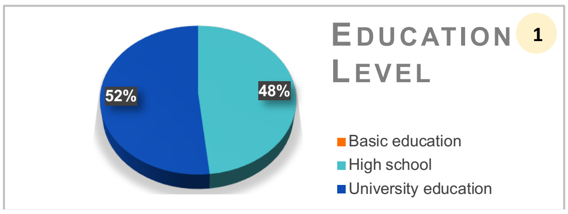


Figure D. 14: Site 1: User Education Level [Graph].

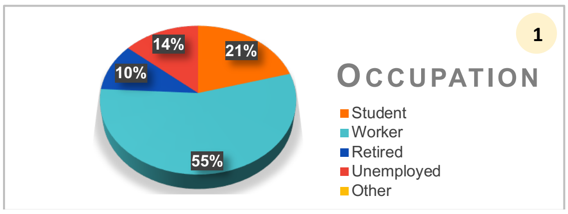


Figure D. 15: Site 1: User Occupation [Graph].

SITE 2 - Public Space and waterfront sound assessment

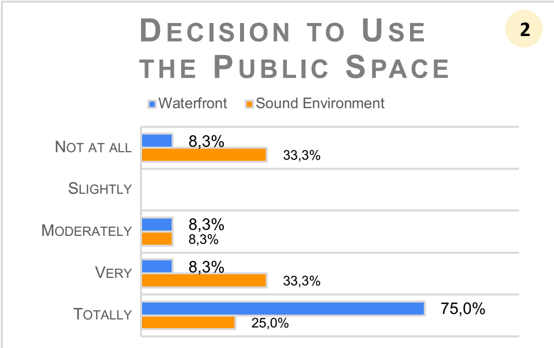


Figure D. 16: Site 2: Parameters that influence on the decision to public space use: Waterfront x Sound Environment [Graph].

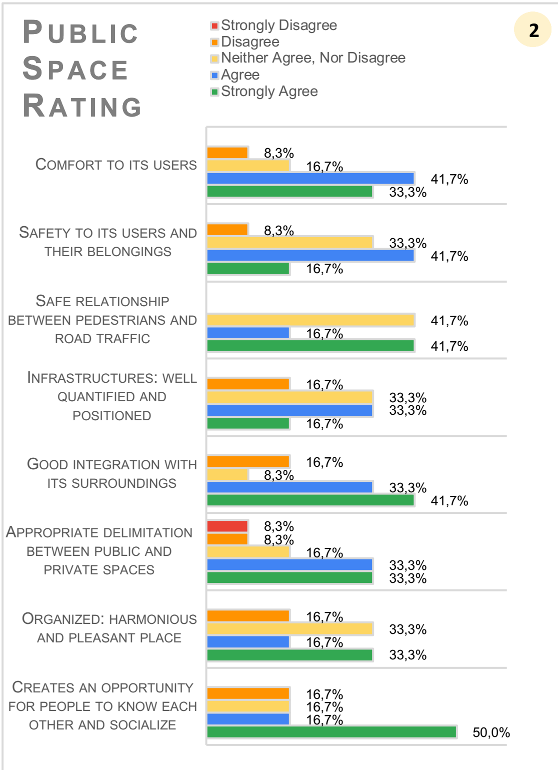


Figure D. 17: Site 2: Public Space Assessment [Graph].

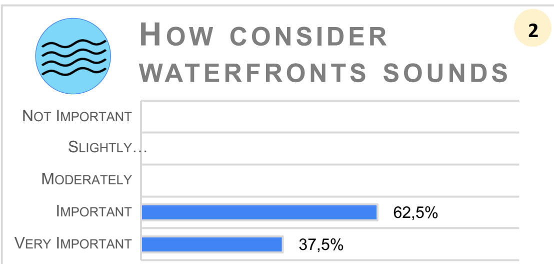


Figure D. 18: Site 2: Importance of sounds waterfront related [Graph].

SITE 2 - Environmental Sound and Soundscape assessment

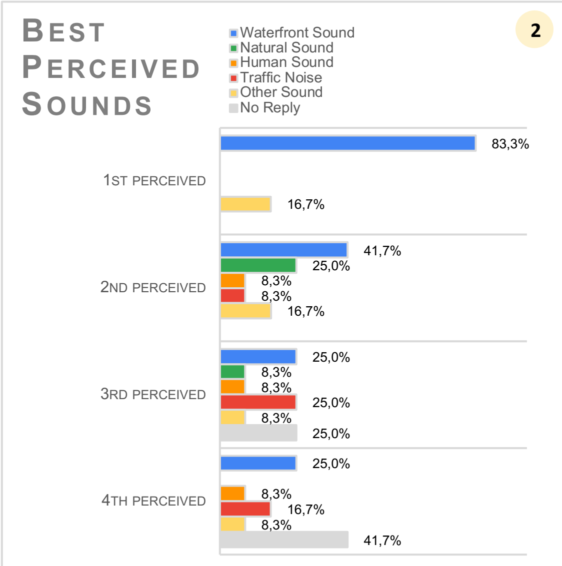


Figure D. 19: Site 2: Most perceived sound sources in the public space [Graph].

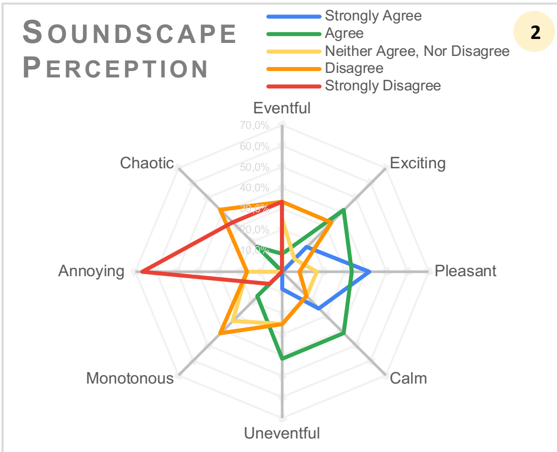


Figure D. 20: Site 2: Soundscape Assessment [Graph].

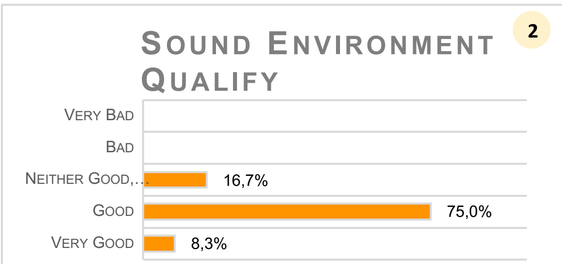


Figure D. 21: Site 2: Sound Environment Assessment [Graph].

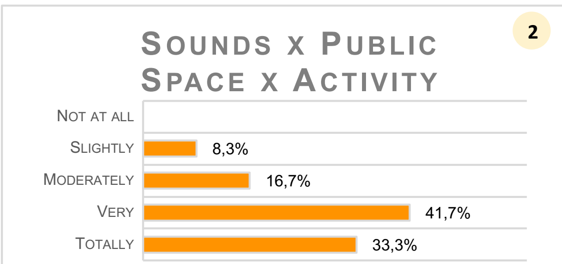


Figure D. 22: Site 2: Relationship between sounds, public space and user activity [Graph].

SITE 2 - User Behaviour

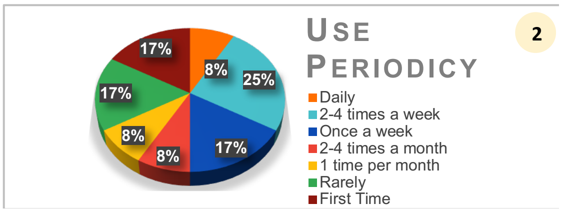


Figure D. 23: Site 2: Public space user periodicity of use [Graph].

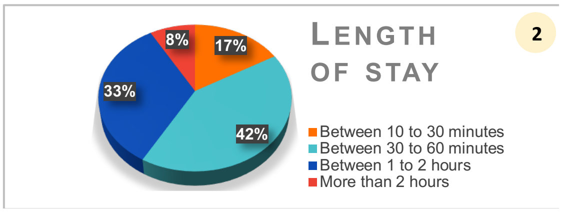


Figure D. 24: Site 2: Public space user length of stay [Graph].

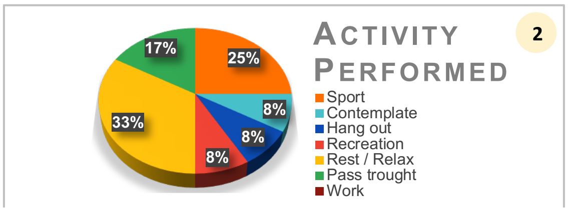


Figure D. 25: Site 2: Reason that led the user to choose the public space [Graph].

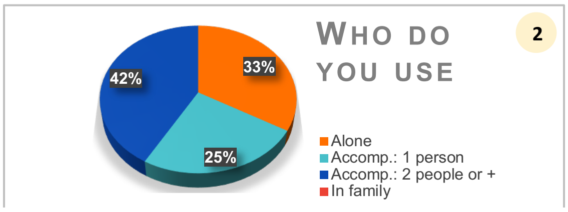


Figure D. 26: Site 2: Who the user usually stays in the public space [Graph].

SITE 2 - User Data

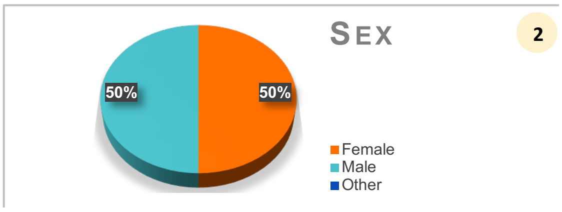


Figure D. 27: Site 2: User sex [Graph].

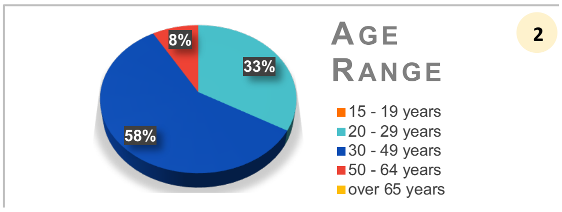


Figure D. 28: Site 2: User age range [Graph].

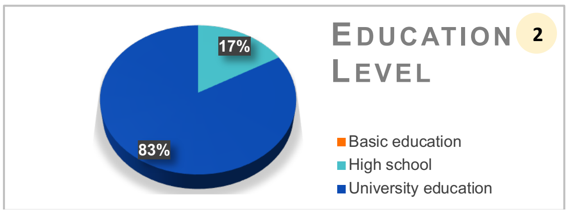


Figure D. 29: Site 2: User Education Level [Graph].

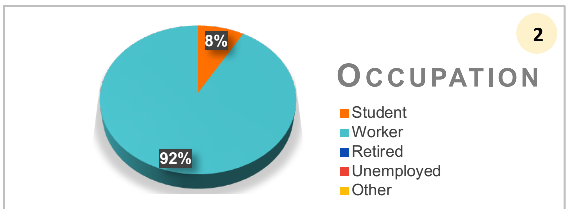


Figure D. 30: Site 2: User Occupation [Graph].

SITE 3 - Public Space and waterfront sound assessment

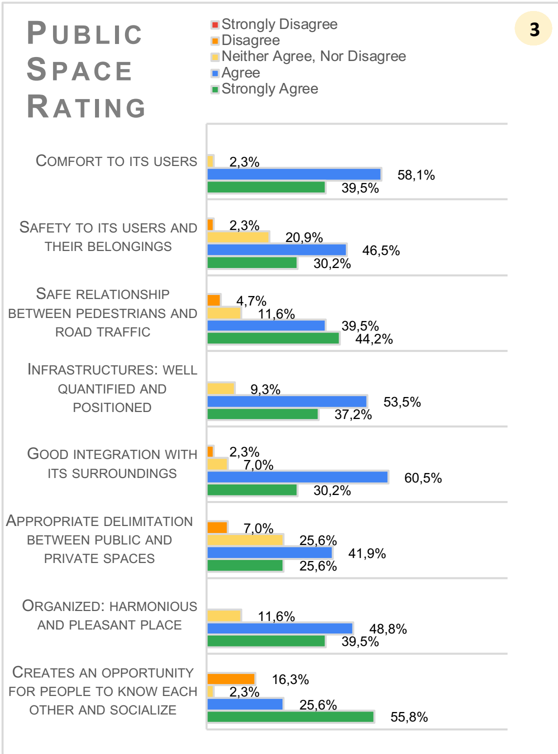


Figure D. 31: Site 3: Public Space Assessment [Graph].

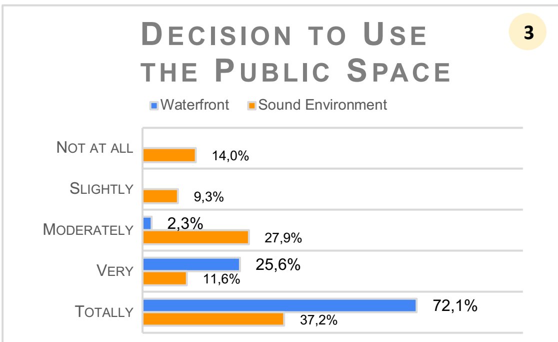


Figure D. 32: Site 3: Parameters that influence on the decision to public space use: Waterfront x Sound Environment [Graph].

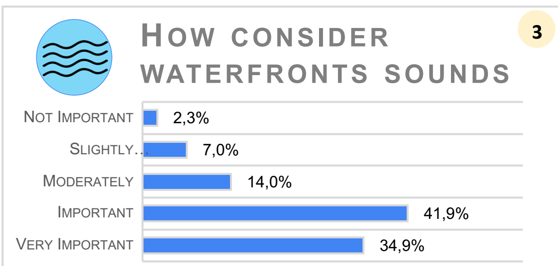


Figure D. 33: Site 3: Importance of sounds waterfront related [Graph].

SITE 3 - Environmental Sound and Soundscape assessment

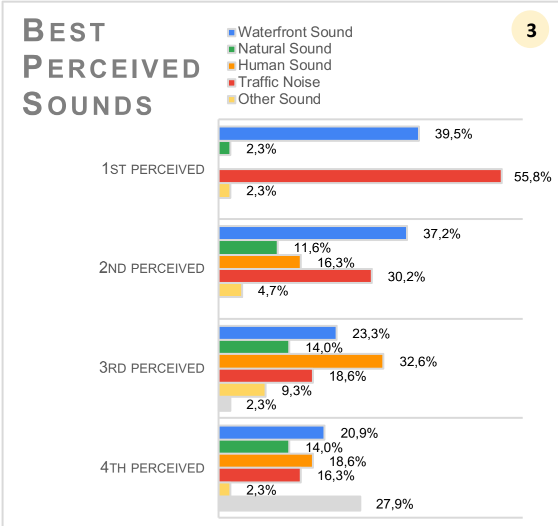


Figure D. 34: Site 3: Most perceived sound sources in the public space [Graph].

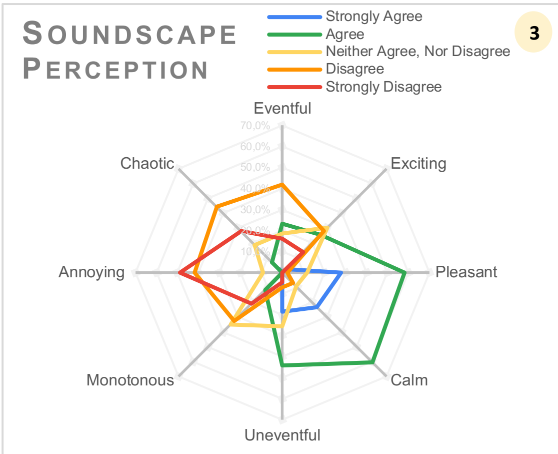


Figure D. 35: Site 3: Soundscape Assessment [Graph].

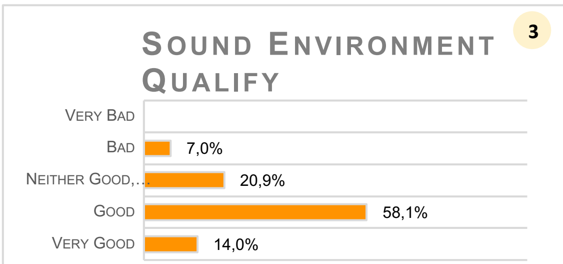


Figure D. 36: Site 3: Sound Environment Assessment [Graph].

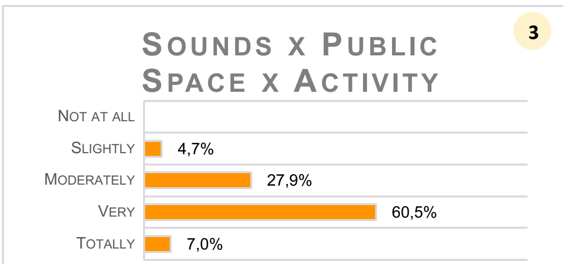


Figure D. 37: Site 3: Relationship between sounds, public space and user activity [Graph].

SITE 3 - User Behaviour

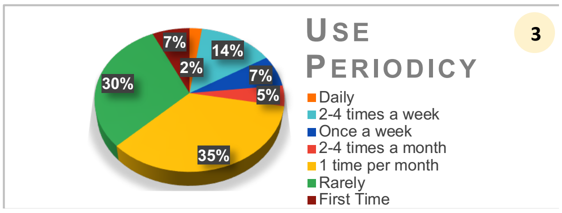


Figure D. 38: Site 3: Public space user periodicity of use [Graph].

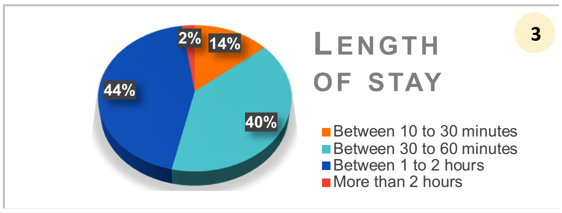


Figure D. 39: Site 3: Public space user length of stay [Graph].

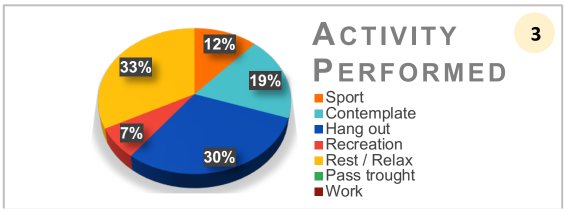


Figure D. 40: Site 3: Reason that led the user to choose the public space [Graph].

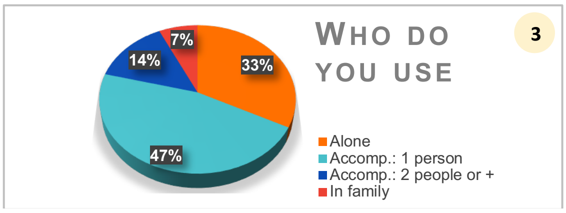


Figure D. 41: Site 3: Who the user usually stays in the public space [Graph].

SITE 3 - User Data

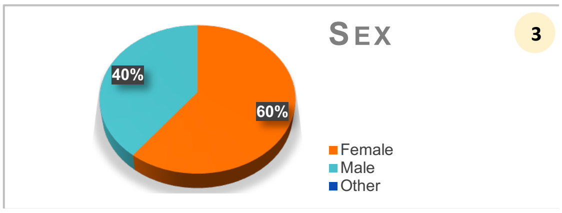


Figure D. 42: Site 3: User sex [Graph].

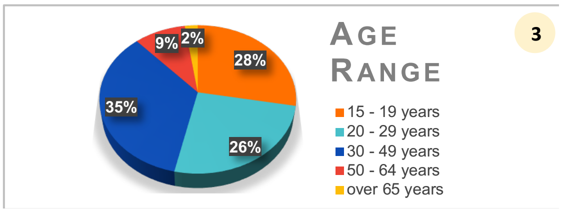


Figure D. 43: Site 3: User age range [Graph].

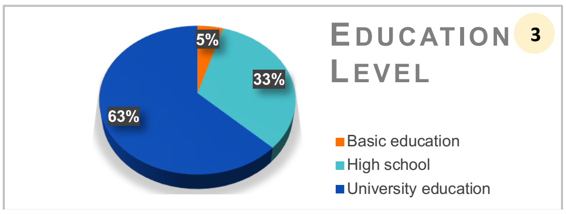


Figure D. 44: Site 3: User Education Level [Graph].

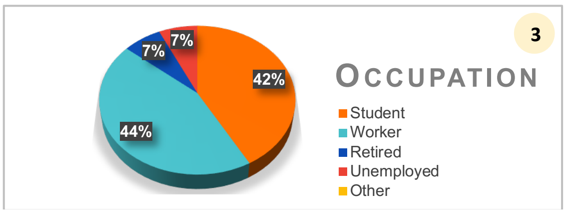


Figure D. 45: Site 3: User Occupation [Graph].

SITE 4 - Public Space and waterfront sound assessment

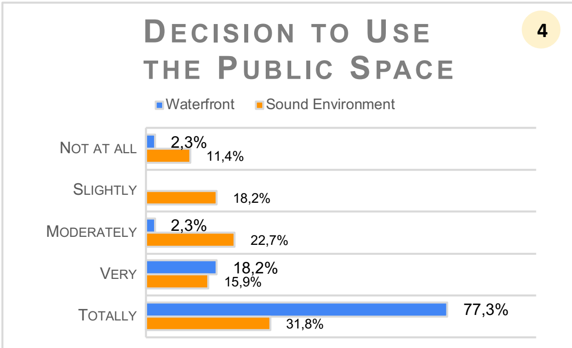


Figure D. 46: Site 4: Parameters that influence on the decision to public space use: Waterfront x Sound Environment [Graph].

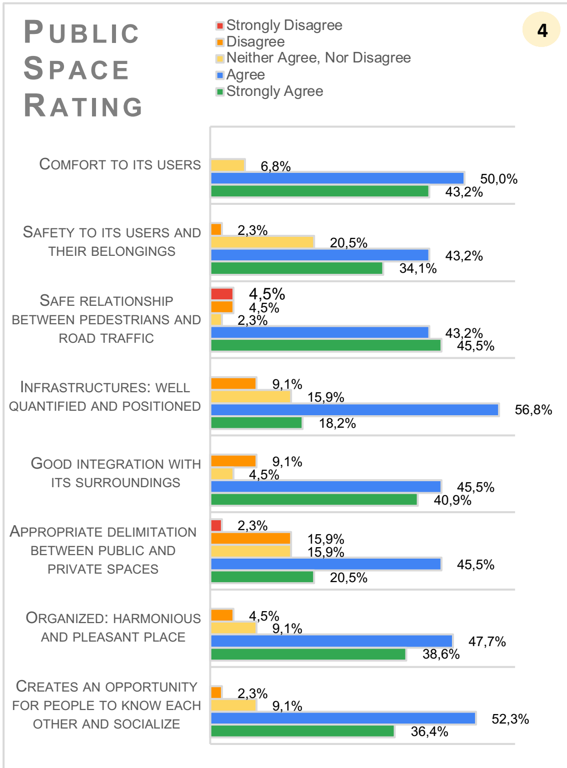


Figure D. 47: Site 4: Public Space Assessment [Graph].

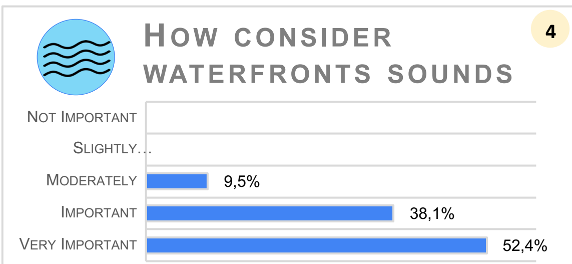


Figure D. 48: Site 4: Importance of sounds waterfront related [Graph].

SITE 4 - Environmental Sound and Soundscape assessment

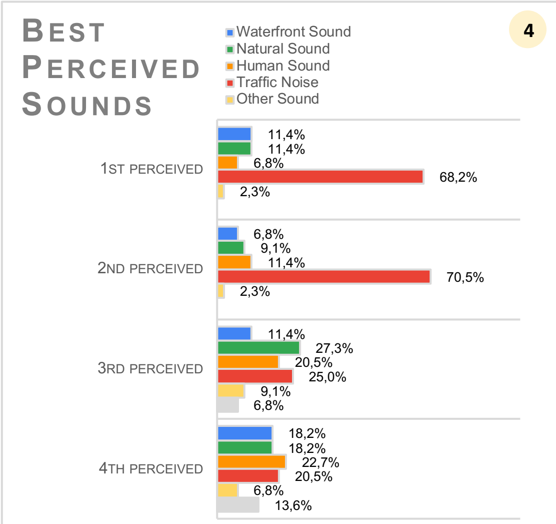


Figure D. 49: Site 4: Most perceived sound sources in the public space [Graph].

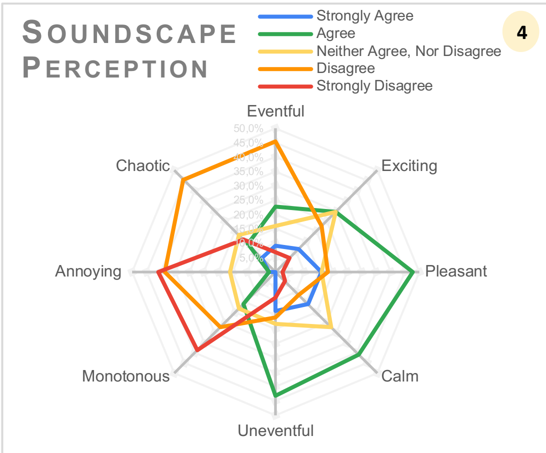


Figure D. 50: Site 4: Soundscape Assessment [Graph].

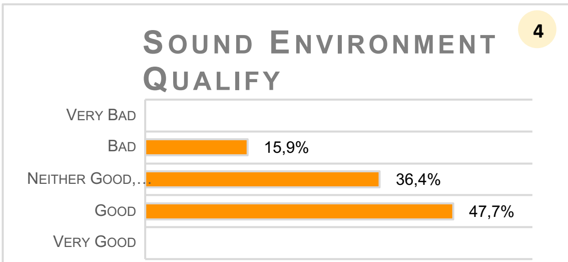


Figure D. 51: Site 4: Sound Environment Assessment [Graph].

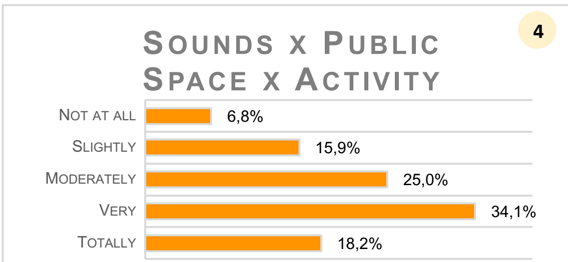


Figure D. 52: Site 4: Relationship between sounds, public space and user activity [Graph].

SITE 4 - User Behaviour

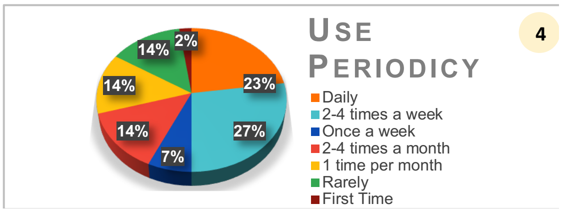


Figure D. 53: Site 4: Public space user periodicity of use [Graph].

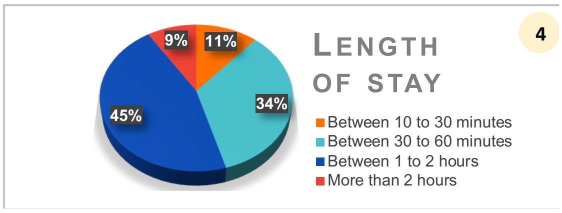


Figure D. 54: Site 4: Public space user length of stay [Graph].

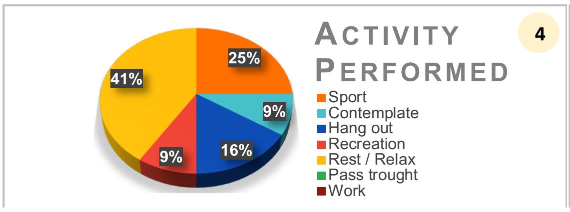


Figure D. 55: Site 4: Reason that led the user to choose the public space [Graph].

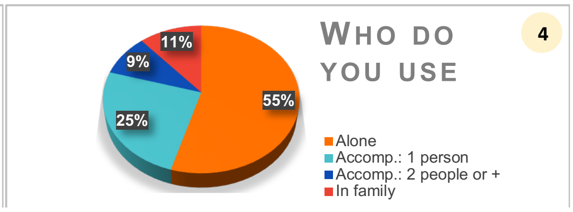


Figure D. 56: Site 4: Who the user usually stays in the public space [Graph].

SITE 4 - User Data

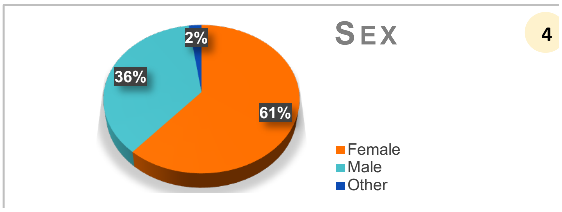


Figure D. 57: Site 4: User sex [Graph].

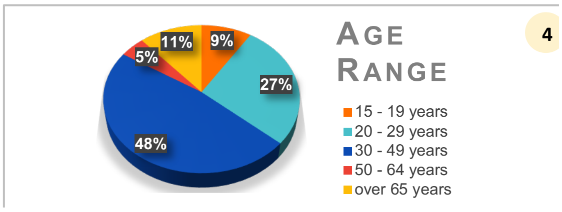


Figure D. 58: Site 4: User age range [Graph].

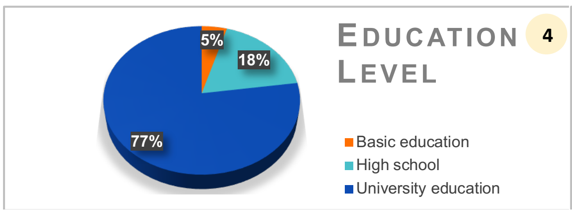


Figure D. 59: Site 4: User Education Level [Graph].

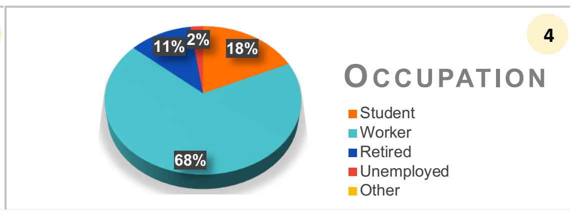


Figure D. 60: Site 4: User Occupation [Graph].

SITE 5 - Public Space and waterfront sound assessment

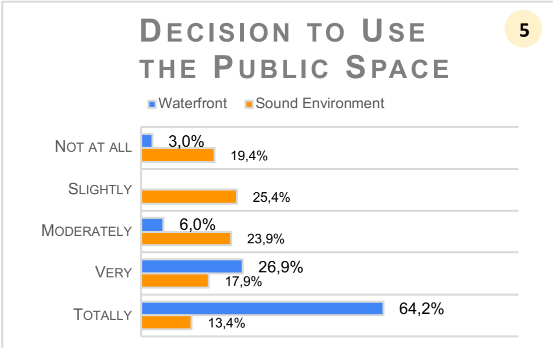


Figure D. 61: Site 5: Parameters that influence on the decision to public space use: Waterfront x Sound Environment [Graph].

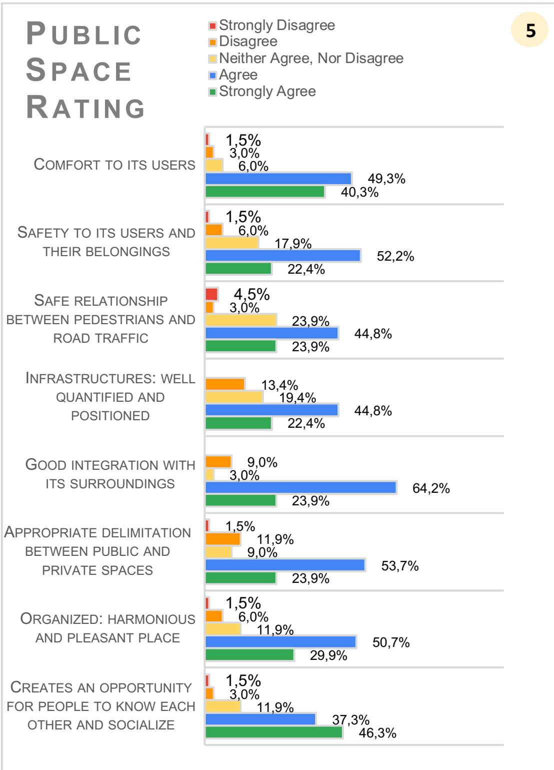


Figure D. 62: Site 5: Public Space Assessment [Graph].

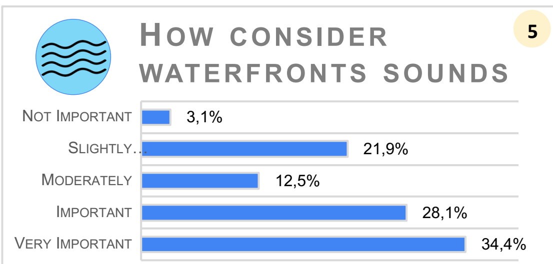


Figure D. 63: Site 5: Importance of sounds waterfront related [Graph].

SITE 5 - Environmental Sound and Soundscape assessment

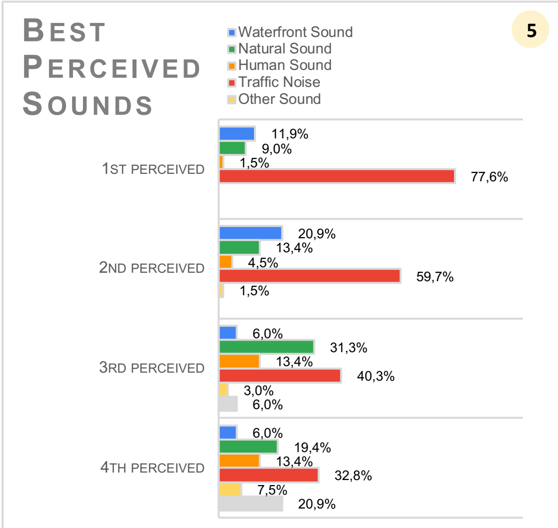


Figure D. 64: Site 5: Most perceived sound sources in the public space [Graph].

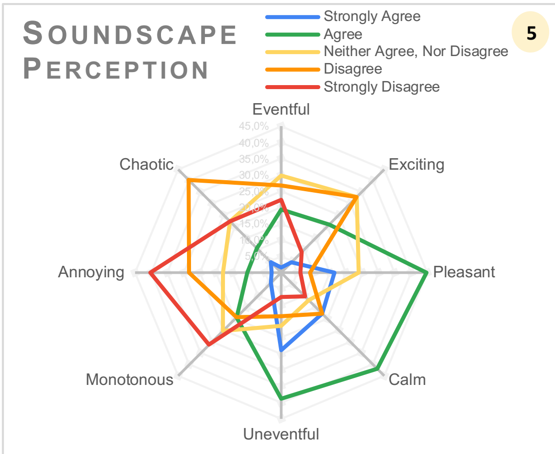


Figure D. 65: Site 5: Soundscape Assessment [Graph].

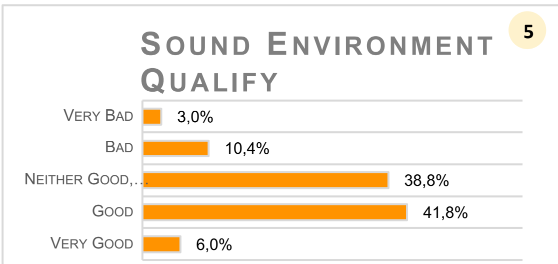


Figure D. 66: Site 5: Sound Environment Assessment [Graph].

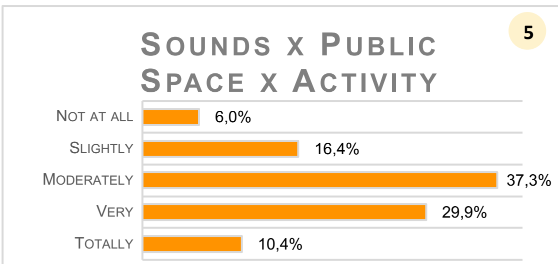


Figure D. 67: Site 5: Relationship between sounds, public space and user activity [Graph].

SITE 5 - User Behaviour

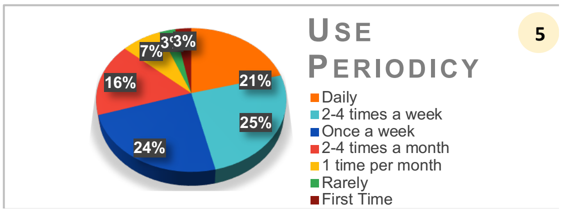


Figure D. 68: Site 5: Public space user periodicity of use [Graph].

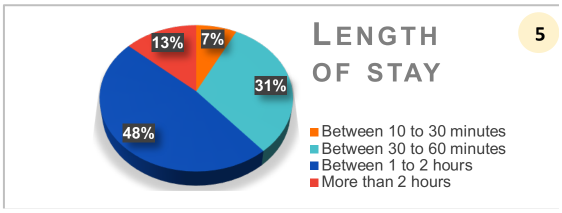


Figure D. 69: Site 5: Public space user length of stay [Graph].

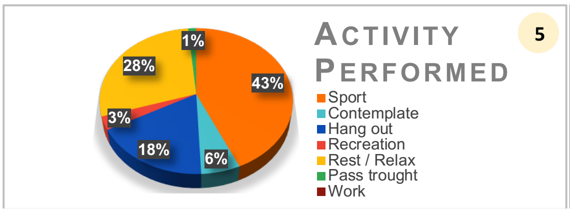


Figure D. 70: Site 5: Reason that led the user to choose the public space [Graph].

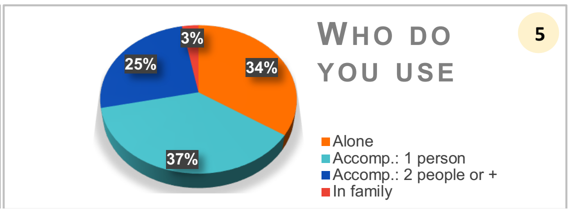


Figure D. 71: Site 5: Who the user usually stays in the public space [Graph].

SITE 5 - User Data

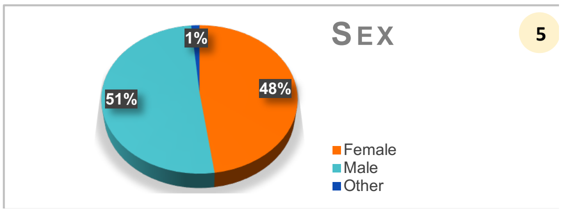


Figure D. 72: Site 5: User sex [Graph].

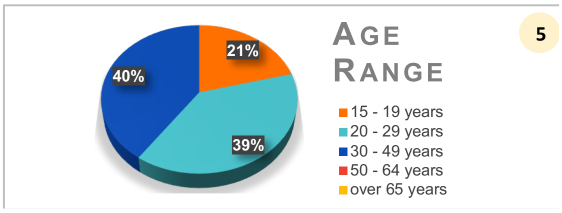


Figure D. 73: Site 5: User age range [Graph].

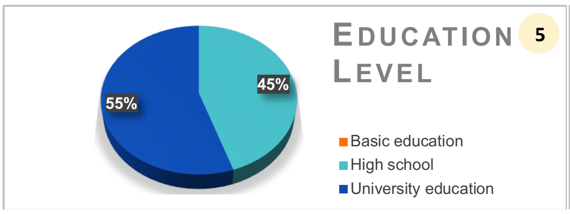


Figure D. 74: Site 5: User Education Level [Graph].

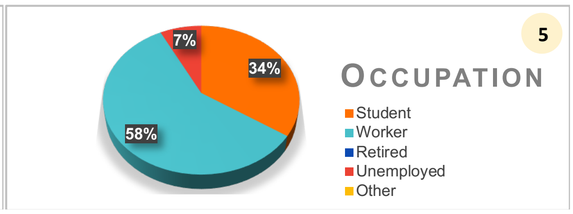


Figure D. 75: Site 5: User Occupation [Graph].

SITE 6 - Public Space and waterfront sound assessment

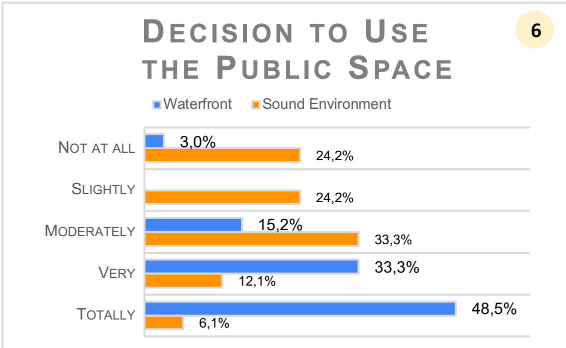


Figure D. 76: Site 6: Parameters that influence on the decision to public space use: Waterfront x Sound Environment [Graph].

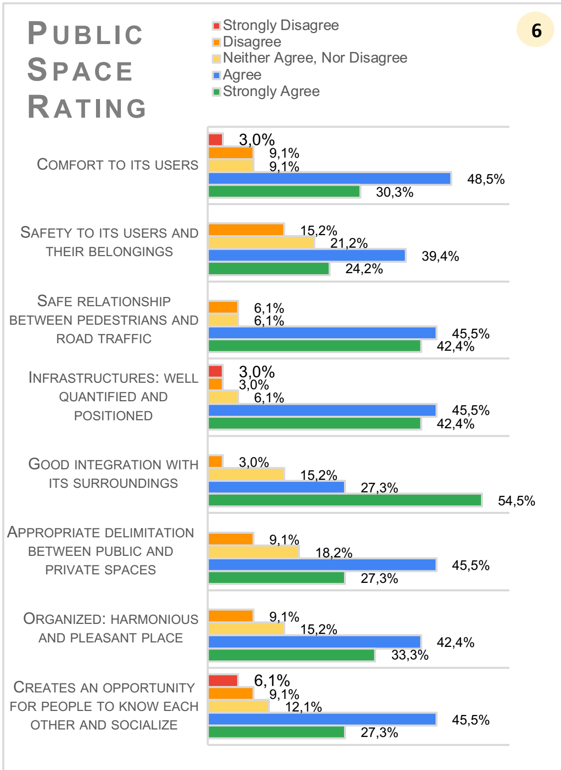


Figure D. 77: Site 6: Public Space Assessment [Graph].

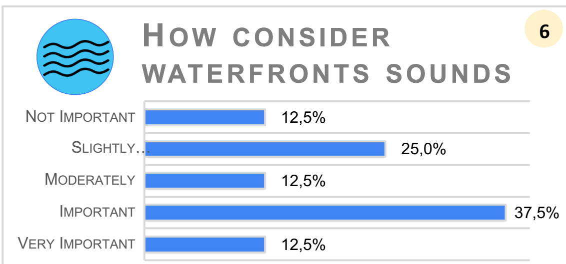


Figure D. 78: Site 6: Importance of sounds waterfront related [Graph].

SITE 6 - Environmental Sound and Soundscape assessment

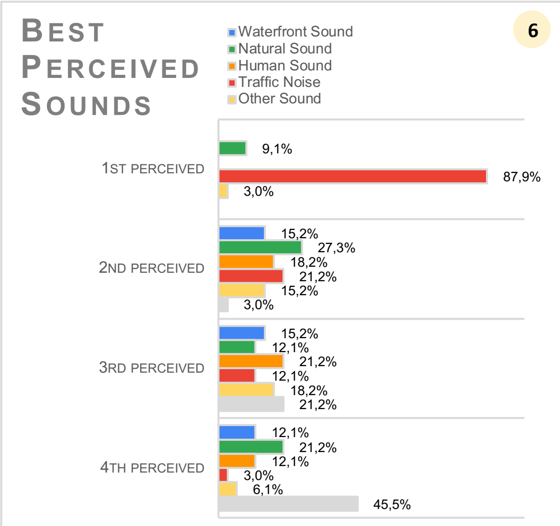


Figure D. 79: Site 6: Most perceived sound sources in the public space [Graph].

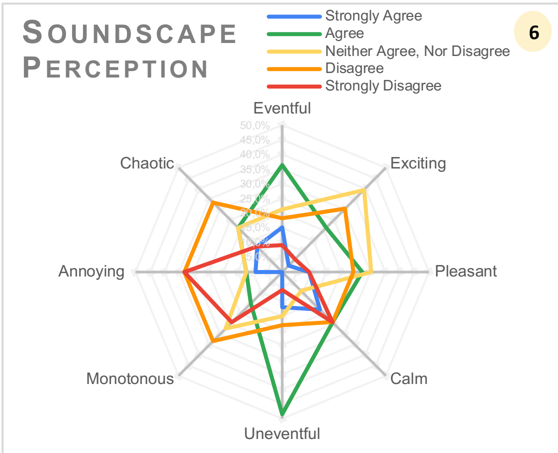


Figure D. 80: Site 6: Soundscape Assessment [Graph].

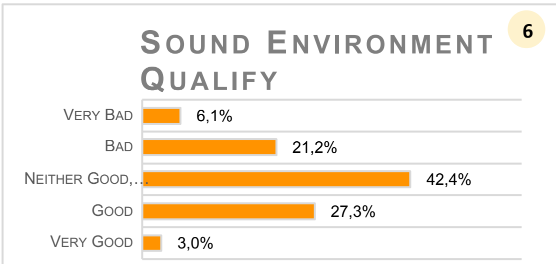


Figure D. 81: Site 6: Sound Environment Assessment [Graph].

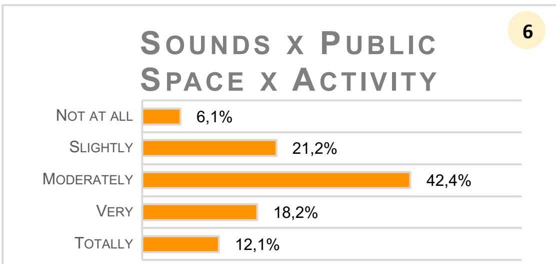


Figure D. 82: Site 6: Relationship between sounds, public space and user activity [Graph].

SITE 6 - User Behaviour

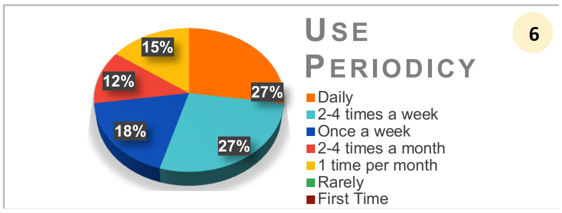


Figure D. 83: Site 6: Public space user periodicity of use [Graph].

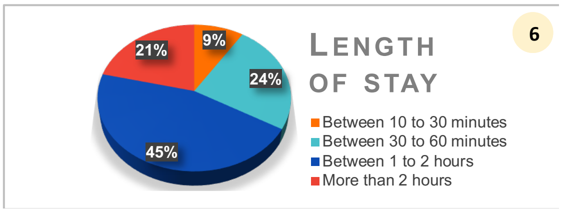


Figure D. 84: Site 6: Public space user length of stay [Graph].

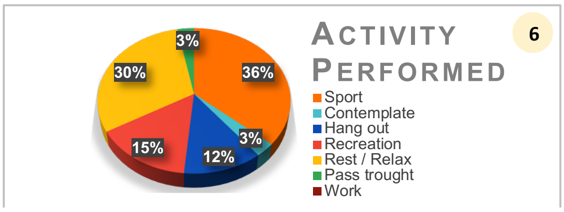


Figure D. 85: Site 6: Reason that led the user to choose the public space [Graph].

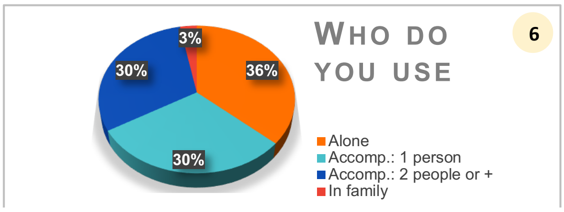


Figure D. 86: Site 6: Who the user usually stays in the public space [Graph].

SITE 6 - User Data

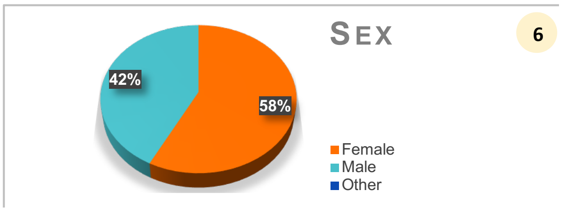


Figure D. 87: Site 6: User sex [Graph].

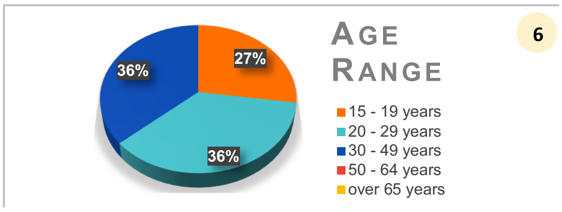


Figure D. 88: Site 6: User age range [Graph].

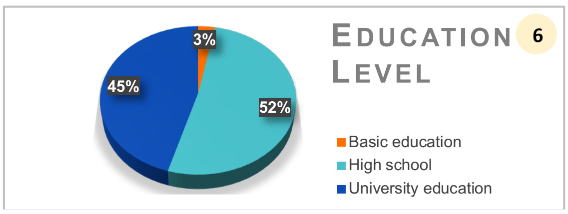


Figure D. 89: Site 6: User Education Level [Graph].

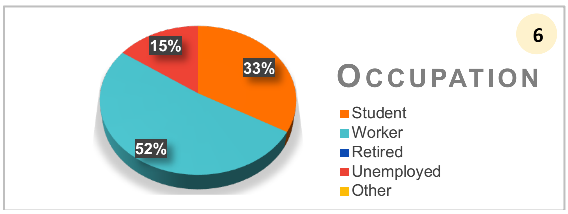


Figure D. 90: Site 6: User Occupation [Graph].

SITE 7 - Public Space and waterfront sound assessment

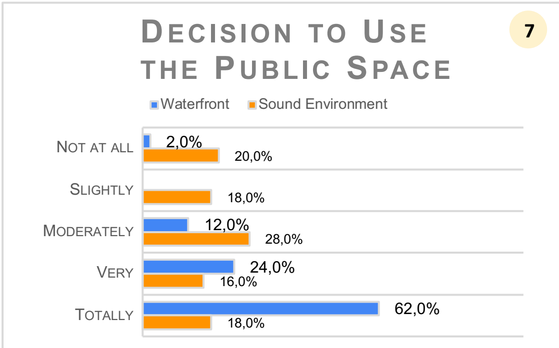


Figure D. 91: Site 7: Parameters that influence on the decision to public space use: Waterfront x Sound Environment [Graph].

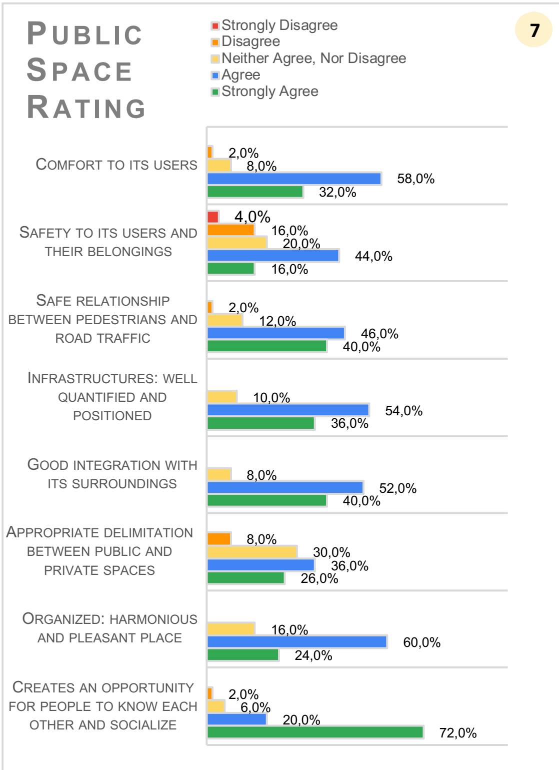


Figure D. 92: Site 7: Public Space Assessment [Graph].

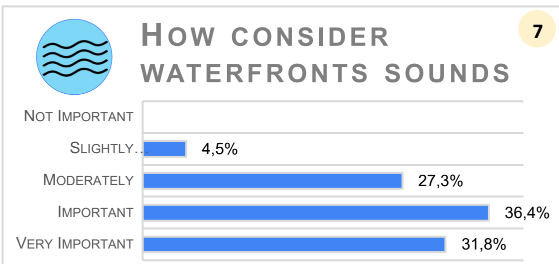


Figure D. 93: Site 7: Importance of sounds waterfront related [Graph].

SITE 7 - Environmental Sound and Soundscape assessment

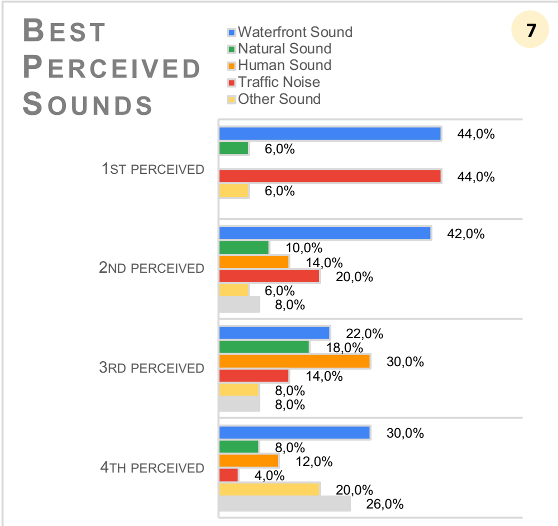


Figure D. 94: Site 7: Most perceived sound sources in the public space [Graph].

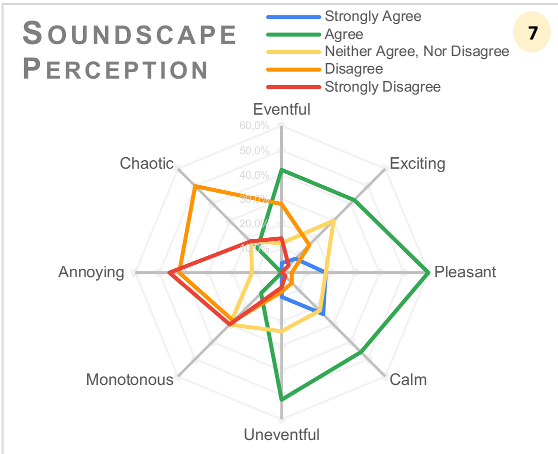


Figure D. 95: Site 7: Soundscape Assessment [Graph].

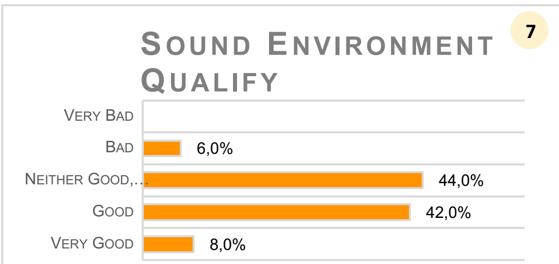


Figure D. 96: Site 7: Sound Environment Assessment [Graph].

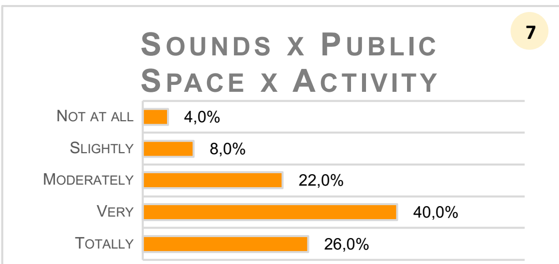


Figure D. 97: Site 7: Relationship between sounds, public space and user activity [Graph].

SITE 7 - User Behaviour

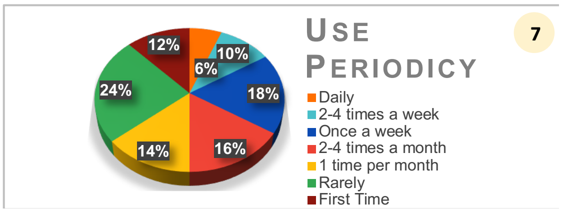


Figure D. 98: Site 7: Public space user periodicity of use [Graph].

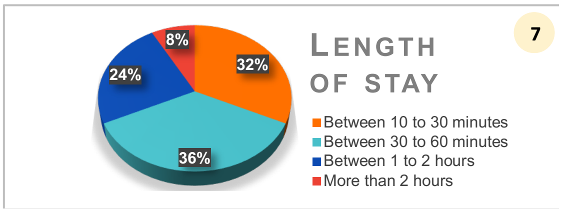


Figure D. 99: Site 7: Public space user length of stay [Graph].

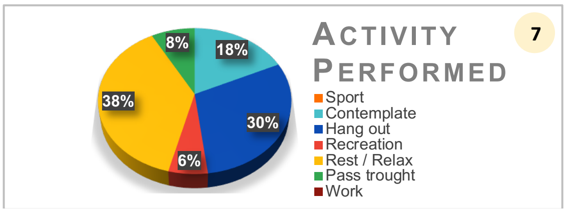


Figure D. 100: Site 7: Reason that led the user to choose the public space [Graph].

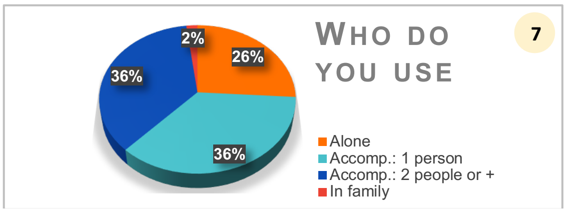


Figure D. 101: Site 7: Who the user usually stays in the public space [Graph].

SITE 7 - User Data

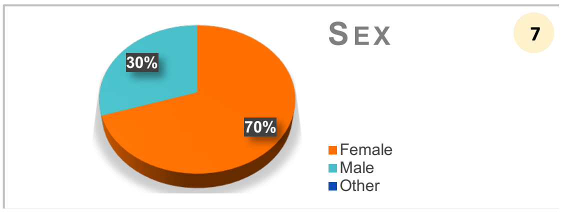


Figure D. 102: Site 7: User sex [Graph].

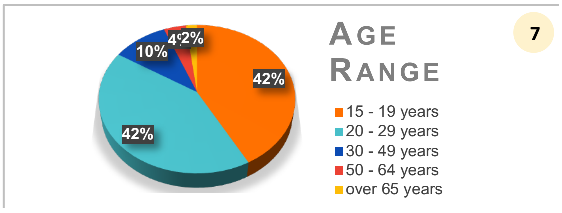


Figure D. 103: Site 7: User age range [Graph].

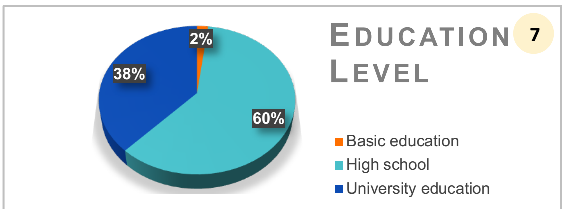


Figure D. 104: Site 7: User Education Level [Graph].

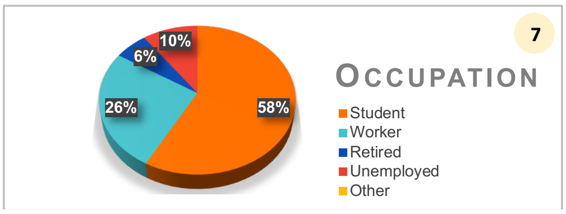


Figure D. 105: Site 7: User Occupation [Graph].

SITE 8 - Public Space and waterfront sound assessment

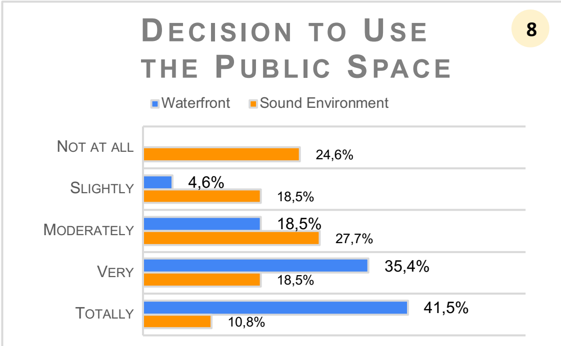


Figure D. 106: Site 8: Parameters that influence on the decision to public space use: Waterfront x Sound Environment [Graph].

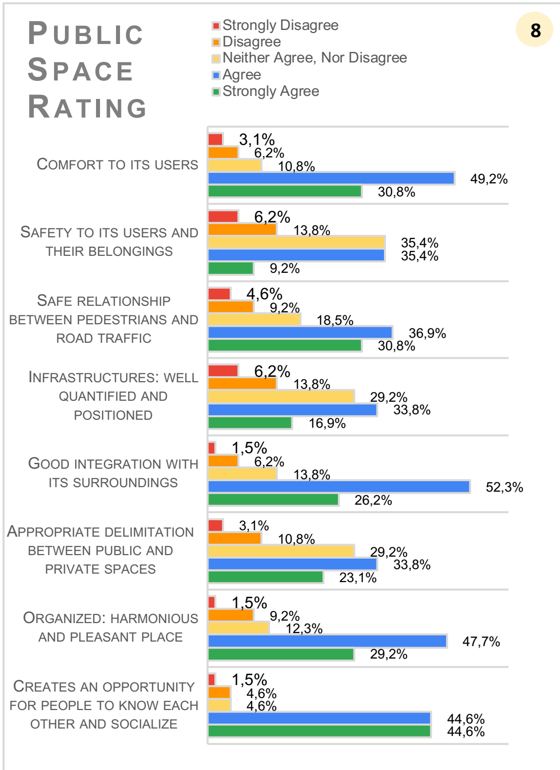


Figure D. 107: Site 8: Public Space Assessment [Graph].

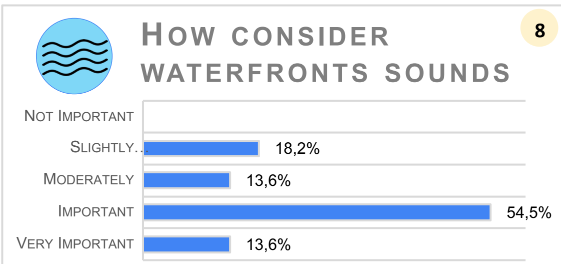


Figure D. 108: Site 8: Importance of sounds waterfront related [Graph].

SITE 8 - Environmental Sound and Soundscape assessment

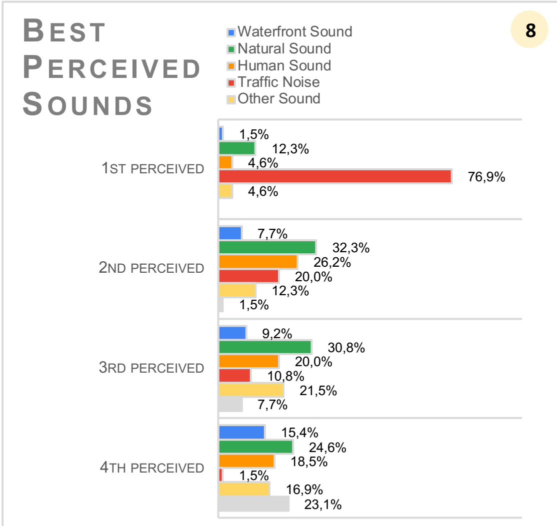


Figure D. 109: Site 8: Most perceived sound sources in the public space [Graph].

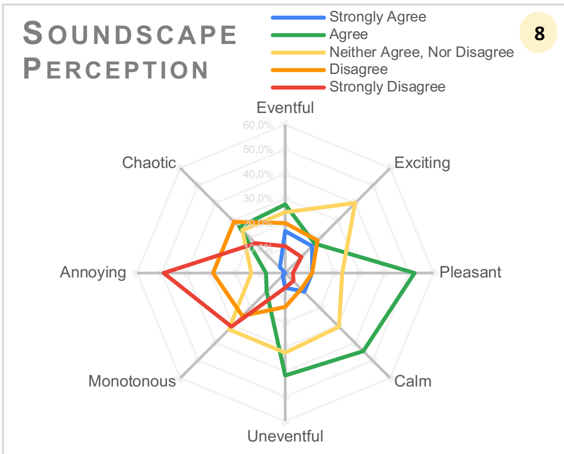


Figure D. 110: Site 8: Soundscape Assessment [Graph].

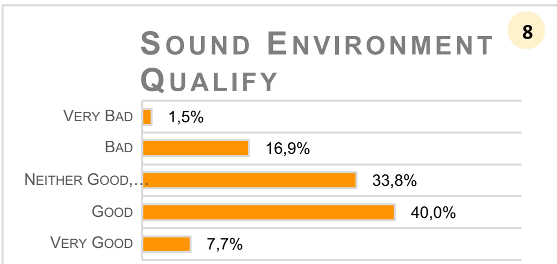


Figure D. 111: Site 8: Sound Environment Assessment [Graph].

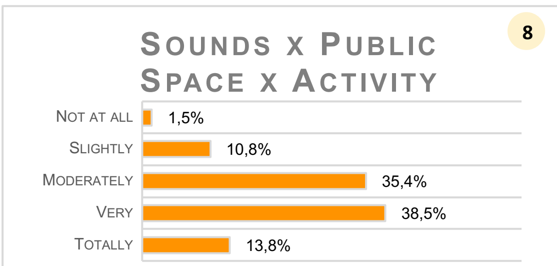


Figure D. 112: Site 8: Relationship between sounds, public space and user activity [Graph].

SITE 8 - User Behaviour

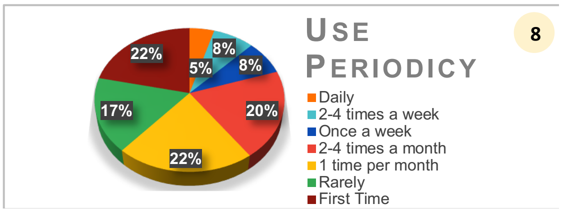


Figure D. 113: Site 8: Public space user periodicity of use [Graph].

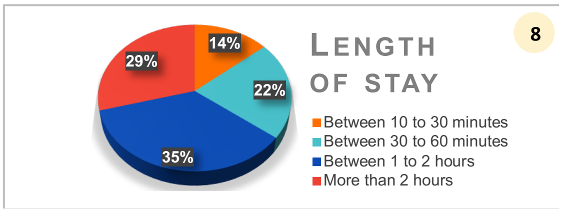


Figure D. 114: Site 8: Public space user length of stay [Graph].

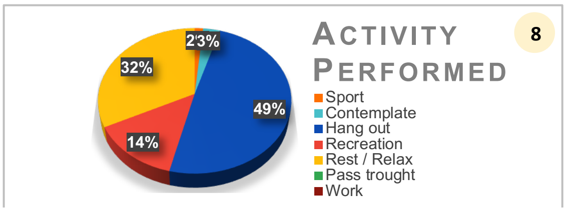


Figure D. 115: Site 8: Reason that led the user to choose the public space [Graph].

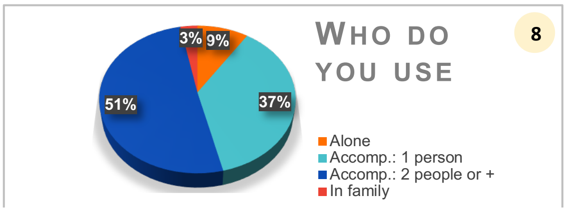


Figure D. 116: Site 8: Who the user usually stays in the public space [Graph].

SITE 8 - User Data

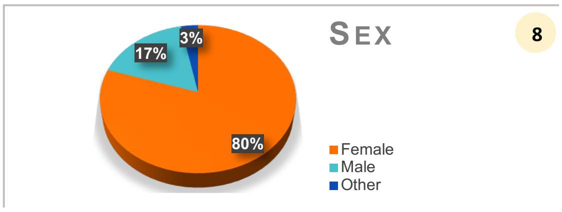


Figure D. 117: Site 8: User sex [Graph].

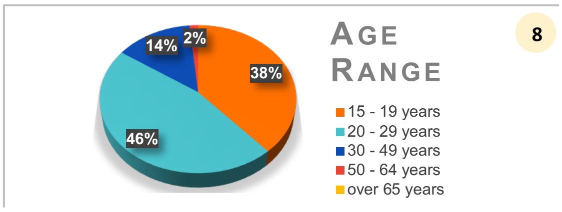


Figure D. 118: Site 8: User age range [Graph].

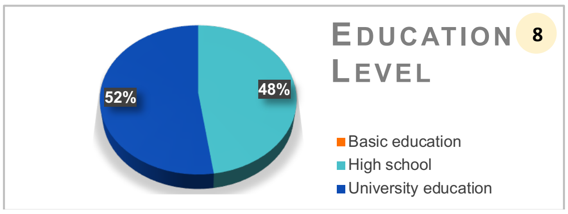


Figure D. 119: Site 8: User Education Level [Graph].

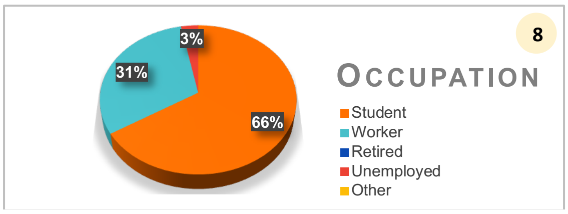


Figure D. 120: Site 8: User Occupation [Graph].

SITE 9 - Public Space and waterfront sound assessment

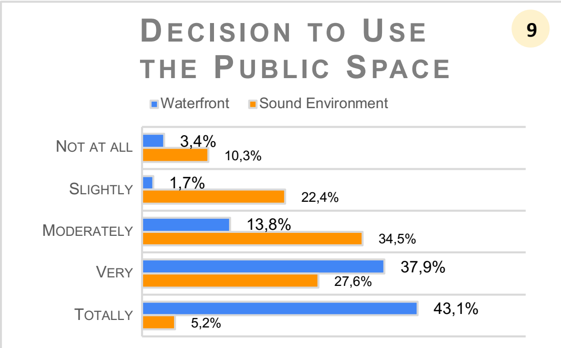


Figure D. 121: Site 9: Parameters that influence on the decision to public space use: Waterfront x Sound Environment [Graph].

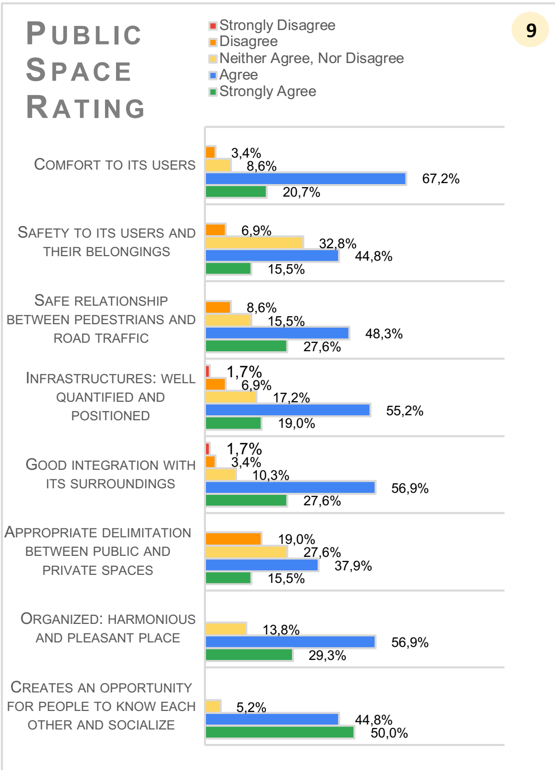


Figure D. 122: Site 9: Public Space Assessment [Graph].

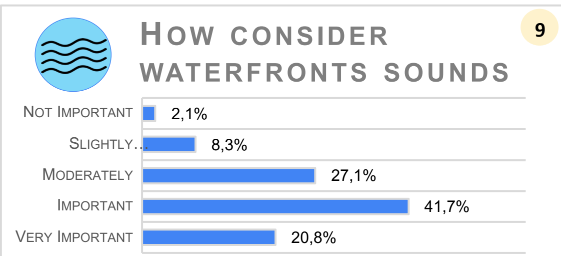


Figure D. 123: Site 9: Importance of sounds waterfront related [Graph].

SITE 9 - Environmental Sound and Soundscape assessment

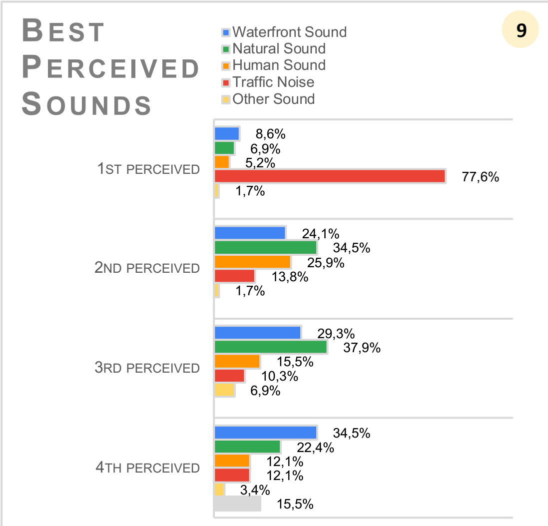


Figure D. 124: Site 9: Most perceived sound sources in the public space [Graph].

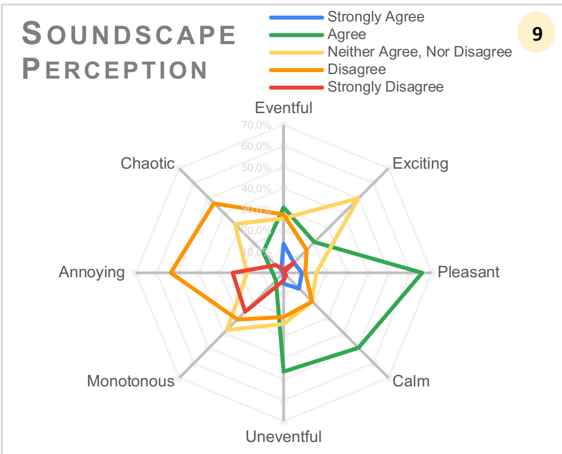


Figure D. 125: Site 9: Soundscape Assessment [Graph].

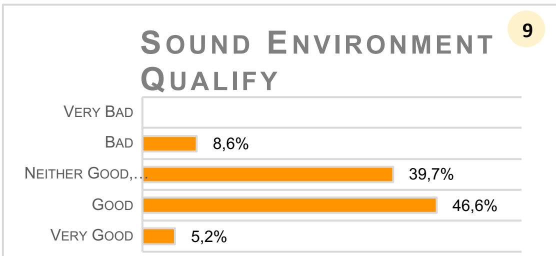


Figure D. 126: Site 9: Sound Environment Assessment [Graph].

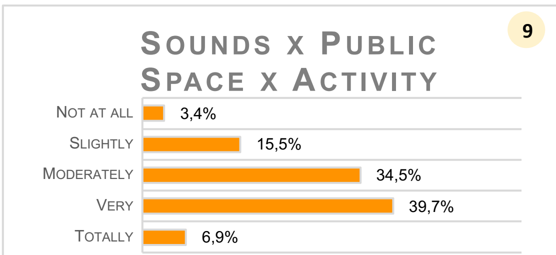


Figure D. 127: Site 9: Relationship between sounds, public space and user activity [Graph].

SITE 9 - User Behaviour

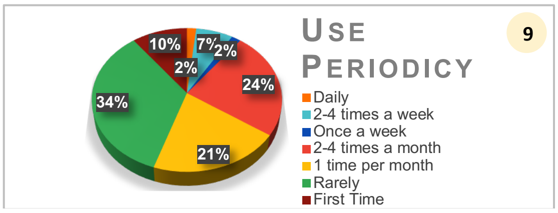


Figure D. 128: Site 9: Public space user periodicity of use [Graph].

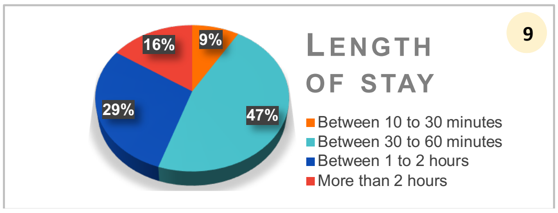


Figure D. 129: Site 9: Public space user length of stay [Graph].

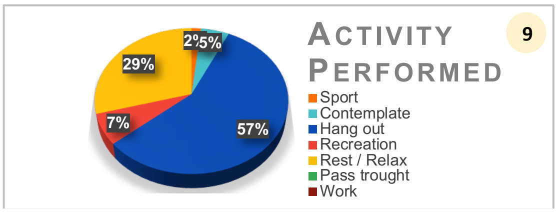


Figure D. 130: Site 9: Reason that led the user to choose the public space [Graph].

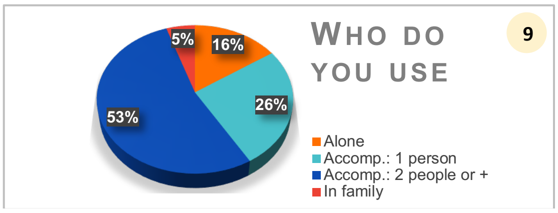


Figure D. 131: Site 9: Who the user usually stays in the public space [Graph].

SITE 9 - User Data

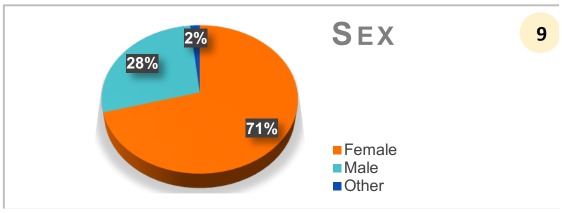


Figure D. 132: Site 9: User sex [Graph].

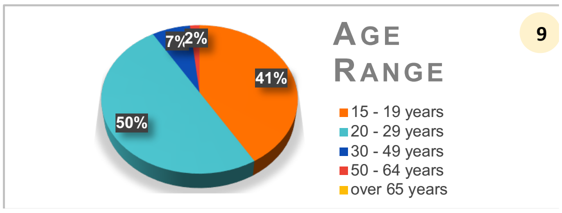


Figure D. 133: Site 9: User age range [Graph].

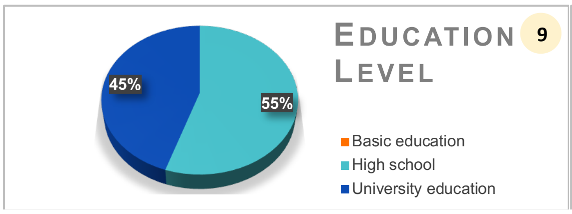


Figure D. 134: Site 9: User Education Level [Graph].

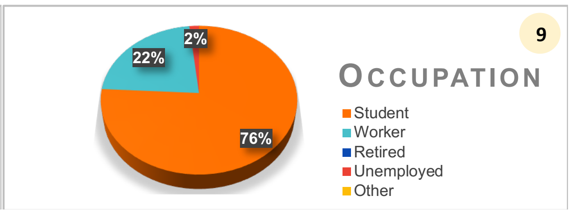


Figure D. 135: Site 9: User Occupation [Graph].

SITE 10 - Public Space and waterfront sound assessment

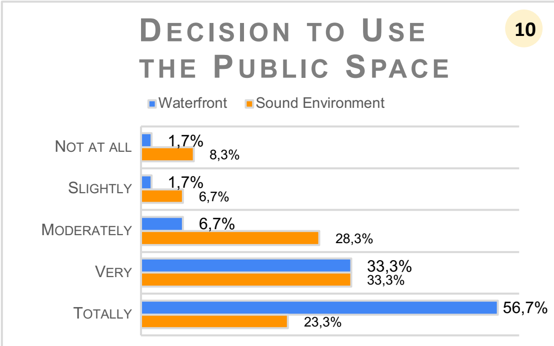


Figure D. 136: Site 10: Parameters that influence on the decision to public space use: Waterfront x Sound Environment [Graph].

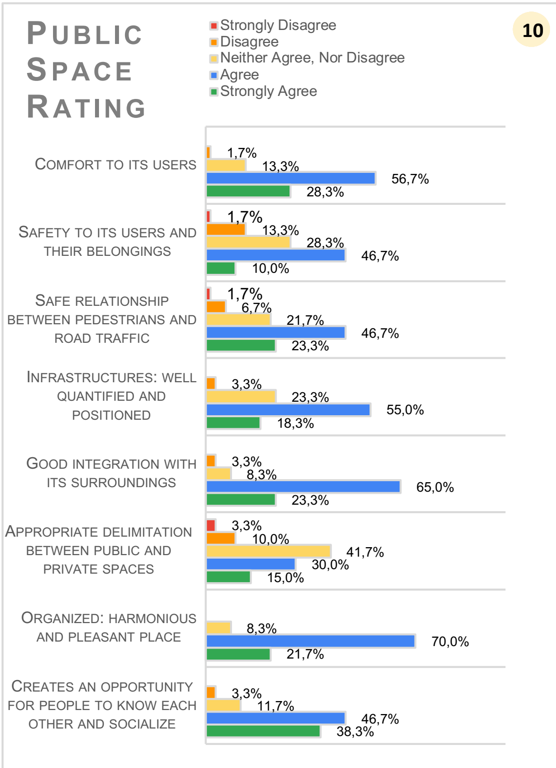


Figure D. 137: Site 10: Public Space Assessment [Graph].

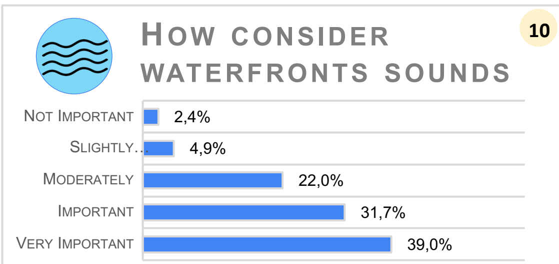


Figure D. 138: Site 10: Importance of sounds waterfront related [Graph].

SITE 10 - Environmental Sound and Soundscape assessment

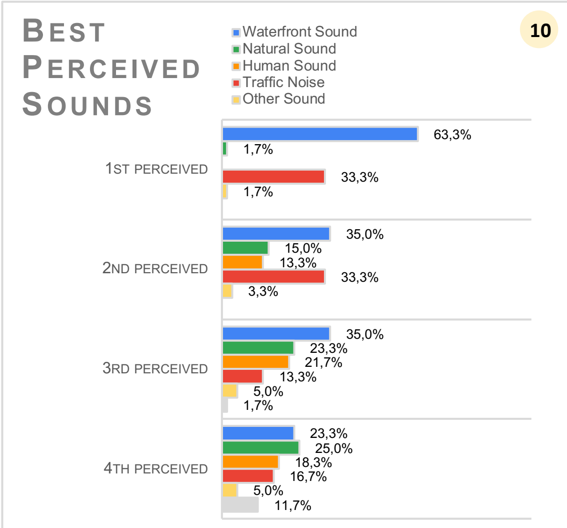


Figure D. 139: Site 10: Most perceived sound sources in the public space [Graph].

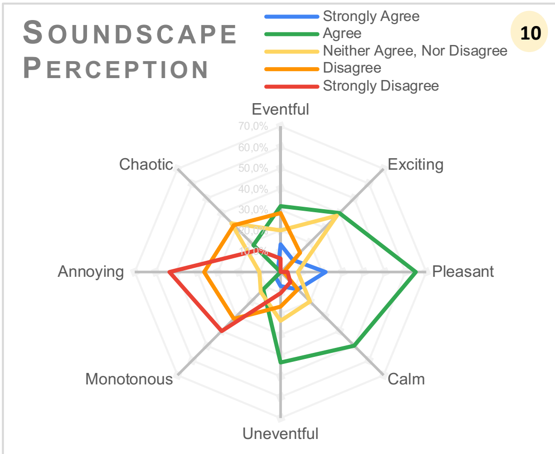


Figure D. 140: Site 10: Soundscape Assessment [Graph].

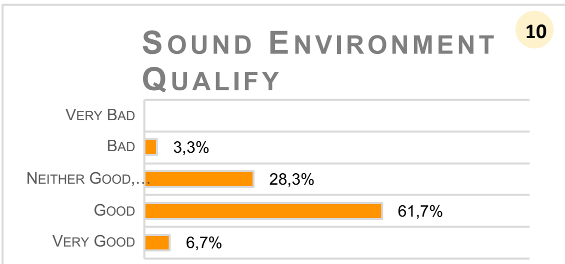


Figure D. 141: Site 10: Sound Environment Assessment [Graph].

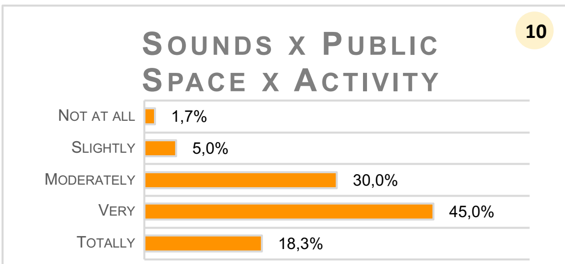


Figure D. 142: Site 10: Relationship between sounds, public space and user activity [Graph].

SITE 10 - User Behaviour

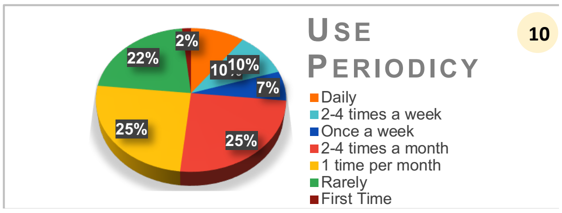


Figure D. 143: Site 10: Public space user periodicity of use [Graph].

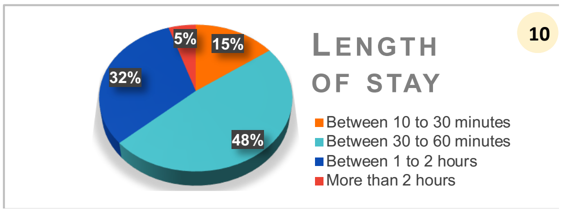


Figure D. 144: Site 10: Public space user length of stay [Graph].

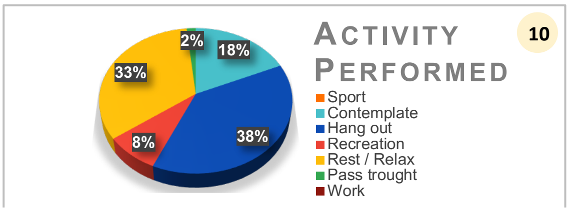


Figure D. 145: Site 10: Reason that led the user to choose the public space [Graph].

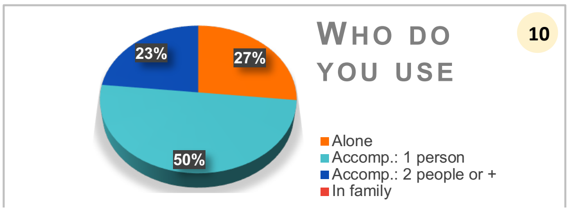


Figure D. 146: Site 10: Who the user usually stays in the public space [Graph].

SITE 10 - User Data

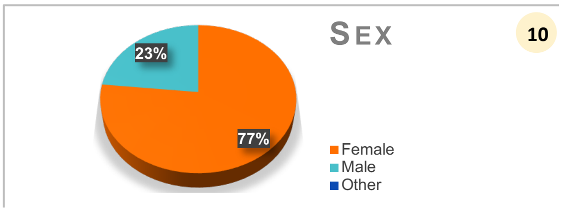


Figure D. 147: Site 10: User sex [Graph].

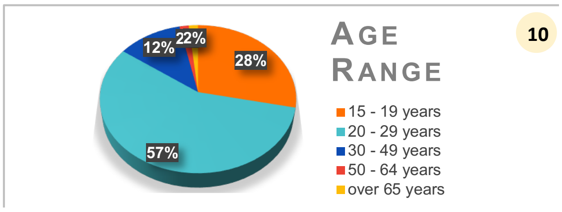


Figure D. 148: Site 10: User age range [Graph].

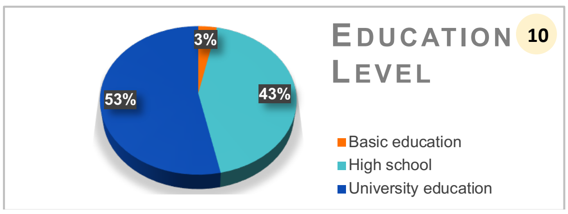


Figure D. 149: Site 10: User Education Level [Graph].

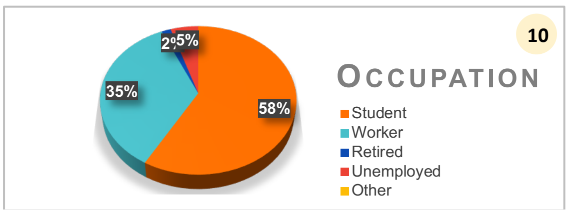


Figure D. 150: Site 10: User Occupation [Graph].

8. ANALYSIS AND DISCUSSION

The data analysis presented in this chapter focus on obtaining significant associations between all the data collected on the case-study and the assessments of the sound environment, that can be used as objective criteria to provide guidance to the urban planner on designing the soundscapes of an urban waterfront area.

In the previous chapters, each objective and subjective data collected from the different sites of the Tejo waterfront were separately presented and some particularities found were detailed.

This chapter is focussed on the analysis of data through a qualitative approach, which the data collected related to the sounds and the sound environments evaluations of the waterfront area were firstly explored and were considered as the core of the research. It is from these main perceptions that the other subjective evaluations were linked to the objective data collected to identify significant relationships for the establishment of objective criteria for the design of a waterfront soundscape.

The correlation analysis started with comparative graphs, site by site, between the evaluations mean scores which adopted the same scale values. Subsequently, the same aspects were investigated by means of statistical analyses, but considering the results from all the Tejo's waterfront sites together, in order to obtain empirical evidence of the associations.

8.1. SOUNDSCAPE QUALITY CORRELATIONS

In order to structure the correlation analyses that follow, firstly, it was necessary to know how all the sound environment evaluations have correlated each other.

It is important, in this section, to identify potential relationships and then to distinguish the aspects that are more associated with a better evaluation of the soundscape, from those that are more associated with a worse evaluation.

Firstly, the assessment of the surrounding sound environment was linked to the appropriateness of the surrounding sound environment, shown in Figure 8.1.

The mean scores obtained were very similar between both assessments, with minimal differences between them, which means they have the same level of appreciation and that, therefore seem very associated.

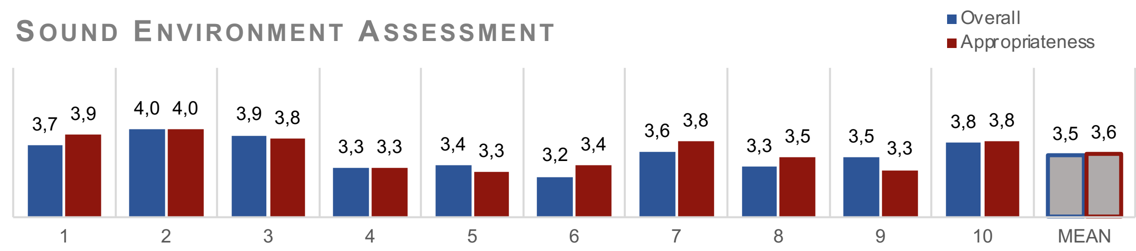


Figure 8.1: Relation between the overall sound environment evaluation and its appropriateness with the place, on each site.

The association can be verified since on the sites where the sound environment was assessed as "not good and not bad", it was regarded as "moderately appropriated" with the place, while, where the sound environment was assessed as “good", it was considered "very appropriated".

Table 8.1 presents the Spearman’s rank correlation analysis between both aspects but considering the assessments results from all the waterfront sites together.

Table 8.1: Spearman's rho correlation coefficients for the relationship between the evaluation of the sound environment and its appropriateness with the site. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	Sound Envir. Appopriateness
Sound Envir. Overall	.585**

The correlation analysis confirms that the aspects are strongly ($r_{spearman}$ 0.585) and significant (*p-value* < 0.01).

Considering the association of both evaluations of the sound environments and the importance they have as recommended aspects to measure the quality of the soundscape of a place, according to ISO 12913-2 (2017), it seemed important to pursue the analysis.

In this sense, proceeding with the correlations analyses between the subjective evaluations related to the sound environments, the overall sound environment evaluation and their appropriateness were linked, in Table 8.2, with the two basic components of the soundscape perception, the Pleasantness and Eventfulness of the sound environment, obtained from the assessments of the eight affective quality items of the sound environment.

The results show that both evaluations present a significant and strong positive correlation with the Pleasantness of the sound environment (rs = 0.582 and 0.563, respectively, p <

0.01), while having a significant but inverse (negative) correlation with the Eventfulness of the sound environment (rs = -0.352 and -0.294, respectively, $p < 0.01$).

Table 8.2: Spearman's rho correlation coefficients for the relationship between the sound environment evaluations (overall and appropriateness) and the basic components of the soundscape perception (pleasantness and eventfulness). Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	Sound Envir. Overall	Sound Envir. Appopriateness
Pleasantness	.582**	.563**
Eventfulness	-.352**	-.294**

The positive and significant coefficients found mean that the more a waterfront sound environment is perceived as "pleasant", the higher it is appreciated and the more appropriate it is considered. On the contrary, the negative and significant coefficients mean that the more the sound environment is perceived as "eventful", the lower it is appreciated and, thus, less appropriate it is.

That is, as confirmed by the Spearman's correlation in Table 8.3, the Pleasantness and the Eventfulness of the sound environment of the Tejo's waterfront present a significant and inverse correlation ($r_s = -.354$, $p < 0.01$), which means that the more the sound environment is perceived as "pleasant", the less it is perceived as "eventful", and vice versa.

Table 8.3: Spearman's rho correlation coefficients for the relationship between Sound Environment Pleasantness and sound environment Eventfulness. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	Eventfulness
Pleasantness	-.354**

Next, the evaluations and perceptions regarding the sound environments correlated so far were related with the sound source category perceived, as shown in Table 8.4.

Table 8.4: Spearman's rho correlation coefficients for the relationship between perception of the Sound Sources categories and the sound environment evaluations and perceptions (overall, appropriateness, pleasantness, and eventfulness). Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	Sound Envir. Overall	Sound Envir. Appopriateness	Sound Envir. Pleasantness	Sound Envir. Eventfulness
waterfront sound	.296**	.256**	.244**	-.092*
natural sound	.134**	.087*	.152**	-0.01
human sound	-0.04	-0.03	-0.02	0.02
traffic noise	-.322**	-.267**	-.308**	0.06
other sound	-.096*	-.110**	-.088*	0.01

From the correlation analysis, it can be noted that the Eventfulness of the sound environment only presents a significant relationship, weak and negative, with the “waterfront sound” perception (r_s = -0.092, $p < 0.05$).

However, the other factors present significant relationships with most of the sound source categories, except the "human sound". The highest correlations were with the “waterfront sound” and the “traffic noise” categories, but while the associations with the “waterfront sound” were positive, those with “traffic noise” were negative.

The positive and significant coefficients mean that the more the perception of "waterfront sound", the more appreciated is the waterfront sound environment, besides being considered more pleasant and appropriate, as well as less eventful. On the contrary, the negative and significant coefficients mean that the more the “traffic noise” is perceived, the less appreciated is the sound environment, besides being considered less pleasant and appropriate.

That is, as confirmed by the Spearman's correlation in Table 8.5, the “waterfront sound” and the “traffic noise” on the Tejo's waterfront sites are on a significant strong inverse relationship (r_s = -.625, $p < 0.01$), which means that the more the “waterfront sound” is perceived, the less the “traffic noise” is perceived, and vice versa.

Table 8.5: Spearman's rho correlation coefficients for the relationship between perception of the “waterfront sound” and the “traffic noise”. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	waterfront sound
traffic noise	-,625**

Lastly, all the subjective evaluations regarding the sounds and the sound environments are shown in Table 8.6, with their mean values obtained, in order to note in detail how their relations are established, site by site.

For comparison purposes, as the mean values presented have different scales, a colour scale was adopted that starts with the green colour and ends with the red colour. The lowest values of the Eventfulness of the sound environment and the highest values of other subjective evaluations are in green colour, while the opposite are in red.

Table 8.6: Comparison between subjective assessments of the sound environments and sound sources categories best perceived.

	Comparative Soundscape Assessments and Sound Source most Perceived									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Sound Envir. Eventfulness	-0,12	-0,16	-0,21	-0,06	-0,12	0,03	-0,10	-0,01	0,00	0,01
Sound Envir. Pleasantness	0,45	0,55	0,38	0,30	0,22	0,19	0,43	0,30	0,29	0,41
Sound Envir. Appropriateness	3,9	4,0	3,8	3,3	3,3	3,4	3,8	3,5	3,3	3,8
Sound Envir. Overall	3,7	4,0	3,9	3,3	3,4	3,2	3,6	3,3	3,5	3,8
Sound Source most perceived	 46%	 47%	 35%	 56%	 64%	 46%	 40%	 37%	 39%	 44%

The comparison results show that, in general, most of the sites presented the same associations found so far, in which:

- sites 2, 3, 7 presented the higher appreciated sound environments, considered more appropriate and pleasant and less eventful, and the sound source category best perceived was the waterfront sound;
- sites 4, 6, 8 and 9 presented the lower appreciated sound environments, considered less appropriate and pleasant and more eventful, and the sound source category best perceived was the traffic noise.

However, some sites presented different associations, in which:

- in site 10, despite being similar to sites 2, 3 and 7, its sound environment is more eventful;
- in site 1, despite being similar to sites 2, 3 and 7, the sound source category best perceived is the traffic noise;
- in site 5, despite being similar to sites 4, 6, 8 and 9, its sound environment is less eventful.

DISCUSSION

From the associations obtained so far, since a positive "overall evaluation of the sound environment" of a place is desirable, as it corresponds to a positive appreciation of its soundscape, it is possible to determine that, for the Tejo's waterfront area:

- a "pleasant" and "appropriate" with the place sound environment and the perception of "waterfront sound" are desirable aspects, due to their positive correlation with the overall evaluation of the sound environment, and, therefore, can be associated to a "positive evaluation" of waterfront soundscape;

- an "eventful" sound environment and the perception of "traffic noise" are undesirable aspects, due to their inverse correlation with the overall evaluation of the sound environment, and, therefore, can be associated to a "negative evaluation" of waterfront soundscape.

Therefore, Table 8.7 summarizes the subjective evaluations regarding the sounds and the sound environments more associated to a "negative evaluation" and those more associated to a "positive evaluation" of a waterfront soundscape.

Table 8.7: Aspects which are associated to a "negative evaluation" and to a "positive evaluation" of a waterfront soundscape.

	Aspects Associated to a Waterfront Soundscape	
	Negative Evaluation	**Positive Evaluation**
Sound Sources:	Traffic Noise	Waterfront Sound
Sound Environment:	Eventful	Pleasant
		Appropriate

8.1.1. Correlations with objective data (sound levels)

According to the results presented in section 6.3, the sound levels measured at the sites are not enough to evaluate the quality of the sound environment since it may be affected by a variety of parameters.

Therefore, it seemed important to know how the aspects found more associated both to a positive and to a negative evaluation of a waterfront soundscape are related to the site's objective sound environment data.

In Table 8.8, for comparison purposes, acoustic data for each site, the mean values calculated for the L_{Aeq} index and the difference between the statistical descriptors L_{A10} and L_{A90}, were inserted together with subjective evaluations regarding the sounds and the sound environments.

As the mean values presented have different scales, the same colour scale used in Table 8.6 was adopted, adding that the lowest values of the L_{Aeq} index and the L_{A10} - L_{A90} tend to be green and the highest values of L_{Aeq} index tend to be red. The results from L_{A10} - L_{A90} were presented twice, in two lines, with different colour scales to the higher values, since sound events can influence negatively or positively the evaluation of sound environments, as exposed in section 6.2.

Considering that high sound levels might be more unpleasant than low levels, from the comparisons it is possible to note that the calculated sound levels seem to be associated to the sound environment evaluations on sites 1, 2, 3 and 7, since the minimum sound levels coincided with the better evaluations, and on sites 4, 5 and 9, where the maximum sound levels coincided with the worst evaluations.

Table 8.8: Comparison between physical parameters and subjective evaluations of the sound environments.

	Comparative: Acoustic Descriptor Mean Values and Soundscape Assessment									
	1	2	3	4	5	6	7	8	9	10
L_{aeq} [dB]	58,0	56,2	60,5	62,7	63,9	60,9	59,8	59,1	64,0	64,8
L_{A10} - L_{A90} [dB]	5,8	6,1	4,4	5,6	3,9	6,0	7,2	7,3	7,6	8,7
L_{A10} - L_{A90} [dB]	5,8	6,1	4,4	5,6	3,9	6,0	7,2	7,3	7,6	8,7
Sound Envir. Eventfulness	-0,12	-0,16	-0,21	-0,06	-0,12	0,03	-0,10	-0,01	0,00	0,01
Sound Envir. Pleasantness	0,45	0,55	0,38	0,30	0,22	0,19	0,43	0,30	0,29	0,41
Sound Envir. Appropriateness	3,9	4,0	3,8	3,3	3,3	3,4	3,8	3,5	3,3	3,8
Sound Envir. Overall	3,7	4,0	3,9	3,3	3,4	3,2	3,6	3,3	3,5	3,8
Sound Source most perceived	46%	47%	35%	56%	64%	46%	40%	37%	39%	44%

From these associations, it is important to highlight that:

- on site 1, although traffic noise is the best perceived sound source category, it seems that the low sound levels contribute to high-quality soundscape;
- on site 5, despite the less variation on its sound levels that contribute to an uneventful sound environment, it seems that the high sound levels together with the predominance of the traffic noise influence the low-quality soundscape;
- on site 9, the large variation of its sound levels and the more eventful sound environment, that seem to be caused mostly by the traffic noise predominance, appear to influence considerably the low-quality soundscape.

The sound levels seem less associated with the sound environments evaluations on sites 6, 8 and 10:

- on sites 6 and 8, the measured sound levels are not high enough to be considered unpleasant, but the evaluations regarding their sound environments were the lowest ones;
- on site 10, the more variation on its sound levels and the more eventful sound environment, seem to be caused mostly by the sounds of the water against to the riverbank, as mentioned in section 6.1, and confirmed by the waterfront sounds predominance. Therefore, despite the high sound levels, the waterfront sounds seem to influence considerably the good evaluations of the site sound environment.

Considering the comparative differences, it seemed important to devise a Spearman's rank correlation, for all waterfront areas, between the mean values calculated for the L_{Aeq} index descriptor, and the same subjective evaluations of the sound environments, including the other aspects associated with a positive and a negative evaluation of the soundscape.

Table 8.9 shows that the calculated sound pressure level (L_{Aeq}) presents significant, although low correlations with just some aspects related, such as the perception of "traffic noise" ($r_s = .092$, $p<0.05$), the Eventfulness of the sound environment ($r_s = .107$, $p < 0.01$), and the appropriateness of the sound environment ($r_s = -.117$, $p < 0.01$).

Table 8.9: Spearman's rho correlation coefficients for the relationship between aspects associated to a waterfront soundscape evaluation and the soundscape and the continuous equivalent sound pressure level index (L_{Aeq}) calculated. Significant correlations are marked with* (p < 0.05) and** (p < 0.01).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Overall	Sound Envir. Appopriateness
L_{Aeq}	,092*	0,037	-0,075	,107**	-0,046	-,117**

The positive correlation may mean that the higher the L_{Aeq} index on the area, the better is the perception of the "traffic noise" and of an eventful sound environment. Whereas the negative correlation may mean that the higher the L_{Aeq} index, the less the sound environment is considered appropriate.

DISCUSSION

From the results with the Spearman's correlation, one can note that:

- the positive correlation of the calculated sound pressure levels with the traffic noise and the Eventfulness of the sound environment indicates that the L_{Aeq} index is more related with the aspects found more associated to a negative evaluation of a waterfront soundscape.

The comparisons with the subjective evaluations of the sound environment show that the sound levels seem to influence some evaluations, but without being determinant.

From the results, it can be understood that:

- the low sound level and its more continuous characteristic may have been "determinants" in the high-quality sound environment of site 1, mainly because the predominance of the perception of the traffic noise which is associated with a negative evaluation of a waterfront soundscape;
- the low sound level may have "influenced" the high-quality sound environments of sites 2, 3 and 7, also favoured by the predominance of the perception of waterfront sound, which contribute to a more positive evaluation of the soundscape;
- the high sound level may have "influenced" the lower-quality sound environments of sites 4, 5 and 9, also assisted by the predominance of the perception of traffic noise, which contribute to a more negative evaluation of the soundscape.

8.1.2. Correlations with user data

It also seemed important to know how the aspects found more associated both to a positive and to a negative evaluation of a waterfront soundscape are related to the user social demographical data and their practices.

Therefore, firstly the practices of the site users were linked with the aspects associated to the evaluation of waterfront soundscape, in Table 8.10, Table 8.11, Table 8.12 and Table 8.13.

Table 8.10: Spearman's rho correlation coefficients for the relationship between aspects associated to a waterfront soundscape evaluation and user' frequency of visit the site. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Overall	Sound Envir. Appopriateness
Daily	,089*	-0,067	0,001	0,005	-0,051	-0,017
2-4 times a week	0,053	-0,022	-0,046	-0,019	-0,005	-0,004
Once a week	-0,009	0,024	,081*	0,008	-0,036	0,018
2-4 times a month	-0,014	0,005	0,041	-0,025	0,058	-0,001
1 time per month	0,024	-,088*	-,078*	0,047	-0,074	-,099*
Rarely	-,101*	,104**	0,004	0,003	0,05	0,045
First Time	-0,034	0,043	0,017	-0,024	0,06	0,075

The different frequencies of the visits to the sites, although present some significant relationships with the evaluations of the sound environment, have low spearman coefficients which mean low correlations. Besides, the significant relations are not very representative, since they were varied, i.e., they did not present substantial differences between users who frequent the site less and those who frequent more.

Table 8.11: Spearman's rho correlation coefficients for the relationship between aspects associated to a waterfront soundscape evaluation and user' length of visit the site. Significant correlations are marked with* (p < 0.05) and** (p < 0.01).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Overall	Sound Envir. Appopriateness
10 to 30 minutes	-,078*	,100*	0,06	-0,033	0,05	0,068
30 to 60 minutes	-0,018	0,06	-0,003	0,026	0,055	0,026
1 to 2 hours	0,003	-0,047	0,053	-0,031	-0,031	-0,005
More 2 hours	,112**	-,138**	-,141**	0,044	-,096*	-,110**

The different lengths of visits on the sites, in turn, presents some significant relationships with the evaluations, that are more representative, although with low spearman coefficients, in which:

- Users who spend less time on the sites, from 10 to 30 minutes, tend to perceive the "waterfront sound" better (r_s = .100, p < 0.05) and less the "traffic noise" (r_s = -.078, p<0.05);
- Users who stay longer, more than 2 hours, tend to perceive the "traffic noise" more (r_s=.112, p < 0.01), and less the "waterfront sound" (r_s = -.138, p < 0.01), appreciate less the sound environment (r_s = -.096, p < 0.05), and consider it as less pleasant (r_s = -.141, p<0.01) and less appropriate (r_s = -.110, p < 0.01).

Table 8.12: Spearman's rho correlation coefficients for the relationship between aspects associated to a waterfront soundscape evaluation and the soundscape and activities on the site. Significant correlations are marked with* (p < 0.05) and** (p < 0.01).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Overall	Sound Envir. Appopriateness
Sport	,155**	-,127**	0,013	-0,045	-0,013	0,02
Contemplate	-0,044	,126**	0,048	-0,048	-0,009	0,011
Hang out	-0,058	-0,007	0,015	0,023	0,011	-0,013
Recreation	-0,031	-0,018	-0,046	0,029	-0,041	-0,031
Rest / Relax	0,039	0,004	-0,047	0,037	0,012	0
Pass throught	-,081*	0,022	0,045	-0,031	0,037	0,021

The different activities performed on the sites were significantly correlated with the perceived sound sources, although also with low coefficients. It can be highlighted that:

- users who were practicing some sport activity on the sites, perceived the "traffic noise" more (r_s = .155, p < 0.01) and less the "waterfront sound" (r_s = -.127, p < 0.01);

- users who were contemplating the landscape, perceived more the "waterfront sound" (r_s= .126, $p < 0.01$);

- users who were passing through the sites, perceived the "traffic noise" less (r_s = -.081, $p< 0.05$).

Table 8.13: Spearman's rho correlation coefficients for the relationship between aspects associated to a waterfront soundscape evaluation and the soundscape and social interaction on the site. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Overall	Sound Envir. Appopriateness
Alone	0,024	0,028	0,005	0,033	-0,049	-0,013
+ 1 person	-0,019	-0,057	-0,012	0,036	0,014	0,027
2 people or +	-0,009	0,033	0,016	-0,064	0,037	-0,017
In family	0,012	-0,004	-0,019	-0,018	-0,003	0,006

Lastly, the different social interactions on the sites were not significantly correlated with any aspect associated to the evaluation of a waterfront soundscape.

In the same way, the profile of the users of the sites was also linked to the aspects associated to the evaluation of waterfront soundscape, in Table 8.14, Table 8.15, Table 8.16 and Table 8.17.

Table 8.14: Spearman's rho correlation coefficients for the relationship between aspects associated to a waterfront soundscape evaluation and user gender. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Overall	Sound Envir. Appopriateness
Female	-0,042	0,015	-0,002	0,062	-0,009	0,025
Male	0,034	-0,011	0,008	-,082*	0,015	-0,021
Other	0,049	-0,021	-0,03	,107**	-0,032	-0,023

Table 8.15: Spearman's rho correlation coefficients for the relationship between aspects associated to a waterfront soundscape evaluation and user age range. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Overall	Sound Envir. Appopriateness
15 - 19	0,023	-0,002	-0,022	0,003	0,03	-0,02
20 - 29	-,086*	0,047	-0,048	-0,016	-0,067	-0,013
30 - 49	,102**	-0,075	0,046	0,037	0,018	0,012
50 - 64	-,087*	0,072	0,057	-0,052	,078*	0,076
over 65	0,018	-0,011	0,019	-0,001	-0,02	-0,028

Table 8.16: Spearman's rho correlation coefficients for the relationship between aspects associated to a waterfront soundscape evaluation and the soundscape and user education. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Overall	Sound Envir. Appopriateness
Basic Education	0,032	-0,024	-0,07	0,008	-0,066	-0,029
High School	0,049	-0,044	-0,027	0,013	0,036	-0,02
University Education	-0,059	0,051	0,049	-0,015	-0,015	0,029

Table 8.17: Spearman's rho correlation coefficients for the relationship between aspects associated to a waterfront soundscape evaluation and the soundscape and user occupation. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Overall	Sound Envir. Appopriateness
Student	-0,053	0,051	-0,022	-0,004	0,037	-0,008
Worker	0,043	-0,04	0,008	0,01	-0,035	-0,007
Retired	-0,025	0,024	0,057	-0,003	0,004	0,01
Unemployed	0,039	-0,04	-0,014	-0,009	-0,008	0,022

All these relationships show that there are no significant correlations between any aspect associated to the evaluation of waterfront soundscape and the different users' characteristics that seem to be important and representative for the research purposes.

DISCUSSION

The correlation analysis shows that the users' practices on the sites were more associated with the sound source categories best perceived than with the other sound environment evaluations. Therefore:

- the "waterfront sound" category is more perceived by users who spend less time in the site and by users who contemplate the landscape, while it is less perceived by users who practice physical activities in the site;
- the "traffic noise" category is more perceived by users who spend longer in the site and by users who practice physical activities in the site, while it is less perceived by users who pass through the site.

In addition, users who stay longer at the sites seemed to appreciate less the sound environment and consider it as less pleasant and less appropriate.

8.1.3. Correlations with user motivations to visit the site

Considering that the sound environment of waterfront sites can directly or indirectly motivate their users to visit and use these places, it is important to understand how the evaluations of these sound environments are associated with the degree of influence that both the "soundscape" and the "landscape" have on people's decision to visit the sites.

In Figure 8.2, the overall sound environment evaluation and its appropriateness was compared to the influence the "soundscape" has on the user decision to visit the site.

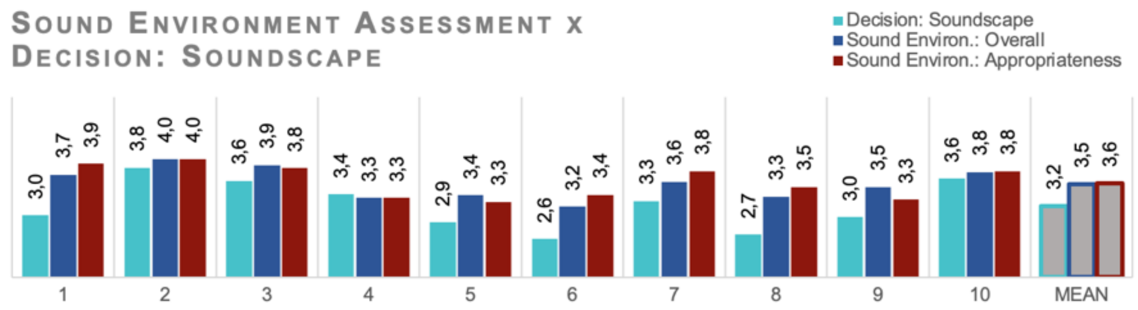


Figure 8.2: Relation between the sound environment evaluations and its influence on people decision to visit the place, on each site.

The mean scores of each evaluation on every site seems are correlated. In general, the soundscape of the sites influenced the users to visit them little lower than their sound environments were assessed, maintaining the same relation on almost every site.

The differences are larger, with a distinct level of appreciation on sites 1, 6, 8, and 9, which mean that their users were less influenced by the soundscape compared to other. In common, all these sites are further away from the water limits.

However, different relations are noted on the comparison between the overall sound environment evaluation and its appropriateness, and the influence the "landscape" has on the user decision to visit the site, as shown in Figure 8.3.

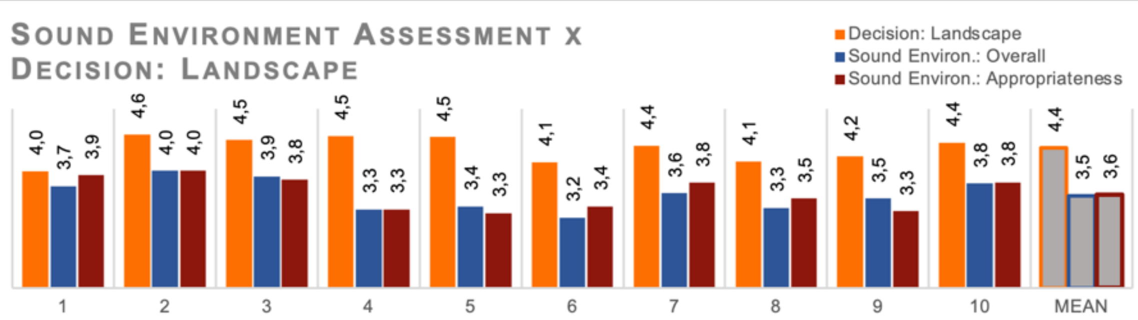


Figure 8.3: Relation between the sound environment evaluations and the "landscape" influence on people decision to visit the place, on each site

The mean scores of the evaluation on all sites seem to have no correlation. In general, the "landscape" of the sites influenced the users to visit them higher than their sound environments were assessed, but the relations varied site by site.

The differences mean a distinct level of appreciation on almost all the sites, except on site 1, and they are even greater on those sites where the sound environments were low-quality evaluated, such as sites 4 and 5.

The Spearman's rank correlation established between the influence that the soundscape and the landscape have on user visit, and the aspects that are positive and negative associated to an evaluation of a waterfront soundscape, showed in Table 8.18, confirms the low association of the "landscape" and the high of the "soundscape" with all the aspects compared.

Table 8.18: Spearman's rho correlation coefficients for the relationship between aspects associated to the waterfront soundscape evaluation and the influence "landscape" and "soundscape" have on the user decision to visit the site, and the importance assigned to waterfront sounds. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Appopriateness	Sound Envir. Overall
Decision: Landscape	-0.029	0.053	.184**	-0.063	.168**	.139**
Decision: Soundscape	-.265**	.285**	.306**	-.102**	.291**	.383**

The influence of the "soundscape" on the user decision to visit the site shows strong relationships and significant with all the aspects, while the influence of the "landscape" shows significant though weak correlations only with the Pleasantness of the sound environment, the overall sound environment evaluation, and its appropriateness with the place.

<u>DISCUSSION</u>

The high correlations between the influence of the "soundscape" on the user decision to visit the site and the aspects associated to the waterfront soundscape evaluation are very important, since they represent a coherence on the user's perception. That is, it is understood that in waterfront sites, the better their sound environments are evaluated, the more they influence people to visit these locations.

Meanwhile, the few and weak correlations with the influence of "landscape" indicate that users' decision to visit the sites due to their landscape is more independent of a high- or low-quality sound environment.

8.1.4. Correlations with public space quality evaluation

Considering that a good evaluation of the quality of the public space can mean or influence on a good evaluation of its sound environment, and vice-versa, it is important to know how much these different evaluations of the waterfront sites' users are associated or not.

Therefore, the subjective evaluations of the sound environments were compared with the evaluations of the quality criteria established for the public spaces, see Figure 8.4.

The comparisons were carried out for every site, where the evaluation of each quality criterion of the public space and the overall evaluation of the sound environment are presented in sequence, using the evaluation of the sound environment appropriateness as the reference for the comparisons, since it is an important criterion in which the relationship between the sound environment and the place was also assessed.

From the graphics, it can be noted that the quality criteria of the public spaces, the overall sound environment and its appropriateness were not assessed in the same way on all the sites. While the quality criteria of the public space have good evaluations on all the sites, the evaluations of the sound environments varied more.

Therefore:

- On sites 1, 2, 3 and 10, all the criteria presented similar evaluation levels;
- On site 7, the quality criteria "safety" and "opportunity to socialize" presented a different evaluation level;
- On site 8, the quality criteria were assessed differently than the sound environment, except for the quality criteria "safety" and "infrastructures";
- On sites 4, 5, 6 and 9, all the quality criteria had higher evaluations than the sound environments.

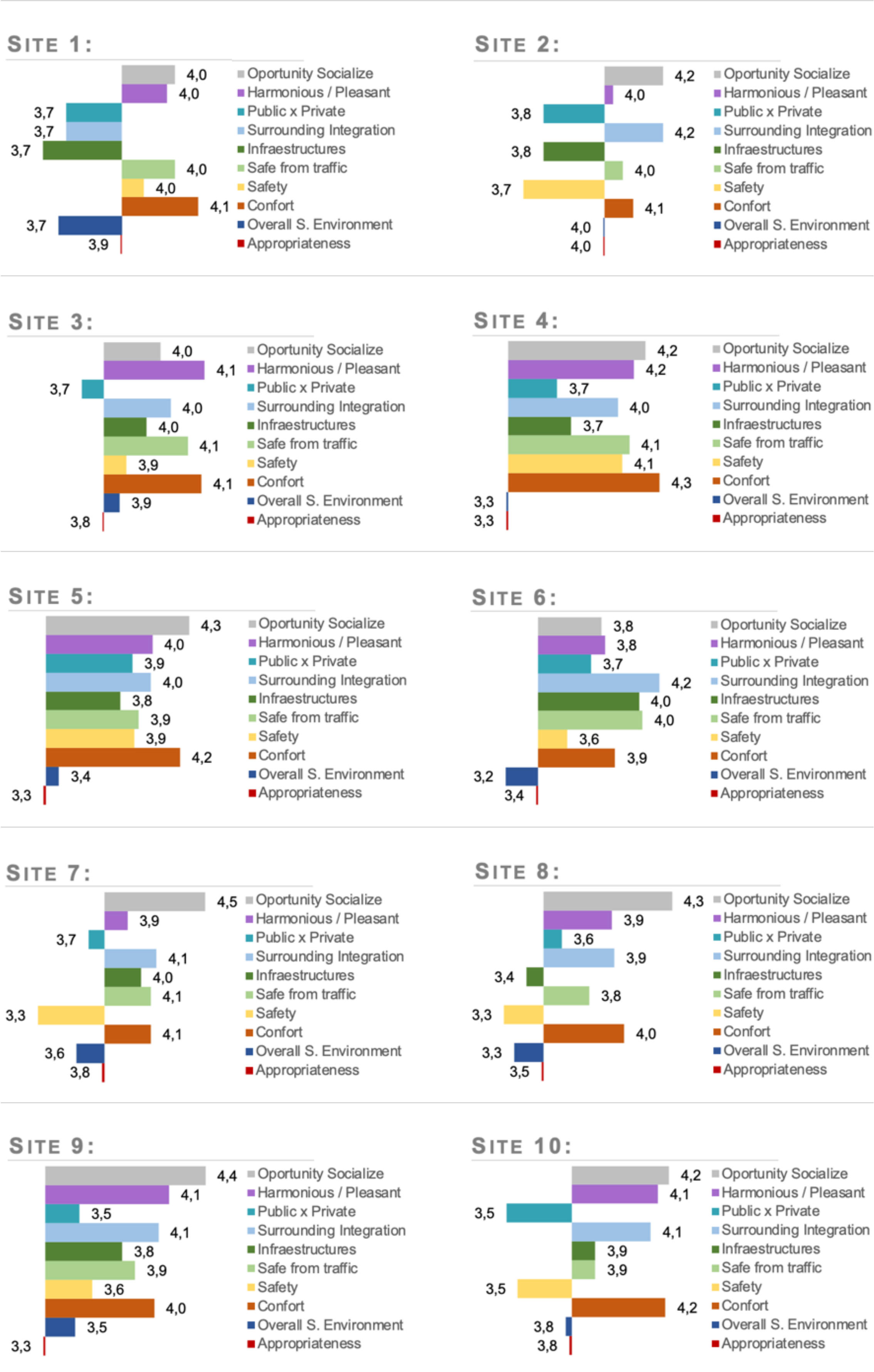


Figure 8.4: Relationship between the sound environment appropriateness and the evaluations of the site's qualifications.

The similarities and the differences found between the evaluations, led to the understanding that the correlations between the factors analysed seem not be so strong. Therefore, a Spearman's correlation analysis was carried out, see Table 8.19, to confirm the association or not among these evaluations' factors, and including the other aspects associated to a waterfront soundscape evaluation.

Table 8.19: Spearman's rho correlation coefficients for the relationship between aspects associated to a waterfront soundscape evaluation and the evaluations of the sites' qualifications. Significant correlations are marked with* ($p < 0.05$) and** ($p < 0.01$).

	traffic noise	waterfront sound	Sound Envir. Pleasantness	Sound Envir. Eventfulness	Sound Envir. Overall	Sound Envir. Appopriateness
Confort to Users	-0.051	0.058	.267**	-.146**	.162**	.195**
Safety	0.053	-0.046	.203**	-.157**	.111**	.142**
Safe from traffic	-0.026	0.007	.181**	-.147**	.150**	.175**
Surroundings Integration	-0.017	0.037	.213**	-.146**	.122**	.181**
Delimitation Public x Private	-0.009	0.031	.180**	-0.058	.084*	.191**
Infrastructures	0.029	-0.037	.113**	-.154**	0.066	.108**
Harmious and Pleasant	-0.059	0.043	.283**	-.095*	.217**	.227**
Oportunity Socialize	-0.071	0.076	.192**	-0.043	.094*	.143**

The results show that the quality criteria of the public spaces have no significant correlation with the perception of both sound source categories, the "traffic noise" and the "waterfront sound".

Comparatively, the Pleasantness of the sound environment shows the higher positive and significant correlation with the evaluations of the quality criteria of the public spaces while the Eventfulness of the sound environment shows the higher negative and significant correlation. In addition, the overall sound environment evaluation has the weaker positive correlation, despite being not significant with some criteria.

The quality criteria "organized: harmonious and pleasant" and "comfort to its users" were the ones with the highest correlations with the aspects correlated, while the criterion "infrastructures well quantified and positioned" was the one with the weakest correlation.

DISCUSSION

The results of the correlations allow to understand that:

- In general, all the quality criteria established for the Tejo's waterfront public spaces were high-quality evaluated, unlike their sound environments;

- the Pleasantness and the Eventfulness of the sound environment are the aspects that presents the stronger correlations with the evaluations of the quality criteria of the public spaces;
- The quality criteria "it is organized: harmonious and pleasant" and "provides comfort to its users" are the ones found more associated to the subjective evaluations of the sound environment of the sites.

8.2. PERCEIVED SOUNDS - LISTENING PANEL (L) VS. INQUIRY RESPONSE (I)

From the analysis of the correlations carried out on section 8.1, it was possible to state that, among all of the correlated aspects, comparatively, the perception of the categories "waterfront sounds" and "traffic noise" were the subjective aspects that had the highest and most significant correlations with the evaluations of the sound environments. Therefore, it is possible to establish that these sound source categories influence directly all the subjective evaluations of the sound environments of the waterfront sites, that, in turn, influence their soundscape evaluation. Considering this, a detailed study regarding the perception of the sound sources on the waterfront sites, can mean one way to understand the perceptual process of waterfront soundscapes.

In subsections 8.1.1 and 8.1.2, it was noticed that the perception of these sound sources can be influenced by the sound levels of the sites and also by some practices of the sites' users. However, these associations seem to be not so determinant on the perception of the sound sources. Therefore, it is important to further explore the sound source perceptual process, mostly to find other influencing factors.

In this sense, a comparative and detailed analysis between the different ranking order of the sound sources best perceived in the sound environments of the Tejo waterfront, obtained from two distinct assessment environments, can point out other aspects related to the sound source perceptual process.

Therefore, on this subsection, the results obtained from the application of the inquiry *in situ*, to the users of the waterfront sites (I), and, from the application of the online form in the laboratory environment, to the listening panel (L) were compared, aiming at highlighting their main differences and similarities.

The results obtained from the two different assessment environments were first compared, in Figure 8.5, considering the whole waterfront.

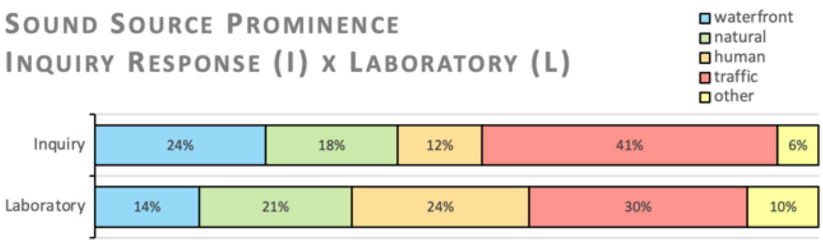


Figure 8.5: Average perception percentual of each sound source on the Tejo's waterfront public spaces [%] obtained *in situ* (I) and in the laboratory (L).

In general, the "traffic noise" was the sound source category best perceived on both assessment procedures, while the "other sound" was the least perceived.

Comparatively, "traffic noise" and "waterfront sound" categories were more perceived *in situ* (41% and 24%, respectively) than in the laboratory (30% and 14%). Conversely, "natural sound" and "human sound" categories were more perceived in the laboratory (21% and 24%, respectively) than *in situ* (18% and 12%).

In Figure 8.6, the best perceived sound sources on the sound environment of each site, as from the two different assessment environments are shown, to a detailed comparison, site by site.

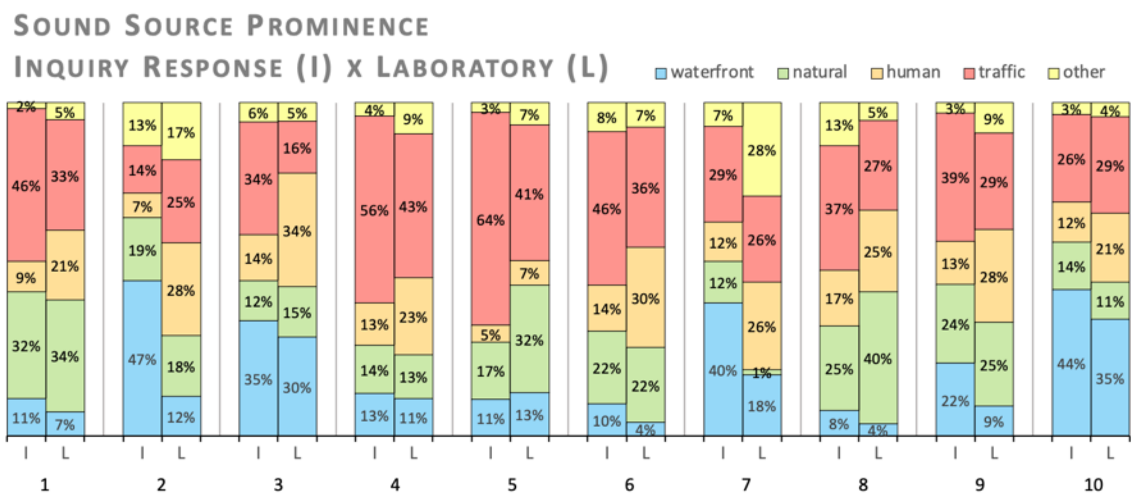


Figure 8.6: Average perception percentual of each sound source on each site [%] obtained *in situ* (I) and in the laboratory (L).

By comparing the perceptions from both assessment environments, it can be noted that the best perceived sound sources were significantly distinct, with great percentage differences, on sites 2, 3, 5 and 7. Where:

- on sites 2 and 7, the "waterfront sound" was much more perceived *in situ*;

- on sites 3 and 5, the "traffic noise" was much more perceived *in situ*;
- on sites 2 and 3, the "human sound" was much more perceived in the laboratory.

On sites 1, 4, 6, 8, 9 and 10, in turn, the percentage differences between both assessment environments were lower, especially on site 10.

At last, Table 8.20 shows the sound sources categories best perceived, on a ranking order, from the most prominent to the least ones, site by site, in which two different comparisons were performed, based on (i) the ranking order, and on (ii) the most prominent sound source.

Table 8.20: Comparative sound source predominance on each site – *in situ* (I) x laboratory (L): from the first to the fifth sound source more perceived.

	1		2		3		4		5		6		7		8		9		10	
	I	L	I	L	I	L	I	L	I	L	I	L	I	L	I	L	I	L	I	L
1st	Traffic 46%	Natural 34%	Waterfront 47%	Human 28%	Waterfront 35%	Human 34%	Traffic 56%	Traffic 43%	Traffic 64%	Traffic 41%	Traffic 46%	Traffic 36%	Waterfront 40%	Other 28%	Traffic 37%	Natural 40%	Traffic 39%	Traffic 29%	Waterfront 44%	Waterfront 35%
2nd	Natural 32%	Traffic 33%	Natural 19%	Traffic 25%	Traffic 34%	Waterfront 30%	Natural 14%	Human 23%	Natural 17%	Natural 32%	Natural 22%	Human 30%	Traffic 29%	Human 26%	Natural 25%	Traffic 27%	Natural 24%	Human 28%	Traffic 26%	Traffic 29%
3rd	Waterfront 11%	Human 21%	Traffic 14%	Natural 18%	Human 14%	Traffic 16%	Human 13%	Natural 13%	Waterfront 11%	Waterfront 13%	Human 14%	Natural 22%	Natural 12%	Traffic 26%	Human 17%	Human 25%	Waterfront 22%	Natural 25%	Natural 14%	Human 21%
4th	Human 9%	Waterfront 7%	Other 13%	Other 17%	Natural 12%	Natural 15%	Waterfront 13%	Waterfront 11%	Human 5%	Human 7%	Waterfront 10%	Other 7%	Human 12%	Waterfront 18%	Other 13%	Other 5%	Human 13%	Waterfront 9%	Human 12%	Natural 11%
5th	Other 2%	Other 5%	Human 7%	Waterfront 12%	Other 6%	Other 5%	Other 4%	Other 9%	Other 3%	Other 7%	Other 8%	Waterfront 4%	Other 7%	Natural 1%	Waterfront 8%	Waterfront 4%	Other 3%	Other 9%	Other 3%	Other 4%

(i) Ranking order

Site 5 was the only waterfront site that presented the same ranking order on both assessment environments.

In general, it is confirmed that the sound source category:

- "waterfront sound" and "traffic noise" were much more perceived *in situ*;
- "human sound" was much more perceived in the laboratory;
- "natural sound" and the "other sound" were similar perceived *in situ* and in the laboratory.

(ii) Most prominent sounds source

By comparing the sound source categories perceived as most prominent on the sound environment of each site, from the two assessment environments, it can be noted that:

- "traffic noise" was considered the most prominent both *in situ* and in the laboratory, on sites 4, 5, 6 and 9;
- "traffic noise" was considered the most prominent *in situ,* while "natural sound" was the most prominent in the laboratory, on sites 1 and 8;
- "waterfront sound" was considered the most prominent both *in situ* and in the laboratory, on site 10;
- "waterfront sound" was considered the most prominent *in situ,* while "human sound" was the most prominent in the laboratory, on sites 2 and 3, and the "other sound", on site 7.

DISCUSSION

In general, it is confirmed that the "waterfront sound" and "traffic noise" was noted more prominent *in situ*, while "human sound" is more prominent in the laboratory.

By comparing the two assessment environments, great differences can be assigned to both the context information and the existing stimuli to their participants, which could influence directly and considerably their perceptions. The panel in the laboratory environment, essentially had sound and visual stimuli, through the sound recordings and illustrative photos of the sites, for their assessments. While *in situ* the user had all the information about the site itself, she/he was familiar with it and was stimulated by all the other senses, in addition to the auditory and visual ones.

Considering this, it is possible to deduce that the differences found between the sound sources best perceived on sites 2, 3 and 7, may have been mostly influenced by the existing differences between both assessment environments. While the similarities found on sites 1, 4, 5, 6, 8, 9 and 10, seem to have been essentially influenced by the in common aspects existing on both assessment environments, therefore, mostly the auditory and visual stimuli.

Site 5, although it has been highlighted with distinct percentages on the sound sources best perceived, presented the same ranking order and the same best perceived sound source, which lead to deduce that the perceptions were much more similar than distinct when comparing results from the two assessment environments.

8.3. PERCEIVED SOUNDS AND SITES STIMULI

The comparisons and discussion presented in the previous subsection showed that the differences on the perceptions regarding the best perceived sound sources from both assessments, in the laboratory and *in situ*, seem to have been influenced by the different directly available information, especially in terms of context and stimuli, and, similarly, the similarities of the perceptions seem to have been influenced precisely by the aspects that both participants had in common, the auditory and visual stimuli.

Therefore, considering the similarities and, mainly, the differences found, it is important to explore the stimuli that users of the waterfront have, which are different from those existing on the laboratory environment, and may, some way, influence their perceptual process, essentially regarding the sound sources.

As evidenced in section 6.1, the sound environment of the Tejo waterfront is characterized by the presence of traffic noise, due to the high traffic on its avenues, streets, and bridge, as well as due to the existing bus terminal. Despite this, as it was already pointed out in subsection 7.1.4.1, the traffic noise was not the best perceived sound source category in all the waterfront sites, and the waterfront sound was the best perceived one on sites 2, 3, 7 and 10. These sites, except site 10, coincide with those highlighted on the discussion in section 8.2, which presented the most different sound sources perceptions between the assessments carried out *in situ* and in the laboratory.

Figure 8.7 and Figure 8.8 show the sound source categories best perceived at each site, where each symbol represents a sound source category, and the symbol different scales represent the proportion the sound source category was perceived on the sound environment compared to the others.

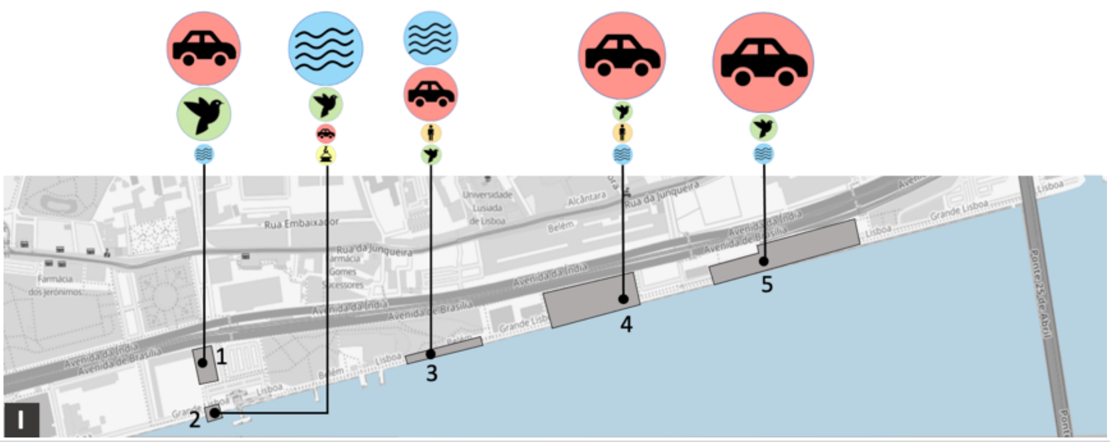


Figure 8.7: Tejo waterfront – Area I – sound source categories best perceived on each site - larger symbol imply higher perception of the category. Sources: ©OpenStreetMap contributors, author adapted.

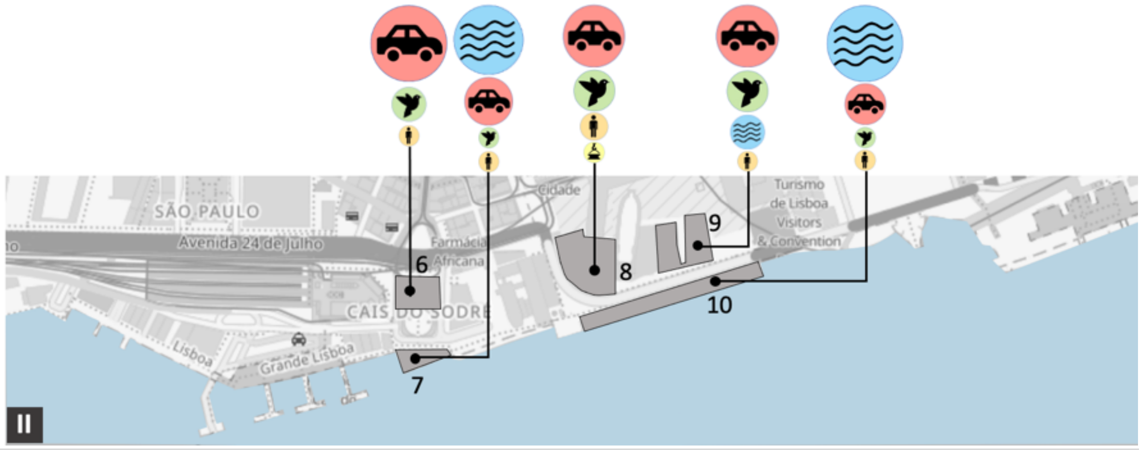


Figure 8.8: Tejo waterfront – Area II – sound source categories best perceived on each site - larger symbol imply higher perception of the category. Sources: ©OpenStreetMap contributors, author adapted.

The figures highlight that the sites in which the waterfront sound was more perceived are located exactly in front of the Tejo waterline, as pointed out in subsection 7.1.4.1. This may mean that, despite the predominance of the traffic noise throughout the Tejo waterfront, the proximity of these sites to the water may stimulate other senses of their users, not only the auditory ones, which influenced them to perceive mostly the sounds water related.

However, it can be noted that "waterfront sound" was not the sound source category best perceived on all the sites in front of the waterline, and, at sites 4 and 5, the “traffic noise” was best perceived.

From Figure 8.9 and Figure 8.10, where the maps and photographs of the waterfront sites are shown, it can be noted that unlike users of the other sites at the waterline, users of sites 4 and 5 usually remain in places that have some physical restriction to the water. These physical restrictions are marked in the maps and highlighted on the photos, by which It can be observe that unlike users of sites 2, 3, 7 and 10 that have a direct access to the water, users of sites 4 and 5 need to cross or a pedestrian walkway or a street to reach the water.

It seems that these physical elements between the user and the water, where allow the crossing of people, bicycles, scooters and even cars, influenced the sound source best perceived on sites 4 and 5. They somehow interrupt a closer relationship with the water, and makes people notice more the "traffic noise" that is the sound source category actually more present in the sound environment, and which also is very determinant to the high levels measured at both sites.

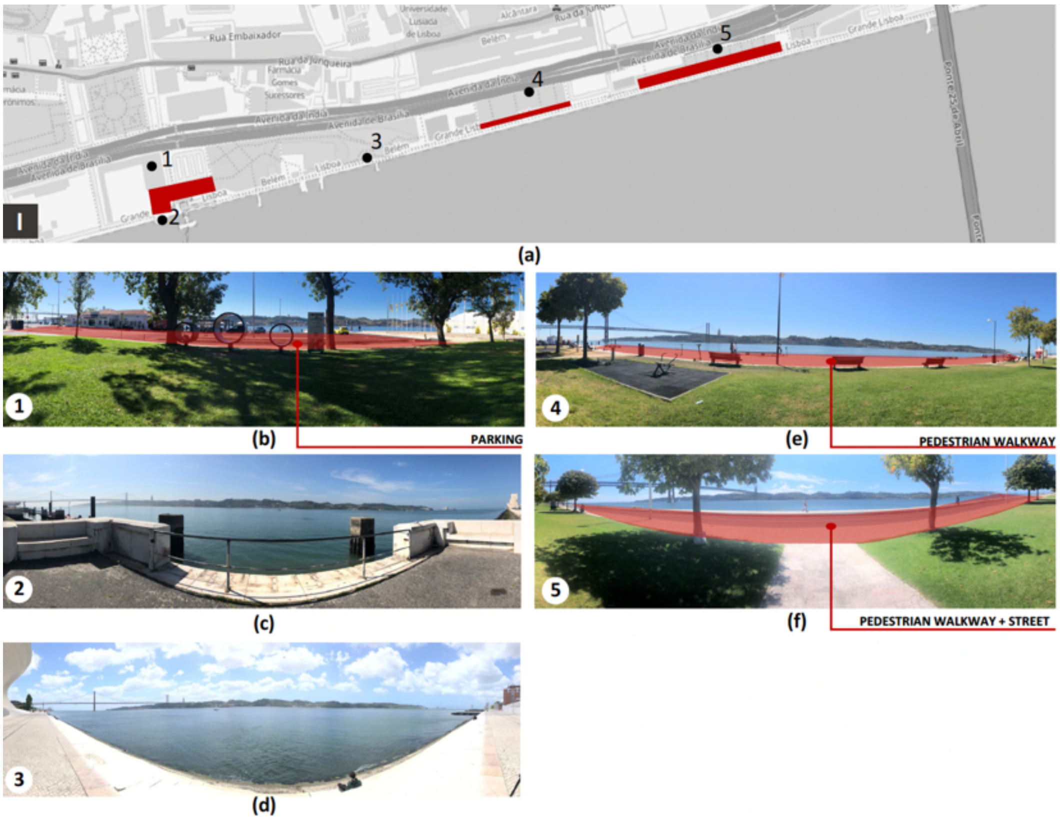


Figure 8.9: (a) Tejo waterfront – Area I – sites and barriers identification. Sources: ©OpenStreetMap contributors, author adapted; (b) Site 1: parking barrier; (c) Site 2: no barrier; (d) Site 3: no barrier; (e) Site 4: pedestrian walkway barrier; (g) Site 5 – pedestrian walkway and street barrier; by Nardi, 2020.

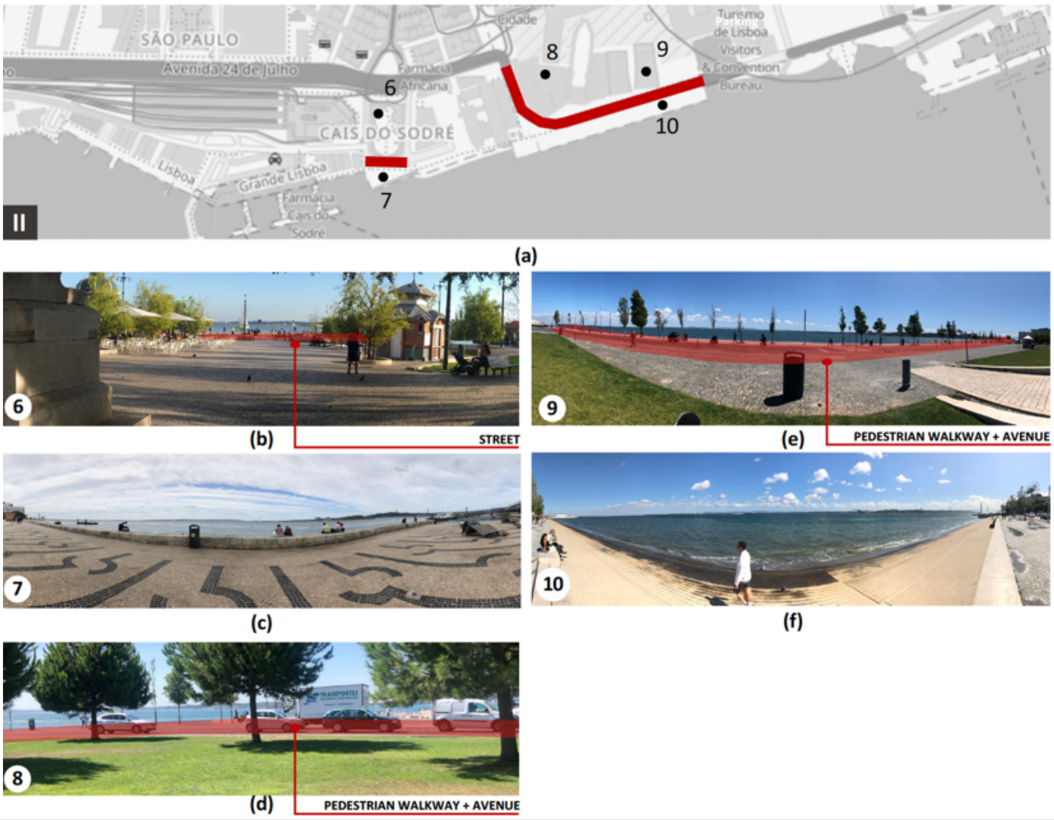


Figure 8.10: (a) Tejo waterfront – Area II – spaces and barriers identification. Sources: ©OpenStreetMap contributors, author adapted; (b) Site 6: street barrier; (c) Site 7: no barrier; (d) Site 8: pedestrian walkway and avenue barrier; (e) Site 9: pedestrian walkway and avenue barrier; (f) Site 10: no barrier; by Nardi, 2020.

On sites 1, 6, 8 and 9, these characteristics might be even more determinant to the traffic noise perception, since besides they are places further away from the water, they are also more restricted to it by physical barriers even more representatives, such as avenues and parking.

DISCUSSION

It seems that an association between the best perceived sound source categories and the relationship the users have with the water exists, as, despite the entire waterfront area being very characterized by the presence of the traffic noise, a closer contact with the water might have influenced a different perception, and the sounds that are more water-related were more perceived.

Contrary to this, any type of barrier between the user and the water seems to denote the perception of the traffic noise, which is usually the sound source category most prominent in the waterfront of the Tejo.

8.4. PERCEIVED SOUNDS VS. WATER RELATIONS

The analysis presented in section 8.3 showed that the “waterfront sound” was the sound source more perceived by the users who were on the places without any obstacles to reach the water. However, this evidence is not empirical in such a way that this association can be clearly stated.

Furthermore, one may observe that the waterfront sites of the Tejo River also have other relationships with the water in addition to the "physical restrictions to the water", which also need to be explored, given the different "distances from the water limits" and "restrictions of the water view".

In this sense, this section is structured around the establishment of statistical correlations, with cross-tabulations, followed by the Chi-Squared Independence Test and by Cramer's V Test, so as to obtain empirical evidence of possible associations between the sound source categories best perceived and the different relationships that waterfront users may have with the water itself.

Meanwhile, before proceeding with statistical correlations, it was necessary to convert both the sound source best perceived and the different relations of the users with the water in comparable data. Therefore, next (i) the weighting method used to establish the sound source category best perceived by the users of the sites, and (ii) the scores adopted that represent the different characteristics of the sites for each relation with the water, are presented.

(i) Weighting the better perceived sound source

On the better perceived sound source classification, the user could list more than once sound sources from the same category, since the free-text answer allowed it. For instance, in Table 8.21, the second interviewee listed "people chatting" as the first sound source best perceived, and "people passing" as the second sound source best perceived, which means twice the same "human sound" category.

Table 8.21: Sound sources perceived order established by free-text answer and. sound sources perceived order established by categories. Sound sources with the same category are highlighted in yellow colour.

Inquiry Interviewee	Sound Sources Perceived Order				Sound Sources Categories Perceived Order			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1	car	wind	people		traffic noise	natural sound	human sound	
2	trees	people chatting	water	people passing	natural sound	human sound	waterf. sound	human sound
3	cars	wind	people chatting		traffic noise	natural sound	human sound	
4	cars	trees	cicada		traffic noise	natural sound	natural sound	
5	trucks	birds	people	wind	traffic noise	natural sound	human sound	natural sound
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
642	cars	bus	water	trucks	traffic noise	traffic noise	waterf. sound	traffic noise

Hence, for classifications like this, it was regarded important to distinguish them by assigning different weights according to the established order, to preserve the recurrence attributed by the user.

Table 8.22: Recoding method to obtain the "sound source best perceived" for each inquiry answer.

*100% *80% *60% *40%

Inquiry Interviewee	Sound Sources Perceived Order				Recoded value for each sound source perceived					Percentual of each sound source perceived					Sound Source most perceived
	1st	2nd	3rd	4th	traffic noise	natural sound	human sound	waterf. sound	other sound	traffic noise	natural sound	human sound	waterf. sound	other sound	
1	traffic noise	natural sound	human sound		1	0,8	0,6			42%	33%	25%	0%	0%	traffic noise
2	natural sound	human sound	waterf. sound	human sound		1	0,8 + 0,4	0,6		0%	36%	43%	21%	0%	human sound
3	traffic noise	natural sound	human sound		1	0,8	0,6			42%	33%	25%	0%	0%	traffic noise
4	traffic noise	natural sound	natural sound		1	0,8 + 0,6				42%	58%	0%	0%	0%	natural sound
5	traffic noise	natural sound	human sound	natural sound	1	0,8 + 0,4	0,6			36%	43%	21%	0%	0%	natural sound
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
642	traffic noise	traffic noise	waterf. sound	traffic noise	1 + 0,8 + 0,4			0,6		79%	0%	0%	21%	0%	traffic noise
	(i)									(ii)					(iii)

Table 8.22 exemplifies the method adopted to define the sound source best perceived, where firstly (i) each perceived sound source category was multiplied by a different weight, according to the order established by the respondent, thus, the highest score, 100%, was assigned to the best perceived sound source, followed by 80%, 60% and 40%, respectively, to the second, third and fourth ones. Next (ii), a percentage was calculated using the weight, or the sum of them, attributed for each sound source category, and, lastly (iii) the category which presented the higher percentage was considered the "sound source best perceived".

(ii) Water relation scores

In order to establish further correlations, the distinct physical restrictions, distances, and views to the water on each waterfront site, needed to receive a score.

Hence, to the distinct "physical restrictions to the water limits", a lower score (1) was assigned to the places with the higher level of restriction, such as the sites 1, 6, 8 and 9, which have large physical barriers to the water access, as parking lots or hight traffic streets, and, consequently, the higher score (4) was assigned to those places with the lower level of restriction, such as the sites 2, 3, 7 and 10, that face the water, without any physical barrier, as shown in Table 8.23.

Table 8.23: Score adopted for the water physical restriction of the public spaces.

Water Physical Restriction	Score Adopted
waterfront restricted by a large barrier (parking, hight traffic street..)	1
waterfront restricted by a small barrier (sidewalk, low traffic street..)	2
waterfront limited restrict on some areas	3
waterfront without restriction	4

For the different "distances from the water limits", the lower score (1) was assigned to the sites furthest to the water limits, site 6, where the users are usually more than 100 meters away from the water edge, and, consequently, the higher score (4) to the places really in front of the water, such as sites 2, 3, 7 and 10, as shown in Table 8.24. The distances measured were considered from the places where the users usually stay at the sites up to the water edge.

Table 8.24: Score adopted for the water edge proximity of the public spaces

Water Proximity	Score Adopted
more than 100 meter	1
between 50 - 100 meters	2
less than 50 meters	3
in front of	4

Lastly, to represent the distinct "restrictions of the water view", the lower score (1) was assigned to the sites with very restricted visibility of the water on the whole area, sites 1 and 6, and, consequently, the higher score (4) to the places with unrestrained view of the water from everywhere, sites 2, 3, 5, 7, 9 and 10, as shown in Table 8.25.

Table 8.25: Score adopted for the water view restriction of the public spaces

Water View	Score Adopted
very restricted view on all the area	1
limited view on all the area	2
limited view on some places	3
irrestricted view on all the area	4

Hence, considering the established relations that the waterfront sites have with the water and the scores set out for each one of them, it was attributed values to every researched site which are presented in Table 8.26.

Table 8.26: Values adopted for the "water relations" of each Tejo's waterfront public spaces.

	1	2	3	4	5	6	7	8	9	10
Water Proximity	2	4	4	3	3	1	4	2	2	4
Physical restriction	1	4	4	3	3	1	4	1	1	4
Water View	1	4	4	3	4	1	4	2	4	4

From the table, it can be noted that site 6 presents the worst relations with the water, with the lower score on all criteria, while sites 2, 3, 7 and 10, have the better water relations, with the higher score.

8.4.1. Statistical Analysis

From the assignment of weights and scores, one cross-tabulation was carried out for each water relation, which shows the best perceived sound sources, according to the different characteristics previously established, for the physical restrictions, the distances, and the views to the water.

(i) Water Physical Restriction

The cross tabulation established for the different physical restriction to the water of the sites, presented in Figure 8.11, shows that the "waterfront sound" category was better perceived on places where people had no water access restrictions, whereas the other sound sources categories were better perceived where people had some physical restriction to the water.

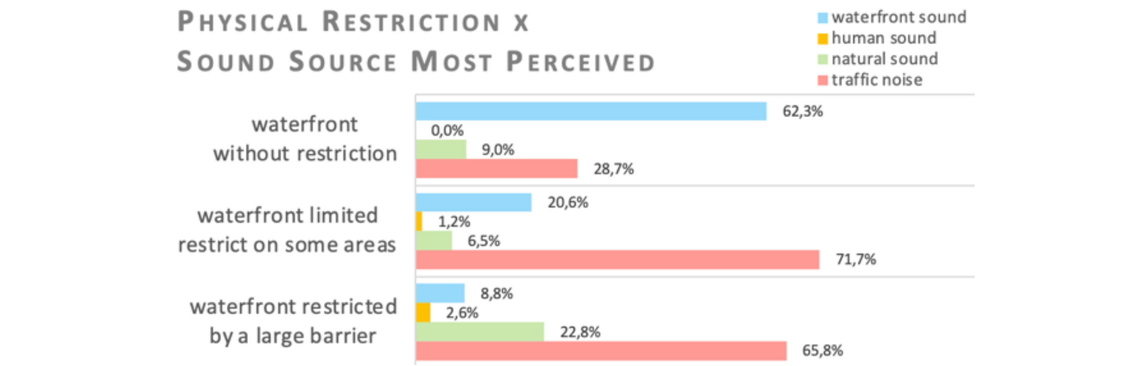


Figure 8.11: Co-relation between the public spaces' physical restriction and the sound source best perceived.

The "traffic noise" stands out as the best perceived category by 65,8% of users who were on places with large barriers to the water, and by 71,7% of users who were on places with some barriers to the water, while it was the best perceived by only 28,7% of users who were on places without restrictions to the water.

On the contrary, the "waterfront sound" category was the best perceived sound source by 8,8% of users who were on places with large barriers to the water, and by 20,6% of users who were on places with some barriers to the water, while it was the best perceived by 62,3% of users who were on places without restrictions to the water. Therefore, the less physical restriction to the water edge, the better the "waterfront sound" is perceived.

(ii) Water Edge Proximity

Figure 8.12 shows the cross-tabulation for the different distances between the sites and the water edge, in which the "waterfront sound" category was more perceived by people located in front of the water edge, while the other sound sources categories were more perceived by people further away from the water limits.

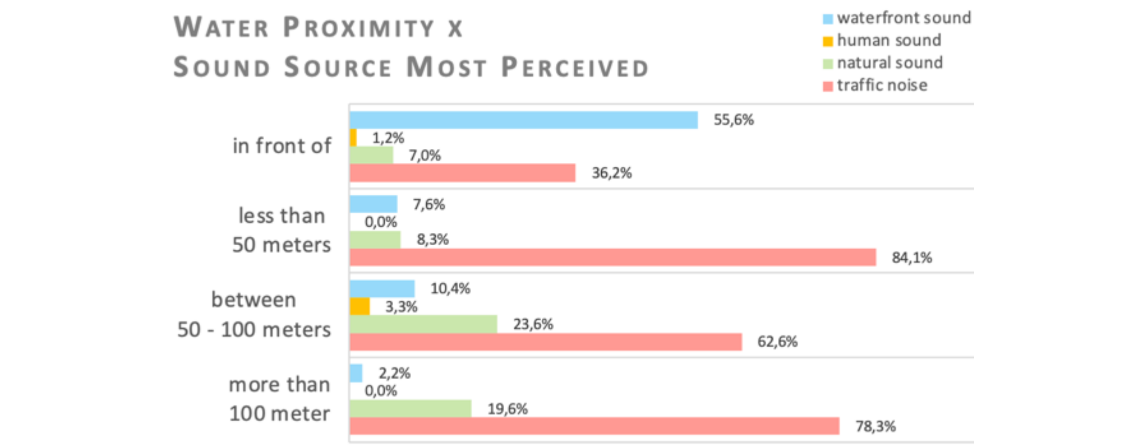


Figure 8.12: Co-relation between the public spaces' water edge proximity and the sound source best perceived.

The "traffic noise" was the best perceived category by more than 60% of people located at any place further from the water edge, in contrast to only 36,2% of people who were in front of the water.

Contrary to the "waterfront sound", that it was the best perceived category by less than 11% of people located at any place further from the water edge, while the best perceived by more than 55% of people who were in front of the water.

(iii) Water View Restriction

Lastly, the cross-tabulation for the water view restriction, presented in Figure 8.13, shows that the "waterfront sound" category was more perceived by people with unrestricted view to the water, while the other sound sources categories were almost equally perceived on the different water visibility possibilities.

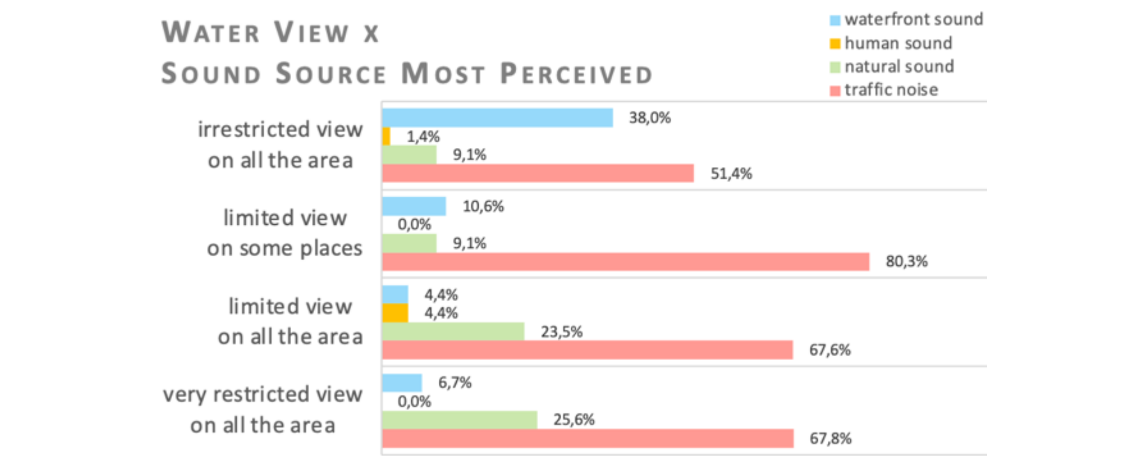


Figure 8.13: Co-relation between the public spaces' water view restriction and the sound source best perceived.

The "traffic noise" was the best perceived sound source category by most people, regardless of the "restriction of view of the water".

Even so, it is worth noting that despite "traffic noise" being the best perceived sound source by 51.4% of the users with an unrestricted view of the water, the "waterfront sound" was also considerably perceived, by 38% of the users.

(iv) Chi-Squared Independence Test

Besides the cross tabulations, a Chi-Squared Independence Test was carried out to test the association between the three different water relations and the sound source best perceived by the users of the waterfront, which it was followed by a Cramer’s V test applied to measure the strength of the association.

The results of the Chi-Squared Independence Test, shown in Table 8.27, revealed a significant association between the variables.

Table 8.27: Association sound source best perceived with the public spaces water relations - Chi-Squared Independence Test.

	Sound Source Most Perceived	
	Pearson χ^2	
	Value	p-value
Water Physical Restriction	174,42	< 0,001
Water Edge Proximity	205,61	< 0,001
Water View Restriction	91,91	< 0,001

The hypothesis of independence between the factors considered is rejected, that is, there is a statistically significant association between the “sound source best perceived” and the “physical restriction to the water” (χ^2 Pearson = 174.42, $p < 0.001$), the “distance between the sites and the water edge” (χ^2 Pearson = 205.61, $p < 0.001$), and “water view restriction” (χ^2 Pearson = 91.91, $p < 0.001$).

Considering this results, a Cramer’s V test was performed to determine the strength of this association, and the results are shown in Table 8.28.

Table 8.28: Association sound source best perceived with the public spaces water relations - Cramer’s V test.

	Sound Source Most Perceived
	Cramer
Water Physical Restriction	0,369
Water Edge Proximity	0,327
Water View Restriction	0,218

The degrees of associations measured by Cramer's V contingency coefficient have been relatively low for every water relation. However, they can be considered statistically significant, i.e., different from zero.

It is possible to note that the association of the best perceived sound source category with the criterion “physical restriction to water” is the stronger ones, when compared with the other criteria defined for the correlation ($\phi = 0.369$), while the association with the criterion “water view restriction” is the weaker ones ($\phi = 0.218$).

DISCUSSION

Through the established correlations, it is possible to understand that not only the physical restrictions between the user and the water, already discussed in section 8.3, but also the distances between the user and the water, and the restrictions of water view, are associated with the sound sources best perceived by users.

Therefore, from the results, it was possible to state that:

- The "waterfront sound" category was always better perceived by users who were closer to the water edge, without physical restrictions in the access and with unrestricted view;
- Most of the sound source categories, except the "waterfront sound", and especially the "traffic noise", were better perceived by people who were farther away from the water edge, with some physical restriction to it and with some restricted view;
- the 'water view restrictions' had the weaker association to the 'best perceived sound sources’ compared to the other relationships the waterfront users may have with the water, namely, the 'physical restrictions to the water limits' and the 'distances from the water limits'.

9. SOUNDSCAPE URBAN ANALYSIS AND PLANNING

The previous chapter 8 focused on the correlations between all the collected data aiming to identify potential relationships with the sound environment evaluations that can serve the urban designer in the soundscape design process for a waterfront urban area.

Firstly, this chapter presents objective criteria based on the significant associations obtained on the case-study which can support the urban planner on the soundscape analysis of a waterfront area.

Secondly, based on such criteria, good practices to be followed by the urban planner and designer in the soundscape analysis process are described, in order to collect data and process it uniformly, and thus to obtain consistent and comparable results.

Finally, a general guideline structured for the soundscape design of a waterfront public space is presented.

Above all, the criteria, the good practices and the general guideline, herein presented, aim to be simple and objective for the urban and design planner, in order to design waterfront public spaces where the soundscape can be a high-quality perceptive component, appropriate to the place and the activities performed by their users and attractive, so that more people visit these spaces and remain in them.

9.1. OBJECTIVE CRITERIA FOR SOUNDSCAPE ANALYSIS

In this section, the objective criteria considered most appropriate to proceed with a soundscape analysis of an urban waterfront area are presented, focussing on essential aspects.

The criteria were established based on the significant correlations found with the sound environment evaluations, on the Tejo River waterfront case-study.

An analysis by using the established criteria allows the urban planner to understand its sound environment, as it is perceived by their users, and to know how it is associated with the public space characteristics, its acoustic characteristics, and the practices of its users.

- *pleasantness and eventfulness of the sound environment*

The results of the statistical correlations (section 8.1) between the assessments and perceptions of the sound environment of the Tejo waterfront, namely, the 'overall assessment', the 'appropriateness', the 'pleasantness' and the 'eventfulness' showed that they are all associated with each other. Therefore, from one of these sound environment evaluations criteria, the other ones be defined.

Considering this, and due to the strong correlation, that the 'pleasantness' and the 'eventfulness' of the sound environment have with the evaluation of the public spaces themselves, as shown in subsection 8.1.4, both these basic components of the soundscape perception were regarded the more appropriate ones to be considered the objective criteria which will directly assess the sound environment on a soundscape analysis of a waterfront area.

- *best perceived sound sources*

The results of the correlations in section 8.1 showed that the best appreciated soundscapes, which presented high-quality, more appropriate, more pleasant, and less eventful sound environments, are associated with the prevalence of the “waterfront sounds” perception. While, on the contrary, the low-quality, less appropriate, less pleasant, and more eventful sound environments, are associated with the prevalence of the “traffic noise” perception.

Hence, the associations proved that the sound sources best perceived, namely the waterfront sounds and the traffic noise, are determinant to the quality of the sound environments, and therefore, they should be considered as other objective criterion for a soundscape analysis of a waterfront area.

- *user practices: lengths of visit and activities*

The results of the statistical correlations in subsection 8.1.2, showed some important associations between the waterfront soundscape evaluation and the users who remain longer in the sites. People who stay more than 2 hours at waterfront sites use to perceive more the traffic noise, less the waterfront sound, and evaluated the quality of the sound environment worse compared to other ones who remain less time in the place.

Therefore, since the length users remain in waterfronts contributes to the understanding of soundscape evaluations, it was regarded another important criterion for the soundscape analysis.

- *acoustic parameters of the sound environment*

The mean value of the measured continuous equivalent sound pressure level (L_{Aeq}) is also other important criterion for soundscape analysis, since the knowledge of the existing sound levels associated with other perception or evaluation of the sound environment, such as the sound source best perceived, for instance, contribute to understand the soundscape, as showed in subsection 8.1.1.

- *public space relationship with the water*

The results of the statistical correlations in section 8.4, showed important associations between the sound sources best perceived and the three different relationships between the waterfront public spaces and the water, which were studied. Particularly, the prevalence of the perception of the waterfront sounds and of the traffic noise proved associated with the physical restrictions between the public spaces and the water, the distances between them, and the restrictions of the water view.

Therefore, since different relationships between the waterfront public spaces and the water, can influence the sound sources best perceived, which, in turn, are determinant to the quality of the sound environments, they should be considered as objective criteria for a soundscape analysis of a waterfront area.

9.2. GOOD PRACTICES FOR SOUNDSCAPE ANALYSIS

Considering the importance of a well-performed analysis of the soundscape to directing its planning and design, in a way to better preserve, improve, or design it, it is essential to collect all the necessary information in an organized and harmonized way and, also, process it appropriately.

To this end, urban designers must consider the soundscape ISO standard method recommendations and the good practices, that add particularities that are specific to the soundscape analysis of waterfront areas.

Therefore, in this section, good practice topics for the soundscape analysis are presented, which comprise information regarding how all the necessary data should be collected and processed, to obtain consistent and comparable results, considering the analysis carried out in the case study of this research and the relevant aspects observed during this process, and the objective criteria presented in item 9.1.

9.2.1. Data collection

The data collection encompasses the application of a questionnaire and a non-participatory observation, that preliminarily should be planned regarding when, how often and where it must occur.

- *when and how often*

Before defining how much and how often data should be collected, a preliminary assessment at the site to be evaluated should be carried out, in order to observe the different uses, users, behaviour, activities and rhythms that may occur in distinct hours of the day and on different days of the week.

It is important that all possible seasonality regarding variations should be encompassed on data collection, what may also include data from different months, depends on the weather variations that may exist at the place throughout the year.

- *where*

Data collection must be conducted in situ, on the waterfront public space itself, since soundscape studies should be primarily conducted as field studies (ISO 12913-2, 2017).

Considering a large area to the data collection, it is recommended to split it in distinct places, considering the differences observed preliminarily regarding their characteristics, users, uses and functions that can give rise to different soundscape.

(i) Data collection: questionnaire application

The evaluation of a waterfront soundscape should be obtained through the application of a questionnaire, where people can expose their perceptions regarding the public space.

The Annex E shows an example of a questionnaire which was structured and can be applied to collect all information needed, which encompasses some of the objective criteria presented on item 9.1, namely, the 'pleasantness' and the 'eventfulness' of the sound environment, the sound sources categories best perceived and the users' practices regarding the space.

Before applying the questionnaire, it is important to note some relevant issues regarding the application itself and to whom they should be directed.

- *questionnaire application*

Questionnaires must be personally handed to be answered preferably autonomously with a minimum of interferences.

- *to whom: participants*

Considering a public space already designed, the questionnaire should be applied to its users, who must be randomly selected, regardless of their socio-demographical profile and the activities they are performing in.

However, since the questions are related to auditory perceptions, it is important the sensibility, when approaching people to hand the questionnaire, to note those ones with hearing issues or disabilities since they are not appropriate to answer the inquiry.

In turn, regarding an urban space to be designed, without use, the in situ assessment shall be carried out through soundwalks, following the recommendations of the method presented at the Annex C of the ISO 12913-2 (2017) standard.

According to the recommendations of that standard, a group of participants, composed of local specialists and members of the community of interest, conducted by a moderator, should carry out listening walks through the waterfront area. Subsequently to the soundwalk, each participant should answer the same questionnaire proposed in the Annex E, to expose their evaluation regarding the soundscape of the area, similarly to a user of the public space.

(ii) Data collection: non-participatory *in situ* survey

The observations aim essentially to collect data regarding the other objective criteria for the soundscape analysis, which were set out in item 9.1, besides those included in the questionnaire. Therefore, the acoustic parameters of the waterfront public space sound environment should be collected, and the relationships people have with the water should be observed.

In Annex F, two tables are presented which were structured to organize and record all the necessary information to be collected, before, during and after the observations.

- *acoustic parameters of the sound environment*

The sound level measurements shall be carried out at the same moment when the questionnaires are applied, always at the same place, which should be as close as possible to where most of users usually remain.

Measurements must be carried out by a sound pressure level meter and it must be conducted according to the procedures described by the standards ISO 1996-1 and ISO 1996-2.

Before starting the measurements, aided by the table shown in Annex F, the place and the date should be registered. During the measurement, unexpected sound events that might occur should be observed and recorded. And, after the measurement, the sound sources noted most prominent during the measurement should be recorded together with the L_{Aeq} index obtained and the file name in which the measurement result was recorded within the sound level meter, although they have already been recorded and registered, it is a good practice to note them for safety, in case of any accident of data loss.

- *public space relationship with the water*

The public space visit to the data collection should be complemented with the annotation of the relationships the public space has with the water, namely, the physical restrictions between them, the distances between them, and the restrictions of the water view.

Considering that the waterfront public space, its surroundings and its location can provide to their users, since from a full contact with the water down to a very restrict contact, it is important that these different characteristics are recorded.

In this sense, for every relationship with the water, four distinct characteristics were established as shown in table in Annex F, that should be noted and marked according to the waterfront public space specific features.

To measure the "distance between the public space and the water", it should be considered the measurement from the place where most of users usually remain until the edge of the water.

Simultaneously with the observations, it is also important to photograph the public space to record its general physical characteristics and mainly its relationships with the water.

9.2.2. Data processing

To proceed with the necessary analyses, some data collected must be processed adequately to be latter used on the comparisons or statistical analysis as necessary. Specifically, it should appropriately determine the eventfulness and pleasantness of the sound environment and adequately weight the sound sources categories best perceived.

- *pleasantness and eventfulness of the sound environment*

These two soundscape dimensions should be determined based on perceived affective quality responses, according to the recommendations of the Annex A of the ISO 12913-3 (2019), described in subitem 3.4.1.

The method consists of calculating the mean values for each soundscape attribute which were qualified through the questionnaires, to then calculate the pleasantness and the eventfulness dimensions from equations (1) and (2), from the obtained averages.

- *best perceived sound sources*

The sound source categories best perceived should be weighted based on the same criterion established for the case-study of this research, detailed in subsection 5.4.1.2.

The method consists of attributing different scores according to the perception order obtained, setting out more importance to the sound sources perceived best. Therefore, to the first best perceived sound source the highest score (100%) should be assigned to the second and third best perceived the medium scores (80% and 60%) are assigned, and the fourth has the lowest score (40%).

From the weighting, it is possible to obtain the percentages contribution of each sound source category, according to the users' perceptions.

9.3. PRACTICAL GUIDELINES FOR SOUNDSCAPE DESIGN

In this section, practical guidelines for soundscape design of a waterfront public space are presented, which were structured considering the objective criteria established in item 9.1.

The guidelines introduce a general guidance and describe some important design criteria that should be considered so as to achieve high-quality sound environment.

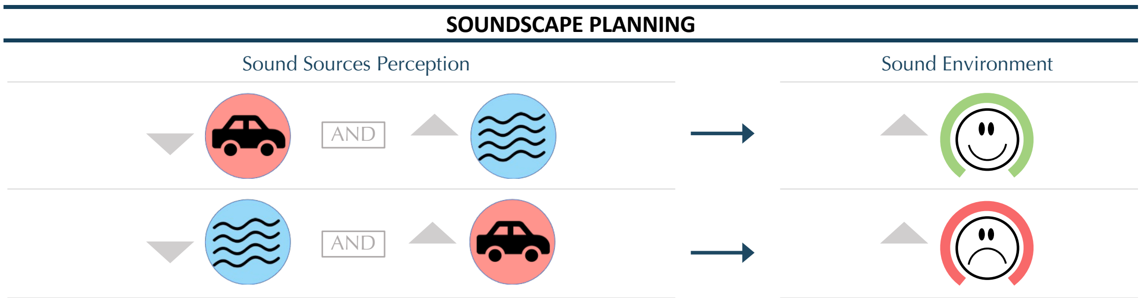
Subsequently, aiming at illustrating how the guidelines proposed could be applied to improve waterfront soundscapes, the main results of the soundscape analysis carried out for the case study of this research are restated and action plans are presented, particularly to those soundscapes which were not so well qualified by the users of the Tejo River waterfront.

(i) General guidance

A successful design of the soundscape of a waterfront area should be sustained by the planning of the sound sources that will better perceived by their users, due to the significant association found between the sound sources best perceived, namely the waterfront sound and the traffic noise, and the evaluations of the sound environment, as summarized in Table 9.1.

One can understand the importance of adopting design criteria which contribute to people perceiving more the "waterfront sounds" and less the "traffic noise", to obtain high-quality, appropriate and pleasant sound environments, as summarized on the first row of the table. Otherwise, if the users perceive more the “traffic noise” and less the “waterfront sound”, the sound environments will likely to be considered low-quality, as shown on the second row.

Table 9.1: Association between sound source best perceived and sound environment evaluation.



(ii) Criteria for soundscape design

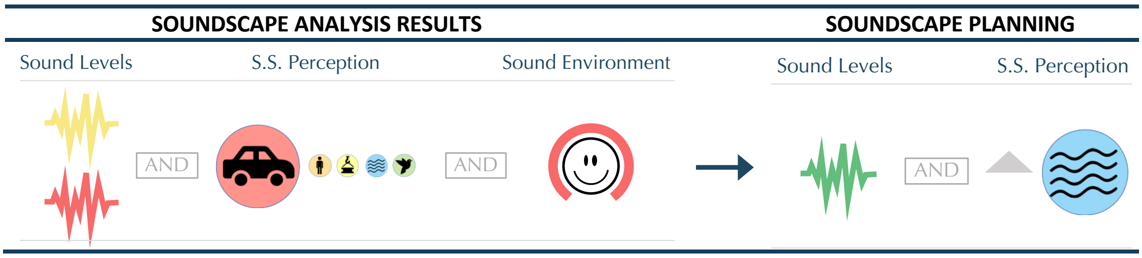
- *to reduce the sound levels*

To design the soundscape of a waterfront area, considering certain soundscape analysis results it will be necessary, firstly, to reduce the sound levels if found to be excessive.

Table 9.2 shows, on the left column, a possible result of a soundscape analysis in which the sound levels are too high, the traffic noise is the sound source best perceived compared to the other ones and sound environment is of low-quality.

From this scenario, an appropriate soundscape planning should necessarily encompass the reduction on the existing sound levels associated to strategies that can rise the "waterfront sound" perception, as represented on the right column from the table.

Table 9.2: Soundscape analysis result which require a soundscape planning with a preliminarily sound level reduction.



- *to define the people relationship with the water*

The importance of favour the perception of “waterfront sounds” to obtain high-quality sound environments, lead to the understanding that the soundscape design of a waterfront area can be carried out by the planning of the relationships that the users of the space will have with the water.

Table 9.3 summarizes the three different relationships the waterfront areas may have with the water which were approached in this research, that should be considered by the urban designer.

From the table, it is possible to understand that strengthening the relationship between user and water is an important design criterion in planning the waterfront public soundscape, since as the closer to the water, the fewer physical restrictions to the water limits and the fewer restrictions of the water view, the more the “waterfront sounds” are perceived. On the contrary, the farther away from the water, the more physical restrictions on the water boundaries and the more restrictions on the view of the water, the more the “traffic noise” is perceived.

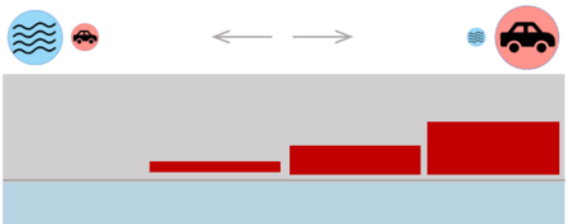
Table 9.3: Association between sound sources best perceived and the three different relation established between the water and user on a waterfront urban area: (a) Water Edge Proximity; (b) Water Physical Restriction; (c) Water View Restriction.

SOUNDSCAPE PLANNING

(a) Water Edge Proximity

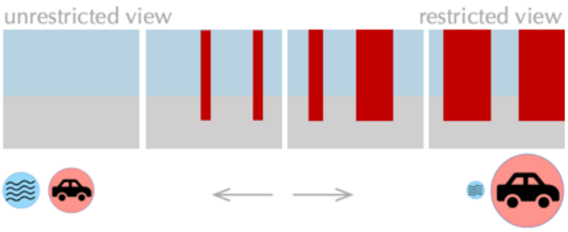
Furthest water limit	→	Traffic Noise
In front water limit	→	Waterfront Sound

(b) Water Physical Restriction



No Barrier	→	Waterfront Sound
Restriction / Barrier	→	Traffic Noise

(c) Water View Restriction



Unrestricted View	→	Traffic Noise Waterfront Sound
Restricted View	→	Traffic Noise

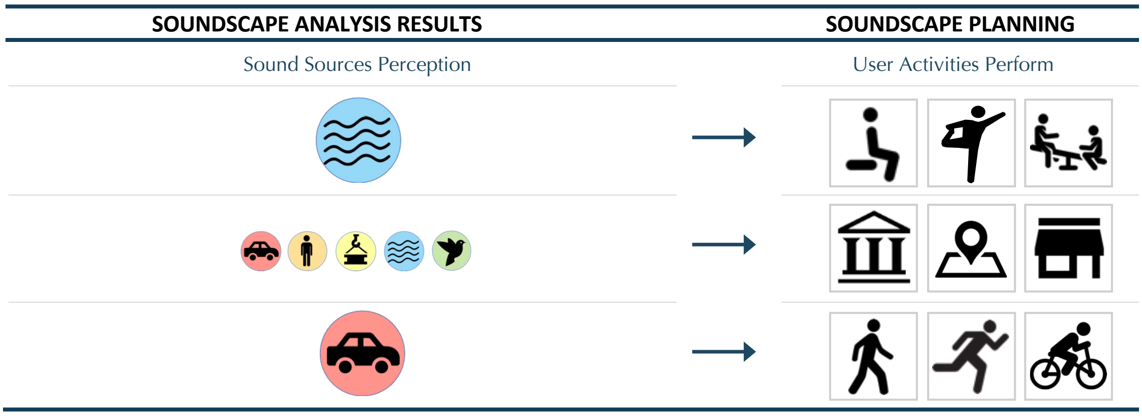
- *to define the uses of the places*

The designing of a waterfront area soundscape can be also carried out by the planning of the uses of the places according to the sound sources best perceived.

The information regarding the sound sources best perceived at a waterfront area serve to plan its spatial organization, since for certain activities, uses or functions that are planned for a place it is important that people perceive more certain sound sources to obtain a high-quality soundscape.

Table 9.4 exemplify three different results of a soundscape analysis regarding the best perceived sound sources, where the uses that ideally should be planned according to these scenarios are shown, considering the associations described in subitem 8.1.2, in which users who stay longer at waterfront areas usually appreciate less their sound environment, the "waterfront sound" is more perceived by users who remain less time in the site, and the "traffic noise" is more perceived by users who spend longer at the site.

Table 9.4: Soundscape analysis results and soundscape planning according to the places uses or functions.



Therefore, to design the soundscape of a waterfront area, the urban designer should give special attention to the places where the "waterfront sounds" had been more perceived than the other ones, where it should be planned for certain uses in which people use to remain longer at the local, i.e., to uses that people remain sitting or standing, to some sports practicing or to equipment use (as playground, gym equipment).

For the places where the "other sound sources" had been more perceived should be planned for activities in which the users will remain less time, such as visiting a tourist spot or a commercial establishment at the place or surrounding.

Lastly, the places where the "traffic noise" had been more perceived than the other ones should serve essentially people transit, where they will just be passing through the local, whether walking or practicing some sport.

9.3.1. Discussion and application

It is understood that it is complex for the urban planner to coordinate the delimitation of spaces, distribution of functions, equipment, activities and uses, so that to achieve high-quality sound environment in all places of a waterfront area, especially considering that it is within an urban context, with a very characteristic sound environment. Nor does it mean that if all the criteria set out are followed, the soundscape will be well appreciated by all the people who will use the waterfront area, since it is a subjective aspect related to the perception of each person, who can be influenced by many other aspects.

Therefore, it is important for the urban designer to establish priorities, in the sense of establishing the most strategic or sensitive or important places in the urban waterfront area which will demand greater efforts for the soundscape designing.

Notwithstanding, based on the results obtained in the analysis of the soundscape of the Tejo River waterfront area, in which the soundscapes of some public spaces were found less qualified than others, it is illustrated how the criteria for designing the soundscape, herein stated, could be used to improve the quality of these sound environments.

(i) Case-study analysis results

Figure 9.1 and Figure 9.2 show the maps of the Tejo River waterfront, where the main results of the soundscape analysis obtained in the case study of this research are shown.

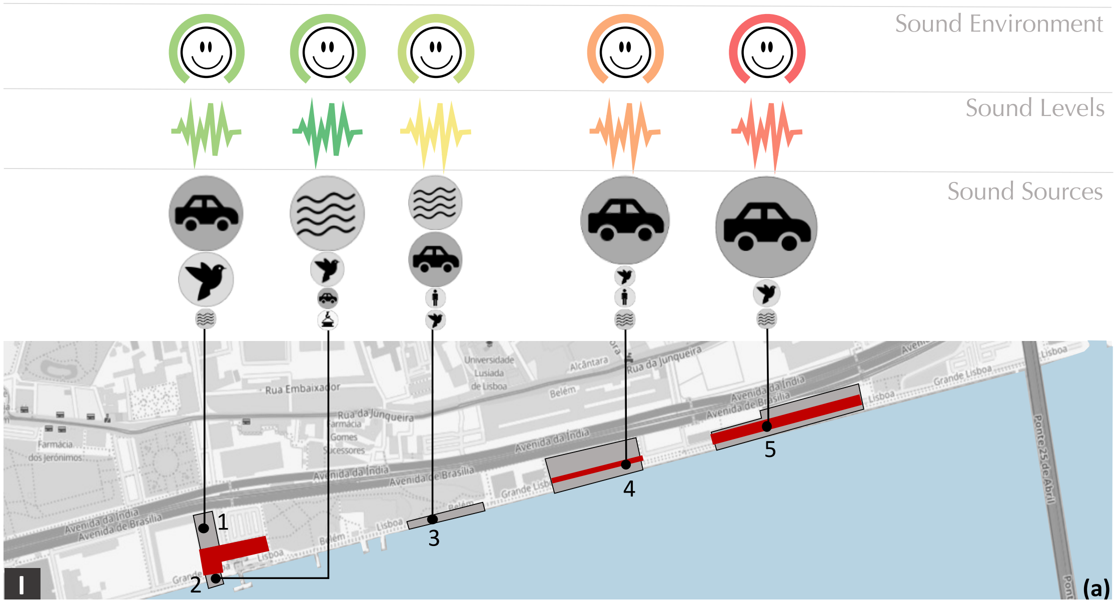


Figure 9.1: Tejo waterfront soundscape analysis results –Area I – sound environment evaluation (red colour imply better evaluation, red colour imply worst evaluation), sound levels measured (red colour imply maximum sound levels, red colour imply minimum sound levels) and sound source categories best perceived on each site (larger symbol imply higher perception of the category). Source: ©OpenStreetMap contributors, author adapted.

The soundscape analysis is shown through a visual representation with symbols and a colour scale that can be pointed out as an example to be adopted to communicate and compare the results obtained. The colour scale differentiates the higher-quality sound environments (green colour) from the lower-quality ones (red colour), and the lower sound levels (green colour) from the higher ones (red colour). While the symbols with different proportions help to differentiate the most predominant sound sources (larger symbols, proportional to the percentage obtained) from the least predominant (smaller symbols, proportional to the percentage).

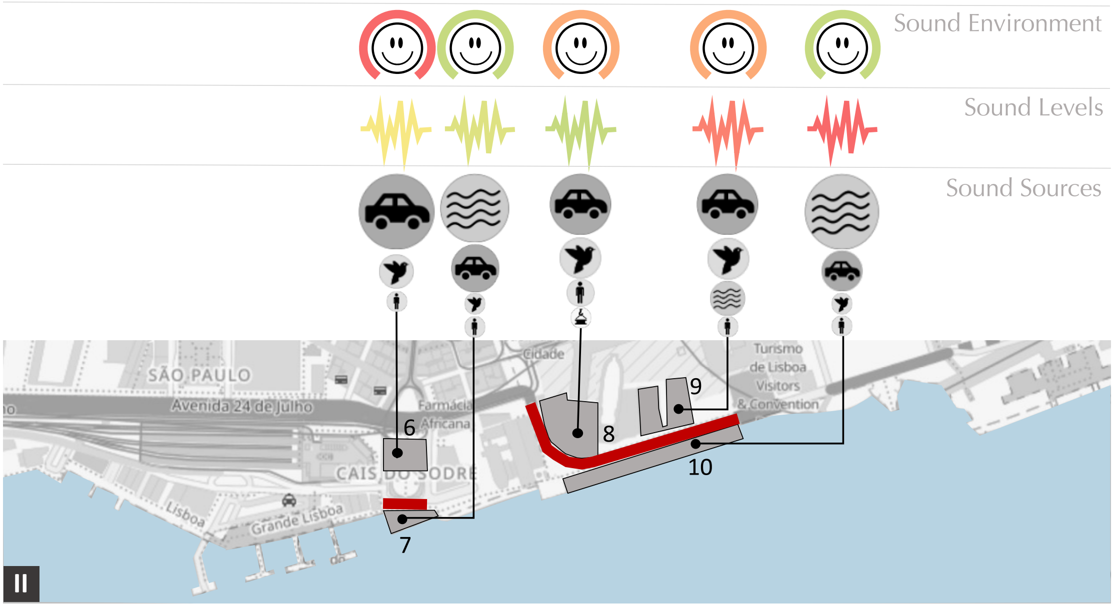


Figure 9.2: Tejo waterfront soundscape analysis results – Area II – sound environment evaluation (red colour imply better evaluation, red colour imply worst evaluation), sound levels measured (red colour imply maximum sound levels, red colour imply minimum sound levels) and sound source categories best perceived on each site (larger symbol imply higher perception of the category). Source: ©OpenStreetMap contributors, author adapted.

Therefore, with the results shown, it is possible to state that the sound environment of the sites 4, 5, 6, 8 and 9, are less qualified compared to the other ones, as it already been pointed out along this research.

(ii) Guidelines application

Considering these sites of the Tejo waterfront, which had presented the less qualified sound environments, some action plans were proposed considering the practical guidelines presented, so as to illustrate how the general guidance and the design criteria can be used on the soundscape designing to improve their quality.

For the sites 4, 5, 6, 8 and 9, tables were structured - Table 9.5, Table 9.6, Table 9.7, Table 9.8 and Table 9.9 - where, on the left column, the analysis results of their soundscapes are shown together with other collected data, including: the users' relationships with the water, the activities they perform on the site and their length of visit at the site.

Table 9.5: Analysis results and some strategies for the soundscape planning of site 4 of the Tejo River waterfront.

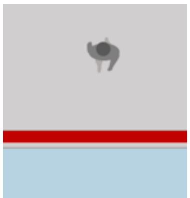
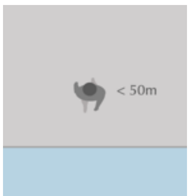
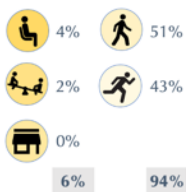
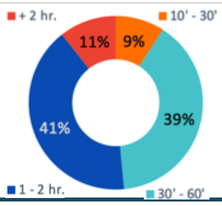
Site 4	ANALYSIS	PLANNING	
sound environment evaluation		reduction of sound levels	▪ from traffic Av. de Brasília Avenue: construction of noise barriers to the site; ▪ from traffic on 25 de abril Bridge: difficult to reduce through simple measures.
		alternative	▪ add “waterfront sound”, by hidden loudspeakers, to mask traffic noise from the bridge.
physical restriction		decrease, relocate remove	▪ crosswalk - unfeasible: well-defined function of interconnecting areas, intense use for walking and physical activities and reduced space to be relocated.
water proximity		-----------	-----------
water view		-----------	-----------
users’ activities		-----------	-----------
length of visit			

Table 9.6: Analysis results and some strategies for the soundscape planning of site 5 of the Tejo River waterfront.

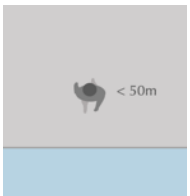
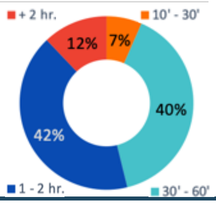
Site 5			
	ANALYSIS	**PLANNING**	
sound environment evaluation		reduction of sound levels	▪ from traffic Av. de Brasília Avenue: construction of noise barriers to the site ▪ from traffic on 25 de abril Bridge: difficult to reduce through simple measures
		alternative	▪ add water sound, by hidden loudspeakers, to mask traffic noise
physical restriction		decrease, relocate remove	▪ crosswalk - unfeasible: well-defined function of interconnecting areas, intense use for walking and physical activities and reduced space to be relocated. ▪ street – relocate/removed: since it doesn't have nor well-defined function and nor well-defined use, and don't have to be exactly on the place it is.
water proximity		-----------	-----------
water view		-----------	-----------
users' activities		decrease people length of visit	▪ provide an alternative use to the area
length of visit			

Table 9.7: Analysis results and some strategies for the soundscape planning of site 6 of the Tejo River waterfront.

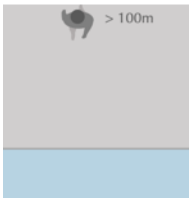
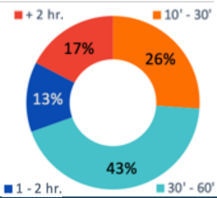
<table>
<tr><th colspan="4">Site 6</th></tr>
<tr><th colspan="2">ANALYSIS</th><th colspan="2">PLANNING</th></tr>
<tr><td>sound environment evaluation</td><td>
</td><td>reduction of sound levels</td><td>▪ from traffic Av. 24 de julho Avenue: construction of noise barriers to the site</td></tr>
<tr><td>ysical restriction</td><td></td><td>decrease, relocate remove</td><td>▪ bus station – relocate it.</td></tr>
<tr><td>water proximity</td><td>
</td><td>relocate benches</td><td>▪ the existing benches can be relocated for a place closer water, furthest from the avenue</td></tr>
<tr><td>water view</td><td></td><td>-----------</td><td>-----------</td></tr>
<tr><td>users' activities</td><td>
</td><td rowspan="2">-----------</td><td rowspan="2">-----------</td></tr>
<tr><td>length of visit</td><td>
</td></tr>
</table>

Table 9.8: Analysis results and some strategies for the soundscape planning of site 8 of the Tejo River waterfront.

Site 8

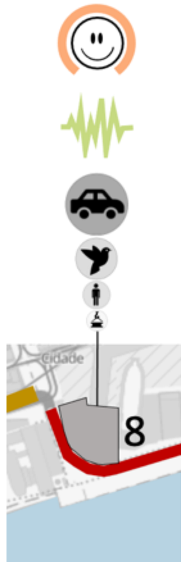
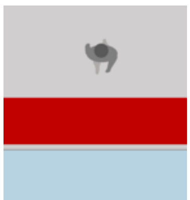
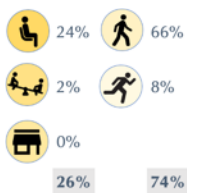
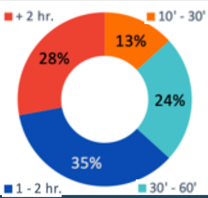
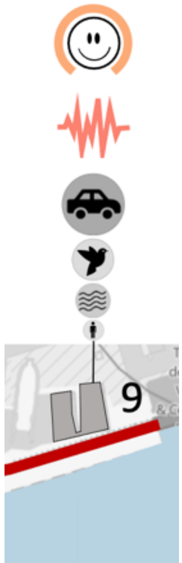
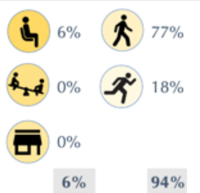
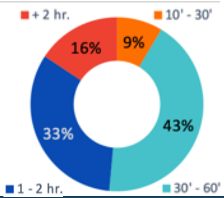
	ANALYSIS		PLANNING
sound environment evaluation		reduction of sound levels	▪ from traffic Av. Ribeira das Naus Avenue: add a smoother coating to the tire tread, in front the site, to reduce friction noise
physical restriction		decrease, relocate remove	▪ Av. Ribeira das Naus Avenue – design a study to relocate it.
water proximity		-----------	-----------
water view		-----------	-----------
users' activities		decrease people length of visit	▪ provide an alternative use to the area
length of visit			

Table 9.9: Analysis results and some strategies for the soundscape planning of site 9 of the Tejo River waterfront.

Site 9	ANALYSIS		PLANNING
sound environment evaluation		reduction of sound levels	▪ from traffic Av. Ribeira das Naus Avenue: add a smoother coating to the tire tread, in front the site, to reduce friction noise.
physical restriction		decrease, relocate remove	▪ Av. Ribeira das Naus Avenue – design a study to relocate it.
water proximity		-----------	-----------
water view		-----------	-----------
users' activities		decrease people length of visit	▪ provide an alternative use to the area
length of visit			

On the right column of the tables, some action plans were proposed, considering the results and the data collected, which encompass strategies such as: to reduce the sound levels; to mask the noise; to decrease, to relocate or to remove crosswalks, streets, bus station and avenues; to decrease people length of visit; and to relocate urban furniture.

It is important to note that the tables present one-off measures, in order to exemplify the planning of improvement in the design of the soundscape. However, it is important to highlight that the soundscape planning must always consider the general strategies for planning the waterfront urban area as a whole.

In addition, since some measures may imply an overall urban planning, the urban designer can plan to improve the appreciation of the soundscape in stages, that is, to apply first some design criteria, follow with the analysis of the results obtained, and then verify the need to act with other criteria.

For each of the 8 scales below, to what extend do you agree or disagree that the present surrounding sound environment is …

	STRONGLY DISAGREE	DISAGREE	NOT AGREE, NOT DISAGREE	AGREE	STRONGLY AGREE
Pleasant	○	○	○	○	○
Chaotic	○	○	○	○	○
Exciting	○	○	○	○	○
Uneventful	○	○	○	○	○
Calm	○	○	○	○	○
Annoying	○	○	○	○	○
Eventful	○	○	○	○	○
Monotonous	○	○	○	○	○

PLEASE, CONSIDER THE CLASSIFICATION BELOW TO RELATE WITH THE SOUND SOURCES HEARD:

WATERFRONT	NATURAL	PEOPLE	TRAFFIC	OTHER
boat water pier seagull	tree bird wind	children footsteps people talking	bus car plane train tram	alarm construction machine music

Please, select the 4 SOUND SOURCES CATEGORIES that you perceive best

	WATERFRONT	NATURAL	PEOPLE	TRAFFIC	OTHER
1st Sound Source	○	○	○	○	○
2nd Sound Source	○	○	○	○	○
3rd Sound Source	○	○	○	○	○
4th Sound Source	○	○	○	○	○

How often do you use this space?	How long do you STAY on average in this space?	What was the main reason that led you to CHOOSE this space?
○ Daily	○ Between 10 to 30 minutes	○ Sport
○ 2-4 times a week	○ Between 30 to 60 minutes	○ Contemplate
○ Once a week	○ Between 1 to 2 hours	○ Hang out
○ 2-4 times a month	○ More than 2 hours	○ Recreation
○ 1 time per month		○ Rest / Relax
○ Rarely		○ Pass through
○ First Time		

Figure E. 1 Model of inquiry to apply.

The 'pleasantness' and the 'eventfulness' of the sound environment are obtained through the assessment of the eight qualities for the sound environment, as specified the Method A of data collection, recommended on the ISO 12913-2 (2017) standard.

The sound sources categories best perceived must be selected by the respondent on a decreasing order, starting with the most noticeable ones, according to a classification presented which includes the "waterfront sound" category.

The users' habits regarding the space should be noted through the selection of the predetermined answers regarding the length they stay on the urban waterfront area, the frequency they visit it and their main motivation to visit it

The ‘pleasantness’ and the ‘eventfulness’ of the sound environment are obtained through the assessment of the eight qualities for the sound environment, as specified the Method A of data collection, recommended on the ISO 12913-2 (2017) standard.

The sound sources categories best perceived must be selected by the respondent on a decreasing order, starting with the most noticeable ones, according to a classification presented which includes the "waterfront sound" category.

The users' habits regarding the space should be noted through the selection of the predetermined answers regarding the length they stay on the urban waterfront area, the frequency they visit it and their main motivation to visit it

Table F. 1 Data to be collected at the sound levels measurements.

Acoustic Data						
Site	**Data**	**Time**	**L_{Aeq}**	**Determinant S.S.**	**File Name**	**Comments**

Table F. 2 Data to be collected about the relations between water and user on the waterfront area.

	Site 1	Site 2	Site 3
Water Physical Restriction			
waterfront restricted by a great barrier (parking, hight traffic street.)			
waterfront restricted by a little barrier (sidewalk, low traffic street.)			
waterfront limited restrict on some areas			
waterfront without restriction			
Water View			
very restricted view on all the area			
limited view on all the area			
limited view on some places			
unrestricted view on all the area			
Water Proximity *[1]			
more than 100 meters			
between 50 - 100 meters			
less than 50 meters			
in front of			

*[1]- *measure from the place where users usually remain at the area and until the water edge*

10. CONCLUSIONS

The present research aims to understand how the soundscape acts as a decision factor for the use of urban waterfronts, considering that a well appreciated, pleasant and appropriate sound environment is a key aspect in attracting people and bringing them together in an urban context in which it is integrated with all its complexity, meaning, and ambivalence.

The research was developed with two main goals in mind: to propose objective criteria which can support the urban planner on the soundscape analysis of a waterfront area; and to establish practical guidelines for the soundscape design of a waterfront public space. They rely on the premise that the urban planners and designers can compile soundscape information in a way to better preserve, improve, or design it at urban waterfronts in seaport cities in order to achieve better integration levels while improving urban vitality, preserving their uniqueness and spatial and sensorial identity.

The research work started with three research questions related to the possible associations that the soundscape appraisal of waterfront public spaces may have with (1) the qualities and characteristics of the public spaces themselves, (2) the perceptions and evaluations of their sound environment, and (3) the motivations, activities and socio-demographic data of their users.

The questions led to the subsequent formulation of the research hypothesis that by establishing a coherent correlation between the aspects presented above, it would be possible to obtain objective soundscape information, that may be useful for the urban designers on a waterfront revitalization, aiming to implement, improve or preserve soundscapes.

The work followed a case-study line of action with an empirical survey on the urban waterfront of the Tejo River, in the city of Lisbon (Portugal), making use of a variety of assessment techniques which included a questionnaire application, a non-participatory in situ survey and a laboratory listening panel.

The assessment was based on the collection of data relating to the public spaces themselves, their users, and their sound environments and the work was carried out over three steps: (1) a study area definition and preliminary assessments, (2) a quantitative assessment and (3) a qualitative assessment.

Subsequently, all information collected were combined and compared, through tables, graphs, maps and statistical analyses, so as to identify potential relationships with the sound environment evaluations

Considering the correlation results, objective criteria and good practices for soundscape analysis were established, and practical guidelines for soundscape design of a waterfront public space were set up.

The objective criteria used on a data collection at waterfront areas, to then proceed to soundscape analysis encompasses five features:

- **(i)** the pleasantness and eventfulness of the sound environment;
- **(ii)** the best perceived sound sources;
- **(iii)** public space relationship with the water;
- **(iv)** acoustic parameters of the sound environment;
- **(v)** user practices: lengths of visit and activities.

A soundscape analysis following these criteria allows the urban planner to understand (i, ii) the waterfront sound environment, as it is perceived by their users, and to know how it is associated with (iii) the public space relationship with the water, (iv) its acoustic characteristics, and (v) the practices of its users.

Considering the importance of the analysis of the soundscape to directing its planning and design, the good practice topics provide information regarding how all the necessary data:

- it should be collected in an organized and harmonized way, both through a questionnaire application and through non-participatory *in situ* survey, and
- it should be processed, to obtain consistent and comparable results.

Lastly, considering the results of a soundscape analysis, practical guidelines for the soundscape design of a waterfront area were established, encompassing general guidance and design criteria.

The general guidance was intended to inform the urban designer about the importance of adopting design criteria which contribute to people perceiving more the "waterfront sounds" and less the "traffic noise", in order to obtain high-quality, appropriate and pleasant sound environments.

The criteria for soundscape design, in turn, were established for planning the urban waterfront areas seeking to favour the perception of the "waterfront sounds" at waterfront areas, and then to achieve high-quality sound environment. It encompasses three design criteria:

(i) to reduce the sound levels;

(ii) to define the people relationship with the water;

(iii) to define the uses of the places.

10.1. MAIN CONCLUSIONS

The research succeeded to fulfil its main goals, with the establishment of objective criteria, good practices and practical guidelines, for the professional practice of urban planners and designers to include the soundscape approach in the analysis, planning and design of urban waterfront public spaces.

The significant correlations found led to interesting conclusions:

- the sound environment of the waterfront public space will be better evaluated, the more 'waterfront sounds[1]' are perceived and the more the sound environment is perceived as 'pleasant' by their users;
- the sound environment of the waterfront public space will be worse evaluated, the more 'traffic noise' are perceived and the more the sound environment is perceived as 'eventful by their users';
- the better the sound environments of the waterfront are evaluated, the more they influence people to visit the public space;
- the high sound level added by the predominance of the perception of traffic noise may contribute to a low-quality appraisal of the sound environments;
- the 'waterfront sounds' are better perceived by users who 'spend less time' in the sites and by users who are in the sites to 'contemplate the landscape';
- the 'waterfront sounds' are less perceived by users who 'practice physical activities' in the sites;
- the 'traffic noise' are more perceived by users who 'spend longer' in the sites

[1] The "waterfront sounds" sound source category was established particularly for this research due to the specific context of the waterfront urban area and included the sounds of boats, pier, seagulls, and water, unlike other soundscape studies and the ISO standard recommendation.

and by users who are ‘practicing physical activities’ in the sites;

- the ‘traffic noise’ are less perceived by users who are ‘passing through’ the sites;
- the sound environment of the waterfront public space is worse evaluated and considered also ‘less pleasant’ and ‘less appropriate’ by users who ‘stay longer´ in the sites;
- the closer the user is to the water, the fewer physical restrictions between user and the water limits and the fewer restrictions the user has of the water view, the more the “waterfront sounds” are perceived;
- the farther the user is to the water, the more physical restrictions between user and the water limits and the more restrictions the user has of the water view, the more the “traffic noise” are perceived.

The main contributions of this research have raised from three significant relationships found on the soundscape analysis carried out on the case study:

(i) the sound environment of the waterfront public space will be better evaluated, the more 'waterfront sound' are perceived;

(ii) the closer the user is to the water, the fewer physical restrictions between user and the water limits and the fewer restrictions the user has of the water view, the more the “waterfront sounds” are perceived;

(iii) the ‘waterfront sounds’ are better perceived by users who ‘spend less time’ at the sites, while the ‘traffic noise’ are more perceived by users who ‘spend longer’ at the sites.

The first relationship (i) is considered the main association found in the scope of the research, which was therefore defined as the general guidance for the soundscape design of a waterfront area. The relationship found led to conclude that the perception of the "waterfront sound" is very desirable in a waterfront area, to obtain a high-quality, appropriate, and pleasant sound environment and to influence people to visit the waterfront public space.

And, from this first association, one can understand the importance of the other ones (ii, iii), since they represent two key paths for people at waterfront areas to perceive better the “waterfront sounds”, to therefore obtaining a good soundscape appraisal.

In this regard, for successful soundscape design of a waterfront public space, the significant correlations validate the importance of planning the relationship with the water people will have, and the activities or functions people will perform, considering that people will appreciate better the sound environments, if possible:

- strengthen the relationship between the people and the water element, making them closer, and with few or without restrictions both physical and visual;
- define activities or functions that people will remain longer at the places where the 'waterfront sound' was more perceived;
- define activities or functions that people will remain for a short period of time or be passing through at places where the other sound sources were more perceived;
- define activities or functions that people will be passing through at places where the 'traffic noise' was more perceived.

To this end, an adequate analysis of the soundscape of the waterfront public space is essential, using the objective criteria that were established in the research, which will reveal to the urban planner:

- The best perceived sound sources, including the "waterfront sounds" category;
- The public space relationship with the water;
- The user practices on the waterfront: lengths of visit and activities.

10.2. FUTURE DEVELOPMENTS

The results presented in this thesis are a contribution for urban planners to include the soundscape approach on the analysis, planning and designing of public spaces of waterfront areas. However, there is much room for improvement and advancement both on the analysing and on the designing of waterfront soundscapes, which allow for further development in future works, as described next.

(1) It would be desirable to apply the objective criteria for soundscape analysis and the practical guidelines for soundscape design to a broader set of case studies at other waterfronts, with other contexts, other sound environment and other users. Soundscape studies in the literature have shown that the appreciation of sound environments may vary according to the context (Herranz-Pascual, García, Diez, Santander, & Aspuru, 2017; Zhao, Zhang, Meng, & Kang, 2018) and different cultures (Engel et al., 2020; Soares &

Bento Coelho, 2016; C. J. Yu & Kang, 2014). Therefore, the development of other case studies would provide further clarification in varied contexts, with different patterns of physical space organization and distribution, and also in other cultures.

As the differences would occur on the public space itself, on its sound environment and on its users, people would probably have other practices, expectations, and motivations, which would result in different evaluations and perceptions.

Therefore, by focussing the study on different waterfronts, it would be possible not only to test the criteria and the practical guidelines established, in order to identify the need for possible changes or to allow their generalization, but also to note the different results that can be achieved.

(2) It would be also desirable to further explore the relationships found between the users and the water, as well as other relationships that may be detected, which can directly influence the appreciation of the soundscape in public spaces on waterfronts.

A more in-depth investigation of this relationship is important not only due to the results found in this research, but also due to the specificity of these public spaces located in waterfronts, which are characterized and differentiated from other public spaces in urban areas, specifically by the presence of water on their proximities.

(3) Considering previous studies, which found that the activities performed by users and their expectations regarding to the place and the soundscape may influence the assessments of soundscapes (Bild, Pfeffer, Coler, Rubin, & Bertolini, 2018; Bruce & Davies, 2014; Jo & Jeon, 2020; Steele et al., 2015), it would be desirable to understand how much other characteristics and motivations of the users of public spaces can be correlated to and can influence their perceptions regarding the sound environments of waterfront areas.

(4) Other previous studies have investigated and found that other human senses, besides the auditory, can also influence people's perception of urban soundscapes (Ba & Kang, 2019; Jeon & Jo, 2020; Yong Jeon et al., 2011). Therefore, it would also be important to explore how much the other users' senses may be acting, together with the auditory ones, in the appreciation of a waterfront sound environment.

(5) Finally, it would be desirable the development of a tool for analysing waterfront public spaces, and also a good practice manual, centred on guidelines for the revitalization or

reorganization planning processes of waterfront areas, which take into the soundscape approach, based on the information contained in this thesis.

10.3. OUTCOMES

The results of the research have already been partially included in an abstract published and poster oral presentation at the Second Urban Sound Symposium (Botteldooren et al., 2021), and in a paper published and oral presentation at the 12th Iberoamerican Congress of Acoustics (Nardi & Bento Coelho, 2022), see Appendix A, B and C.

It is intended to publish the results from this thesis also in specialized journals.

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Abstract

Abstracts of the Second Urban Sound Symposium

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Abstract: Following the successful first Urban Sound Symposium held at Ghent University in 2019, the second edition in 2021 had to face the challenges of the pandemic. The symposium turned this challenge into an opportunity for giving easier access to practitioners and experts from around the globe who are confronted with urban sound in their professional activities. It was organized simultaneously in Ghent, Montreal, Nantes, Zurich, London and Berlin by researchers at Ghent University, Mc Gill University, Université Gustave Eiffel, EMPA, University College London and TU Berlin. The online event created opportunities for interaction between participants at poster-booths, virtual coffee tables, and included social activities.

Keywords: urban sound; environmental sounds; soundscape; noise control

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1. Introduction

The program of the Urban Sound Symposium 2021 included invited keynote talks by eminent researchers from around the world in a single stream as well as in panel discussions on emerging issues. It took place online. The main themes were urban sound planning and design, urban sound propagation and control, sound technologies, and urban soundscape analysis. There was also an option for contributed talks in the form of virtual poster-stands where recent research was showcased and discussed with peers. The latter contributions were subject to review before acceptance. Abstracts of keynote presentations and accepted posters are reported in the following sections. More info on the Symposium can be found on the website (https://urban-sound-symposium.org/ (accessed on 20 May 2021)).

2. Keynote Presentations

2.1. Urban Trends and Their Impact on Soundscape

Dick Botteldooren [1] and Arnaud Can [2]

[1] Ghent University, Belgium
[2] Gustave Eiffel University, France

Urban sound is a product of the way our cities are organized and our society functions. The emergence of new sound sources in the last century has shaped the urban sound environments we know today. Fluidification of living rhythms, sprawl and intensification, aspirations for the acoustic sensor suite. It will also outline potential applications of the data with regard to soundscape monitoring.

3.17. Waterfront Urban Public Space Soundscape Evaluation: Lisbon Case Study from the Users' Perspective

Aline Ventura Nadi

Instituto Superior Técnico, University of Lisbon, Portugal

Waterfront urban public spaces have their own identity and unique sound characteristics, both derived from a combination of the urban context and water features. Their acoustic assessment is better accomplished by adopting a holistic approach, in which the soundscape appraisal becomes particularly important since it integrates significant factors such as context, user's perception and sound environment. A study of the soundscape of waterfront public spaces from their users' perspective was conducted aiming at understanding their subjective appraisal regarding (1) the relevance attributed to the characteristic sounds of a waterfront environment (water, pier, seagulls, boats), (2) the influence that the visual and the sonic aspects hold on the decision to use these public waterfront spaces and (3) the overall soundscape quality. A questionnaire was administered to 500 users in 10 Tejo River (Lisbon) waterfront urban public spaces between the months of August and December 2020. The results show that the public spaces, where the sound environment most influences their users' decision to use it, have a direct and proportional relationship with its overall soundscape quality and with the degree of importance that is given to the characteristic sounds of waterfront areas. These findings will be correlated with other perceptive factors such as visual features to further understand the factors that contribute to a user's decision to use waterfront public spaces.

3.18. Exploring Sound Sensing to Improve Quality of Life in Urban Living

Emily Corrigan-Kavanagh, Mark Plumbley, Marc Green and Andres Fernandez

University of Surrey, UK

Following the successful application of AI and machine learning technologies to the recognition of speech and images, computer systems can automatically analyze and recognize everyday real-world sound scenes and events. This new technology presents promising potential applications in environmental sensing and urban living. Specifically, urban soundscape analysis could be used to monitor and improve soundscapes experienced for people in towns and cities, helping to identify and formulate strategies for enhancing quality of life through future urban planning and development. Nevertheless, realizing the potential of AI for sound in urban living presents challenges. Current research uses cases that are often unrealistic, lacking appropriate end-user feedback and engagement. In response, this research will employ a range of participatory approaches that will explore how people feel about sounds in their locality and how they would like to change them. The use of participatory approaches will begin with world cafés to direct project outcomes from stakeholders, bringing "AI for Sound" technology out of the lab to realize its potential benefit to society and the economy. A world café is a participatory approach typically set in a café-style environment where participants engage in three 20 min discussions on a question posed in small groups (max of five), ending with a harvest session where everyone together collates conclusions drawn from conversations. In response to the COVID-19 pandemic, we are organizing the world cafés as "virtual world cafés" to engage with residents while adhering to UK national lockdown and social distancing restrictions. Our virtual world cafés follow the original world café style utilizing a video conference tool. For example, virtual Breakout Rooms are used to divide participants into small conversation groups on the same call to help identify themes around how people would choose to change their urban sound environments and the contexts that facilitate this as a way of directing future research into associated AI for sound solutions. This virtual poster reports

WATERFRONT URBAN SPACE SOUNDSCAPE ASSESSMENT: LISBON CASE STUDY

Aline Ventura Nardi; J. Luis Bento Coelho
Instituto Superior Técnico, University of Lisbon, Lisbon, Portugal

USS 2021

Introduction

Urban areas at water's edge are places that have their own identity, with uses, visual elements, and sound particularities that derive from the combination of the urban context with water features (urban and maritime culture). Their sound environment carries important dynamic information from their reference sources, such as sounds of water, wind, birds, or boats, which provide meaning to the soundscape, allowing an identity relationship with their users. However, the essentially urban characteristics of such areas provide distinctive peculiarities to their characteristic sound environment, due to the insertion of other sources, with their own features, such as human, traffic and operational sounds [1], [2].

Due to this complexity, a new or rehabilitation design for a waterfront urban public space should include a careful analysis of the original situation as well as changes that will occur on the sound atmosphere, but the entire process of sound perception in the space should also be considered [3]. In this sense, the soundscape method offers the possibility to be integrated into the design planning or management process [4], by adopting a holistic approach since it integrates the sound environment with equally significant factors such as the context and the user's perception, which produce a high variability in the sound environment quality appraisal [5]–[7].

On the soundscape planning process, the user characteristics and their sonic interests and preferences should be a priority, in line with the context: place, activities, sound composition, and environmental features [3].

Therefore, as a first stage for the soundscape design, the context shaped both by the sensory stimulations and by the personal dimensions, must be defined [3], [4]. Therefore, it will include the characteristics of the environment and the users, their behaviour and knowledge about the space, such as cultural meaning, expectations and motivations to use the place and to carry on an activity [8]–[10]. In this regard and taking into account that urban waterfront public spaces feature unique as well as characteristic context and sound environment, the importance of a preliminarily knowledge on the appreciation of the soundscape from their users' perspective must be undertaken.

Most previous studies about waterfront area soundscape have focused on the influence of the visual and the acoustic parameters on the subjective soundscape appraisal [1], [2], [11]. However, a different approach can be proposed to evaluate the relationship between the people's visit motivation, along with their behavioural factors, and the quality attributed to the spaces' soundscape.

Concerning the waterfront urban public space visitor's motivation, this initial study essentially seeks to find out the degree of influence that both waterfront proximity and its soundscape have on the users' decision to use the site. A study on their responses was carried out to find out the degree of importance people give to waterfront related sounds (e.g., water, pier, seagulls, boats) and how that is nuclear to their soundscape appraisal.

Method

The Study Area

The research analysed ten different waterfront public spaces on the urban context of the Tejo river, in Lisbon (Portugal). The selected sites are located in two different parts of the river waterfront, as seen in Figure 01 (a, b, c, d) and identified in Table 01.

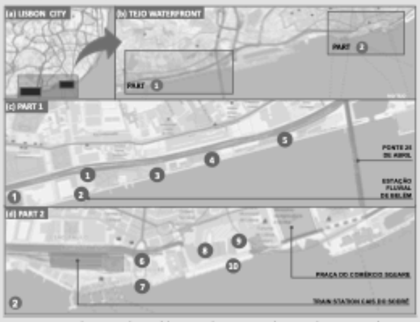

Figure 01 | Study area – urban public spaces location (a) Lisbon City (b) Tejo Waterfront (c) Part 1 (d) Part 2. Source: ©OpenStreetMap contributors – author adapted [Map]

Not all the selected public spaces have a direct or total water landscape view, such as sites 1, 6, 8, and 9. These sites were chosen since they are close to the waterfront and usually have a long-term use.

Table 01 |	Public Spaces Analysed
1	Terreiro das Missas Grass Area
2	Estação Fluvial de Belém Area
3	Museum of Art, Architecture and
4	Jardim Docas da Ponte - Part 1
5	Jardim Docas da Ponte - Part 2
6	Jardim de Roque Gameiro - Bench
7	Jardim de Roque Gameiro -
8	Ribeira das Naus - Tree Area
9	Ribeira das Naus - Grass Area
10	Ribeira Das Naus - Centre Area

Field Survey

To better understand the soundscape of the waterfront urban public spaces, a questionnaire was applied between August and December 2020 aimed at obtaining objective and subjective responses from their public spaces users.

About five hundred people were randomly selected and interviewed in the ten waterfront sites. Social demographic data obtained about the participants are shown in Table 02, where each category is presented.

Table 02 | Percentual of users: social and demographic data

Factor	Category	[%]
Age Range	15 - 19 years	28,2
	20 - 29 years	41,2
	30 - 49 years	24,9
	50 - 64 years	3,3
	over 65 years	2,4
Sex	Female	66,6
	Male	32,3
	Other	1,1
Education	Basic	1,7
	High school	44,3
	University	54,0

Results

The first part of the inquiry regarded user's subjective responses, which are shown on Table 03. For the results analysis, a five-level Likert scale was used where the highest score (5) meant the higher level of agreement with the specific item/attribute and the lowest score (1) meant the lower level of agreement.

Table 03 | Relation between question aplied on the questionnaire with responses and score adopted for the data analyses

Variable		Question	Type of Response / Score
DLO	Decision: Location	Does the WATERFRONT proximity influences your decision to use this space?	Likert item: 1-5 1 "Not at all"/5 "Totally"
DSS	Decision: Soundscape	Do the different SOUNDS you hear influence your decision to use this space?	Likert item: 1-5 1 "Not at all"/5 "Totally"
IWS	Importance Water.Sounds	In the sound set you hear, how do you consider the SOUNDS RELATED to the WATERFRONTS?	Likert item: 1-5 1 "Not Imp."/5 "Very Imp."
SSQ	Soundscape Quality	Overall, how would you describe the present surrounding SOUND ENVIRONMENT?	Likert item: 1-5 1 "Very Bad"/5 "Very Good"

At first, by two distinct questions, the interviewee was asked about the level of influence that both the waterfront proximity (DLO) and the soundscape (DSS) play in his/her decision to use the public space. For all the surveyed sites, their position in front of the water substantially influences more their users (from "very" to "totally" influential) on the decision to the use the site rather than the sound environment (from "slightly" to "moderately" influential), as shown in Figure 02

It is understood that the low influence that the soundscape has on the users' motivation for the waterfront site use may relate to the masking of its characteristic sounds, such as sounds of water, seagulls, boats, and piers, due to other existing sound sources inherent to the local urban context.

Figure 02 | Parameters that influence on the decision to public space use: Waterfront x Sound Environment – higher score imply higher influence on decision to use the public space [Graph].

Then, the user was required to answer about the level of importance that he or she attributes to characteristic sounds related to waterfronts (IWS), such as water, seagulls, boats and piers. With the exception of public space "3", where these sound sources were considered "moderately important", the sounds were considered as "important" or "very important", as can be seen in Figure 03.

It was noted that the sites where less importance was attributed to the waterfront sounds (5, 6, 8 and 9), are basically the same where the difference of influence regarding waterfront position and soundscape is greater (5, 6, 7 and 8).

Therefore, it seems that the users who were less influenced by the soundscape on their decision to use the place, are also those who less value the characteristic waterfront sounds.

The last subjective question regarded the overall soundscape quality assessment (SSQ), which, in general, was considered positive for all public spaces. As shown in Figure 04, the soundscape was regarded as "good" to the sites 1, 2, 3, 7, 9 and 10, and "neither good, nor bad" not so good for spaces 4, 5, 6 and 8.

Figure 03 | Importance of sounds waterfront related – higher score implies higher waterfront importance [Graph].

Figure 04 | Soundscape Quality Assessment – higher scores imply higher level of agreement with the soundscape quality [Graph].

It should be noted that the urban spaces where the users attributed a lower value to the soundscape quality, except space "4", are also those where the users were less influenced by the soundscape on their decision to use the place, as well as those where the waterfront sounds were less valued.

On the second part, the objective users' data were collected to obtain further information about her or his activities and/or expectations regarding the public space use. The frequency of use, the time they remain on the space, their activities in the space, and with whom they use the space were questioned.

Correlation: Qualitative vs. Quantitative Data

Collected behavioural data were correlated with users' subjective results, as shown in Figure 05 (a, b, c, d).

Some findings regarding this correlation between the user' evaluations and their behaviour are highlighted:

Correlation with the DLO and DSS:

Those who used the site with their families were little influenced by the soundscape in their decision to use the place, but they were very influenced by its waterfront location.

Users who spent more time in the place were more influenced by the soundscape on their decision to use the public space compared to those who remain less time.

People who are practicing sports are totally influenced by the waterfront location but moderately influenced by the soundscape on their decision to use the public space. At a lesser extent, this also occurs with the users who are socializing, enjoying on some way, or just passing through.

Users whose intention is to stay and contemplate the landscape are influenced, almost on the same proportion, by both the waterfront location and the soundscape.

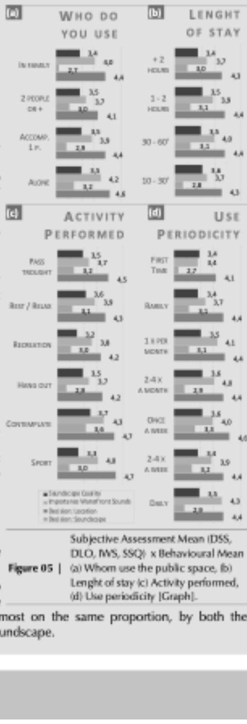

Figure 05 | Subjective Assessment Mean (DSS, DLO, IWS, SSQ) x Behavioural Mean (a) Whom use the public space, (b) Lenght of stay (c) Activity performed, (d) Use periodicity [Graph].

Correlation with the SSQ:

People who use the public space to contemplate the landscape evaluated the soundscape with a higher quality when compared to other users.

The soundscape was evaluated with moderate quality by those users who went to the space for recreation purposes (playground use or outdoor activities) or to practice sport.

Correlation with the IWS:

Users who rarely use the public space as well as those who were there just once evaluated the waterfront characteristic sounds as less important than more frequent users.

A Spearman's rho correlation statistical analysis [12] was conducted among the subjective user evaluations. The results, shown in Table 04, depict a very significant relationship among the qualitative data collected: DLO, DSS, IWS and SSQ (2-tailed, with all p value < 0.01).

Table 04 | Relationships between subjective user' evaluations

		DLO	DSS	IWS
DSS	ρ coefficient	0,259		
	p	0,000		
IWS	ρ coefficient	0,421	0,609	
	p	0,000	0,000	
SSQ	ρ coefficient	0,141	0,35	0,327
	p	0,002	0,000	0,000

Strength of Correlation: Strong; Moderate; Weak; Very Weak

A strong correlation was found between the degree of importance assigned to the waterfronts related sounds (IWS) and the degree of influence that the soundscape plays in user' decision to use the public space (DSS), with a ρ coefficient (251) = 0,609 (considering ρ = 1 represents an unrealistically perfect correlation, and ρ = 0 implies no linear correlation between the variables). In turn, the strength of correlation between the degree of importance attributed to these sounds (IWS) and the degree of influence that the waterfront proximity has on the user' decision to use the public space (DLO) was moderate, with a ρ coefficient (251) = 0,421.

A moderate correlation was also found between the degree of quality assigned to the soundscape of the place (SSQ) and the degree of influence that the soundscape plays in user' decision to use the public space (DSS), with a ρ coefficient (461) = 0,350.

Conclusions

Urban waterfront spaces have unique characteristics defined by the combination of urban and water contexts, which shape their environment and their users' perception and thus their soundscape. This study aimed at better understanding the perceptual process of the users of these public spaces at the Tejo river waterfront (Lisbon, Portugal), based on correlations between objective and subjective data, collected through questionnaires applied in the places.

The main findings of this study can be summarized:

- urban spaces with the lowest grade regarding its soundscape quality match those where the users least value the waterfront sounds as well as where the soundscape influences them least on their intention to use;
- Users who spend more time in the place are more influenced by the soundscape on their decision to use the public space compared to those who stay less time;
- Users whose main activity on the place is to contemplate the landscape are considerably influenced by the soundscape on their decision to use the place. Also, these users are those who evaluated the soundscape with a higher quality when compared to other users;
- users who use the public spaces more often evaluated the characteristic sounds related to waterfronts as more important;
- a very significant relationship among the qualitative data collected;
- a very strong correlation was found between the degree of importance assigned to the waterfront sounds and the influence of the soundscape on the user's decision to use the place;
- a moderate correlation was found between the degree of quality assigned to the soundscape of the place and the influence that the soundscape plays on the user's decision to use the public space.

The results indicate that the soundscape of waterfront public spaces influences the visitor's motivation, which is related to the activity that the user will perform on the site and that, in turn, influences the soundscape appreciation.

One should note that the variables associated with the waterfront spaces visiting motivations and with the soundscape appraisal must be further explored, considering more variables, such as the visual aspects, and the perceived affective quality of the sound environment. Further research will be conducted given the different landscape and functional characteristics of waterfront public spaces in order to extend the conclusions to other waterfront areas.

Notwithstanding these limitations, the results have confirmed that the soundscape approach can provide very useful information for effective planning strategies aimed at preserving and improving the quality of waterfront urban spaces.

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A study on Lisbon waterfront urban public space soundscape

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Abstract

Waterfront areas can provide ample possibilities as restorative sites that contribute to improve people's quality of life. In this sense, their soundscape becomes an important perception factor to be considered in their analysis or urban space planning process. Nevertheless, how the waterfront sound environment is perceived by the users has been scarcely studied.

In order to understand the soundscape perceptive process related to waterfront public spaces, from the user's perspective, a study of 10 Tejo River waterfront urban public spaces in the city of Lisbon, Portugal, was carried out. Sound source identification started with a soundwalk programme which also helped the site selection. Sound environment data were recorded and a questionnaire was applied to 500 users. The sound recordings and the users' responses were analysed in the laboratory, where the predominance of each perceived sound source was identified and quantified.

Despite the fact that all studied public spaces featured a direct relationship with the river, and perhaps since local traffic sounds generally dominate the acoustic environment, only in some sites the waterfront characteristic sounds (water, boats, seagulls, pier) were those most frequently identified by the users. Here, the more perceived sound sources, mostly natural sounds and those related to the waterfront, produce a masking effect relative to other sounds that were detected as having a higher temporal predominance in the laboratory. The research results were correlated with other user's subjective evaluations, in order to better understand the waterfront public space soundscape appreciation process.

Keywords: technical paper, FIA, Sobrac, acoustics, vibration

PACS: 43.28. Hr

1. INTRODUCTION

Soundscape studies are attracting worldwide interest, and changing the historical view of "sounds", that focus on the human perception of acoustic environments, with an alternative approach on managing sound in the urban environments [1]. This is the reason for which, the environment researchers and professionals, started to question how modern cities should "sound like", instead of just "look like" [2].

Cities or city areas at the water's edge are places that have their own identity, with uses, visual elements, and also sound particularities that are derived from the combination of the urban context with the water (urban and maritime culture). The sound environment of these areas carries important dynamic information from its reference sources, such as the sounds of water, winds, birds, or boats, which give meaning to their landscape, allowing an identity relationship with their users. However, the current and essentially urban use of such areas usually produce distinctive peculiarities to this characteristic sound environment, due to the presence of other sources, with its own features (such as human, traffic and operational sounds).

Nevertheless, especially in these waterfront areas, the soundscape approach is not usually considered, both on the analysis and planning, as one of objective determinants to the project concept to be considered by the urban planners in their design process.

Therefore, this research aims to carry out a soundscape semi-empirical study of a waterfront urban area from the urban designer's perspective.

The urban waterfront area of the Tejo River, on Lisbon city (Portugal), was explored, focusing on a detailed study regarding the most perceived sound sources, in order to contribute to the understanding of the perceptual process of its soundscape.

The work followed a case-study line of action with an empirical survey on different public spaces of the Tejo's waterfront, which included *in-situ* observations, data collection, laboratory tests, and a comprehensive cross analysis.

2. STUDY AREA

Ten sites from the Tejo River waterfront were selected for study. They are distributed over two large areas named as Area I and Area II, as shown in Figure 1.

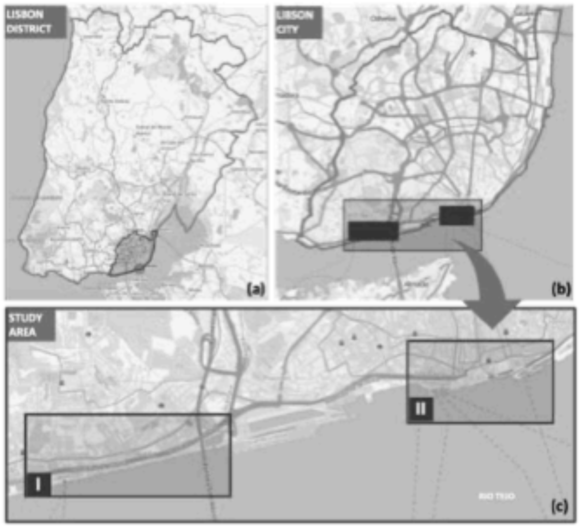


Figure 1: Waterfront area location: (a) Lisbon District, (b) Lisbon Municipality, (c) Tejo's River Waterfront with Area I and Area II location: *©OpenStreetMap contributors, author adapted.*

Area I is located between the Doca de Belém dock and the 25 de Abril Bridge, and comprises five selected public spaces, sites 1 to 5, as shown in Figure 2.

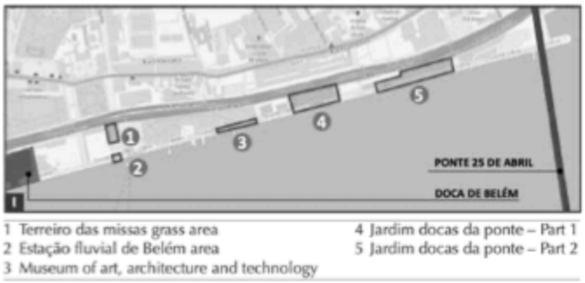
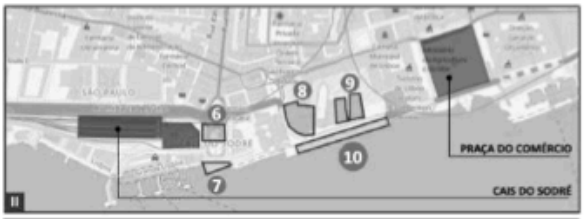


Figure 2: Area I with the location of sites 1 to 5. *Source: ©OpenStreetMap contributors – author adapted*

Area II, located between the Cais do Sodré train station and the Praça do Comércio square, comprises also five public spaces, sites 6 to 10, as shown in Figure 3.



6 Jardim de roque gameiro – bench area
7 Jardim de roque gameiro – river bank area
8 Ribeira das naus - tree area
9 Ribeira das naus - grass area
10 Ribeira das naus - center area

Figure 3: Area II with the location of sites 6 to 10. *Source: ©OpenStreetMap contributors – author adapted*

3. METHODOLOGY

The data collection for the qualitative evaluation of the sites was carried out through two simultaneous procedures, one consisting on the application of questionnaires to the users of each site, and the other on sound recordings and measurements on the sites.

The application of the questionnaires made it possible to obtain information on the users' perception regarding the sound environment of the sites.

While the inquiries were applied, the local sound sources and the moment they were perceived were identified and registered, in a way to capture the existing temporal sound composition of the sound environment. Sound pressure measurements were also carried out.

The sound recordings together with all the information gathered were organized and analysed on a laboratory environment and later listened by a laboratory listening panel, in which the sound environments were assessed subjectively, according to the panel members' perception.

3.1 Inquiry

The inquiry was designed based on recognised research about soundscape and supporting information specified on the ISO soundscape standards [3].

The second part of the inquiry was built especially focusing on the data collection regarding the user perception about the different types of sounds and the overall sound environment of the sites, in which, firstly, the acoustic environment of the site is characterized by the sound sources heard and identified. Therefore, the user is requested to list those sounds that he/she perceived best, in a decreasing order, starting with the most dominant ones, as in Figure 4.

Please list the 4 SOUND SOURCES (eg traffic, birds, people talking, wind, water, machine noise, music, train, etc.) that you perceive best.

Start with the most noticed source.

1 ____________________
2 ____________________
3 ____________________
4 ____________________

Figure 4: Inquiry second part: sound perception.

The sound sources perceived by the site users were compared later with the answers obtained by the laboratory listening panel. In order to make the data obtained from both methods comparable, since the perceived sounds on the sites were listed by free-text answers, a classification of these responses considering the same categorization applied on the laboratory panel was necessary.

Therefore, a classification was established, following Table 1 criteria, mostly based on ISO 12913-2 [3] recommendations, but introducing the "waterfront sounds" category, in line with the research objectives.

Table 1: Classification of the sound sources.

Waterfront Sound	Natural Sound	Human Sound	Traffic Sound	Other Sound
boat	birds	ball	airplane	alarm
boat whistle	cicada	palms	bus	ambulance
pier	dog barking	people	cars	bicycle
seagull	wind	sneeze	helicopter	construction
water		whistle	motorcycle	drag objects
			train / tram	kiosk operation
			truck	music
			tuktuk	scooter

In addition to the categorization, it was also found necessary to attribute more importance to the established ranking order of the sound sources, putting more weight to those which were perceived best.

In this sense, a weighting criterion was set up which consisted of attributing different scores according to the perception order, where the highest score (100%) was assigned to the first most perceived sound source, a medium score (80% and 60%) to the second and third ones, and the lowest score (40%) to the fourth.

A practical example of the weighting procedure is shown in Table 2, where the values from the second up to the fifth column, group (i), represent the number of listeners who ranked the specific sound source respectively as the first, second, third, or fourth most perceived.

Table 2: Tutorial to weighting the sound sources ranking established by listeners.

	Public Space 7									
	Sound Source Perceived				Ranking Order Weighted (i)				Total	%
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	(ii)	(iii)
Waterfront Sound	9	2	1	4	9,0	1,6	0,6	1,6	12,8	18%
Natural Sound	0	0	1	1	0,0	0,0	0,6	0,4	1	1%
Human Sound	0	16	7	3	0,0	12,8	4,2	1,2	18	26%
Traffic Sound	9	4	7	4	9,0	3,2	4,2	1,6	18	26%
Other Sound	8	4	9	7	8,0	3,2	5,4	2,8	19	28%

100% 80% 60% 40%

The values from the sixth to the nineth column, group (ii), represent the applied weighting, in which the numbers of listeners were multiplied by the factors 100%, 80%, 60% and 40% respectively according to the perceived order. Then, the tenth column (iii) shows a sum of the values weighted for each sound source category. Lastly, the eleventh column (iv) presents the percentages obtained which means the contribution of every sound source category on the acoustic environment, according to the user's perception.

3.2 Laboratory listening panel

The listening panel was set up so as to obtain a subjective assessment of the sound environment of the waterfront sites, in a laboratory environment. Essentially, it was asked to the panel members which sound sources they perceived best by watching and listening to ten videos that represented each one of the Tejo waterfront sites, composed of an audio sample of its sound environment and of illustrative photographs of the place.

The listening panel was composed by non-acoustical experts and not necessarily familiar with the waterfront sites, with different socio-demographical characteristics, such as gender, age, occupation, and education. The participants were sent an e-mail with the video, the link for the online form access and a tutorial which explained how to autonomously perform the assessment.

As participants were supposed to have a good hearing, since auditory accuracy was required, the listener's hearing ability was entrusted to a self-declaration at the moment when he/she agreed to participate in the panel.

The set up of the listening panel was adapted to the covid-19 pandemic situation by creating a safe environment for the participants. In this sense, (i) the sound environment of each site was characterized and presented in a virtual way, and (ii) an on-line form was structured and built, for an individual and autonomous assessment by the panel members.

For the panel implementation, the various sound recordings needed to be summarized in a single audio sample for each site, that could represent its sound environment according to its temporal sound composition.

Firstly, at the IST Acoustics laboratory environment, each sound recording was analysed using the computer program "*Audacity*", in order to characterize the sound environment of each site, by recording the sound sources categories perceived and the time period they remained being noted. By using that software, as shown in Figure 5, (i) the changes on the sound time history of each recording could be observed through the visual information of its sound wave, and then (ii) each sound source perceived were identified, aided by the annotations carried out *in-situ*, from the exact instant when it started to be noted until when no longer could be perceived.

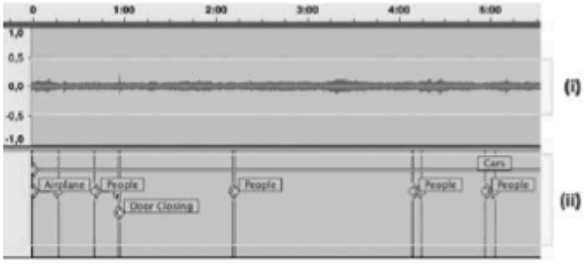


Figure 5: Sound recorded, and sounds labelled by Audacity Software.

Hence, considering the sound source categories and the time period that each one was perceived on the recording, as shown on the example of site 9 in Table 3, (i) the percentage of the recording time of every category was calculated, (ii) to then calculate an average of the percentages of the categories and to obtain the temporal sound composition of the sound environment for each site.

Table 3: Sound environment characterization. Example of the mean calculation of each sound source perceived from the recordings

Site 9						
Recordings	Waterfront Sound	Natural Sound	Human Sound	Traffic Sound	Other Sound	
1	100,0%	0,0%	100,0%	100,0%	0,0%	(i)
2	3,3%	0,0%	17,4%	100,0%	5,8%	
3	100,0%	0,4%	21,8%	100,0%	1,1%	
4	2,9%	0,5%	41,1%	100,0%	0,0%	
5	100,0%	1,6%	3,5%	100,0%	8,0%	
7	15,7%	0,3%	12,5%	100,0%	10,3%	
Mean	53,6%	0,5%	32,7%	100,0%	4,2%	(ii)

By taking into account the resulting temporal sound composition for every sound environment, an audio sample was composed for each site by combining parts of the sound recordings, in a way to contemplate, as much as possible, the same percentages of the different sound source categories.

For the on-line form application, short videos were composed for each site, with an approximate duration of 1 minute and 45 seconds each, by combining the audio sample and a sequence of six representative photographs of the place. The images aimed to provide visual information on the site, such as its characteristics, its surrounding environment, and, mainly, its relationship with the water.

The videos were complemented by an online form to be filled in by the listener sequentially following the presentation of each site. The form asks for the four sound source categories which the respondent perceived best by watching the video with the sound environment recording composed, starting with the most relevant ones as shown in Figure 6.

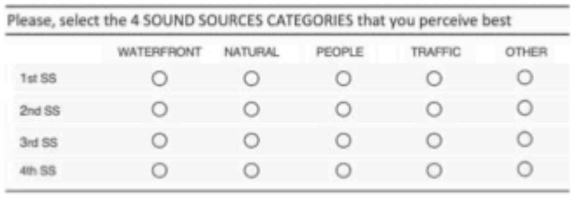


Figure 6: Laboratory panel form question regarding the sound sources perceived on the video of each site of the electronic form about.

For an appropriate sound source categorization, the listener was previously introduced by a tutorial regarding its classification, as shown in Figure 7, in line with the criteria established in Table 1.

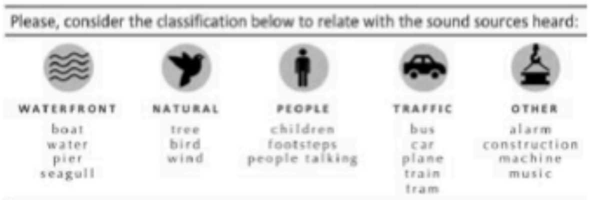


Figure 7: Orientation for the sound source classification to answer the electronic form.

Similarly to the inquiry results processing, the panel's best perceived sound source categories, for each site, were weighted in the same way, from the first to the fourth category, using the method illustrated in Table 2.

Through the weighting procedure, a higher importance was attributed to those sound source categories best perceived making the results from the listening panel comparable to the inquiry responses.

4. RESULTS

The inquiry was applied to 642 users, aged between 15 to 71 years, with 411 being women and 231 being men (M age = 28,5 years).

The application of the questionnaires covered different days of the week, different periods of the day and different seasons of the year.

The laboratory listening panel comprised a group of 26 listeners that voluntarily participated on the laboratory experiment, with 16 being women and 10 being men (M age = 42,5 years).

The results obtained from the site' users (I) and from the panel listeners (L) were correlated, in order to compare the sound sources best perceived obtained from the two approaches, i.e., from the site users *in-situ*, assessed through the inquiry (I), and, at a laboratory environment, assessed through the online form (L) by the laboratory panel members.

Figure 8 represents the general percentages regarding the sound sources most perceived by the sites' users (I) and by the panel listeners (L), considering the assessments for all the waterfront area places.

The general perception demonstrated that, despite the sites being in a waterfront environment, in which their characteristic sounds could have been the most perceived, the "traffic sounds" were still the best perceived, perhaps due to the urban characteristics of the waterfront.

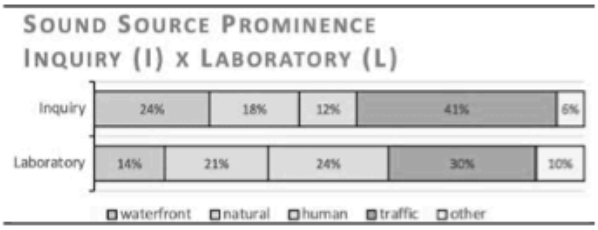


Figure 8: Average perception percentage of each sound source on the Tejo's waterfront public spaces [%] obtained on the inquiry (I) and on the laboratory (L).

Comparatively, the "traffic noise" category was more perceived by the users of the sites (41%) than by the panel listeners (30%). Likewise, "waterfront sound" was also more perceived by the users (24%) than by the listeners (14%), even with a temporal sound composition which includes the "waterfront sound", and also with the visual support of the photographs which illustrate the relationships of the sites with the water.

In contrast, the "natural sound" and the "human sound" categories were more perceived by the panel listeners (natural: 21% / human: 24%) than by the users of the sites (natural: 18% / human: 12%). It is important to highlight that while the "human sound" was the second sound source category more perceived by the listeners, it was only the fourth perceived by the users.

The comparation between the perceived sound sources obtained from both assessment approaches was also carried out site by site, as shown in Figure 9.

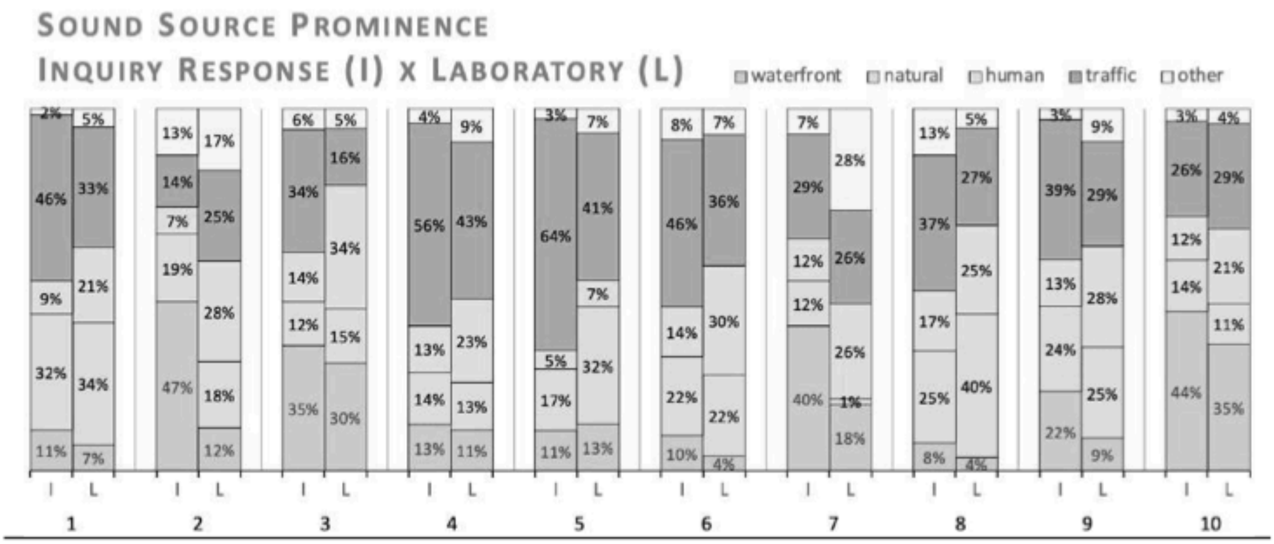


Figure 9: Average perception percentual of each sound source on each site [%] obtained on the inquiry response (I) and on the laboratory response (L).

When comparing both assessment environments, one can note that the most perceived sound sources were significantly distinct on sites 2, 3, 5 and 7.

It stands out that the sound sources categories much more perceived by the users than by the listeners are the "waterfront sound" on the sites 2 (47% by users, 12% by listeners) and 7 (40% by users, 18% by listeners), and as the "traffic noise" on the sites 3 (34% by users, 16% by listeners) and 5 (64% by users, 41% by listeners). On the other hand, the "human sound" was perceived much more by the listeners than by the users on the sites 2 (23% by listeners, 7% by users) and 3 (34% by listeners, 14% by users).

On sites 1, 4, 8 and 10 the percentage differences between both assessment methods were lower, meaning that the perceptions were very similar, especially on site 10.

Table **4** shows the sound sources categories most perceived from both assessment environments, on a ranking order, from the most prominent to the least.

From the table, two analyses can be performed from the two method results, namely, (i) the established ranking order and (ii) the sound sources that dominate the sound environment.

The ranking orders from both assessment methods presented most differences on the sites 2 and 7, while presented an equal order only on site 5.

In general, one can note that both the “waterfront sound” and the "traffic noise " categories were more prominent by the users of the sites, except in site 2, while the “human sound” was more prominent for the panel listeners.

Concerning the “natural sound” and the "other sound", the results obtained from both methods were similar, as far as, on some sites they were more perceived by the listeners and better noticed by the users.

Regarding the sound sources that dominate the acoustic environment, it was possible to observe that the “traffic noise” category dominated the sound environment at both assessment environments on sites 4, 5, 6 and 9. However, on sites 1 and 8, while the “traffic noise” was also the most perceived category by the users of the sites, for the panel listeners, it was the “natural sound” category.

On site 10, the “waterfront sound” category dominated the sound environment of both assessment environments. However, on sites 2, 3 and 7, while the “waterfront sound” was also the most perceived category by the sites’ users, for the panel listeners it was the “human sound” on sites 2 and 3, and the “other sound” on site 7.

Table 4: Comparative sound source predominance on each site – Inquiry Response (I) x Laboratory Panel Response (L): from the first to the fifth sound source more perceived.

	1		2		3		4		5		6		7		8		9		10	
	I	L	I	L	I	L	I	L	I	L	I	L	I	L	I	L	I	L	I	L
1st	46%	34%	47%	28%	35%	34%	56%	43%	64%	41%	46%	36%	40%	28%	37%	40%	39%	29%	44%	35%
2nd	32%	33%	19%	25%	34%	30%	14%	23%	17%	32%	22%	30%	29%	26%	25%	27%	24%	28%	26%	29%
3rd	11%	21%	14%	18%	14%	16%	13%	13%	11%	13%	14%	22%	12%	26%	17%	25%	22%	25%	14%	21%
4th	9%	7%	13%	17%	12%	15%	13%	11%	5%	7%	10%	7%	12%	18%	13%	5%	13%	9%	12%	11%
5th	2%	5%	7%	12%	6%	5%	4%	9%	3%	7%	8%	4%	7%	1%	8%	4%	3%	9%	3%	4%

Lastly, in Figure 10 andFigure **11**, the best perceived sound sources at each site, respectively by the sites’ users (I) and by the panel listeners (L), were introduced on the waterfront area maps. The different scales of the symbols of each sound source category represent the proportion that each one was perceived on the different sites, i.e. the larger symbols represent the most predominant categories, whereas the smaller symbols represent the least perceived.

For the site users (I), one can note that the “waterfront sounds” category dominates the sound environment of those sites that are really in front of the water, except for sites 4 and 5. Specifically at these sites, the "traffic sounds" was the sound source category perceived as predominant on the sound environment, which leads to conclude that this dominance might be masking the “waterfront sounds”, which it was noticed as common in the areas with this water relation. The masking effect seems to be quite relevant here.

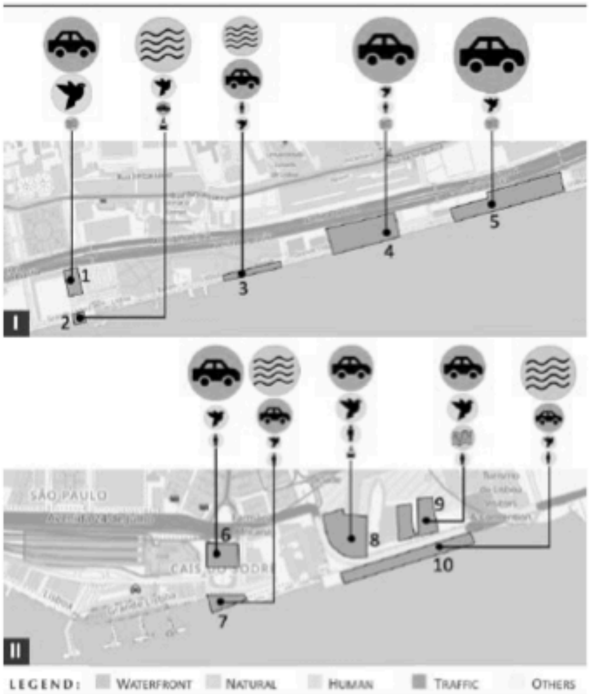


Figure 10: Tejo waterfront – Areas I and II - sound source categories most perceived on each site by their users (I) -larger symbol imply higher perception of the category. *Sources: ©OpenStreetMap contributors, author adapted.*

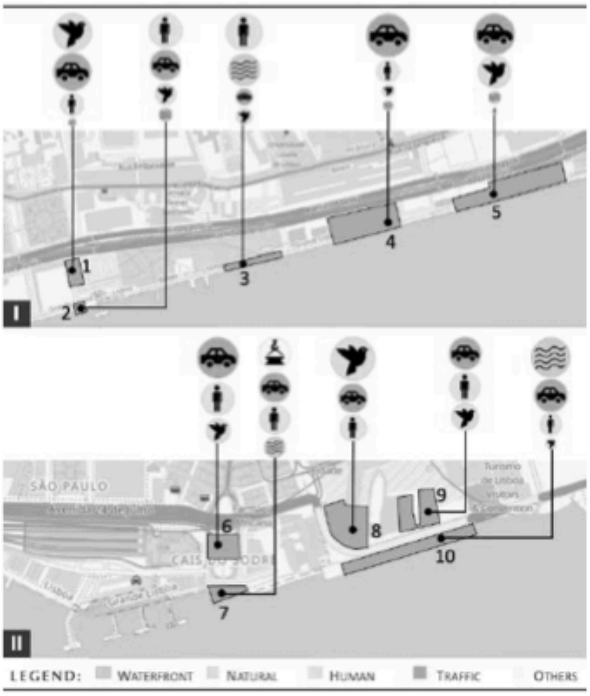


Figure 11: Tejo waterfront – Areas I and II - sound source categories most perceived on each site by the listening panel (L) -larger symbol imply higher perception of the category. *Sources: ©OpenStreetMap contributors, author adapted.*

For the panel listeners (L), the "waterfront sound" category was also best perceived on the sites that are closest to the Tejo River, but only on sites 3 and 10. However, regarding the other perceived sound source categories, no relations with the position of the sites on the waterfront were found.

5. DISCUSSION AND CONCLUSIONS

By comparing the two assessment environments, large differences can be assigned to both the context information and the existing stimuli to their participants, which could influence directly and considerably their perception process.

The listening panel member essentially had sound and visual stimuli, through the sound recordings and illustrative photos of the sites, for their assessment, whereas the user, *in situ*, had all the information about the site itself, she/he was familiar with it and was stimulated by all the other senses, in addition to the auditory and visual ones.

Considering this, it is possible to deduce that the differences found between the sound sources most perceived on sites 2, 3 and 7, may have been mostly influenced by the existing differences between both assessment environments. While the similarities found on sites 1, 4, 5, 6, 8, 9 and 10, seem to have been essentially influenced by the common aspects existing on both assessment environments, thus, mostly the auditory and visual stimuli.

The sites that presented the most different sound source perceptions between the assessments carried out *in situ* and at the laboratory, were the same ones where the "waterfront sound" was the best perceived sound source category by the waterfront users, except at site 10. And, as showed in Figure 10, these sites are located exactly in front of the Tejo waterline, which may mean that their proximity to the water can stimulate other senses of the users, not only the auditory one, which influenced them to perceive mostly the water-related sounds.

Despite this relation found between water proximity and "waterfront sound" perception, on sites 4 and 5, the "traffic noise" was the most perceived instead of the "waterfront sound".

Figure 12 shows that unlike users of the other sites at the waterline, that have a direct access to the water, the users of sites 4 and 5 usually remain in places with some physical restriction to the water, highlighted on the maps and on the photographs in Figure 13.

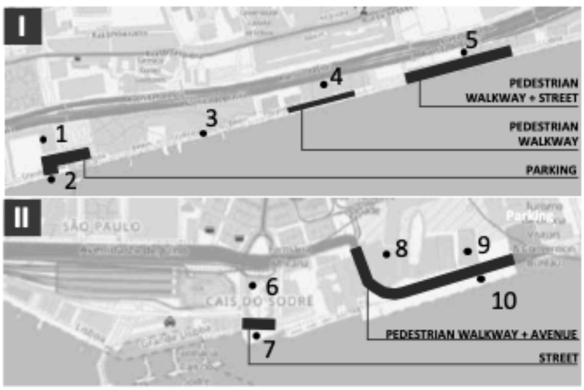


Figure 12: Tejo waterfront – Areas I and II – sites and barriers identification. Sources: ©OpenStreetMap contributors, author adapted.

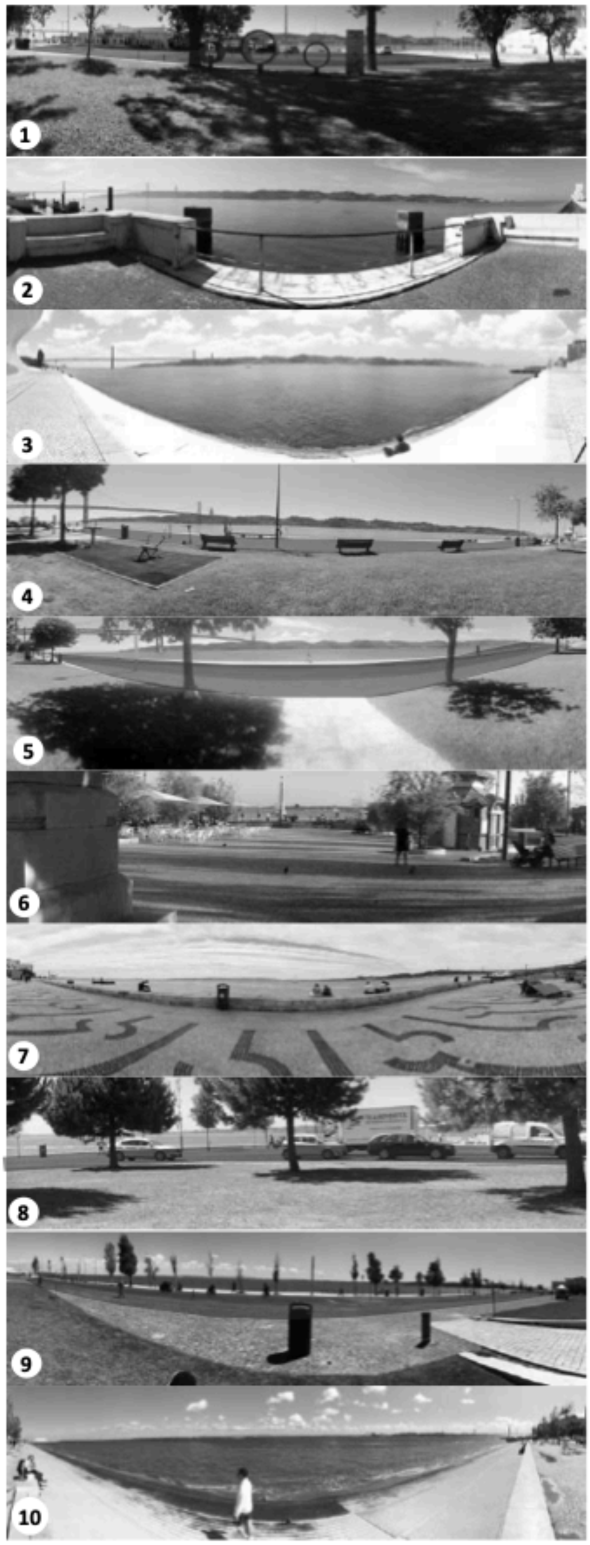


Figure 13: Tejo's waterfront sites with their physical barriers highlighted on red areas, except on sites 2, 3, 7 and 10, without barrier; *by Nardi, 2020.*

It seems that these physical elements placed between the user and the water, which nevertheless allow the crossing of people, bicycles, scooters and even cars, influences the perception of the sounds on sites 4 and 5. They somehow interrupt a closer relationship with the water, and makes people notice more the "traffic noise" that is reported as the sound source category actually more present in the sound environment.

On sites 1, 6, 8 and 9, these characteristics might be even more determinant to the traffic noise perception, since besides being further away from the water, these places are also more restricted to it by physical barriers even more representatives, such as avenues and parking.

Overall, it seems that an association between the most perceived sound source categories and the relationship that the users establish with the water exists, since, despite the entire waterfront area being characterized by the presence of the traffic noise, a closer contact with the water might have influenced the perception of sounds that are more water-related.

Contrary to this, any type of barrier between the user and the water seems to emphasize the perception of the traffic noise, which is usually the sound source category most prominent in the waterfront of the Tejo River.

Therefore, since different restrictions to the water can impact on the overall perception of the sound environment and on the composing sound sources, they should be considered an objective criterion for the analysis and planning of the soundscape of a waterfront area.

The design of the soundscape of an urban waterfront area must be supported by the careful planning of the sound sources that will be perceived, which in turn, must be supported by the planning of the possible relationships between the user and the water.

ACKNOWLEDGEMENTS

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