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Personal evaluation structure of environmental sounds: experiments of subjective evaluation using subjects' own terms

Keiji Kawai[a,*], Takaya Kojima[b], Kotaroh Hirate[c], Masahito Yasuoka[d]

[a]*Graduate School of Science and Technology, Kumamoto University, 2-39-1, Kurokami, Kumamoto 860-8555, Japan*
[b]*Building Research Institute, Tachihara, Tsukuba, Ibaraki 305-0802, Japan*
[c]*Department of Architecture, Graduate School of Engineering, The University of Tokyo, Tokyo 113-8656, Japan*
[d]*Department of Architecture, Faculty of Engineering, Tokyo University of Science, Tokyo 162-8601, Japan*

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Abstract

In this study, we conducted an experiment to investigate the evaluation structure that lies at the basis of peoples' psychological evaluation of environmental sounds. In the experiment, subjects were given cards on each of which a name of one of the environmental sounds in the specified context is written. Then they did the following three tasks: (1) to sort the cards into groups by the similarity of their impressions of the imagined sounds; (2) to name each group with the word that best represented their overall impression of the group; and (3) to evaluate all sounds on the cards using the words obtained in the previous task.

These tasks were done twice: once assuming they heard the sounds at ease inside their homes and once while walking outside in a resort theme park. We analysed the similarity of imagined impression between the sounds with a cluster analysis and clusters of sounds were produced, namely, sounds labelled "natural," "transportation," and so on. A principal component analysis revealed the three major factors of the evaluation structure for both contexts and they were interpreted as preference, activity and sense of daily life.

*Corresponding author. Tel.: +81-96-342-3567; fax: +81-96-342-3569.
E-mail address: kawai@arch.kumamoto-u.ac.jp (K. Kawai).

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1. Introduction

Relationships between the sound environment and people's perception have been studied in the context of noise evaluation. In such studies, noises are typically described by a quantitative metric such as sound pressure level and peoples' responses to noises are represented by a single evaluation of annoyance. This approach is considered to be reasonable because an outcome of noise evaluation studies is expected to be reflected in noise policies, which are usually in the form of some quantitative regulation to guard against unacceptable noises. However, some aspects of the psychological effect of the sound environment needs a qualitative description. For example, in a quiet neighbourhood, a sound of rather low level coming from a specific source may cause trouble. Furthermore, some studies focus on good sound environments (soundscape). Such studies have to deal with not only the quantitative aspect of sounds but also the qualitative aspect, that is, the meaning of sound. Also, as for the studies on good sound environment, it is necessary to deal with not only annoyance but also with multidimensional evaluations which include such concepts as good, lively, calm, natural, etc.

This study of good sound environments focuses on the multidimensional evaluations and aims to gain knowledge about peoples' "evaluation structure" regarding environmental sounds. It uses the term "evaluation structure" to indicate a set of criteria, which are in the peoples' memory and which they use for evaluating environmental objects and their dimensional structure.

Several studies [1–9] on the multidimensional evaluation of sounds have been conducted since the semantic differential method was proposed by Osgood [10]. Most of the earlier studies were conducted on the timbre of sounds and later studies extended the study field to environmental noise. However, there is one major problem in the selection of evaluation scales. These studies selected suitable adjectives for subjective evaluation scales of the sounds comprehensively from dictionaries or thesauruses. If the evaluation scales, selected by researchers, were different from the constructs which subjects employ to evaluate sounds, the evaluation structure extracted using such scales would be more or less different from the real one. As the subjects' own terms were used as the evaluation scales in this study, we consider it possible to reveal the evaluation structure, which the subjects actually experience themselves. The aim of this study is to learn about peoples' evaluation structure for environmental sounds. A previously designed method [11] was used which implies using each subject's own terms to evaluate environmental sounds.

2. Experiment

The experiment was designed to obtain personal evaluation structure of the sound environment. In the beginning, subjects were given cards with the names of environmental sounds. The subjects were asked to imagine the sound on each card as if they heard the sound in the following two contexts: (a) assuming they heard the sounds at ease inside their home (*at home*); and (b) while walking joyfully in a seaside theme park (*theme park*). We tested these two contexts in order to examine whether the evaluation structure differed according to the situation and also whether such differences could be detected by our method.

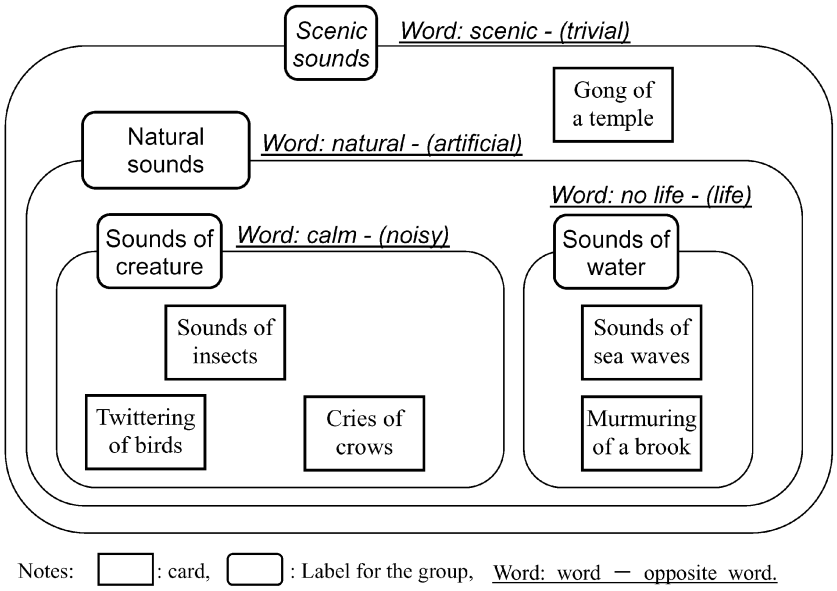

Fig. 1. Partial example of tasks 1 and 2 by a subject.

The experiment consisted of the following three tasks:

1. Subjects were asked to sort the cards naming the different sounds into groups by the similarity of their impressions. At the first step, only sounds of most similar impressions were formed into groups; in the following steps, the previously produced groups were treated as a sound and again the most similar sounds were formed into groups; the procedure was repeated until there were five groups (Fig. 1). The number of cards was 36 for *at home* [12] and 45, which was based on our 24 h survey of the sound environment, for *theme park* [13].
2. Subjects were then asked to assign to each group of sounds a word that best represented their overall impression, and then to think of a word with the opposite meaning. These pairs of words were considered to be representations of the subjects' evaluation structure for evaluating environmental sounds (Fig. 1).
3. Finally, each subject was asked to evaluate all sounds on the cards using different evaluation scales constructed specifically for that subject. These were 7-step scales with the word pairs that the subject had chosen in task 2 as the endpoints of the scales.

All the 19 subjects were Japanese students of both genders in their twenties. The words identified in this paper are English translations of the Japanese words.

3. Analysis

The data from each of the three tasks were analysed as follows: (a) Cluster analysis using data from task 1. (b) Corresponding analysis using the data from tasks 1 and 2. (c) Principal

component analysis using data from task 3. The results from (b) and (c) are similar, that is with an evaluation structure either rough or somewhat detailed. However, tasks 1 and 2 are quite simple and easy for subjects to perform while task 3 is burdensome both for the researcher and subjects.

3.1. Clusters of sound

Similarity between sounds was defined as the number of subjects who put a sound in the same group as another sound in task 1. Then the similar data were put into a cluster analysis (average

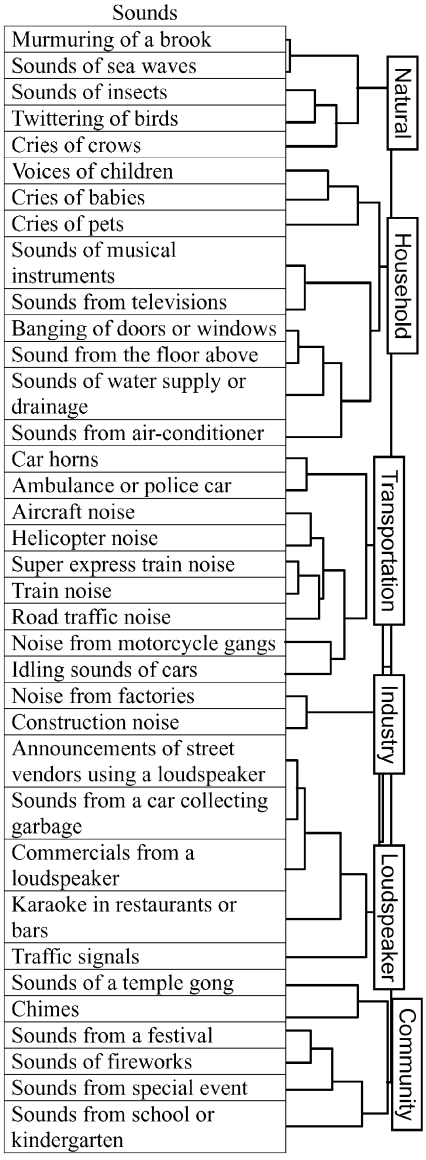

Fig. 2. Clusters of sounds (context: *at home*).

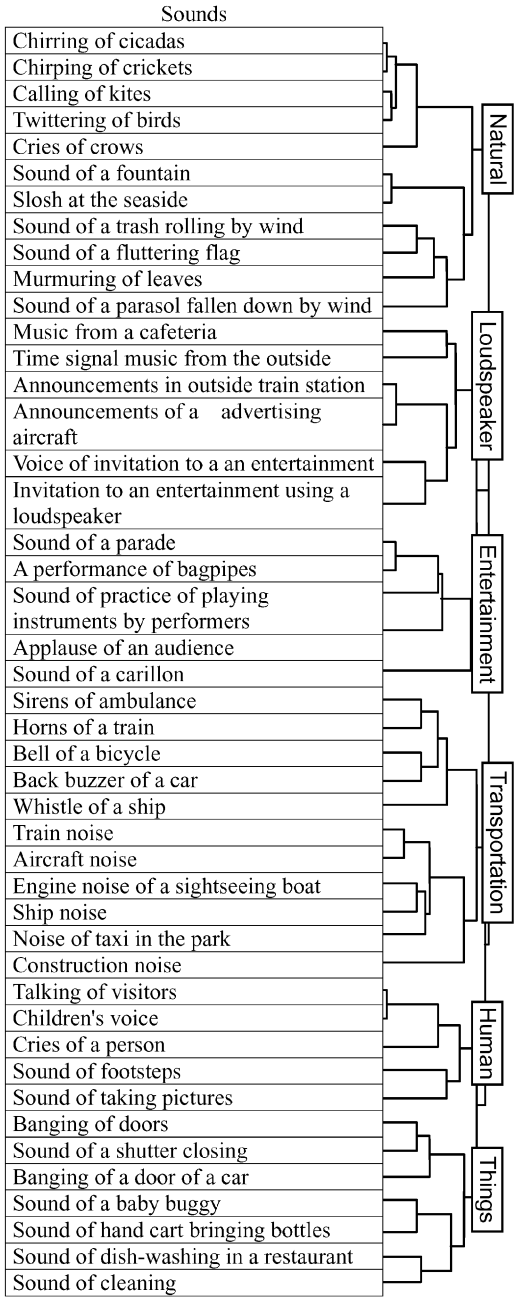

Fig. 3. Clusters of sounds (context: *theme park*).

linkage). Figs. 2 and 3 show the dendrogram of clusters for each context. Clusters of sounds pertaining to sounds of nature, transportation, public address system, and so on were produced for both contexts while there were differences between the contexts in the separation of indoor/

outdoor sounds or in the existence of amusement sounds. Looking in detail, the sound of "Cries of crow" was relatively far from the sounds of other creatures and the sounds of "Street gangs" and of "Car exhaust noise" were relatively far from other transportation sounds.

3.2. Correspondence analysis

A matrix of the sounds vs. the groups of sounds, in which the value of each element was 1 if a sound was included in a group and 0 if not, was put into a correspondence analysis. Since words of impressions were assigned to every sound group in task 2, the result of this analysis illustrates which words correspond to a sound and the position of sounds and words on the major dimensions obtained by the analysis.

The sounds are plotted on the first three major dimensions in Figs. 4 and 5 with the labels for the clusters indicated in the graph. It was apparent that the sounds belonging to each of the clusters are located close to each other. The variances of scores of the sounds for the three major dimensions are 10%, 9% and 9% of the total variance *at home* and 10%, 8% and 8% for *theme park*, respectively.

The relationships between the sounds and the words of impressions were examined (Tables 1 and 2). Each word was related to one of the clusters using the criterion of the similarity between a word and a cluster with respect to the profile of the score to first three dimensions. The following relationships between the words and the sounds were observed: natural sounds corresponded to words such as "calm," "tranquil," "a perception of seasons," or "at ease." Transportation sounds corresponded to "uncomfortable," "annoying," "noisy," etc. (the words were originally written in

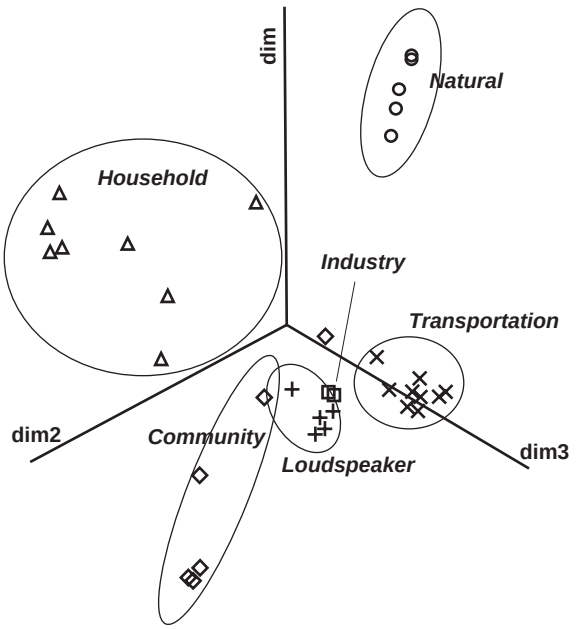

Fig. 4. Scatterplots of the sounds on the correspondence dimensions (context: *at home*).

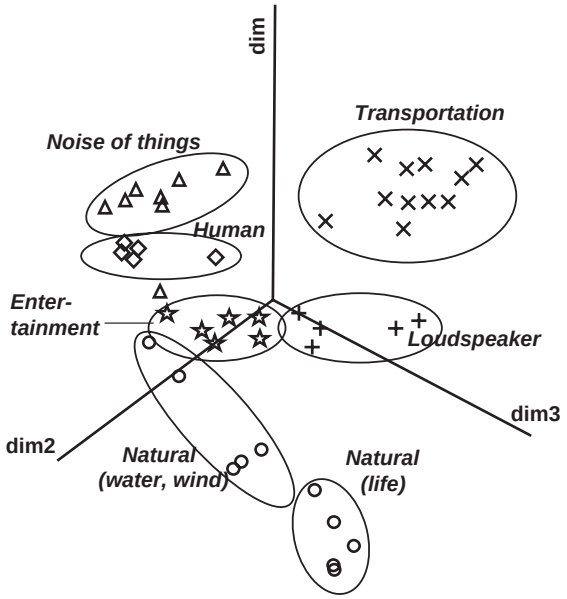

Fig. 5. Scatterplots of the sounds on the correspondence dimensions (context: *theme park*).

Table 1
Sounds and the corresponding word-pairs (context: *at home*)

Name of cluster	Corresponding word-pairs
Natural	Quiet, calm–noisy Rural–urban Natural–artificial
Household	Human–mechanical Domestic–social Presence–absence of life
Transportation	Unpleasant–pleasant Changing–still Noisy–quiet
Industry	Unpleasant–pleasant Mechanical–natural Monotonous–varied
Loudspeaker	Active–still Annoying–quiet Occasional–continuous
Community	Pleasant–calm Relieving–irritating Lively–deserted

Table 2
Sounds and the corresponding word-pairs (context: *theme park*)

Name of cluster	Corresponding word-pairs
Natural	Unwinding–stressful Refreshing–exhausting Sense the seasons–everyday
Human	Life–thing Pleasant–uninteresting Verbal–meaningless
Noise of things	Active–still Restless–calm Artificial–natural
Transportation	Restless–calm Noisy–quiet Enjoyable–usual
Loudspeaker	Loud–inaudible Lively–quiet Noisy, artificial–quiet, natural
Entertainment	Joyful, exciting–uninteresting Lively–quiet Varied–monotonous

Japanese). The transportation sounds also corresponded to the words of something like "a perception of travelling" in the *theme park* where the sound of boats or airplanes seemed to give such a positive impression. The sound "Cries of crows" was related to such words as "weird" or "ominous" by a few subjects and probably that was the reason for the difference between the sound of crows and the sound of other creatures, as observed in the result of cluster analysis.

3.3. Principal component analysis

The data from task 3, obtained with subjective evaluation by using the subject's own words as personal evaluation scales, were analysed to find the evaluation structure by means of a principal component analysis. All the subjects' evaluation scales were treated as different variables in this analysis. The number of variables was 280 *at home* and 292 in the *theme park*.

The sounds and all subjects' scales were located on the same principal components of evaluation structure. The contribution of first three components to the total variation of the subjects' evaluation were 32%, 13%, 7%, respectively *at home* and 25%, 17%, 9% in the *theme park* (Tables 3 and 4). The first three components of both contexts were interpreted as preference (or good–bad evaluation), activity, and sense of daily life, with their total contribution approximately at 50%. The fourth and fifth components could not be clearly interpreted, but could be described as pertaining to continuity or meaningfulness of sounds.

The highest absolute principal component loading value of each subject's words was calculated to find how the evaluation structure is shared among subjects. The reason for using the highest factor loading value was that if at least one of a subject's words had a high correlation with a

Table 3
Evaluation structure (context: *at home*)

Principal component ( ): contribution	Correlating word-pairs	Correlating sound clusters ( ): *correlating sound*
PC1 Preference (32.1%)	Annoying–calm Noisy–quiet Natural–cultural	+Transportation +Industry −Natural
PC2 Activity (12.8%)	Presence–absence of life Lively–mechanical Lively–empty	+Community +Loudspeaker −Transportation
PC3 Daily life (7.2%)	Sense community feeling–not... Casual–formal Daily–unusual	+Household −Transportation (−*Sounds of fireworks*)

Table 4
Evaluation structure (context: *theme park*)

Principal component ( ): contribution	Correlating word-pairs	Correlating sound clusters
PC1 Preference (25.0%)	Irritating–relieving Unpleasant–pleasant Artificial–natural	+Transportation −Natural
PC2 Activity (16.8%)	Lively–deserted Joyful–empty Exciting–gloomy	+Entertainment +Loudspeaker −Noise of things
PC3 Daily life (9.2%)	Common–strange Usual–special Daily–unusual	+Human +Noise of things −Entertainment

component, we could assume the subject evaluates environmental sounds based on that factor. The result shows that the first component had a high correlation ($r > 0.6$) with at least one word of each subject. The second and third components had high correlation with the words of most of the subjects, while the correlation of the rest of the components with the words varied depending on the subjects. From these results, we determined that the common dimensions in evaluating environmental sounds were three, namely, preference, activity and sense of daily life. With respect to the sounds, natural sounds and transportation sounds were located at opposite positions to the first component (preference) in both contexts (Figs. 6 and 7). This means the natural sounds are typical good sounds and the transportation sounds are typical bad sounds in the subjects' memory. Other sound groups did not have a high loading on the first component but had a high loading on the second or third components. This means that these types of sounds are rather neutral or diverse in respect of the good–bad evaluation.

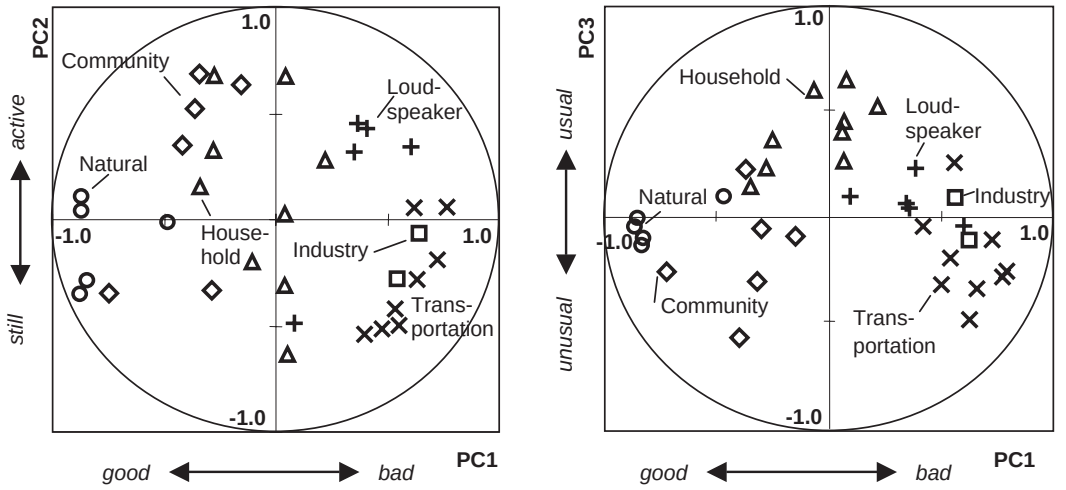

Fig. 6. Scatterplots of the sounds on the principal components (context: *at home*).

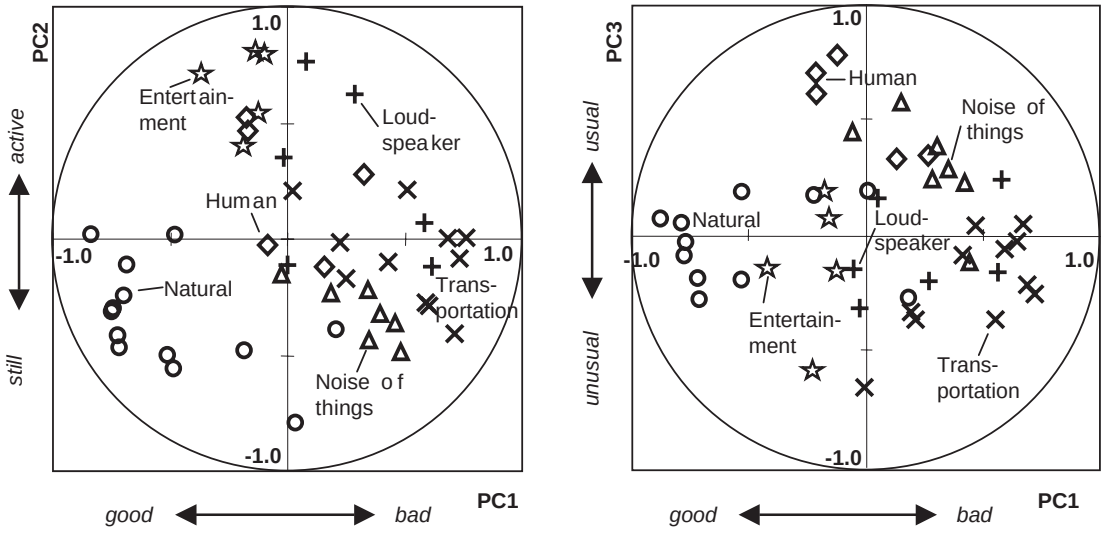

Fig. 7. Scatterplots of the sounds on the principal components (context: *theme park*).

4. Comments

The study is an attempt to determine the evaluation structure of environmental sounds. The clusters of sounds such as natural or transportation sounds were produced through the grouping task. Since these obtained clusters are based on the similarity of peoples' impressions, the result can be a basic finding for the qualitative description of the sound environment according to the type of sound. We showed that the evaluation structure, that is, the relationships between the sounds and impressions and the position of them on the major dimensions of evaluation, was roughly revealed through a corresponding analysis using the data from the grouping and labelling

tasks that are rather easy to perform. The outcome of the results of subjective evaluation with personal evaluation scales shows clearer relationships between the sounds and the words than that of previous analysis because, in the data from task 3, a sound was evaluated with all of the subject's words while the sound groups were associated with only one word that represented the impression in the data from tasks 1 and 2. We found that the three major dimensions of the evaluation structure are preference, activity and sense of daily life.

The results are limited because of the small sample of subjects for the experiment. However, it probably is not desirable to aim to find the universal evaluation structure by accumulating results of numerous experiments with various kinds of people because the evaluation structure is supposed to be originally variable, depending on the people and the time stage of their life. On the other hand, this methodology can be applied to a real life situation: for example, a survey of residents to whom specific sounds or visual objects in their residential area are presented for evaluations would reveal their evaluation structures that reflect their life in the area and the result might contribute to town planning, by leading the residents to some acceptable agreement [14].

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