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EVALUATION OF DIYARBAKIR GAZI STREET SOUND ENVIRONMENT PERCEPTION BY SOUNDSCAPE APPROACH

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Abstract: *In this study, it was aimed to measure the perception of sound environment of users in urban spaces with sound quality metrics (loudness, sharpness, roughness, and fluctuation strength). For this purpose, a questionnaire was applied to participants in Gazi Street, Suriçi district of Diyarbakir, which was selected as a field study. In the questionnaire study, participants were asked about the demographic / personal characteristics, questions about the purpose and duration of use of the space, and 35 adjective pairs with 5 bipolar scales in order to determine the perception of the sound environment. Binaural sound recordings were also performed simultaneously when the survey was conducted. The quantitative data of the loudness, sharpness, roughness, and fluctuation strength metrics of these sound records are calculated. By analyzing the results obtained from the questionnaire and the quantitative data of the sound recordings, correlations between the sound environment perception of the users and the sound quality metrics were determined. Apart from the quantitative data of sound recordings, the effect of the parameters (demographic / personal / social) which can affect the perception of the sound environment in urban spaces has been tried to be determined. In addition, the relationship between quantitative data of sound recordings and meteorological data has also been analyzed.*

Key words*: Soundscape, Sound environment, Sound quality, Diyarbakir*

1. Introduction

In recent times, when studies about acoustic comfort were examined, the term “soundscape” has been often encountered and this term has been used in many disciplines [1]. Within etymology, the term “-scape” is defined as “area, place, field of vision” [2]. In ISO 12913-1 (2014), soundscape is described “acoustic environment perceived or experienced and/or understood by a person or persons” [3].

At first, the primary soundscape concept was confronted in music and acoustic ecology studies. In a quick process, the integrated approach of sound environment and perception stimulated more interests in other disciplines (acoustics, architecture, environmental health, psychology, sociology and urban studies, etc.) [4-6]. In evaluation of acoustic comfort through soundscape, both annoyance from noise and effects of different sounds peculiar to the analyzed field can be considered. Sound

environments of urban places are objectively measured, and also, users' subjective data about their perception can be assessed. The importance of soundscape in urban planning, designing and managing has been increasing in improving and/or increasing users' life quality day by day. Soundscape has not been only considered under noise control, it has dealt with sound concept as a source, one of the components of spatial planning and designing process. Soundscape studies have been done about the effective usage, design and management of sound resources [7-12].

In soundscape studies, various acoustic parameters and subjective data of users have been evaluated. In addition to standard acoustic quantities, researchers emphasize that psychoacoustic parameters (sound quality metrics), which are related to human perception, should be assessed in sound environment evaluations. In this study, acoustic and psychoacoustic parameters obtained by physical measurements and questionnaires made by subjective evaluators of users were used to investigate the region where the study was performed in terms of acoustic comfort.

The Suriçi region, the historical region surrounded by the walls of Diyarbakır was chosen as a study area. The region is one of the places where lots of sound sources are available to be heard in urban areas. This region involves various sound sources including not only traffic or human sounds but also soundmarks which belong to the region. Different sound sources exist together, which makes us have a great variety of quantitative information. In this study carried out in Gazi Street of the Suriçi Region, quantitative data of equivalent continuous sound pressure level, loudness, sharpness, roughness, fluctuation strength metrics were calculated and the subjective data of users were evaluated.

Equivalent continuous sound pressure level represents a fixed level which shows changes at levels in a certain period, is generally measured as A weighted sound level and is the equivalent one of noise in terms of energy [13]. $L_{Aeq,T}$ is used to determine sound pressure level in a certain T period. Its unit is desibel (dB). It is estimated using the Equation 1 [14].

$$L_{Aeq,T} = 10\lg\frac{\frac{1}{T}\int_{t_1}^{t_2} p_A^2(t)\,dt}{p_0^2}\ \text{dB} \qquad (1)$$

T: during a stated time interval of duration (starting at t_1 and ending t_2)

$p_A(t)$: the A-weighted instantaneous sound pressure at running time t

$p_{(0)}$: the reference sound pressure 20 μPa

The term "**sound quality**" described as "the original feasibility of sound in accordance with technics, objectives and/or tasks" started to be used in 1980s [15]. Psychoacoustic metrics were introduced for the evaluation of sound quality. [16]. Psychoacoustic metrics were defined as the mathematical model of sound perception. In this paper, loudness, roughness, sharpness and fluctuation strength metrics of the sound quality (psychoacoustic) metrics were examined.

Loudness is a type of subjective feeling in sound volume. Its unit is phon (P), its values are equal to SPL values in 1kHz [16]. Sound quality metrics are estimated based on time series of values regarding loudness metrics [17]. Zwicker and Fastl (1999) emphasised that the sense-stimulant relation of loudness metrics could be measured when the question of how a sound was high or soft was answered. They suggested that sensual satisfaction depended on loudness metrics [16].

Sharpness is an indicator of spectral balance between low and high frequencies [15]. Its unit is 'acum'. Taking only one of them into account, sharpness of one sound may be confused with sharpness of the other sound. Zwicker and Fastl (1999) stated that a sense of sharpness could be related with density, furthermore, it was closely associated with sensual pleasantness. When the sharpness value became high, the users' pleasantness level became lower [16].

Time-wise change of sound has two types of effects. One of them is **roughness**, the other one is **fluctuation strength**. **Roughness** represents temporary, slow changes of nearly 70 Hz in sound volume. Its unit is "asper". The values of roughness metrics is estimated from the intervals of 500 ms in time series of loudness metrics [17]. Roughness is a modulation based metric described as creak, grate, peep. Examples involving wuthering sounds such as a shaver or a sewing machine can be given as examples to roughness sounds. This type of sound generally creates unpleasant effects [15].

Fluctuation strength is estimated based on nonstable loudness and represents temporary, slow changes of nearly 4 Hz in sound volume [17-18]. Its unit is "vacil". When the Kang modulation frequency is between 13 Hz and 300 Hz, fluctuation strength turns into roughness effect [15]. The values of fluctuation strength are estimated from the intervals of 1000ms in time series of loudness [17].

In this study, the users' soundscape perceptions in urban places and the quantitative information about A-weighted equivalent continuous sound pressure level (L_{Aeq}) and loudness, roughness, sharpness and fluctuation strength from the sound quality metrics were statistically analyzed.

2. Methodology

In this paper, a field study was carried out in the Gazi Street of Diyarbakır Suriçi Region. Noise level measurements and sound records were done in the study area, the questionnaire was applied to the users. Binaural sound records were done at the relevant 5 points (Figure 1) in the Gazi Street. The questionnaire application was done in concurrence with these measurements. The questionnaire questions consisted of two sections. In the first section, the users' gender, age, education level (illiterate, primary school, secondary school, high school, university), income level (not working, less than minimum wage, minimum wage-3000TL, 3001-5000TL, 5001TL and over), reasons for coming to the area (for work, tour and shopping, passing on the way) and frequencies of coming (for the first time, a few times in a year, a few times in a month, a few times in a week) were asked. In the second section of the questionnaire study, the users were required to respond to 35 adjective pairs in the 5 point bipolar scale to determine how the soundscape in the Diyarbakır Suriçi Region was perceived by the users (Table 1).

The questionnaire study was done by 25 (female:16, male:9) participants. A-weighted equivalent sound pressure level (L_{Aeq}) and sound quality metrics (loudness, roughness, sharpness, fluctuation strength) were calculated from the sound recordings performed concurrently with the participants' survey applications. In addition, meteorological data (temperature, humidity, wind speed) were obtained from the Diyarbakır Meteorology Regional Directorate on the day and time of the recording (Table 2).

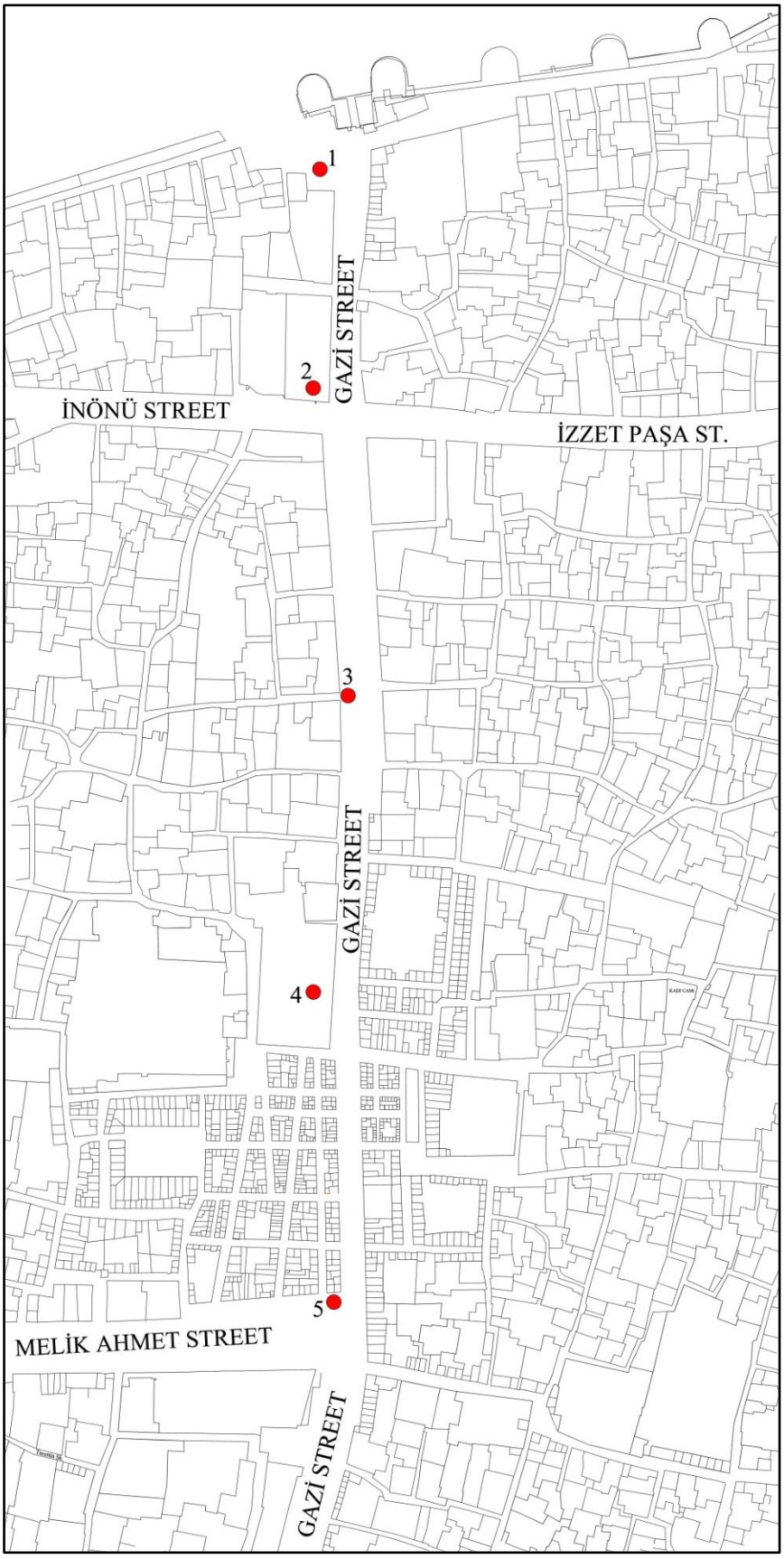

Figure 1. Points of questionnaires and sound recordings

Table 1. Adjectives used in differential analysis

Adjectives	1	2	3	4	5	Adjectives
Unpleasant						Pleasant
Calming						Agitating
Ordinary						Effective
Not Preferred						Preferred
Unsocial						Social
Meaningless						Meaningful
Melancholic						Cheerful
Disturbing						Comfortable
Distracting						Motivating
Oppressive						Liberating
Strange						Familiar
Not Reassuring						Reassuring
Stressing						Relaxing
Ugly						Nice
Eerie						Not Eerie
Stifling						Roomy
Suprising						Not Suprising
Boring						Interesting
Noisy						Quiet
Artificial						Natural
Deserted						Lively
Not Distinct						Distinct
Discordant						Harmonic
Far Away						Nearby
Sonorous						Not Sonorous
Rough						Smooth
Grating						Not Grating
Sharp						Not Sharp
Hard						Soft
Strong						Weak
Unclear						Clear
Irregular						Regular
Unbalanced						Balanced
Unsteady						Steady
Varied						Simple

Table 2. Quantitative data from field study

Survey number	App. point	Temp. (C)	Hum. (%)	Wind speed (m/sn)	L_{Aeq} (dB)	Loudness (sone)	Roughness (asper)	Sharpness (acum)	Fluct. str. (vacil)
1	1	13,20	68	0,80	70,0	28,8	1,63	1,768	1,14
2	1	13,20	68	1,80	69,6	27,3	1,54	1,729	1,11
3	1	13,30	69	0,10	67,9	26,1	1,84	1,712	1,16
4	1	13,10	68	1,20	67,5	26,2	1,56	1,675	1,10
5	1	13,00	66	0,70	69,0	27,2	1,51	1,714	1,09
6	2	12,80	67	0,70	70,7	30,7	1,52	1,806	1,14
7	2	12,70	68	0,30	79,8	39,2	1,96	1,974	1,15
8	2	12,70	68	0,00	69,6	27,9	1,49	1,732	1,14
9	2	12,60	70	0,60	70,0	28,8	1,45	1,699	1,12
10	2	12,40	69	0,60	72,9	32,0	1,68	1,855	1,19
11	3	12,20	70	0,70	73,5	35,2	1,56	1,935	1,23
12	3	12,20	71	0,60	71,4	30,1	1,51	1,662	1,04
13	3	12,20	72	0,60	72,9	32,5	1,58	1,631	1,19
14	3	12,10	74	1,00	71,6	31,3	1,60	1,766	1,01

15	3	12,00	74	1,60	72,0	34,8	1,70	1,509	1,20
16	4	11,90	75	0,60	78,5	38,3	1,36	1,586	1,14
17	4	11,70	76	0,60	67,9	25,2	1,37	1,740	0,97
18	4	11,70	78	0,70	67,9	25,4	1,41	1,782	0,97
19	4	11,50	78	0,50	68,3	26,3	1,35	1,746	1,00
20	4	11,30	79	0,40	67,9	25,3	1,47	1,804	1,07
21	5	11,20	80	0,00	71,1	29,9	1,57	1,682	1,13
22	5	11,10	81	0,00	72,9	35,6	1,44	1,741	1,22
23	5	11,10	81	0,50	73,0	34,3	1,61	2,022	1,23
24	5	11,20	81	1,30	78,2	45,0	1,73	2,793	1,18
25	5	11,20	82	1,70	73,1	34,8	1,55	1,802	1,23

3. Findings

In this study, quantitative data from the sound records, meteorological data and the users' subjective perception were statistically analyzed. The correlation between the L_{Aeq} and the sound quality metrics (loudness, roughness, sharpness, fluctuation strength) obtained from sound recordings with meteorological data (temperature, humidity, wind speed) was not statistically significant ($p > 0,05$) (Table 3).

Table 3. Relation between meteorological data with acoustic and sound quality data

		L_{Aeq} (dB)	Loudness (sone)	Roughness (asper)	Sharpness (acum)	Fluctuation strength (vacil)
temperature	Pearson Correlation	-0,248	-0,347	0,303	-0,292	-0,051
	p	**0,233**	**0,089**	**0,142**	**0,157**	**0,808**
humidity	Pearson Correlation	0,162	0,281	-0,262	0,292	0,029
	p	**0,440**	**0,173**	**0,206**	**0,156**	**0,892**
wind speed	Pearson Correlation	0,057	0,170	0,066	0,129	0,066
	p	**0,788**	**0,416**	**0,756**	**0,538**	**0,755**

The participants' gender, age, education level, income level, reasons and frequency for coming to the area were compared with their responses to 35 adjective pairs about sound environments. When the analyzes made by X^2 test are evaluated;

- Gender affected the frequencies of responses to the adjective pair of reassuring-not reassuring in statistically significant ways (X^2=3,472; p=0,034). Females considered sound environment reassuring rather than males. In addition, it was affective on the adjective pair of stifling- roomy (X^2=10,159; p=0,038). Most of the females stated that they were neutral in sound environment, the males considered more stifling.
- The age of the participants did not become statistically significant in the adjective pairs.
- Education level affected the frequencies of responses to the adjective pair of ordinary-effective in statistically significant ways (X^2=20,833; p=0,045). Most of the high school graduates regarded sound environment to be very effective, the primary school students regarded them to be ordinary, the university graduates as very ordinary. It affected the frequencies of responses to the adjective pair of sharp-not sharp in statistically significant ways (X^2=21,326; p=0,046). The university, high school and primary school graduates regarded them to be neutral.
- Income level affected the frequencies of responses to the adjective pair of disturbing- comfortable in statistically significant ways (X^2=26,183; p=0,045). While the ones with high income (3000

TL and over) considered disturbance of sound environment to be neutral, the ones with low income and not working found it to be more comfortable. In addition, income level was affective on the adjective pair of stifling- roomy (X^2=26,411; p=0,049). While the ones with high income regarded stifling- roomy situation of sound environment to be neutral, the ones not working suggested it to be some roomy and the ones with low income suggested it to be very stifling, respectively. The frequencies of responses to the adjective pair of varied-simple were statistically affected in significant ways (X^2=29,146; p=0,023). Most of the participants considered sound environment to be very varied.

- When their reasons for coming to the field and their responses to the adjective pairs were studied, it affected the frequencies of responses to the adjective pair of unpleasant - pleasant in statistically significant ways (X^2=26,190; p=0,045). The ones coming to shopping thought to be more pleasant rather than the others. The reasons for coming affected the frequencies of responses to the adjective pair of strange-familiar in statistically significant ways (X^2=27,619; p=0,035). Employees, shoppers and the passersby considered sound environment to be familiar, the ones coming for tour expressed to be strange.
- When their frequencies for coming were assessed, the frequencies of responses to the adjective pair of noisy-quiet were affected in statistically significant ways (X^2=18.173; p=0,033). As the ones coming every day considered to be highly noisy, the ones coming a few times in a week or a few times in a month regarded to be less noisy, the ones coming in shorter times (a few times in a year) assessed to be quiet. The frequency for coming affected the frequencies of responses to the adjective pair of regular-irregular in statistically significant ways (X^2=27,783; p=0,012). The ones coming a few times in a year considered to be regular, the others stated that there was an irregular sound environment.

When statistically comparing the participants' responses to 35 adjective pairs about soundscape perception regarding sound environment of Gazi Street with L_{Aeq}, loudness, roughness, sharpness and fluctuation strength (Table 4);

Table 4. Relation between adjective pairs and acoustic-sound quality metrics

Adjective pairs		**L_{Aeq} (dB)**	**Loudness (sone)**	**Roughness (asper)**	**Sharpness (acum)**	**Fluc. Strg. (vacil)**
Unpleasant-Pleasant	Pearson Correlation	-0,154	-0,124	-0,250	0,169	-0,379
	p	0,463	0,556	0,229	0,418	0,062
Calming-Agitating	Pearson Correlation	-0,407	-0,364	-0,465	0,020	-0,330
	p	**0,044**	0,074	**0,019**	0,923	0,107
Ordinary-Effective	Pearson Correlation	-0,161	-0,078	-0,191	-0,111	-0,114
	p	0,442	0,712	0,360	0,599	0,588
Not Preferred-Preferred	Pearson Correlation	-0,197	-0,198	-0,284	0,156	-0,257
	p	0,344	0,343	0,169	0,456	0,214
Unsocial-Social	Pearson Correlation	-0,346	-0,249	-0,108	0,027	-0,201
	p	0,090	0,231	0,608	0,900	0,335
Meaningless-Meaningful	Pearson Correlation	-0,356	-0,338	-0,449	0,109	-0,415
	p	0,081	0,099	**0,025**	0,604	**0,039**
Melancholic-Cheerful	Pearson Correlation	-0,333	-0,325	-0,219	0,098	-0,331
	p	0,104	0,112	0,294	0,642	0,106
Disturbing-Comfortable	Pearson Correlation	-0,051	-0,041	-0,105	0,184	-0,311
	p	0,808	0,846	0,617	0,380	0,130
Distracting-Motivating	Pearson Correlation	-0,228	-0,276	-0,205	0,280	-0,490
	p	0,274	0,182	0,326	0,175	**0,013**
Oppressive-Liberating	Pearson Correlation	0,115	0,128	0,114	0,326	-0,050

	p	0,584	0,544	0,587	0,111	0,812
Strange-Familiar	Pearson Correlation	0,284	0,308	-0,233	0,082	-0,098
	p	0,168	0,135	0,262	0,697	0,642
Not Reassuring-Reassuring	Pearson Correlation	-0,049	-0,021	-0,043	-0,051	-0,217
	p	0,815	0,922	0,839	0,808	0,298
Stressing-Relaxing	Pearson Correlation	-0,108	-0,110	-0,224	0,016	-0,374
	p	0,608	0,601	0,283	0,939	0,066
Ugly-Nice	Pearson Correlation	-0,256	-0,238	-0,360	-0,069	-0,429
	p	0,218	0,253	0,077	0,742	**0,033**
Eerie-Not Eerie	Pearson Correlation	0,067	0,066	-0,225	-0,009	-0,401
	p	0,751	0,755	0,280	0,964	**0,047**
Stifling-Roomy	Pearson Correlation	-0,202	-0,167	-0,298	0,196	-0,386
	p	0,332	0,424	0,148	0,349	0,057
Suprising-Not Suprising	Pearson Correlation	-0,202	-0,115	0,014	-0,200	-0,187
	p	0,334	0,583	0,948	0,337	0,372
Boring-Interesting	Pearson Correlation	-0,172	-0,114	-0,307	-0,090	-0,367
	p	0,412	0,586	0,136	0,667	0,071
Noisy-Quiet	Pearson Correlation	-0,120	-0,177	-0,317	-0,251	-0,314
	p	0,568	0,398	0,123	0,227	0,126
Artificial-Natural	Pearson Correlation	0,086	0,103	-0,296	-0,210	-0,164
	p	0,682	0,626	0,151	0,315	0,433
Deserted-Lively	Pearson Correlation	-0,091	-0,028	-0,157	-0,120	-0,220
	p	0,666	0,895	0,454	0,568	0,290
Not Distinct-Distinct	Pearson Correlation	-0,052	-0,034	-0,396	0,179	-0,270
	p	0,805	0,873	0,050	0,392	0,191
Discordant-Harmonic	Pearson Correlation	-0,047	-0,110	-0,211	0,085	-0,367
	p	0,822	0,600	0,310	0,688	0,071
Far Away-Nearby	Pearson Correlation	0,059	0,002	0,090	0,281	-0,061
	p	0,780	0,991	0,669	0,174	0,773
Sonorous-Not Sonorous	Pearson Correlation	0,239	0,233	-0,104	0,137	-0,135
	p	0,249	0,262	0,622	0,514	0,521
Rough-Smooth	Pearson Correlation	-0,082	-0,073	-0,409	-0,015	-0,226
	p	0,698	0,727	**0,042**	0,942	0,277
Grating-Not Grating	Pearson Correlation	0,000	-0,034	-0,221	-0,104	-0,243
	p	0,999	0,872	0,288	0,621	0,241
Sharp-Not Sharp	Pearson Correlation	-0,234	-0,176	-0,444	-0,230	-0,343
	p	0,261	0,399	**0,026**	0,269	0,094
Hard-Soft	Pearson Correlation	-0,280	-0,227	-0,428	-0,306	-0,426
	p	0,175	0,275	**0,033**	0,137	**0,034**
Strong-Weak	Pearson Correlation	0,170	0,248	-0,084	0,013	0,004
	p	0,417	0,232	0,690	0,952	0,983
Unclear-Clear	Pearson Correlation	0,048	0,012	-0,173	0,403	-0,172
	p	0,819	0,953	0,407	**0,046**	0,411
Irregular-Regular	Pearson Correlation	-0,179	-0,123	-0,443	0,101	-0,184
	p	0,391	0,557	**0,027**	0,631	0,378
Unbalanced-Balanced	Pearson Correlation	-0,277	-0,235	-0,381	0,062	-0,257
	p	0,180	0,258	0,060	0,768	0,214
Unsteady-Steady	Pearson Correlation	-0,124	-0,110	-0,402	0,056	-0,032
	p	0,555	0,600	**0,046**	0,792	0,881
Varied-Simple	Pearson Correlation	-0,032	-0,107	-0,288	0,297	-0,212
	p	0,879	0,611	0,163	0,150	0,308

- As the correlation between the participants' responses to the adjective pair of calming-agitating and L_{Aeq} was statistically significant ($p<0,05$), the correlation between the other adjective pairs and L_{Aeq} was not significant ($p>0,05$).
- There was no significant correlation between any adjective pairs and loudness.

- As there were statistically significant correlations between the responses to the adjective pairs calming-agitating, meaningful-meaningless, rough-smooth, sharp-not sharp, hard-soft, irregular-regular, unsteady-steady and roughness from sound quality metrics ($p<0,05$), there was not a significant correlation in other adjective pairs ($p>0,05$).
- While there was only a significant correlation between the adjective pair of unclear-clear and sharpness ($p<0,05$), there was not a significant correlation in other adjective pairs ($p>0,05$).
- A significant correlation was found between the adjective pairs of meaningful-meaningless, distracting-motivating, ugly-nice, eerie-not eerie, hard-soft and fluctuation strength ($p<0,05$). But there was not a significant correlation in other adjective pairs ($p>0,05$).

4. Conclusion

By focusing on the soundscape approach, this paper measured the users' perception about sound environment with objective and subjective data in the Gazi Street of Diyarbakır Suriçi. Meteorological data and quantitative data about sound environment were analyzed. The relations between 35 adjective pairs and the users' personal/social characteristics and quantitative data of sound environment were researched. As a result of this study;

• There was not a significant relation between meteorological data (temperature, humidity, wind speed and L_{Aeq} and sound quality (loudness, roughness, sharpness, fluctuation strength) metrics.

• There was not a significant relation between the quantitative data about loudness and the adjective pairs.

• The females considered sound environment more reassuring rather than the males. The males thought sound environment to be more stifling than the females.

• As most of the high school graduates thought sound environment to be very effective, the primary school graduates thought to be ordinary, very ordinary for the university graduates.

• As the ones with high income dealt with the disturbance of sound environment as neither disturbing nor comfortable, the ones with low income and the ones not working thought it to be some comfortable.

• The participants coming to the area for shopping considered sound environment pleasant rather than the others.

• Employees, shoppers, and passers-by considered sound environment to be familiar, participants who traveled for a while stated that the sound environment was strange.

• As the ones coming to the area every day considered sound environment to be highly noisy, for the ones coming a few times in a week or a few times in a month as less noisy, for the ones coming in shorter times (a few times in a year) as quiet.

• As the users coming to the area a few times in a year thought sound environment to be regular, the others stated to be irregular.

This study showed that the users' perceptions about sound environment could change in accordance with the parameters such as gender, age, social and cultural characteristics. When examining the sound environment of a region, not only quantitative information but also subjective information must be taken.

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