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# Questionnaire analysis survey for acoustic investigation – Preliminary considerations

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## ABSTRACT

**The noise in the areas between ports and logistic platforms is investigated from a subjective point of view in the TRIPLO (TRansports and Innovative sustainable connections between Ports and LOgistic platforms) EU project. Besides activities such as noise monitoring, mapping, short-term measurements, port and road traffic flows analyses, also subjective surveys can give useful indications on the strategies to be proposed for a better management of the problem.**
**The interest towards the people involvement is a widely spread practice, as the strategies to manage the noise pollution should start from the evaluation of the population annoyance level.**
**To use the most suitable approach, a preliminary investigation on the questionnaire surveys already experimented has been developed and a synthesis of the main aspects that should be considered is presented.**

**Keywords:** Subjective evaluation, survey, noise perception
**I-INCE Classification of Subject Number:** 61 – Perception of sound

## 1. INTRODUCTION

The quality of the sound environment significantly affects health, comfort, and productivity of the exposed subjects. The negative effects can show as discomfort, interference in verbal communication, sleep disturbances, behaviour alteration, and psychological conditions. The stress conditions that may result can affect health, also contributing to the appearance of serious diseases, mostly related to the cardiovascular, respiratory and nervous system.

In everyday life, the human ear classifies a sound event as annoying because of various attributes (frequency, occurring) even if not necessarily directly connected to the sound level. The perception is not absolute but the human hearing tends to create its own reference sound of the sound event and to compare the sound to this reference [1].

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The problem should therefore be faced from two different points, one quantitative, with the measurement of the physical parameters that contribute to determining the environmental noise, and a qualitative one, with the subjective evaluation by the involved subjects.

EU regulations highlight the importance of citizen participation in the environmental noise evaluation, but consider procedures aimed at disseminating information, rather than at knowing the subjective perception of the problem. For example, the END Directive [2] indicates to member states the obligation to publish noise maps and action plans every five years.

In this case, the role of the population is 'passive', as it is provided with a series of information, but does not collect personal opinions on the results of the technical choices made. An 'active' study system, on the other hand, allows collecting data extensively on more or less large samples, to perform mathematical / statistical investigations.

### 1.1 Acoustical parameters and perception

Understanding how sound waves are received and converted inside our brain is a very complex operation and what we "feel" is not only a physiological consequence linked to the shape of our ear but also involves psychological implications.

Among the various disciplines related to the study of acoustics, psychoacoustics deals with the study of human perception of sounds [3]. It therefore also deals with the search for a parameterization of individual processing to acoustic stimuli.

In order to describe noise from a perceptive point of view, psychoacoustics introduces a series of new specific descriptors such as loudness, roughness, sharpness, fluctuation strength, and others. These descriptors therefore also take into account the temporal development of the different components of the considered noise.

In general, the sound wave is a tool for transmitting information useful to the subject or interfering with his psychophysiological state or with his activities. In the first case it is appropriate to speak about 'sound', while in the second one usually the term 'noise' can be used as an 'unwanted sound' that the subject perceives as negative for his comfort.

It is assumed that most of the noise is interpreted as annoyance or pollution, but the criteria for defining the acoustic comfort level in an environment are not yet easy to determine.

## 2. REVIEW OF NOISE ASSESSMENT QUESTIONNAIRES

There are several ways to analyse the noise perception, depending on the method of investigation that is assumed. Among these, for example, the reproduction of a sound field in an anechoic chamber can be mentioned: this method has the advantage of strictly delimiting the characteristic of stimuli, but does not represent reality from the natural context in which listening takes place. The evaluation of a space depends on the way in which it responds to multiple needs such as functionality, or overall comfort (acoustic, thermal, lighting and ventilation).

The perception calls multisensory aspects and therefore cannot ignore the psychic and psychological conditions of the subject. The methods of subjective investigation represent a very valid means to know the perceptive parameters, and therefore to bring the individual judgment closer to the value measured with the instruments.

Experience in this area has shown that the use of evaluation or satisfaction questionnaires provides an important support for acoustic analyses and offers a series of information that enriches the survey.

In the external environment, there are many sources: vehicular traffic, railway traffic, recreational activities, commercial activities, etc. Clearly, the auditory perception is strongly influenced by the concomitance of several simultaneous sound phenomena.

The urban structure of cities can be characterized by areas where one source of noise rather than another prevails, areas in which event coexistence conditions occur, or 'silent' areas where noise levels remain low.

In these cases, it may be useful to found to the comparison between objective and subjective data, to determine the differences perceived between the various areas of the same or another city.

This type of comparison was made between the cities of Lyon and Nantes [4], choosing situations as representative as possible of specific urban forms (architectural styles) and of the activities carried out (human occupation, natural setting, road traffic). The study analysed these areas to see if they really represented sound landscapes that are distinctive from a perceptual point of view and / or from an acoustic point of view. By making the position of the surveyed participants correspond to the measurement points, it was possible to associate the acoustic parameters with preliminary perceptual factors. A questionnaire was then proposed to a population sample, initially developed with open questions, and concluded with a semantic differential grid. This led to the search for perceptual and cognitive factors based on the psychological theories of: sound identification [5], categorization, and linguistic representations [6].

The open questions concerned the activities of the subjects (their category as inhabitants or workers or students), the knowledge of the urban situation, the global evaluation of the place and, finally, the assessment of the sound environment. The semantic grid was used mostly to evaluate the external sound environment. The differential applied to quantify the variation of the results has been conceived on the basis of two different choices of answer with antithetical meaning that have therefore assumed the role of 'extremes of scale'. To avoid a purely bipolar structure that would inevitably derive from it, with consequent forced answers on extreme positions, it was decided to use a dynamic scale composed of seven intervals. The nine sound evaluation fields for the application of the semantic grid are defined in Table 1.

| **Acoustical Features** | **Attributes of Scales (English translation)** |
|---|---|
| Strength | Quiet - Loud |
| Spatial occupancy | Little attending - Very attending |
| Spatial arrangement | Organised - Disorganised |
| Spatial localisation | Nearby - Far |
| Temporal balance | Steady - Unsteady |
| Time evolution | Established - Evolutive |
| Clarity | Hubbub - Distinct |
| Activity | Monotonous - Varied |
| Assessment | Pleasant - Unpleasant |

***Table 1*** *- Definition of the attributes of the nine differential semantic scales*

Simultaneously with the survey, three acoustic recordings lasting 15 minute were made at the selected positions and at different times of the day (morning, midday and afternoon). The acoustic parameters were calculated as statistical measurements of the sound levels in dB(A): LAeq, Lmax and Lmin, L90, L50, L10 and the amount of energy related to the sound event (StD: standard deviation of the time evolution of LAeq). Moreover, peak levels have been considered with respect to the background noise (considered as L90). To identify the frequency modulations of each urban situation, the

use of accurate psychoacoustic indicators defined by Zwicker was used, such as volume level (N and N10), sharpness and roughness [3]. To these was added another parameter G, the so called 'center of gravity of the spectrum' and relative to the average of sound power frequency spectra, in order to reduce the interpretative difficulty of noises at low frequencies. In this case, the data processing was dealt by using the correspondence analysis (CA), an advantageous technique to analyze a large number of variables derived from the decomposition of a phenomenon.

A similar study [7] in the external environment concerned the study of fourteen cities in five European countries where 9200 surveys were collected for a whole year. The procedure in this case also provided for a subjective phase, by completing a questionnaire and an objective one with measures on the spot. Five scales of judgment were used to evaluate the sound environment: very quiet; silent; neither silent nor noisy; Noisy; very noisy.

The researchers chose characteristic sounds of the examined area, that is to say the typical sources of noise in open urban public spaces. The acoustic comfort was also evaluated on the basis of five linear scales similar to those used for the sound environment: very comfortable; comfortable; neither comfortable nor uncomfortable; uncomfortable; very uncomfortable.

The sound levels (Leq) were measured at each site, including the mean and standard deviation (STD) of one-minute measurement Leq values, as well as their statistical levels L90, L50 and L10.

In these evaluations, it seems that a high correspondence emerges between the measured sound levels and the results of the subjective survey; in fact, the increase in Leq corresponds to an increase in the average evaluation score towards the “very uncomfortable” level. Although for a long time the Leq has been widely adopted as a general index of environmental noise assessment [8], for urban open public spaces, the results of this study suggests that the background sound level is another essential parameter. In fact, the lower this value is, the greater the feeling of tranquillity increases, even when the noise reaches high levels.

Overall, in urban open public spaces, individual assessment of changes in noise level corresponds to changes in dB (A) values, increasing or decreasing, while the assessment of acoustic comfort is more complex. People tend to be more tolerant in relation to comfort, because they do not depend only on the sound level, but on other factors connected to it.

Another important result of the research refers to the age of the interviewed population. In terms of acoustic comfort, most adolescents expressed an unsatisfactory judgment, contrary to the positive judgment obtained by more mature people (over 55).

There are also other differences in terms of sound preference: older people appreciate more natural sounds and / or culturally relevant sound elements, while young people between the ages of ten and seventeen prefer an extremely stimulating and lively soundscape.

There was no significant difference between male and female individuals, both in terms of subjective assessment of sound level and acoustic comfort. Other factors that influence the perception of the sound environment are the interactions between visual and auditory perception, especially when the sounds are closely linked to the landscape, giving the user a sense of involvement and a feeling of greater comfort. Visual information has a different influence on auditory judgment. In urban areas, it has been found that the more pleasant the visual approach, the less polluted the sound evaluation. Some elements that are not negligible, because of their influence on the research carried out in the field of noise in the external environment, are represented by:

- the influence of the visual landscape on the sound and vice versa,
- the morphology of the territory (size and shape of the area),
- the geographical and urban location,
- the urban environment (characteristics of the neighbourhood and / or area, population density, type of accommodation)
- the characteristics of the places.

Given the number of variables, very often the only use of a questionnaire may not be sufficient to obtain a detailed picture of the perceptual influence in the evaluation of the phenomenon.

To consider this extreme variety of aspects, some French researchers [9] used a larger survey than the one carried out through questionnaires. In fact, in addition to an individual questionnaire, the subjects were asked to take photographs of the places and to participate in a group discussion. In the next phase, the perceptual analysis has gone further, considering also a graphic aspect: the interviewees were asked to graphically represent ideal soundscapes as opposed to environments considered unpleasant.

From the 'sound maps' (Sonic mind maps) made in this way, it was observed that the vegetation, in reference to the public green, represents one of the greatest idealizations within a sound landscape: the acoustic atmosphere is made pleasant by the presence of natural sounds. The survey, clearly of a qualitative nature, has therefore highlighted that the presence of vegetation and the urban form are of great importance in the assessment of the sound environment.

Given the complexity of the analysis of a sound landscape, multiple studies have proposed a methodological approach, to take into account many aspects besides the purely acoustic one.

One of these is based on the application of fuzzy logic. The importance of this method [10] is based on its resemblance to human reasoning, to obtain results that are not necessarily exact but very good. The analysis process is set on a 'membership function' able to independently correlate, but with the help of weighting indices, a set of input data with the outputs. The success of this approach is identified in several studies related to the noise problem in relation to the work efficiency in noisy environments [11], the definition of noise pollution discomfort [12,13], the forecast of train noise [14], and of the communication interference [15]. This technique was also used to study the sound quality of a series of public spaces in the city of Cordoba, Argentina [16].

The approach followed in the study is the use of fuzzy logic for the understanding of a system of spaces through the analysis of acoustic or psychoacoustic indicators or descriptors that are highlighted as identifying traits of sound quality and soundscape. A widespread or blurred system, like the one just described, is structured in some fundamental phases: "fuzzification" or diffusion of input variables, inference, or logical deduction through the evaluation and formulation of control rules, and "defuzzification", that is, data output to calculate the output results. At the base of the process there is always an important phase to obtain the acoustic parameters, and a phase of investigations to obtain the subjective data, obtained through a survey.

The questions asked make, first of all, reference to the age, sex and activity of people, reasons for the use of space, distance from the area in which they live, and the average time in which the subjects are stationed in a place. A further development consisting of sound recordings for analysis relating to the calculation of psycho-acoustic parameters such as volume, sharpness, and roughness was considered. This made it possible to define the quality of the soundscape and the environment in general through structured queries with a five point bipolar scale arranged as follows: "very pleasant",

"pleasant", "right", "unpleasant", and "very unpleasant". The noises chosen for the analysis were divided into three categories: anthropic, natural, and artificial sounds. For each of the three types the answers were presented in a classification of five points, according to the following alternatives: "not heard", "little felt", “felt", "very felt", "completely dominant". The purpose of the scale was also to represent the level of satisfaction through a further scale of judgment: "pleasant", "rather pleasant", "satisfying", "quite annoying" and " annoying ' '.

The analysis confirmed that noise levels below 65-70 dBA are more influenced by the type of source rather than by the average sound level. The evaluation of the soundscape aims to use the concept of annoyance for situations in which the sound levels are lower than the values mentioned above. The quality of sound in urban spaces associated with the range of acceptability, for those sound levels for which no discomfort has been caused, has been shown to depend on factors conditioned by cultural and social models. Therefore, in parallel with the study of the presence and / or discomfort levels connected to a sound landscape, the variables relating to user perceptions should be taken into greater consideration and supported with the psychoacoustic indicators used for quality studies.

Sound classification plays a very important role in understanding the degree of influence of noise sources in the perceptive evaluation of a sound landscape. In relation to the sources, people express a positive judgment when they are linked to acoustic comfort, relaxation, communication, spatiality, and dynamics. The condition is relaxing if the sound is of natural origin, while it becomes discomforting when the sound is mechanical and artificial. Good communication, on the other hand, is associated with the prevalence of anthropogenic noise.

The identification of the sources of noise pollution allows to understand the importance that they have in the urban context. The most common sound source in the city is vehicular traffic, followed by the railway one. Most of the European population is exposed to urban traffic noise, caused by heavy vehicles, light vehicles and motorcycles and is generated by their structural components. In particular they can be classified as: engine, air resistance, rolling of the tires, accessory engines (air conditioning system, radiator fan, etc.) as well as the activation of the brakes. It is therefore important to have guidelines to limit the problem, considering, first of all, direct interventions on the roads. On the other hand, some management measures typical for urban areas, even if not aimed only for acoustic purposes, could be able to indirectly improve the sound landscape. An example of this potential is the design of shared roads . This type of design aims to reduce the dominance of motor vehicles, which is common on conventional roads, promoting pedestrian and cycling activities that use the road as a "place" in addition to its purposes of mobility and access [17].

The key characteristic of shared roads includes the mixed use of road spaces for the transit of motor vehicles, characterized by little physical separation or little regulatory control, homogeneous sidewalks that do not differ from the roadway, as in traditional cases, and urban furniture that encourages more social activities [18,17]. Shared-street design has been applied in the urban areas of many cities and has produced a significant increase in safety and comfort levels [19,20], without compromising the efficiency of mobility and access to vehicle transit. In addition to these well-known benefits, the planning of shared roads can also influence the sound landscape through the transformation of the urban planning, with respect to the visual interaction in the field of environmental perception [21,22].

Starting from these hypotheses, a group of researchers [23] presented an empirical survey to understand how the design of shared roads and traffic restrictions, are associated

with changes in the visual landscape and the acoustic environment, in terms of human experience local. Virtual reality (VR) has been used as a tool, by means of a 3D interface that generates a real or imaginary environment and simulates in real time the user's presence in this space through multiple sensorial channels [24].

Auralization technology has been associated with the virtual system for real-time visualization. Specifically, it is the combination of a sound, whether recorded or simulated on a computer, associated with the acoustic characteristic of an environment, used to reproduce the listening conditions in a specific position of that space.

In addition to the interaction with the virtual reality, the compilation of real-time surveys online was experimented in order to quickly and intuitively simulate the real behavioural and emotional aspects of the participants within the proposed environment. The use of surveys in real time allows direct control over the experience of the virtual environment and is an innovative attempt to understand the sound landscape in relation to the emerging citizen participation in the field, to the initiatives concerning urban planning [25].

## 3. CONCLUSIONS

The considerations made in the present work highlight the need of the subjective investigations to support scientific quantitative analysis. From the analysis of some research in this field, the importance of non-acoustic aspects on subjective sound perception can be highlighted.

The number of aspects and the methodologies applied to consider their weight are decidedly extended and could be organized to allow a better general interpretation.

The analyzed approaches certainly do not represent an exhaustive picture of the problem, but they contribute to highlighting some of the fundamental elements to provide a solid basis for the development of new survey techniques that allow a more complete consideration of the sound phenomenon and related aspects. The logic of construction of the questions is a complex operation mainly due to the difficulty of formulating questions aimed at obtaining a precise response.

The analysis presented is generally valid for all types of noise, whether they are anthropogenic, industrial, or other. In particular, this preliminary analysis was carried out to structure in a more informed and targeted way a questionnaire with reference to the effects of the noise of transport infrastructures in general and of port and back-harbour infrastructures in particular.

In fact, the noise associated with these last ones presents particular aspects, because, in addition to involving sources due to the equipment on ships, such as engines, chimneys, sirens, etc., it also includes sources of other contexts, such as cranes for the loading and unloading of goods, road and / or rail traffic, etc.

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