A Study on the Documentation and Analysis of the Urban Acoustical Environment in Terms of Soundscape

Kentsel Akustik Çevrenin İşitsel Peyzaj Yaklaşımı ile Belgelenmesi ve Analizi Üzerine Bir Çalışma

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Soundscape is a relatively new concept that defines the acoustical environment by the interaction of multiple sound sources and environmental parameters. Soundscape concept treats the sound environment as a multi-dimensional entity, based on the complex interaction between sound source, physical environment and human beings. A method for documenting the sound environment based on sound recordings provides qualitative data while the quantitative data is supplied by conventional acoustic measurements. Acoustical perception; in other words, how a person perceives the sound, is the subject focused on in this method. The review of the related literature shows that there is not a common agreement on t the properties of the subjective and objective data, the methods of data collection and evaluation, or the statistical methods to be used in the correlation. Therefore, a wide-frame study aiming to develop an approach based on soundscape for the evaluation, conservation and rehabilitation of acoustical comfort in urban areas, has been planned and realized. The process followed in this study, on documenting and analyzing the sound environment via sound recordings is presented in this article. Accordingly, the method of deriving the sound recordings which refer to the actual sound environment and confirming their quantitative and qualitative accuracy, are described through field work.

Key words: Soundscape; sound recording; urban acoustical environment.

İşitsel peyzaj, çoklu ses kaynakları ve çevresel parametreler arasındaki ilişkiye bağlı olarak oluşan işitsel ortamın -olumlu ya da olumsuz yargılardan bağımsız olarak- saptanması şeklinde tanımlanmakta ve son yıllarda kentsel akustik çevre üzerine yapılan çok sayıda çalışmaya konu olmaktadır. İşitsel peyzaj yaklaşımı, ses kaynağı, etki ortamı ve insan arasındaki çoklu etkileşime dayanarak ses ortamını çok boyutlu biçimde ele almaktadır. Bu yaklaşımda, sadece nicel belirlemeler sağlayan geleneksel akustik ölçmelere ilave olarak, nitel veri oluşturmak amacıyla ses kayıtları ile sağlanan bir belgeleme yöntemi kullanılmaktadır. İşitsel peyzaj çalışmaları için oldukça önemli olan bu belgelemede önemli olan işitsel algılama; yani insanın sesi nasıl duyduğudur. İşitsel peyzaj üzerine yapılan çalışmalarda; öznel ve nesnel verinin özellikleri, elde etme ve değerlendirme yöntemleri ile bunları ilişkilendirmede kullanılacak istatistiksel yöntemler gibi pek çok konuda bir uzlaşma bulunmadığı görülmektedir. Bu irdeleme üzerinden, 'işitsel peyzaj kavramının kentsel akustik konforun değerlendirilmesinde, korunmasında ve iyileştirilmesinde kullanılabilmesi için bir yaklaşım önerisi geliştirmek' amacıyla kapsamlı bir çalışma yapılmıştır. Tamamlanan bu çalışmada izlenen, işitsel peyzaj yaklaşımı üzerinden ses ortamın ses kayıtları ile belgelenmesi ve analiz edilmesi süreci, bu makalede sunulmaktadır. Buna göre, gerçek ses ortamı yansıtan ses kayıtlarının nasıl elde edildiği ve bu kayıtların gerçek ses ortamı yansıtma durumunun nitel ve nicel olarak nasıl doğrulandığı alan uygulamalı bir çalışma olarak anlatılmaktadır.

Anahtar sözcükler: *İşitsel peyzaj; ses kaydı; kentsel akustik çevre.*

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Introduction

The word 'soundscape' was first introduced by Schafer[1] to denote an auditory equivalent to landscape, defined as an environment created by sound, without any judgment about what we hear. Schafer[2] categorized the main themes of a soundscape as keynotes (the basic sounds of the landscape created by its geography and climate), signals (foreground sounds which are surprising, sudden or annoying) and soundmarks (sounds by which one can identify a place). Soundscape is documented over sound recordings which allow qualitative as well as quantitative analysis of the sound environment.

The observation of the insufficiencies of the conventional methods, associating acoustical comfort to the sound level (mainly L_{Aeq}) led soundscape studies gain increasing importance in the evaluation of urban noise. Soundscape concept treats the sound environment as a multi-dimensional entity, based on the complex interaction between sound source, physical environment and human being. Derivations of objective and subjective data from field and laboratory studies, and attempts of correlating these data, are the common features of the soundscape studies. The flow diagram (Figure 1) derived after a widespread examination of soundscape literature summarizes the main scheme of soundscape studies. On the other hand the review of the related literature shows that there is not a common reconciliation about the properties of the subjective and objective data, the methods of data collection and evaluation, the statistical methods to be used in the correlation. Researches published on soundscape display a great variety of aim, area selection, evaluation criteria, and methodologies.

Depending on this, a long-term study[3] has been started in order to develop an approach based on the components of soundscape for the evaluation, conservation and rehabilitation of acoustical comfort in urban areas. The originating point of this study is the findings of previous studies[4-7] which are 'soundscape quality may be judged depending on its components (keynotes, signals, soundmarks)', and 'the perceptibility of the soundmark may be an important factor on the evaluation'.

In this study, in-situ measurements and sound quality metrics are utilized to acquire the objective data, whereas pairs of adjectives suitable for describing the sound environment, surveys, jury and listening tests are used to obtain the subjective data, in order to develop the purposed approach.

Proper documentation of the sound environment is the challenge of this study, depending on the fact that accurate analysis of the sound environment depends on accurate documentation. This article covers the documentation and analysis of the study and presents this process in 3 steps;

1st step; documentation of the sound environment in the field.

2nd step; edition, analysis and evaluation of the sound recordings in laboratory environment.

3rd step; comparative statistical analysis of the subjective data.

1st Step; Documentation of the Sound Environment in the Field

This part of the study aims to obtain proper objective and subjective data about the sound environment. Consequently, this step gives a summary of the information about selection of the pairs of adjectives and field study including the parts about determination of study areas and description of their sound environments, achievement of in-situ measurements and binaural sound recordings and application of surveys.

Selection of the Pairs of Adjective

Semantic differential test is utilized to examine the quality of sound environment as the common technic used for subjective evaluation in soundscape researches. In this test, subjects are expected to judge the sound by means of pairs of adjectives using a given scale. There are two basic challenges in the selection of the pairs of adjectives; the adequacy to the cultural, sociological, linguistic formations (vernacular language) of the related community, and the capability to describe the concerned sound environment.

In this context, the pairs of adjectives are listed according to the soundscape literature,[8-18] and are translated in Turkish considering the national researches related to the adjectives,[19-21] as well as the findings of

[1] Schafer, 1969
[2] Schafer, 1977, p.9-10
[3] Ozcevik, 2012
[4] Ozcevik et. al, 2007
[5] Ozcevik, Yuksel Can, 2008
[6] Ozcevik et. al, 2009
[7] Ozcevik, Yuksel Can, 2010
[8] Raimbault et. al. 2003, p.1241-56
[9] Raimbault, 2006, p.929-37
[10] Botteldooren et. al. 2006, p.105-23
[11] Brambilla, Maffei, 2006, p.881-6
[12] De Coensel, Botteldooren, 2006, p.887-97
[13] Nilsson, Berglund, 2006, p.903-11
[14] Berglund, Nilsson, 2006, p.938-44
[15] Cho, Cho, 2007
[16] Altınsoy et. al. 1999
[17] Lyon, 2003
[18] Nakashima et. al. 2007
[19] Orhon, 2009
[20] Şenyiğit, 2010
[21] Internet

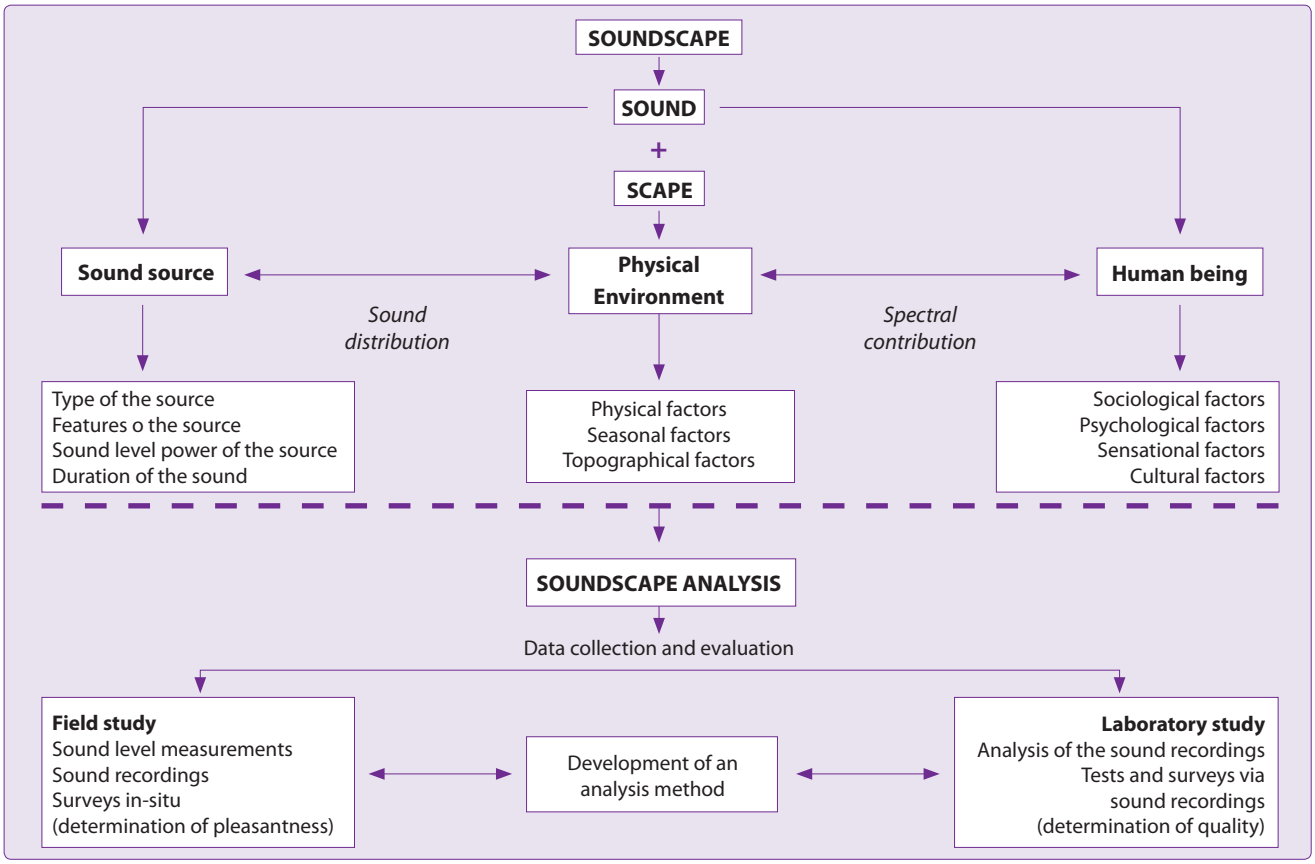

Figure 1. The complex interaction among sound source, physical environment and human being, at the soundscape researches.

pilot studies realized by the authors as a part of the wide-frame study. 30 pairs of adjectives selected to be used for the study are determined in English (EN) and in Turkish (TR) as listed below (Table 1).

Field study

Urban squares and streets which are transit crossing and/or recreational spaces of the urban life, and which have specific sound environment due to the diverse range of sound sources and the physical environment, are selected for this study to analyse the urban acoustical comfort.

Study Areas and Sound Environments

Four noisy urban areas, known to be assessed as having different acoustical pleasantness (having a pleasant soundscape or not) and chosen to exemplify Istanbul's specific identity by their soundscapes (Beşiktaş and Ortaköy Pier Squares, Bağdat Street and Barbaros Boulevard) are chosen and investigated. Sound sources that form the soundscape in selected areas are listed and soundmarks are determined (Table 2) by the observations on site, interviews with citizens and findings of in-situ pilot studies. Previsions of the acoustical satisfaction are introduced by considering the soundmarks' perceptibility, preponderancy and continuity in time, spatial effects and familiarities.

Sound Measurements and Binaural Sound Recordings

Soundwalk method providing the binaural sound recordings is used for this study in order to evaluate the soundscapes of the selected urban areas. The soundwalks are done at the season having suitable climate conditions to acquire high quality binaural recordings; on the day the sound environment exemplify the identity of the area and at the time interval where predicted soundmarks are present.

Binaural recordings and measurements of overall sound levels are simultaneously obtained. In the walks which lasted at 15 min., the routes for soundwalks are determined in order to have a general opinion about the sound environments of the selected areas, by considering how citizens act in these areas in their daily life (Figure 2).

The Survey on-Site

A survey form is prepared in order to be used for the

Table 1. Selected pairs of adjectives (EN and TR versions)

Pairs of adjectives			
EN version	**TR version**	**EN version**	**TR version**
Quiet-Loud	Sessiz-Gürültülü	Continuous-Discontinuous	Devamlı-Devamsız
Pleasant-Unpleasant	Memnuniyet Verici-Mem.Ver.Değil	Steady-Unsteady	Monoton-Değişken
Comfortable-Disturbing	Rahatlatıcı-Rahatsız edici	Calming-Eventful	Sakin-Hareketli
Stressing-Relaxing	Stres Yaratıcı-Dinlendirici	Lively-Deserted	Yaşayan-Terk Edilmiş
Artificial- Natural	Yapay-Doğal	Joyful-Empty	Neşeli-Durgun
Calming-Agitating	Yatıştırıcı-Heyecanlandırıcı	Exciting-Gloomy	Coşturucu-İç Karartıcı
Boring-Exciting	Sıkıcı-İlgi Çekici	Weak-Strong	Zayıf-Güçlü
Preferred-Not Preferred	Tercih Ederim-Tercih Etmem	Soft-Loud	Yavaş-Hızlı
Open-Enveloping	Açık-Sarmalayıcı	Dark -Light	Boğucu-Ferah
Harmonic-Discordant	Ahenkli-Ahenksiz	Muffled-Shrill	Boğuk-Net
Soft-Hard	Yumuşak-Sert	Dull-Sharp	Donuk-Keskin
Sharp-Not Sharp	Keskin-Keskin Değil	Light-Heavy	Hafif-Ağır
Crowded-Uncrowded	Kalabalık-Tenha	Smooth-Rough	Pürüzsüz-Pürüzlü
Organised-Disorganised	Düzenli-Düzensiz	Unclear-Distinct	Karışık-Ayırtedilebilir
Nearby-Far Away	Yakın Plan Ses-Uzak Plan Ses	Common-Strange	Alışılmış-Farklı

Table 2. Main characteristics of soundscape in selected areas, determinations of the soundmarks and previsions of the acoustical satisfaction

Study areas	Sources that form the soundscape	Soundmarks	Prevision of the acoustical satisfaction
Beşiktaş Pier Square	Dense traffic and sea transportation through Bosphorus Piers, bus and taxi stops Functional diversity in square Commercial hails as a type of sales approach	Traffic and sea transportation noise, sounds from the pier, sounds of wind, sea/wave, birds, sale approach (commercial hails) and voices	Unsatisfactory
Ortaköy Pier Square	Sea transportation through Bosphorus Pier and mosque Functional diversity in square Commercial hails as a type of sales approach	Sea transportation, sounds from the pier, sounds of wind, sea/wave, birds, shopping, Ezan, sale approach (commercial hails) and voices	Satisfactory
Bağdat Street	Dense traffic (public transportation, luxury and modified cars) Music broadcast from the cars Pedestrian, bycles and buggies Functional diversity at street Commercial music broadcast	Traffic noise, sounds of children and shopping, music and voices	Unsatisfactory
Barbaros Boulevard	Dense traffic Urban park near the street Student activities due to the proximity of the street to the university campus and highschool Functional diversity at street	Dense traffic noise, siren and voices	Unsatisfactory

studies on the subjective perception and evaluation of the soundscape. Questions in survey are gathered from soundscape literature and rearranged in consequence with the findings of mentioned pilot studies to obtain fast/practical, reliable and compatible subjective evaluation on site.

Figure 2. Routes of the soundwalks in the selected areas.

The survey form is composed of two parts; a questionnaire part where the general information about sound environment with the soundmarks and their pleasantness are investigated; and a semantic differential test where the quality of sound environment is analyzed. The questionnaire part consisted of 16 questions on the categories about personal information, area usage, congruity of the physical environment to the respondents expectations (general judgment, listing the several environmental factors -given as landscape, scenery, vegetation, cleanliness, safety, clean air, silence, odour, functional structure, location, ratio between constructed and circulation/recreational areas, building heights, historical/touristic value, sales approach, social aspects, entertainment structure-; according to priority on the perception of area and their congruity to the respondents expectations), sound environment evaluation of the area (determination of soundmark/s of the area and the satisfaction from the soundmark/s).

In semantic differential test, the selected 30 pairs of adjectives are used to determine acoustical pleasantness in detail. For each selected areas, 30 surveys are done by 120 citizens who are randomly selected on-site and have no hearing problems.

2nd Step: Edition, Analysis and Evaluation of the Sound Recordings in Laboratory Environment

This part of the study aims to obtain proper data to be assessed if the subjective evaluation of soundscapes in laboratory environment is consistent with the data obtained from the field study. Therefore, this step describes the laboratory study including analyses of sound quality metrics, applications of jury and listening tests, after given brief information about sound quality and the metrics.

Sound Quality and the Metrics

The term of 'sound quality', introduced in the 1980's, is defined as 'the adequacy of a sound in the context of a specific technical goal and/or task'[22] Sound quality is not an inherent property of the sound. It is rather

[22] Blauert, 1994

something that develops when listeners are exposed to the sound and judge it with respect to their desires and/or expectations in a given context. Consequently, the usage of noise indicators such as SPL or L_{Aeq} is not sufficient to define the sound quality, in other words quantitative/objective data derived by the current indicators describing the sound environment is insufficient. Therefore psycho-acoustics and physical manner of the humans experiencing the sound environment are taken into consideration. In this way, the attributes of the sound that can be calculated and/or measured and the responses of the listener to the sound are considered respectively as the objective and subjective dimensions of the sound.[19]

Sound quality metrics alias psycho-acoustic parameters/quantities, mostly improved by Zwicker,[23] are defined as the mathematical model of sound perception. The applicability of these metrics in sound quality evaluation has been successfully proved.

The metrics which are commonly used in the researches can be listed as; Zwicker loudness, sharpness, roughness, fluctuation strength, tone-to-noise ratio and prominence ratio. All metrics refer a specific attribute of the sound by a single scalar quantity; loudness is linearly proportional to SPL; sharpness can be regarded as a measure of tone colour; roughness is governed by temporal variations of a sound and reaches a maximum for modulation frequencies around 70 Hz; fluctuation strength deals with the modulation frequencies around 4 Hz; tone-to-noise ratio regards if the pure tone is dominant or not; prominence ratio indicates the prominence of tonal components of the sound.

The subjective evaluation of sound quality is obtained by the jury and listening tests. Sound quality concept, is generally being used for stable/stationary signals e.g., in an industrial product, for mechanical sound sources. On the other hand the increased usage of sound quality concept for the evaluation of urban sound environment is observed in recently published and ongoing researches.[10,24-34]

Laboratory Study

The laboratory study has been carried out to investigate the subjective understanding of the areas including the subjects' evaluation of physical and psycho-acoustical perception of the records and the objective analysis of the records by utilizing the technically and statistically feasible software.

Therefore, firstly the original sound recordings which lasted approximately 15 min. and obtained by the soundwalk method, are edited to suit the laboratory tests. Then the sound quality metrics are calculated by using software, and finally jury and listening tests are realized by using the edited recordings. The appropriate and accurate re-organisation of the 15 min. sound recordings is of utmost importance for the reliability and repeatability of the research. The issues which are considered and the steps of the re-organisation of the sound recordings are as follows;

• Short time average is preferred for the analysis of the fluctuating sound environment, instead of long time average.

• The usage of short time segments is preferred for laboratory tests instead of the original recordings (15 min), in order to avoid the subjects' distractions and to ensure the subjects' concentration.

• Depending on the hypothesis of the mentioned wide-frame research ("soundscape quality may be judged depending on its components (keynotes, signals, soundmarks), and the perceptibility of the soundmark may be an important factor on the evaluation"), two different 5 minutes' periods of each recording are decided to be utilized for the study; one is "continuous 5 minutes' period" which is selected according to the continuous segment having complete auditory data of sound environment, especially predicted soundmark/s of related urban area; the other is "edited 5 minutes' period" which is arranged by 'Wavepad Sound Editor' software considering the segments having only the predicted soundmark/s.

• Several pilot studies were actualized to inquire the attempt of using two different 5 minutes' periods. According to the findings of the pilot studies, it is realized that there is no differences between the subjective evaluations of two periods selected from the same sound environment, moreover, they are assessed as belonging to the same recordings by the subjects. Therefore, the "edited 5 minutes' period" is selected to analyze for both subjective and objective evaluations of the sound environments in laboratory study.

• Nine sound segments prepared through the division of the 15 minutes' period into 3 minutes with 1.5 min. overlap by using 'Wavepad Sound Editor' software (0-3 min., 1.30-4.30 min., 3-6 min., 4.30-7.30

[10] Botteldooren et. al. 2006, p.105-23
[19] Orhon, 2009
[23] Zwicker, Fastl, 1999
[24] Guastavino, 2006, p.945-51
[25] Genuit, Fiebig, 2006, p.952-8
[26] Schulte-Fortkamp et. al. 2007
[27] Dubois, Guastavino, 2007
[28] Axelsson, 2009
[29] Louwerse et. al. 2006
[30] Defreville, Lavandier, 2005
[31] Faus et. al. 2007
[32] Poxon et. al. 2009
[33] Fiebig et. al. 2009
[34] Romero et. al. 2010

min., 6-9 min., 7.30-10.30 min., 9-12 min., 10.30-13.30 min., and 12-15 min.), are decided to be used separately for objective evaluations in order to verify if the edited 5 minutes' period reflects the whole recording.

• Instantaneous changes in sound level are decided to be evaluated due to the fact that the sound is fluctuating in time. In the laboratory study the objective evaluation is realised through statistical calculations depending on the relevant literature.[35-37]

It is obvious that the 'edited 5 minutes' samples has to be analyzed in order to confirm their quantitative and qualitative accuracy regarding the actual sound environment. Statistical calculations of the sound quality metrics for the edited 5 minutes' period, and the selection of nine sound segments each having 3 minutes' period utilized for the quantitative confirmation are explained in the following section. The comparative analysis between the on-site survey and the laboratory tests (jury and listening tests) realised for the qualitative confirmation is presented at the 3th step.

The study areas, L_{Aeq} levels of the edited 5 minutes' periods together with the average levels of nine sound segments each having 3 minutes' period and their standard deviations are given in Table 3. Data reported in Table shows that the L_{Aeq} levels of the edited 5 minutes' periods and average levels of nine 3 minutes' periods are considerably close to each other.

Analyses of Sound Quality Metrics

The edited 5 minutes' periods and the nine sound segments each having 3 minutes' period are transferred to sound quality software 'B&K PULSE Sound Quality', to determine the sound environment quality of the selected areas via the sound quality metrics.

Table 3. L_{Aeq} levels of the edited 5 minutes' periods and the average L_{Aeq} levels of nine sound segments each having 3 minutes' period with their standard deviations

	L_{Aeq} levels		
Study areas	**Edited 5min. period**	**Average of nine 3min. periods**	**Std. dev. of 3min. periods**
Beşiktaş Pier Square	84.85	82.55	1.27
Ortaköy Pier Square	84.19	82.44	1.88
Bağdat Street	83.96	84.15	1.35
Barbaros Boulevard	86.26	85.86	2.15

[35] De Coensel et. al. 2005, p.175-94
[36] Rychtarikova, Vermeir, 2011
[37] Dökmeci, Kang, 2011

The instantaneous values of six sound quality metrics regarding to the edited sound recordings are calculated by the software; however, only four metrics (Zwicker loudness, sharpness, roughness and fluctuation strength) which refer significant results, are selected to be used for this study. The results of statistical calculations are also taken into consideration. The ratios used for these calculations are determined as %5 or %10, %50, and %90 or %95 which respectively imply the exceptional events, the possible state and the continuous state.

Statistical values of the metrics which are calculated for the edited 5 minutes' period are compared with the average values for the nine 3 minutes' periods, concerning the areas. The graphs seen in Figure 3 shows that the values of the metrics for the edited 5 minutes' periods are in the standard deviations interval of the related metrics for the nine 3 minutes' periods meaning that the edited 5 minutes' period samples are quantitatively accurate. The statistical values of the metrics related to mentioned recordings are used in the study.

Jury and Listening Tests

30 subjects who don't have hearing bias, listened the edited 5 minutes' period samples of the areas at designated array; Bağdat Street-Beşiktaş Pier Square-Barbaros Boulevard-Ortaköy Pier Square, by using headphones with active noise control. No information about the recordings is given to the subjects; they are requested to do the listening and the jury tests. For each area, each of the tests is done under controlled conditions in order to achieve 120 subjective evaluations of the related sound environments. Consequently, the proper subjective data, displaying the qualitative accuracy of the edited 5 minutes' samples to be used in the laboratory study, is obtained.

Jury test: 30 pairs of adjectives listed in Table 1, are utilized to examine the quality of sound environment in jury test.

Listening test: Subjects are asked to write down what they heard in free technique, and they are requested to explain the recording's area, to make estimation of the area and to define the sound sources.

3rd Step: Comparative statistical analysis of the subjective data

The aim of this part of the study is to assess if there is a qualitative correlation between edited sound recordings and the actual sound environment. In this part, comparative analysis between the field and the

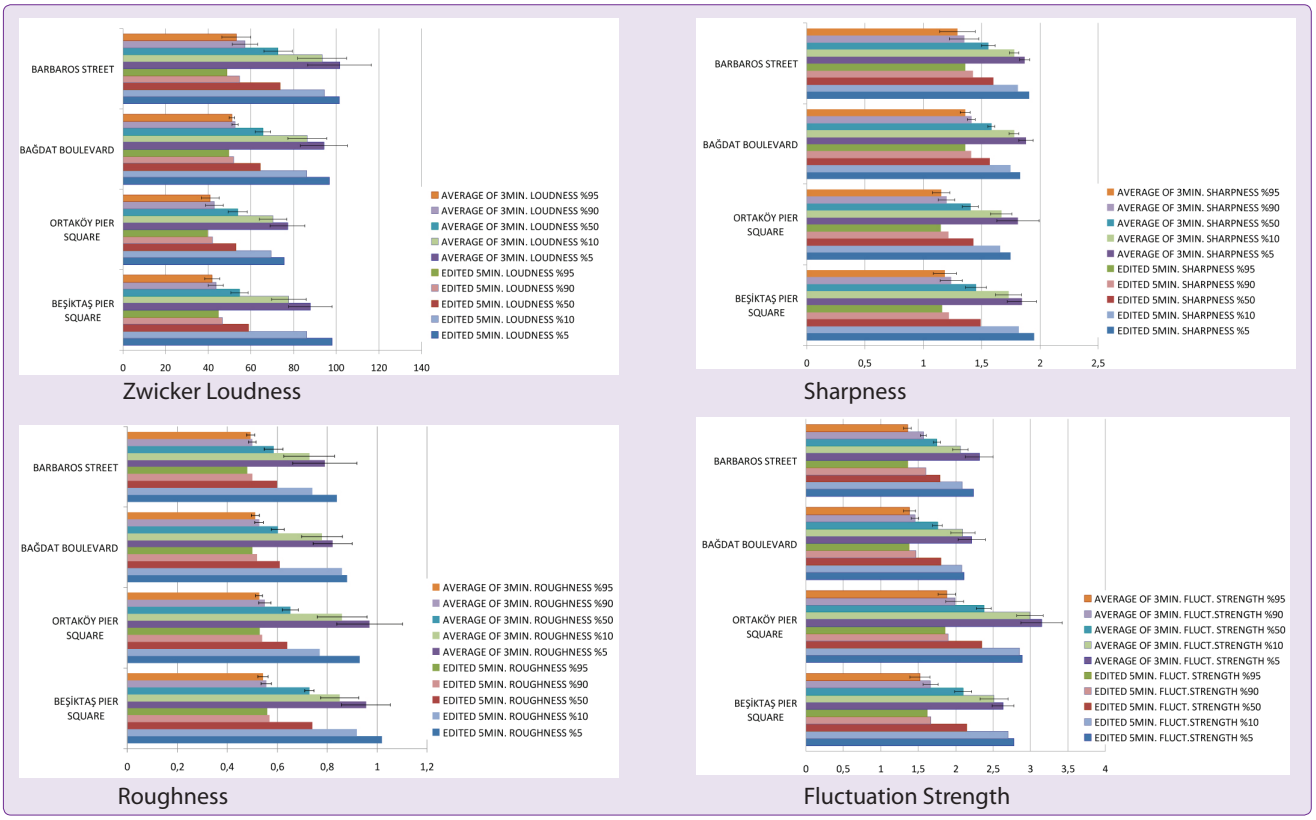

Figure 3. Graphs showing the statistical values of the sound quality metrics calculated for the edited 5 minutes' period together with the average values for the nine 3 minutes' periods and their standard deviations, concerning the areas.

laboratory studies which is realized in four areas, is revealed by using statistical software SPSS 18.

Statistical reliability is calculated for each data on a percentage basis according to Cronbach's Alpha value which necessitates the percentage rate over %60, referring the reliability of data in interest. This value is %79 for the survey; %63 for the questionnaire part and %86 for the semantic differential test and %80 for the jury tests.

Comparative Analysis Between Semantic Differential Tests and Jury Tests

Comparisons of the Variance analysis

Variance analysis (valuing the Post Hoc Test after ANOVA test) is separately done with the data held from semantic differential test and jury test in order to investigate the relation (the similarities and/or differences) among the evaluations of sound environments. Pairs of adjectives showing statistical significance are found by using the results of these analyses (Table 4).

T-Test analysis

T-Test analysis is done with the pairs of adjectives utilized to examine the quality of sound environment via the semantic differential test in the field and the jury test in the laboratory, in order to investigate the relation (the similarities and/or differences) among the evaluations of the adjectives realized at the two different environments (the field and the laboratory). Pairs of adjectives showing statistical significance are found by using the results of this analysis (Table 5).

Comparative Analysis Questionnaire Surveys on-Site and Listening Tests

The texts held from the laboratory listening tests and the responses held from the questionnaire surveys on site are summarized in Tables 6-9; one for each area. Mentioned tables are organized to visualize the subjective relationship of the field and laboratory studies, as well as to give a clear comparison of the results obtained from these two different types of subjective evaluations.

It is seen that there is a consistent relation within the two different types of subjective assessments in these areas. The physical environments are assessed as 'congruous' in all fields, but acoustical environments are generally defined as 'bad' except Ortaköy Pier Square

Table 4. The results of the variance analysis utilizing the field and laboratory data

The evaluation of variance analysis utilizing	The pairs of adjectives **do not denote significant statistical differences**	The sound environment of **Ortaköy Pier Square** is evaluated as **different**	
The field data Semantic differential tests	• 'Crowded – Uncrowded' • 'Continuous–Discontinuous' • 'Muffled – Shrill' • 'Dull – Sharp' • 'Unclear – Distinct' • 'Calming – Eventful'	• 'Quiet – Loud' • 'Pleasant - Unpleasant' • 'Comfortable –Disturbing' • 'Stressing – Relaxing' • 'Artificial – Natural' • 'Calming – Agitating' • 'Boring – Exciting' • 'Harmonic – Discordant' • 'Soft – Hard'	• 'Sharp – Not Sharp' • 'Joyful – Empty' • 'Exciting – Gloomy • 'Soft – Loud' • 'Dark – Light' • 'Light – Heavy' • 'Smooth – Rough' • 'Common – Strange'
The laboratory data Jury tests	• 'Artificial – Natural' • 'Calming – Agitating' • 'Open – Enveloping' • 'Nearby – Far away' • 'Continuous–Discontinuous' • 'Lively – Deserted' • 'Weak – Strong' • 'Muffled – Shrill' • 'Dull – Sharp' • 'Common – Strange'	• 'Quiet – Loud' • 'Pleasant – Unpleasant' • 'Comfortable –Disturbing' • 'Stressing – Relaxing' • 'Preferred - Not Preferred' • 'Soft – Hard' • 'Organised –Disorganised' • 'Soft – Loud' • 'Dark – Light' • 'Smooth – Rough'	• 'Unclear – Distinct' • 'Calming – Eventful'
Both of the data Semantic differential tests and Jury tests	• 'Artificial – Natural' • 'Calming – Agitating' • 'Open – Enveloping' • 'Crowded – Uncrowded' • 'Nearby – Far away' • 'Continuous–Discontinuous' • 'Lively – Deserted' • 'Weak – Strong' • 'Muffled – Shrill' • 'Dull – Sharp' • 'Unclear – Distinct' • 'Common – Strange' • 'Calming – Eventful'	• 'Quiet – Loud', • 'Pleasant - Unpleasant' • 'Comfortable –Disturbing' • 'Stressing – Relaxing' • 'Boring – Exciting' • 'Preferred - Not Preferred' • 'Harmonic – Discordant' • 'Soft – Hard' • 'Sharp – Not Sharp' • 'Organised –Disorganised' • 'Steady – Unsteady' • 'Joyful – Empty' • 'Exciting – Gloomy'	• 'Soft – Loud' • 'Dark – Light' • 'Light – Heavy' • 'Smooth – Rough'

by the subjects. The definitions of soundmark/s in both of the assessment types, support each other and they are in correspondence with the predictions. The areas are estimated correctly depending on the definitions of soundmark/s, moreover a certain number of the subjects called the area by its proper name for each.

The findings held from this analysis obviously display that acoustical satisfaction of the sound environment is affected by the soundmarks', depending on their perceptibility, preponderancy and continuity in time, spatial effects and familiarities. In other words, 'the presence and perceptibility of satisfactory soundmark affect the assessment of the soundscape, positively'.

Review

A wide-frame research is realised in order to develop an approach based on soundscape for the evaluation, conservation and rehabilitation of acoustical comfort in urban areas. The hypothesis of this study is determined as; "soundscape quality may be judged

Table 5. The results of the T-Test analysis utilizing the field and laboratory data

The sound environments of the fields are evaluated **as similar** due to the two different environments	The pairs of adjectives **denote significant statistical differences** regarding the two different environments	
• 'Quiet - Loud'	• 'Pleasant - Unpleasant'	• 'Weak - Strong'
• 'Artificial - Natural'	• 'Comfortable - Disturbing'	• 'Dark –Light'
• 'Calming - Agitating'	• 'Stressing - Relaxing'	• 'Muffled - Shrill'
• 'Open - Enveloping'	• 'Boring - Exciting'	• 'Dull - Sharp'
• 'Soft - Hard'	• 'Preferred - Not Preferred'	• 'Unclear - Distinct'
• 'Sharp - Not Sharp'	• 'Harmonic - Discordant'	• 'Common - Strange'
• 'Crowded - Uncrowded'	• 'Organised - Disorganised'	
• 'Calming - Eventful'	• 'Nearby - Far Away'	
• 'Lively - Deserted'	• 'Continuous - Discontinuous'	
• 'Soft - Loud'	• 'Steady - Unsteady'	
• 'Light - Heavy'	• 'Joyful - Empty'	
• 'Smooth - Rough'	• 'Exciting - Gloomy'	

depending on its components and the perceptibility of the soundmark may be an important factor on the evaluation".

The process followed in this study, on documenting and analyzing the sound environment is presented in this article with 3 steps. The general assessment of these steps can be summarized as follows;

At the 1st step

The field study part of the proposal is presented in order to document the actual sound environment. The objective of this step is to create a basis to be used in further soundscape researches. The selection of the pairs of adjectives, in-situ sound measurements, binaural sound recordings, surveys are the steps of this part.

Table 6. Overall data obtained from the subjective assessments of soundscape in Beşiktaş Pier Square

İnferences Based on the Laboratory Listening Tests		**Responses of the Questionssaire Survey on-site**	
Beşiktaş Pier Square			
Spatial evaluation	All subjects correctly defined the area as open and 73% of the subjects as a long the front, 47% as pier, 30% as transportation area, 23% as transit crossing area.	**Reasons of coming to this place**	67% 'transportation' 13% 'calming down/relaxing'
Recognition of the function	All subjects noted that there are many functions in the area. 73% of the subjects described the area as a commercial place		
Assessment of the acoustical environment	53% of the subjects used the adjectives 'crowded and eventful', 40% 'noisy/loud', 20% 'common', 13% 'boring and disturbing' to assess the acoustical environment.	**Congruity of the physical environment to the respondents expectations (using the listed environmental factors)**	**Factors** / **Uncongruous** / **Neautral** / **Congruous** Landscape 20% 13% 67% Scenery 0% 7% 93% Silence 80% 13% 7% Functional struc. 13% 7% 80% Location 0% 0% 100% Sales approach 57% 13% 30%
			Generally the environment is assessed as 53% 'congruous'
		Assessment of the acoustical environment	**bad** / **neutral** / **good** 57% 33% 10%
Determination of the sound sources	All subjects defined voices, traffic noise and sound of the electronic ticketing of public transportation. 63% of the subjects defined sound of sales approach and ship/motor's siren, 57% siren and sound of wind, 27% sounds of gammon and teaspoon/cutlery.	**Determination of soundmark/s of the area and the satisfaction from the soundmarks/s (response alternatives 'Satisfactory', 'Neutral', 'Unsatisfactory')**	**Sound sources** / **Soundmark** / **Satisfaction category** Wind 53% 47% satisfactory Sea/wave 90% 90% satisfactory Ship/motor noise 100% 83% satisfactory Ship/motor's siren 93% 77% satisfactory Voices 97% 40% neutral Sales approach 83% 77% unsatisfactory Traffic noise 100% 100% unsatisfactory Hom 100% 100% unsatisfactory
Estimation of the area, definition of the soundmark/s	77% of the subjects called the area as pier and 30% as bus stop, based on the voices, traffic noise and sound of the electronic ticketing of public transportation. 33% of the subjects called Beşiktaş Pier Square by it's proper name by considering inter alia sound of sales approach, ship/motor's siren and siren.		

Table 7. Overall data obtained from the subjective assessments of soundscape in Ortaköy Pier Square

İnferences Based on the Laboratory Listening Tests		Responses of the Questionssaire Survey on-site	
Ortaköy Pier Square			
Spatial evaluation	All subjects correctly defined the area as open and along the front. 17% of the subjects defined as square which is closed to traffic and including a playground and 50% mentioned that there are some cafes and restaurants in the area.	**Reasons of coming to this place**	37% traveling around/overseeing the scenery 20% calming down/relaxing 17% working 10% meeting with friends 10% spend joyful time
Recognition of the function	All subjects noted that there are many functions in the area and they described the area as a commercial place.	**Congruity of the physical environment to the respondents expectations (using the listed environmental factors)**	**Factors** / **Uncongruous** / **Neautral** / **Congruous** Landscape 3% 24% 73% Scenery 0% 0% 100% Silence 20% 27% 53% Functional struc. 7% 16% 77% Location 3% 4% 93% Sales approach 43% 17% 40 Generally the environment is assessed as 53% 'congruous'
Assessment of the acoustical environment	50% of the subjects used the adjectives 'crowded', 30% 'calming', 20% 'eventful and loud/noisy but not disturbing', 17% 'comfortable-relaxing and unclear but light' to assess the acoustical environment.	**Assessment of the acoustical environment**	**bad** / **neutral** / **good** 16% 27% 57%
Determination of the sound sources	All subjects defined voices and ship/motor's siren. 60% of the subjects defined sound of sales approach, 53% sounds of children, 43% sounds of gammon and teaspoon/cutlery, 33% sounds of sea/wave and 27% music and sound of birds.	**Determination of soundmark/s of the area and the satisfaction from the soundmarks/s (response alternatives 'Satisfactory', 'Neutral', 'Unsatisfactory')**	**Sound sources** / **Soundmark** / **Satisfaction category** Bird 67% 67% satisfactory Wind 67% 63% satisfactory Sea/wave 97% 97% satisfactory Voices 93% 33% satisfactory Ezan 77% 57% satisfactory Shopping 53% 37% satisfactory Pier usage 93% 67% satisfactory Ship/motor noise 100% 90% satisfactory Ship/motor's siren 93% 80% satisfactory Sales approach 83% 77% satisfactory
Estimation of the area, definition of the soundmark/s	70% of the subjects called the area as pier and square, based on the voices, sound of sales approach and ship/motor noise. 37% of the subjects called Ortaköy Pier Square by it's proper name.		

Table 8. Overall data obtained from the subjective assessments of soundscape in Bağdat Street

İnferences Based on the Laboratory Listening Tests		Responses of the Questionssaire Survey on-site	
Bağdat Street			
Spatial evaluation	All subjects correctly defined the area as open and a street. 50% of the subjects mentioned that there are some cafes and restaurants in the area.	**Reasons of coming to this place**	30% eating-drinking something/shopping 23% working 20% meeting with friends 10% traveling around 10% spend joyful time
Recognition of the function	All subjects noted that there are many functions in the area and they described the area as commercial place.	**Congruity of the physical environment to the respondents expectations (using the listed environmental factors)**	**Factors** / **Uncongruous** / **Neautral** / **Congruous** Landscape 13% 7% 80% Scenery 27% 16% 47% Silence 67% 17% 16% Functional struc. 14% 9% 77% Location 10% 3% 87% Sales approach 10% 3% 87% Generally the environment is assessed as 93% 'congruous'
Assessment of the acoustical environment	70% of the subjects used the adjectives crowded-complex, 37% noisy/loud but not disturbing, 27% common, 23% event ful-dynamic and burdensome but lively to assess the acoustical environment.	**Assessment of the acoustical environment**	**bad** / **neutral** / **good** 60% 23% 17%
Determination of the sound sources	All subjects defined voices, traffic noise and music. 40% of the subjects defined sound of cutlery, 27% sound of children/baby, 7% sound of modified vehicles.	**Determination of soundmark/s of the area and the satisfaction from the soundmarks/s (response alternatives 'Satisfactory', 'Neutral', 'Unsatisfactory')**	**Sound sources** / **Soundmark** / **Satisfaction category** voices 93% 40% satisfactory children 50% 27% satisfactory shopping 60% 27% satisfactory music 60% 330% satisfactory traffic noise 100% 100% unsatisfactory hom 97% 97% unsatisfactory
Estimation of the area, definition of the soundmark/s	All subjects called the area as street, based on the voice and traffic noise. 47% of the subjects called Bağdat Street by it's proper name by considering inter alia music and sound of cutlery.		

30 pairs of adjectives (given in Table 1) are selected and used in the semantic differential test. The evaluation of subjective data held from this step showed that the soundscapes can be discriminated by using appropriate pairs of adjectives. Consequently the steps of the selection of the pairs of adjectives had been

Table 9. Overall data obtained from the subjective assessments of soundscape in Barbaros Boulevard

İnferences Based on the Laboratory Listening Tests		Responses of the Questionssaire Survey on-site	
Barbaros Boulevard			
Spatial evaluation	All subjects correctly defined the area as open and a street. 23% of the subjects as transportation artery.	**Reasons of coming to this place**	50% transportation 40% working
Recognition of the function	All subjects noted the area as transit crossing space and 17% of the subjects as a space which has rarely pedestrian circulation.	**Congruity of the physical environment to the respondents expectations (using the listed environmental factors)**	**Factors** / **Uncongruous** / **Neautral** / **Congruous** Landscape 23% 17% 60% Scenery 17% 6% 77% Silence 90% 3% 7% Functional struc. 3% 20% 77% Location 3% 4% 93% Sales approach 20% 27% 53%
Assessment of the acoustical environment	70% of the subjects used the adjectives noisy/loud, 47% high attendence-complex, 27% burdensome, 23% eventful but boring and 13% common dark and disturbing to assess the acoustical environment.		Generally the environment is assessed as 93% 'congruous'
		Assessment of the acoustical environment	**bad** / **neutral** / **good** 73% 14% 13%
Determination of the sound sources	All subjects defined voices, traffic noise and music. 43% of the subjects defined sound of wind 33% music, sound of cat and children/baby.	**Determination of soundmark/s of the area and the satisfaction from the soundmarks/s (response alternatives 'Satisfactory', 'Neutral', 'Unsatisfactory')**	**Sound sources** / **Soundmark** / **Satisfaction category** voices 77% 37% unsatisfactory traffic noise 100% 97% unsatisfactory hom 100% 97% unsatisfactory siren 60% 57% unsatisfactory
Estimation of the area, definition of the soundmark/s	All subjects called the area as street, based on densely traffic noise and 53% of the subjects as main street based on inter alia voices and sound of students; moreover, 17% called Barbaros Boulevard by it's proper name.		

clarified by the studies realized in this part of the research. On the other hand, the soundmarks of the areas are highlightened by the questionnaire part of the survey. The information obtained from this part of the research is used in the next step which is laboratory study.

At the 2nd step;

A proposal for edition, analysis and evaluation of the sound recordings in laboratory environment is developed in order to evaluate the soundscape upon the sound quality concept and the metrics. The procedure of the proposal can be summarized as follows;

• Editing the recordings to cover predicted soundmarks to 5 minutes' period.

• Preparing 3 minutes segments (with 1,5 minutes overlap) to confirm the quantitative values of edited 5 minutes' period regarding the actual sound environment by using statistical values of the sound quality metrics.

• Realizing jury and listening tests with sufficient number of subjects.

The information obtained from this part of the research is used in the next step which is the comparative analysis between the field and the laboratory studies.

At the 3rd step;

Comparative analysis of the subjective data derived from the field and the laboratory studies is revealed by using statistical software, in order to confirm the qualitative accuracy of the edited 5 minutes' period regarding the actual sound environment. According to the evaluation of this step;

• The pairs of adjectives showing statistical significance by using the statistical analyses (comparisons of variance analysis and T-Test analysis) between the semantic differential tests and jury tests are listed.

• The consistencies are defined by using the results of questionnaire surveys on-site and listening tests. Accordingly, the inferences based on the laboratory listening tests are in correspondence with the responses on the questionnaire on-site.

The overall analysis of all steps showed that the edited sound recordings (5 minutes) used for the laboratory study, are in good correlation both with the full recordings (15 minutes) taken in situ and the actual sound environment of the fields.

Depending on the findings and results, the proposal based on soundscape for documentation and analysis of the urban acoustical environment can be described with the titles/headings listed below;

• Selecting the study areas known to be assessed/judged as having different acoustical pleasantness

• Determining the sound sources and the soundmarks in selected areas and predicting the acoustical

satisfaction

• Making in-situ measurements (sound measurements and binaural sound recordings) with soundwalk method at the season having suitable climate conditions to acquire high quality binaural recordings; on the day the sound environment exemplify the identity of the area and at the time interval where predicted soundmarks are present

• Realizing the survey on-site composed of two parts; a questionnaire part and a semantic differential test, with sufficient number of subjects

• Editing the sound recordings to suit the laboratory study into the 5 minutes' period covering only the predicted soundmarks

• Preparing the 3 minutes segments with 1,5 minutes overlap in order to confirm the quantitative accuracy of edited 5 minutes' period regarding the actual sound environment

• Calculating and evaluating the statistical values (%5 or %10, %50, and %90 or %95) of the sound quality metrics (Zwicker loudness, sharpness, roughness and fluctuation strength) for the recordings (edited 5 minutes' period and nine 3 minutes' segments)

• Realizing jury and listening tests with sufficient number of subjects

• Analyzing the subjective data by statistical software (calculating Statistical reliability)

• Comparing the semantic differential test and jury tests in order to determine the pairs of adjectives denote significant differences regarding the sound environments of selected areas and the environments where the evaluations of the adjectives realized (the field and the laboratory)

• Comparing the questionnaire surveys on site and the listening tests in order to confirm the qualitative accuracy of edited 5 minutes' period regarding the actual sound environment.

Another important outcome of this article is to propose an approach to correlate the sound quality metrics with the semantic differential test. Depending on this, this study will allow a methodology that will simplify the evaluation of soundscapes by using sound recordings and sound quality metrics.

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