The relationship between sound source and urban soundscape

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Abstract. Noise analysis of urban area is usually conducted according to noise level measurement. The noise level measurement concept only considers how loud the overall acoustic environment but not how people perceived each sound source. The soundscape concept has become a new alternative to analyse acoustic environment. This concept tries to understand the perception of the acoustic environment from the interaction between the sound sources and people who use the space. This study tries to understand the relationship between sound sources in an urban area with people’s perception related with three feeling: Relaxation, Dynamic, and Communication/Communality. An experiment was conducted using 26 simulated urban acoustic environments. The stimuli were composed using six sound sources: The sound of hubbub, urban traffic, construction noise, music, event sounds, and water fountain. The analysis was conducted using forward logistic regression. The perception of Relaxation is affected by the sound of music, urban traffic, and construction noise. The perception of Dynamic is affected by the sound of hubbub, urban traffic, and event sounds. The perception of Communication is affected by the sound of hubbub and water fountain. This result indicates that the perception of acoustic environment are related to specific sound source inside the environment.

1. Introduction
Nowadays, noise measurement methods are still widely used to rate the sound in urban areas. Noise measurement methods only rate sounds according to noise level, without consideration of discrete sound objects [1]. The soundscape method attempts to understand the perception of a soundscape from the interaction of the sound objects inside it, hoping to create a better auditory environment by using positive sound objects and working more with people’s perceptions rather than simply the overall sound level measurement [2]. Using the noise measurement approach, as long as the sound level of a soundscape exceeds a certain level, it will be considered an unpleasant soundscape. With the soundscape approach, however, the focus is on how people who use the space feel about the soundscape and their interaction with sound objects in the soundscape. Researchers have therefore begun to investigate the factors affecting the perception of soundscapes, and one of the factors being investigated is the interaction between sound objects and the rating of the soundscape [1].

A soundscape environment is formed by the sound objects inside it. Sound object in here is taken as a source of sound in a soundscape including behaviours (movement and position in space), distribution in time (event sound or background sound), sound level, and interactions with the environment. Some studies have tried to find the relationship between these sound objects and the perception of the soundscape as a whole [1,3–5]. These studies have grouped sound objects according to how they are perceived, and not how they affect the overall perception of the soundscape. In addition, the previous studies have not clearly defined which specific sound objects significantly affect the perception of a soundscape, nor how specific sound objects affect the rating of soundscape compared to other sound objects.

This study tries to understand the relationship between sound objects in a soundscape to the perception of soundscape representing with three perceptions: Relaxation, Dynamic, and Communication/Communality.
2. Method
The experiment was conducted using simulated soundscape composed using six sound sources: the sound of hubbub, music, water fountain, traffic noise, construction noise, and the event sound source. The description of the sound sources is shown in table 1. Variation of sound level are also given. The length of each stimulus was one minutes. The stimulus of the experiment is shown in table 2. The experiment was conducted in a listening room and reproduced using two-dimensional reproduction system which can reproduce immersive sound including the position and movement of sound source in space.

Sound objects in a soundscape are considered to affect the ratings of the total soundscape; for example, natural sound is believed to increase the perception of pleasantness [3,4], whereas human sound is considered to increase perceptions of eventfulness. In this study, the natural sound is represented by the sound of water fountain, and human sound is represented using the sound of hubbub.

Mechanical or artificial sounds correspond with unpleasant ratings of a soundscape [1]. The sound of mechanical sound is represented by the sound of construction noise and traffic noise. The sound of music was also selected because there are evidence showing the relationship between music and relaxation [6,7].

Twenty-one participants (15 male, 6 female) joined the experiment voluntarily. The entire participants were undergraduate and master students (22-27 years old, M = 24.6, SD = 2.38) of Engineering Physics Department, ITB with the background of engineering and acoustic.

The experiment was conducted individually. Each of participants gave the rating of each stimulus (which was played in random order) according to three perceptions: Relaxation, Dynamic, and Communication. The perceptions were selected according to the study of soundscape dimension in urban area [8,9]. The questionnaire used 11 points Likert scale and made using Microsoft Excel as shown in Figure 1.

3. Results and discussion
Analysis of the data is conducted using two approaches: Stepwise Linear Regression and Stepwise Logistic Regression. The logistic regression is calculated using the output of one/zero so the data need to be transform first before this regression is implemented. The Linear Regression is evaluated from the value of Pearson’s Correlation Coefficient (R) from the models, shown in Table 3, while the Logistic Regression is evaluated from the value of percentage of correct prediction of the model, shown in Table 4.

The linear model gives Pearson’s coefficient correlation (R) between 0.475-0.635. The highest correlation is shown by the linear model for Communication indicating a good prediction of the model. The logistic model can predict the data between 63.9%-81.4%. The highest model is shown by the model for the perception of Communication. This result is consistent with the linear model and the model also indicates a good prediction.

Further analysis is conducted from the linear and logistic models as shown in Table 5 and 6. The linear and logistic model shows similar characteristic. The models show that there are correlation between the sound source and the perception of the acoustic environment.

The perception of relaxation is related to the sound of music, traffic noise, and construction noise. The negative value of Beta (B) represents the relation to the perception of comfortable while the positive value Beta (B) represent the relation to the perception of uncomfortable. The sound of music related to the perception of comfortable and the sound of traffic noise and construction related to the perception of uncomfortable.

The perception of dynamic is related to the sound of hubbub, event sound, and traffic noise. The entire significant sound sources make the soundscape perceived as dynamic soundscape (indicated by the negative value of B).

The perception of communication is related to the sound of hubbub and water fountain. The sound of hubbub makes the soundscape to be perceived as communal (indicated by the negative value of B) while the sound of water fountain is related to the perception of private (indicated by the negative value of B).
Table 1. Sound source description.

| No | Sound Source   | Description                                                                 |
|----|----------------|-----------------------------------------------------------------------------|
| 1  | hubbub         | the sound of people talking in the background                               |
| 2  | music          | the sound of people playing relaxing music with string instrument           |
| 3  | water fountain | the sound of water fountain in the background                               |
| 4  | traffic noise  | the sound of traffic noise in the background                                |
| 5  | construction noise | the sound of construction noise in the background                           |
| 6  | event sound    | the combination of the sound which occurs once and in the short period. It consist of: the sound of footstep, the sound of trolley bag, bike being pushed, and bird chirping |

Table 2. Stimulus used in the experiment

| No | Sound Source 1 | Sound Source 2 | Sound Source 3 |
|----|----------------|----------------|----------------|
| 1  | People 0       | Music 0        |                |
| 2  | People 0       | Fountain 0     |                |
| 3  | People 0       | Music -10      |                |
| 4  | People 0       | Fountain -10   |                |
| 5  | People -10     | Music 0        |                |
| 6  | People -10     | Fountain 0     |                |
| 7  | People 0       | Music 0        | Event          |
| 8  | People 0       | Fountain 0     | Event          |
| 9  | People 0       | Music -10      | Event          |
| 10 | People 0       | Fountain -10   | Event          |
| 11 | People -10     | Music 0        | Event          |
| 12 | People -10     | Fountain 0     | Event          |
| 13 | People 0       |               | Event          |
| 14 | Music 0        |               | Event          |
| 15 | Fountain 0     |               | Event          |
| 16 | Traffic 0      | Fountain 0     |                |
| 17 | Traffic 0      | Music 0        |                |
| 18 | Traffic 0      | People 0       |                |
| 19 | Traffic 0      |               |                |
| 20 | Construction 0 | Fountain 0     |                |
| 21 | Construction 0 | Music 0        |                |
| 22 | Construction 0 | People 0       |                |
| 23 | Construction 0 |               |                |
| 24 | Fountain 0     |               |                |
| 25 | Music 0        |               |                |
| 26 | People 0       |               |                |

*a*0 indicates that the sound was reproduced at the actual sound level and -10 indicates that the sound was reproduced 10 dB below the actual level

Figure 1. Questionnaire used in the experiment.
Table 3. Correlation coefficient of linear model

| Perception      | R    |
|-----------------|------|
| Relaxation      | .475 |
| Dynamic         | .337 |
| Communication   | .635 |

Table 4. Percentage correct of logistic model

| Perception      | Percentage Correct |
|-----------------|--------------------|
| Relaxation      | 68.3%              |
| Dynamic         | 63.9%              |
| Communication   | 81.4%              |

Table 5. Soundscape linear model according to the perception of relaxation, dynamic, and communication

| Relaxation     | B     | Std. Error | Standardized Beta | Sig.  |
|----------------|-------|------------|-------------------|-------|
| Constant       | .020  | .144       |                   | .891  |
| Music          | -.022 | .003       | -.295             | .000  |
| Traffic        | .030  | .004       | .285              | .000  |
| Construction   | .022  | .004       | .218              | .000  |

| Dynamic       | B     | Std. Error | Standardized Beta | Sig.  |
|---------------|-------|------------|-------------------|-------|
| Constant      | .365  | .184       |                   | .048  |
| Traffic       | -.034 | .004       | -.354             | .000  |
| Event         | -.726 | .212       | -.148             | .001  |
| Hubbub        | -.010 | .003       | -.143             | .001  |

| Communication | B     | Std. Error | Standardized Beta | Sig.  |
|---------------|-------|------------|-------------------|-------|
| Constant      | .772  | .176       |                   | .000  |
| Hubbub        | -.053 | .003       | -.608             | .000  |
| Fountain      | .014  | .003       | .151              | .000  |

Table 6. Soundscape logistic model according to the perception of relaxation, dynamic, and communication

| Relaxation     | B     | Sig.  | Exp(B)  |
|----------------|-------|-------|---------|
| Music          | -.018 | .000  | .983    |
| Traffic        | .025  | .000  | 1.025   |
| Construction   | .018  | .000  | 1.018   |
| Constant       | -.115 | .380  | .891    |

| Dynamic       | B     | Sig.  | Exp(B)  |
|---------------|-------|-------|---------|
| Hubbub        | -.006 | .035  | .994    |
| Event         | -.417 | .037  | .659    |
| Traffic       | -.024 | .000  | .976    |
| Constant      | .042  | .808  | 1.042   |

| Communication | B     | Sig.  | Exp(B)  |
|---------------|-------|-------|---------|
| Hubbub        | -.040 | .000  | .961    |
| Fountain      | .011  | .002  | 1.011   |
| Constant      | .163  | .329  | 1.177   |
4. Conclusion

This study has confirmed that there is a relationship between the perception of acoustic environment (according to the perception of relaxation, dynamic, and communication) and the specific sound source. The perception models have been developed using linear regression (Pearson’s correlation between 0.337-0.635) and logistic regression (Percentage Correct between 63.9%-81.4%). The models from both analysis shows consistent result. The perception of relaxation is affected by the sound the sound of music, traffic noise, and construction noise. The perception of dynamic is affected by the sound of hubbub, event sound, and traffic noise. The perception of communication is affected by the sound of hubbub and water fountain.

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