# Soundscape mapping in urban contexts using GIS techniques

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## ABSTRACT

Urban acoustic environments consist of various sound sources including traffic noise, human-generated sounds, and natural sounds that affect the soundscape perception of a given location. However, these sound sources are indistinguishable by noise maps that are based on sound pressure levels. Hence, soundscape maps based on the perception of sounds are necessary to describe an acoustic environment more accurately. Presented herein is a study of soundscape perception, which employs GIS techniques to generate soundscape maps in various urban settings including commercial, business, recreational, and residential spaces. Soundscape perceptions and physical characteristics of the acoustic environments pertaining to these urban settings were evaluated from questionnaire surveys and acoustic measurements, respectively. The results demonstrate how soundscape perceptions and spatial variation in urban soundscapes are closely related to their corresponding urban contexts.

Keywords: Soundscape, Soundscape map, Context, I-INCE Classification of Subjects Number(s): 56.3

## 1. INTRODUCTION

Noise maps illustrate the distribution of calculated sound pressure levels from environmental noises (for example, traffic and industry) in a given area. Noise mapping is widely used to recognize noise exposure and to identify areas where action is required, as well as quiet areas where noise exposure should not increase. Mathematical models of environmental noise emission and propagation outdoors are used to calculate sound pressure levels in noise maps, but the results may not accurately reflect the measurements. Sound environments normally consist of noise, natural sounds, and sounds from human activities, yet noise maps are generally based on a single noise source. In particular, noise maps that visualize sound pressure levels do not accurately represent human perceptions of acoustic environments (1,2). Researchers have suggested the use of soundscape mapping to achieve a holistic understanding of acoustic environments, based on both perceptual and physical factors, as an approach to overcome the limitations of noise mapping (3,4). Previous studies have primarily discussed concepts for developing soundscape maps, yet limitations to their practical application as alternative maps still exist. In addition, the effects of various urban contexts on soundscape perception have been examined less closely. The present study, thus, aims to investigate urban soundscape perception in various land uses including commercial, business, recreational, and residential spaces, and suggests a technique for creating soundscape maps based on GIS techniques.

## 2. Urban soundscapes mapping

### 2.1 Case study

In this study, a northern urban area in Seoul, Korea was selected as a case study for developing

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soundscape maps as shown in Figure 1(a). The case study area was divided using a grid comprised of 118 meshes, each measuring 150 m x 150 m, as depicted in Figure 1(b). The study area spans a varied urban topography and consists of differing land uses including commercial and office districts, parks, residential areas, city streams and squares.

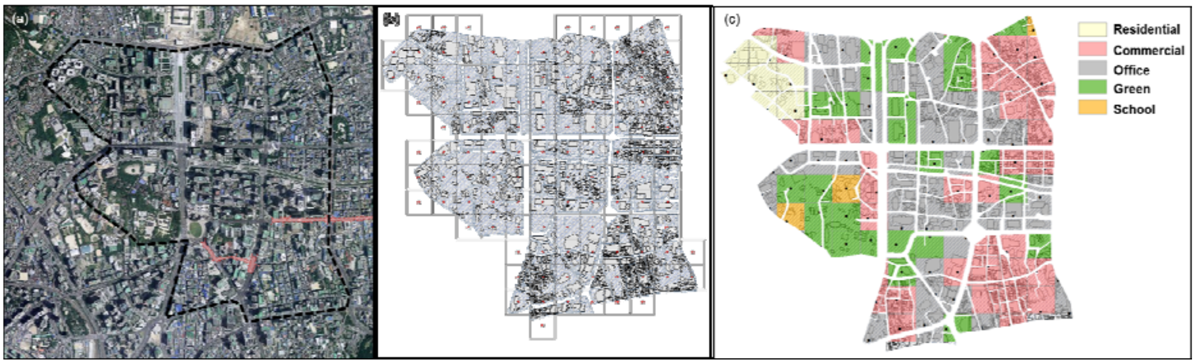


Figure 1 – (a) Arial photo of study area (Google map), (b) division of meshes (150 m x 150 m), and (c) land uses

### 2.2 Questionnaire

The questionnaire for evaluating soundscapes was designed based on previous studies (5–7) and included questions concerning different qualities of the soundscape. Firstly, perceived sound sources were assessed in terms of four types of sounds: traffic noise, technological sounds, human-made sounds, and natural sounds. These were rated using the following five responses: “Do not hear at all,” “Hear a little,” “Hear moderately,” “Hear a lot,” and “Dominates completely.” Secondly, soundscape perceptions of people were evaluated using the following eight attributes: pleasant, chaotic, exciting, uneventful, calm, annoying, eventful, and monotonous. In addition, the landscape quality was evaluated using the following twelve adjectives: appealing, uninteresting, harmonious, complex, open, familiar, repulsive, interesting, closed, unfamiliar, simple, and disharmonious. All adjectives and attributes were evaluated using a 5-point Likert scale.

### 2.3 Procedure

On-site evaluations were performed over three days in May 2014 in order to collect the objective and subjective soundscape data. Investigators examined each mesh of the research area during three time periods: morning 09:00–11:30, daytime 13:00–15:30, and nightfall 18:00–20:30. In each mesh, acoustic environments were recorded for 5-minutes using a binaural microphone (B&K, Type 4101) and a portable field recorder (Zoom, H4n). Further, soundscape perceptions describing the quality of acoustic environments and perceived loudness of sound sources were evaluated using the questionnaire. Overall, 354 total recordings (118 locations × 3 time periods) were obtained.

## 3. Results

### 3.1 Visualization of perceived sounds

Figure 2 depicts the spatial distribution of perceived traffic noise in the case study area during three different time periods. For example, the level of traffic noise in the morning as seen in Figure 2(a) was perceived to be less dominant compared with that during daytime and nightfall. This is presumably due to the relatively small volume of traffic in the morning, since the evaluation time periods occurred after the morning rush hour to the offices. During the daytime, traffic noises were predominantly identified in the office districts along the main traffic roads, as illustrated in Figure 2(b). Perceived traffic noise was found to gradually decrease in the evening, as shown in Figure 2(c). It is worth noting that traffic noise was rarely identified in urban green areas.

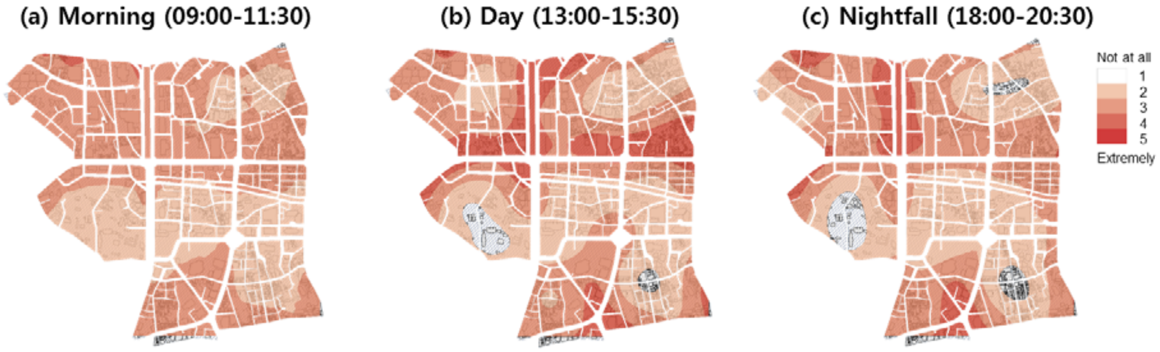


Figure 2 – Spatial distribution of perceived traffic noise at three different time periods

Sounds identified from human activities over three different time periods are visualized in Figure 3. Studies mainly identified human sounds in green areas and commercial districts during the morning, as illustrated in Figure 3(a). Sounds from children enjoying outdoor activities were perceived in urban parks, while sounds from people opening stores were observed in the commercial district. During the daytime and nightfall, human sounds were dominantly perceived in the commercial district as shown in Figures 3(b) and 3(c).

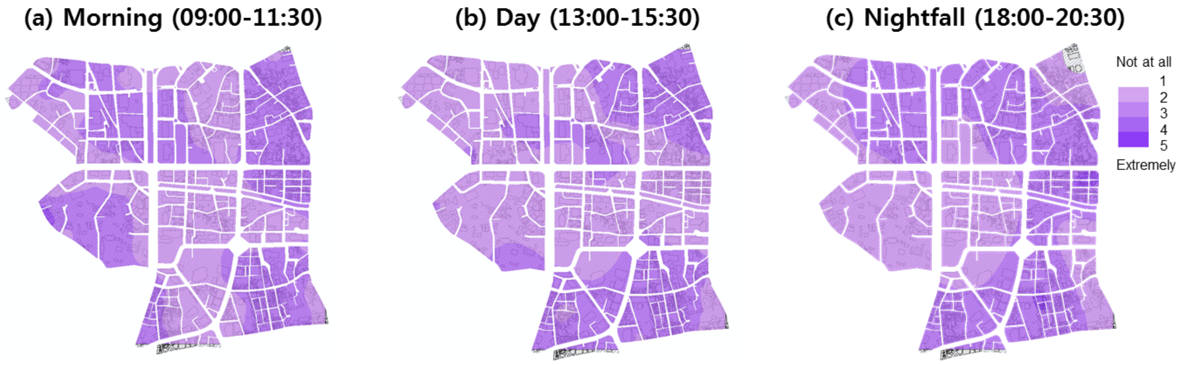


Figure 3 – Spatial distribution of perceived human sounds at three different time periods

The perceived loudness of natural sounds over three time periods is likewise illustrated in Figure 4. Natural sounds were mainly heard in urban green areas during the morning and the daytime. In urban parks, bird songs and tree rustling sounds were frequently identified, but the intensity of these natural sounds were relatively weaker than the sounds from traffic and human activities. During daytime, water sounds from fountains were perceived at locations containing water features. It is interesting to note that the perception of natural sounds significantly decreased during nightfall, which is shown in Figure 4(c). These findings imply that natural sounds are concentrated in certain areas and time periods.

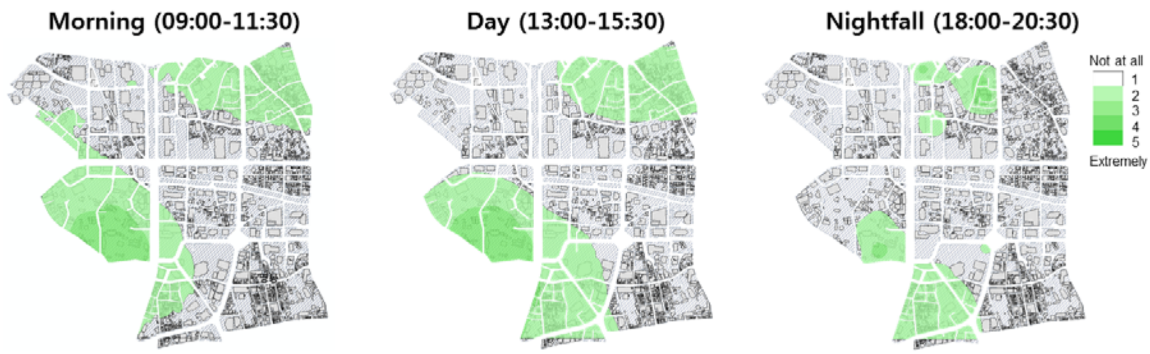


Figure 4 – Spatial distribution of natural sounds at three different time periods

### 3.2 Relationship between perceived sound sources and acoustic and landscape index

Correlation analyses between perceived sound sources with acoustic and landscape indexes were performed, and $L_{Aeq}$ at each evaluation location was calculated using audio recordings. Building coverage and road ratios in each grid were calculated in the landscape index using Arc-GIS v10.0 (3). Table 1 shows Pearson's correlation coefficients among the perceived loudness of sound sources and the acoustic and landscape index. The perceived loudness of traffic noise significantly correlated with $L_{Aeq}$ revealing over 0.5 correlation coefficients for each time period. The correlation between the perceived loudness of traffic noise and the road ratio was statistically significant at 0.01 levels. There were no significant relations between the perception of traffic noise and building coverage during the morning and daytime, while significant correlation was found during nightfall ($p<0.05$).

With regard to perception of human sounds, significant correlations were found in $L_{Aeq}$ during the daytime and nightfall periods. This indicates that increments of perceived human sounds may increase sound pressure levels. In addition, a positive relationship was found between human sounds and the building coverage ratio at nightfall. During this time period, people generally leave their offices and move to commercial districts, where the building coverage ratios are higher than in other urban areas. Unlike perceived traffic noises, perceived human sounds did not significantly correlate with road ratios.

On the other hand, natural sounds display a negative correlation with $L_{Aeq}$, indicating that natural sounds were perceived in locations in which background noises were typically low. Statistically significant correlations were found between natural sounds and building coverage ratios at 0.05 levels. Building coverage ratios in urban green areas, where natural sounds were frequently perceived, are relatively lower than the ones in office and commercial districts.

Table 1 – Pearson's correlation coefficients among perceived loudness of sound sources, acoustic and landscape index (*p<0.05, **p<0.01)

| Sources | Period | $L_{Aeq}$ | Building coverage-ratio | Road-ratio |
|---|---|---|---|---|
| Traffic noise | Morning | 0.55** | -0.11 | 0.42** |
| | Daytime | 0.59** | -0.14 | 0.40** |
| | Nightfall | 0.53** | -0.20* | 0.41** |
| Human sounds | Morning | -0.07 | 0.15 | -0.11 |
| | Daytime | 0.20* | 0.04 | 0.08 |
| | Nightfall | 0.20* | 0.32** | -0.14 |
| Natural sounds | Morning | -0.36** | -0.18* | -0.17 |
| | Daytime | -0.38** | -0.22* | -0.11 |
| | Nightfall | -0.19* | -0.21* | -0.07 |

## 4. Conclusions

In the present study, physical and perceptual soundscape data were collected throughout a case study area to develop soundscape maps, which were created based on GIS techniques. Our findings illustrate that loudness of perceived sound sources from traffic, human activities, and nature differed according to the urban setting and time period. Additionally, the dominance of perceived traffic noises exhibited a positive correlation with sound pressure levels, while natural sounds displayed a negative correlation with $L_{Aeq}$. Human activities were also found to increase the sound pressure levels, while building coverage ratios showed a positive correlation with the identification of human sounds. In the future, spatial and temporal relationships between soundscape and landscape factors will be investigated.

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