# SOUND AMBIENT ENVIRONMENT OF URBAN PLACES: COMPARISON OF SOUND APPRAISAL FACTORS WITH ACOUSTICAL PARAMETERS

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ABSTRACT: This work aims at investigating appraisal of urban soundscapes. The method consists of two simultaneous on-site procedures in various urban situations in two French cities. First, passers-by were required to express their opinion about soundscape through questionnaires. Second we recorded samples of soundscapes and calculated acoustic parameters. The crossing analysis shows that the sound level suited to the description of boulevards, but for similar sound level situations (square, market, or schoolyard) two perceptive factors are needed: one spatial dimension can be correlated with indicators as background noise or standard deviation, whereas temporal one reveals differences in citizen perceptual attitudes.

## 1. INTRODUCTION

This paper presents a crossing analysis of inquiries data and acoustical parameters describing sound ambient environment of urban places. Several locations in Nantes and Lyon (France) have been selected for proceeding on site experimentation: inquiries and measurements. The aim of this work is to scrutinise the appraisal factors coming from statistical analyses of a differential semantic grid justified thanks to accuracy of free answers. The understanding of the open questions part of the questionnaire will not be detailed in this article.

## 2. INQUIRIES AND MEASURMENTS PROTOCOLS

### 2.1 Selection of Urban Situations

Locations have been chosen following spatial, temporal and function criteria to define the notion of urban situations [Maffiolo 1999]. We selected varied places with the concern to evaluate contrasted ambient environment interpretations. Function was the main criteria for this selection. Then the analyses of the inquiries and measurements data looked forward if those places effectively presented distinguished soundscapes. In order to observe the repetitiveness of the data, we selected similar situations in two different French cities, Nantes and Lyon. For time and financial reasons, only situations of square and boulevard were matched in those two towns: the "place du Commerce" (PN) and the "rue de Strasbourg" (BN) in Nantes, paired with the "place de la République" (PL) and the "rue E. Herriot" (BL) in Lyon. We opted for the surrounding of the “Molière” school (EN) in Nantes and also for two market places in the area of Lyon: the “Quai Saint Antoine" (ML) and the "Villeurbanne" market (MV).

### 2.2 Questionnaire

Passers-by and inhabitants answered on site to the questionnaire. We set up a question paper built on open questions and concluding with a differential semantic grid. The open question leaflet includes questions about the activity of the persons, their knowledge of the site and their impressions of those soundscapes. In the meantime, we have tested a semantic differential grid built up on ten specific words describing acoustical features. Minima of thirty persons have been questioned per site to appraise statistical data processing. Finally, both verbalisations and statistical analysis of the judgements give complementary results about perceptiveness of urban soundscapes. The open questions are about the person’s category (inhabitants or passers-by with professional motivations or simply coming by), the global assessments concerning the location and next the sound ambient environment judgement. Following those open questions, the differential grid topic is only in regard to the sound ambient environment evaluation. The grid is made of ten questions:

- The Intensity (quiet "silencieux" or loud "bruyant");
- The Spatial qualities like occupancy (little / very attending " peu / très présent" sounds) and arrangement (organised "ordonné" or disorganised "désordonné" sounds) and localisation (nearby "proche" or far sounds "lointain");
- The Temporal qualities like poise (steady "stable" or unsteady "instable") and progression (established "figé" or evolutive "évolutif");
- The Blend of sound events (brouhaha or distinct);
- The Content of the sound ambient environment (monotonous "monotone" or varied "varié");
- Finally, the assessment (pleasant "plaisant" or unpleasant "déplaisant").

Each question of the differential grid is followed by another request to justify the answers of individual persons, which analyses attest the meaning of each words of this particular list.

### 2.3. Acoustical Measurements

Simultaneously of those inquiries, we have done three acoustical recordings of a quarter of an hour, at different specific moments of the day and for each location of boulevards, squares, market places and school yard. The external acquisition set consists of one transducer linked to a small acquisition unit (a single channel microphone), which transfers data in real-time to a notebook computer. This instrument allows several functions such as recording the raw audio signal (like a DAT recorder), measuring the noise level time history (like a data logging integrating sound level meter) or showing the changing real-time frequency spectrum (like a frequency analyser).

## 3. METHODS

We use the multidimensional statistical analyses methods to examine minutely the inquiries data (software SPAD). Observation of the grid answers showed that, for the same conditions, people disagreed in their evaluations of soundscapes. A detail study of their verbal justifications showed a lack of consensus that can be attributed to different ways of processing in listening [Raimbault 2002]. Therefore, the statistical histograms descriptions of each question of the differential grid reveal that it is more pertinent to fulfil a factorial analysis (FCA) of the rank table of the inquiries data in stead of a classical PCA. We truly think that not to calculate the average of the answers improves the data analysis. Moreover, the linguistic analyse of the open questions verbalisations reveals that it is significant to keep differences of interpretation in the data table. The verbalisations report shows that a question is interpreted following three assessments categories: one for each words of the question (for sample: monotonous or varied) plus a “middle” class which presents different meanings considering different questions. So, we grouped the data ranks following the linguistic judgements analysis for each question of the differential grid.

It raises several questions about which physic parameters should be selected to interrelate with judgement criteria. Categorisation into sector related indicators appeared to be a possible solution. Most of urban noises resulted from many varied mixed sources, which couldn't be pulled away from the background of the urban environment. The sound intensity level remained a normalised information. Nevertheless, it should be underlined that even from a physical point of view, the notion of average intensity for complex acoustic stimuli like urban soundscape is problematic. Therefore, our study focused on the acoustical standard parameters such as statistical measures of sound level more an estimation of the number of standing out occurrences. In view of the temporal evolution of those coming out levels in the setting, we considered this number compared to its rising time period for a specific interval. We also calculate the Loudness level and the Sharpness and the Roughness psycho-acoustic parameters.

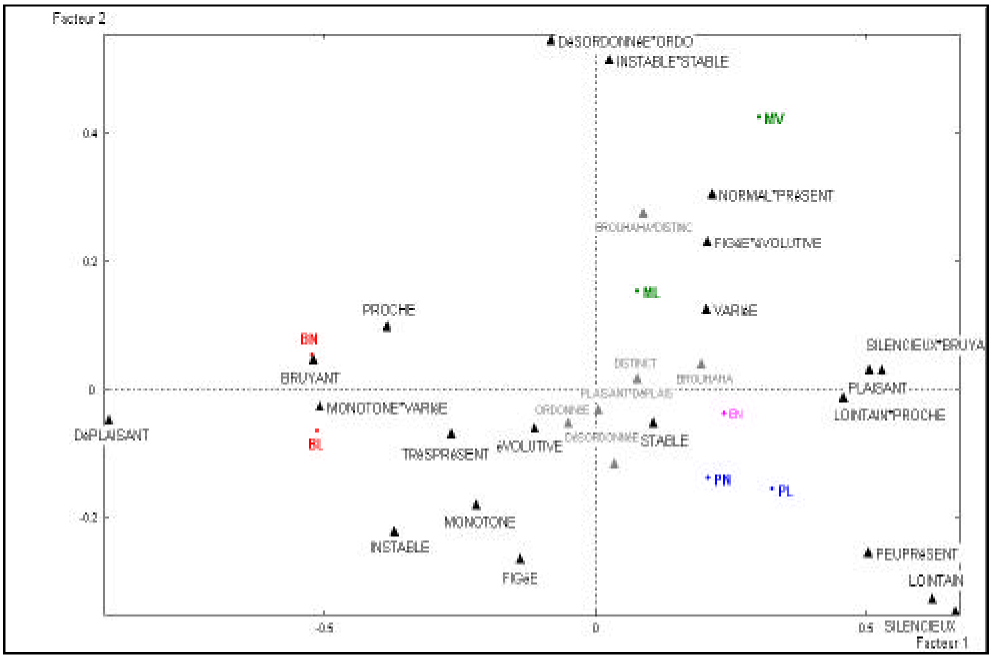
We performed a principal component analysis of the ratings (inquiries data and acoustical parameters) to obtain a simplified representation of all the semantic grid answers and the measurements.

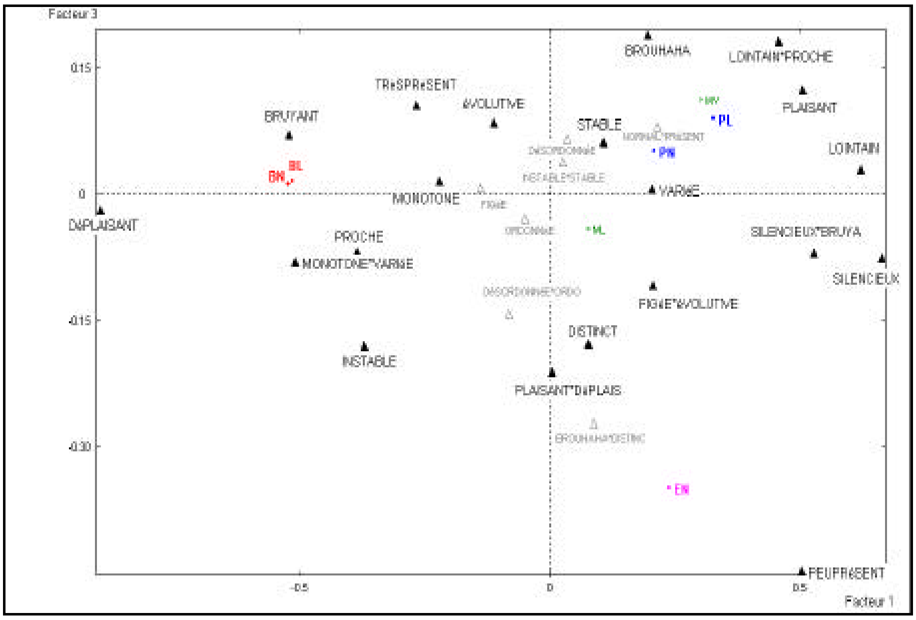
## 4. RESULTS

### 4.1 Inquiries data

To interpret the component analysis of the inquiries ranks, we have to consider the coordinates, the contributions and the square cosines of the data to qualify their representations in the projection (Figure 1). The analysis of the semantic grid answers shows three main axes construing 91% of the data. The axis 1 (67%) distinguishes the judgements (pleasant / unpleasant) which oppose the boulevards ("loud" with the proximity of sound sources) to the other locations. The axis 2 (15%) is explained with the adjectives describing the sound dynamics (steady/ unsteady and organised/ disorganised) and shows that there is more variance between persons about the adjectives than between locations. This analysis reveals the lack of consensus about the semantic of the words and/ or the disagreements about the sound situations. Therefore, we have to be careful about the second axis interpretation because it makes standing out the different ways of processing in listening [Raimbault 2002, Barron 1988].

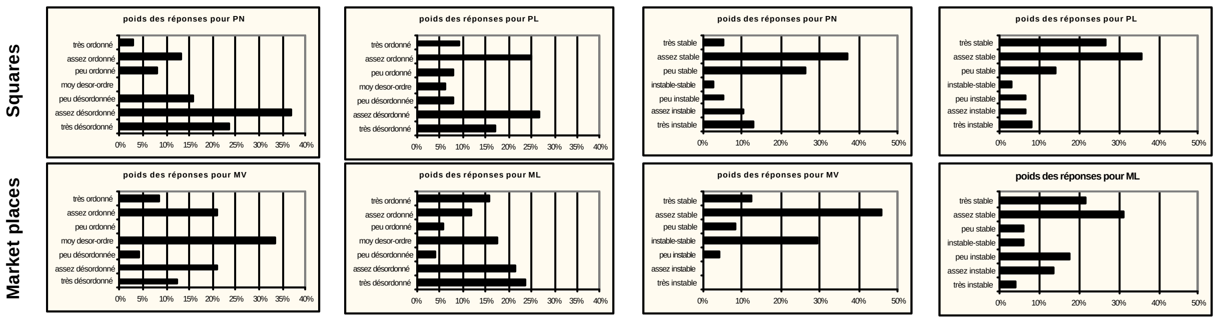
**Figure 1. Projection of the locations and the inquiries categories for the factorial axes 1 – 2 and 1 – 3.**






Temporal dimensions (steady/ unsteady and organised/ disorganised) are interpreted in different ways for the squares and the markets locations (Figure 2): markets are mostly judged with the middle category whereas squares, which interpretations distinguish two groups of persons. The axis 3 (8%) provide the means of the schoolyard which is not accurately characterise with the previous axes. This third axis is linked to the spatial attributes and opposes the “distinct” features of the schoolyard to the “brouhaha” and “far” appraisals of the squares.
Those results show that axis 1 and 3 expound a linearity of the semantic attributes whereas the second axis analysis notices a lack of consensus.

**Figure 2. Histogram descriptions of the market places and squares for the questions steady / unsteady and organised / disorganised.**

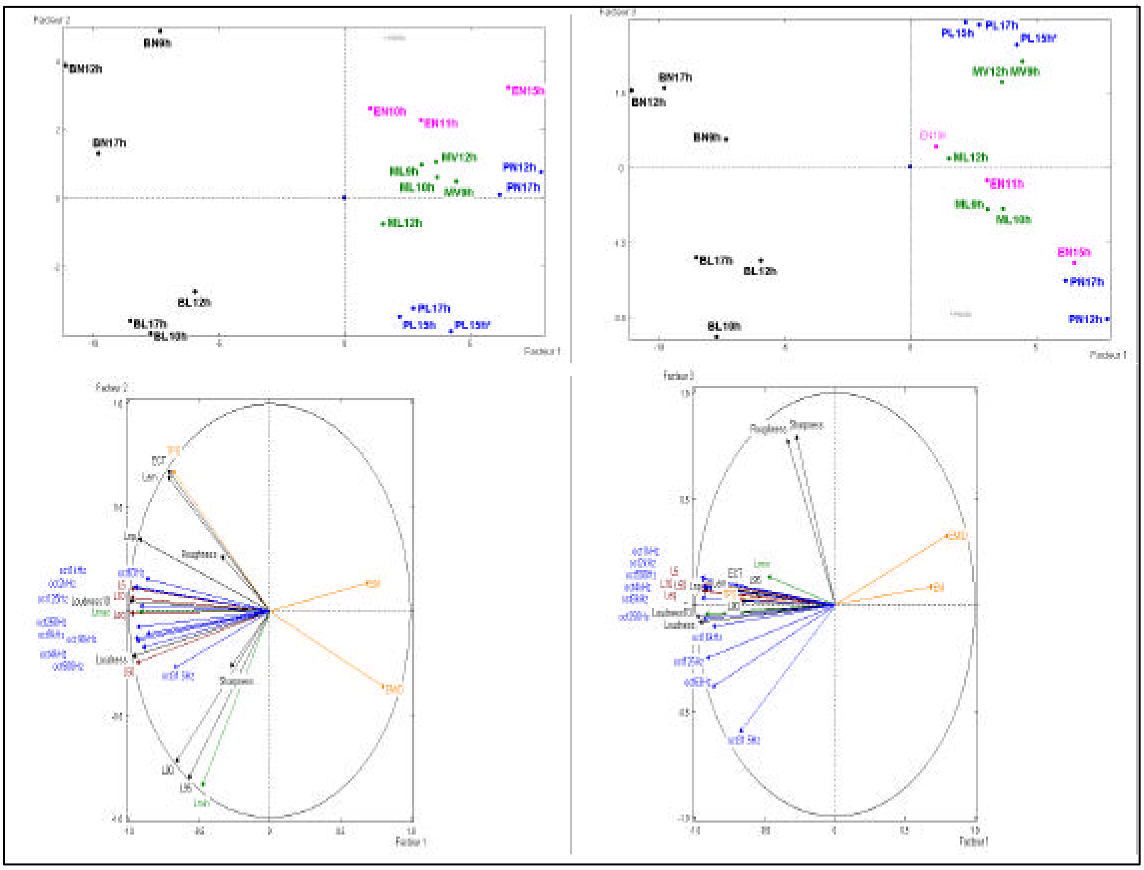



## 4.2 __Acoustic data__

The component analysis of the acoustical data extracts the discriminating parameters for each sound ambient location. The analysis shows three main axes construing 92% of the data variance (Figure 3).
- The axis 1 (70%) separates the boulevards associated with high sound levels ($L_{Aeq}$ or Loudness) from other urban locations (characterised with great number of standing out levels). This result is logical because, the more the sound level is high, the less the number of standing out occurrence is. All the sound bandwidths are correlated to the sound levels measurements ($L_{Aeq}$ or Loudness).
- The axis 2 (15%) opposes the sound situations in Nantes and the one in Lyon according to the sound level amplitude (standard deviation parameter and Lem) and the background noise level ($L_{min}$ and $L_{90}$ or $L_{95}$). This is once more logical: the more the background noise is low, the more the amplitude level could be high. So, from a measurement point of view, the background noise

seems to distinguish the studied towns. We suggest that the background noise could be a density of activities measurements linked to the definite town and not the definite location.
- The axis 3 (8%) discerns the timbre notions (the Roughness and Sharpness measurements) oppose to the low frequencies bandwidths. Those differences between squares and markets are explained thanks to functional specificity: the market ML is nearby a high traffic roadway and the square PN is nearby a tramway and a bus station.

**Figure 3. Projection of the locations for the factorial axes 1 and 2 and correlation circle of the acoustical parameters corresponding.**

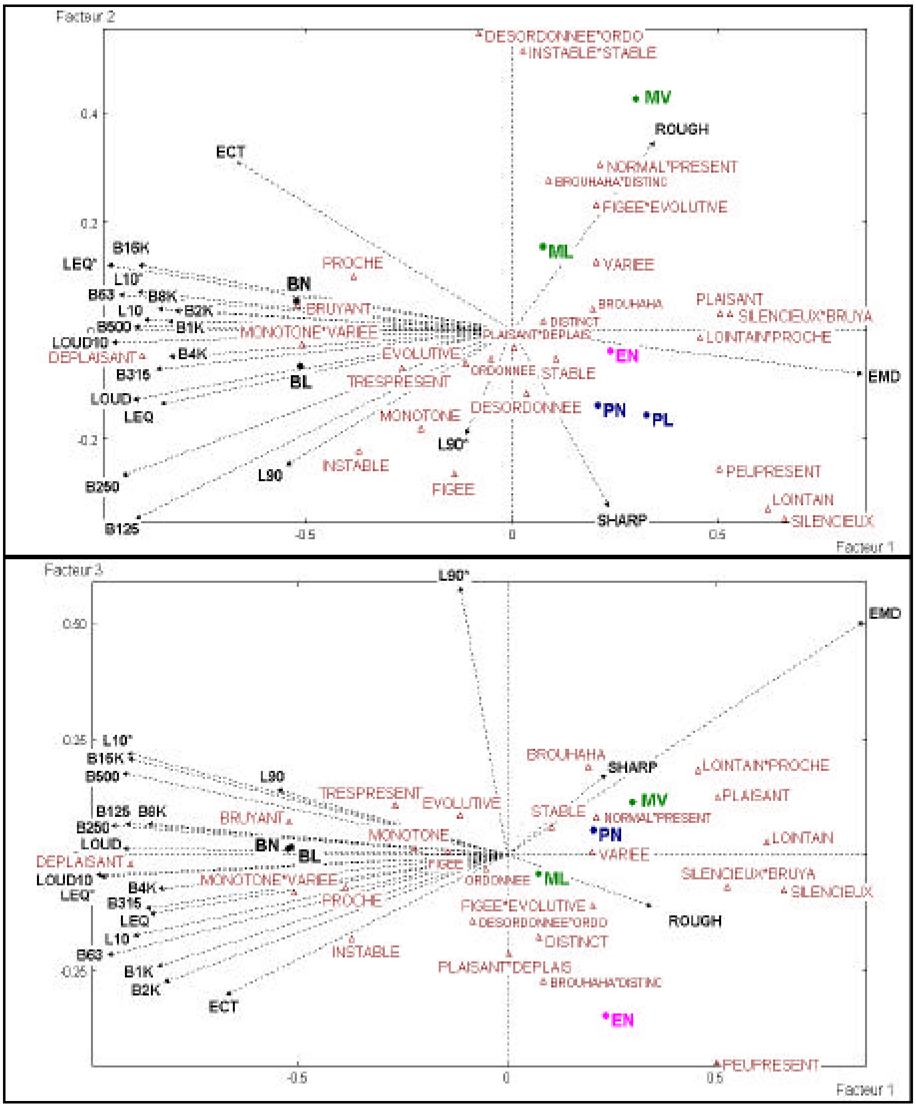


The findings clearly established the distinguishing features between the boulevards and the other urban locations and confirmed that the importance of further analyses about sound power frequency spectrums and its time history.

### 4.3 <u>Crossing the inquiries and acoustic data</u>

The method crossing the inquiries and the acoustical data projects the acoustical parameters as illustrative variables on the previous component analysis of the inquiries categories (presented 4.1). Because the acoustical data were evaluated as representative for the three moments of the day, we keep only one significant measure per parameter except for the weak values: the sound levels ($L_{Aeq}$, $L_{90}$, $L_{10}$), correlated to the main axis 1, contribute to stagger the schoolyard situation (Figure 3). So, two values are observed for those level parameters: one for the morning and one for the afternoon (indicate with a *). The analysis reveals three main axes. The first, link to the judgement (pleasant/ unpleasant) is correlated with the sound level ($L_{Aeq}$, $L_{10}$, LOUD and $LOUD_{10}$). The boulevards data provide heavily to the shaping of this first axis. The Loudness appears very well correlated to this sound strength notion, for a measurement of 15 minutes [Zwicker et al 1999]. The statistical histograms descriptions of the inquiries data help to understand the second axis: the interpretation of questions describing the soundscape dynamics notifies that there are more variance between persons about the adjectives than between locations. The acoustical measures linked with this axis are the amplitude and the background noise. Nevertheless, this relationship is false because those data simply tend to be independent from the sound level ones, which characterise the first axis. The third axis explained the schoolyard interpretation thanks to the occupancy adjectives, in association with the background noise and the number of standing out level.

**Figure 4. Projection of the active data (locations and inquiries categories) and illustrative data (acoustical parameters) for the factorial axes 1 – 2 and 1 – 3.**




## 5. CONCLUSION

The review of the statistical results proves the interest to observe crossing analyse of inquiries and physical data. So, we observe how to “fit” the sensible interpretation of urban soundscapes with acoustical measurements. The distinction between persons about the attributes interpretation points to the limits of unique physical description of an acoustic phenomenon that produced different representations.

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