Abstract
An index of sound recognition of an area, i.e. LSRC5/2, has recently been developed through reanalyzing a matrix composed of the results of 1240 respondents placed in rows, and responses to 39 sounds in columns. This was done by arranging the answers to questions in a questionnaire survey carried out by random sampling at Yokohama city in 1991. The index is a reproduction from a trail of sound environments in daily lives based not on measured acoustic data but on the recognition of the long-term memories of respondents. It indicates the level of ambiguity to our total sound environments. The index will become a useful target for land use planning, travel demand management, life enjoyment, and so on.

Keywords: sound; recognition; environment; attitude; behaviors

Introduction
When addressing the sound environments of our residential areas, there is a tendency to concern us only with unfavorable sounds (better known as noise) through noise control, noise prevention, noise annoyance evaluation, noise effects and other anti-noise activities (Schultz, 1978; Porter, Berry & Frindell, 1998; Staples, Cornelius & Gibbs, 1999). Brown & Rutherford (1994) suggested the use of waterfalls to mask city noises. Tamura (1997) proved the effects of landscaping on the feeling of annoyance by experiments and surveys. Such an understanding of sound is to a certain extent influenced by the fact that many outstanding problems concerning noise are a result of the development of industry, increases in traffic, concentrated populations in large cities, and a lack of awareness of our community. About 30% of environmental disputes in Japan are caused by noise (The Ministry of the Environment, 2001, February).

By listening a little more carefully, however, one can realize that our life is full of sounds of various natures (Schafer, 1977, 1993). The sound of voices of children playing outside, the chirping of sparrows and crickets, the sound of water, the sound of a bell in the temple, and the voices of sellers tend to be missed in our everyday lives. However, these sounds form, and will continue to do so in the future, our regional sound environments (Shima & Tamura, 1994; Sasaki, 1994).

Sounds in residential areas have ambiguous aspects to them. But the ambiguous sounds environments are the result of our daily behaviors after all. So knowledge of the environments will lead us thinking about our daily behaviors. Significant improvements to the environment come from behavioral changes. Dwyer, Porter, Leeming & Oliver (1997) pointed out that it goes without saying that the degradation of the earth’s environment is caused largely by behavior, and the solution to the problems of environmental quality must come primarily from behavioral change.

There are important indices for rating outputs of behavioral change to solve the problems of environmental quality, for example air temperature, biochemical oxygen demand, industrial waste and so forth. The sound condition in residential areas is an important index too. Noise prevention is, in all senses, important for developing and for maintaining the region. Sounds from the viewpoint of familiarity may not be ignored. It is necessary to understand these two characteristics of sound environments by thoroughly analyzing these quantitative and qualitative aspects, both for the sake of us and for the future generations to come.

Can we understand the ambiguous sound environments from analyzing acoustic data? This is possible if the physical measurements will result in acoustic data that reproduces the environments sufficiently well. But physical measurements can be used to analyze only part of the noise environment. This is because of restrictions in measuring time, difficulties associated with sound source discrimination, and confusion with rating familiarity. The acoustic data tends to consist of quantitative aspects of the environment.

Trails of ambiguous sounds environments in residential areas are stored in the long-term memory of inhabitants while they are living in their houses and
surroundings. It is expected that the recognition (Koyaizu, 1981) of their long-term memories will make quantitative and qualitative reproduction of the environments in their total region.

This study investigates 1240 respondents’ answers to a question in a survey based on random sampling that was carried out 10 years ago. Results of the survey were previously analyzed and presented in a final report and through some oral papers (Kashima, Tamura, Shima & Sawada, 1994, 1995). In this survey, people were asked to rate 39 specified sounds originating from outdoors, heard while they were inside their houses. Sounds were rated in one of the following 4 categories: inaudible, favorable, neither favorable nor annoying, or annoying. Based on these results, a matrix that consisted of the 1240 respondents placed in rows and the responses to the 39 sounds in columns was prepared for reanalyzing.

**Outline of the Survey**

This survey, conducted from October to early December 1991, should be taken into account when studying the structure of the consciousness of sounds familiar to the people of Yokohama City (Japan). In this survey, 1600 people of both sexes aged 12 years old or above were randomly chosen at a rate of 100 people per ward from the computerized resident register. This was carried out following the permission of the Personal Information Protect Agency. The questionnaire was developed with reference to a report (Nanba, Igarashi, Kuwano, et al., 1992) of the Committee of Social Survey on Noise in the Acoustical Society of Japan and research (Shima & Tamura, 1994) concerning sounds representing areas. It was designed to include not only negative features but also positive features of sound environments in living areas, though the report of the Committee addressed only the negative aspects.

The mailing method was used to carry out the distribution and collection of the questionnaires. Requests for replies were issued a total of three times. In the end, 1240 people finally responded, yielding a 77.5% valid response rate. Female respondents accounted for 55% of the total, which was larger than the 49% of females in the general population of Yokohama. The age distribution of the respondents was similar to that of people in Yokohama. The respondents living in two exclusive residential districts class 1, 2 or residential districts accounted for above 80% of the total respondents, while the percentage of those living in neighborhood commercial districts, commercial districts or quasi-industrial districts was about 15%.

**Classification of 39 Sounds**

Thirty-nine sounds were selected from various outdoor sounds heard in daily lives and they represent the ambiguous sound environments in residential areas.

The question asked in the survey was “Are the following 39 sounds coming from outdoors audible in your house? Please check for each particular sound”. People were asked to respond to one of 4 categories, i.e. “1. Inaudible”, “2. Favorable”, “3. Neither favorable nor annoying”, and “4. Annoying” for each sound. These answers are named (I), (F), (N), and (A), respectively. Responses to this question were aggregated based on each sound and assessed using the following equations:

\[
\text{Po (observed rate in %)} = \frac{O}{T} \times 100, \\
\text{Pf (favorable rate in %)} = \frac{F}{O} \times 100, \\
\text{Pn (neither favorable nor annoyed rate in %)} = \frac{N}{O} \times 100, \\
\text{Pa (annoyed rate in %)} = \frac{A}{O}. 
\]

T: the total number of valid participants, 
O: the number of respondents who heard a particular sound (= F+N+A), 
F: the number of respondents who heard a particular sound and found it favorable, 
N: the number of respondents who heard a particular sound and felt it neither favorable nor were annoyed by it, and 
A: the number of respondents who heard a particular sound and felt annoyed by the sound.

The variable Po is the rate of respondents who chose any one of (F), (N), and (A) relative to the total respondents of 1240, classified as “observed rate” of a sound that they heard in their surroundings, and predicts a quantitative component of the recognition of the sound. Pf, Pn, and Pa are indices of favorable feelings, feelings that are classed as neither favorable nor annoying, and annoying feelings, respectively. The set of three variables, i.e. (Pf, Pn, Pa), represent the inhabitant’s attitude towards the sound, whether favorable or not favorable, and represents a qualitative component of sound recognition.

A total of 39 values for Po and 39 sets of (Pf, Pn, Pa) in Yokohama city area indicate the quantity and quality of the recognition of the ambiguous sound environments in the area, respectively.

Using these three variables representing the qualitative features of sounds, the 39 sounds were classified into three groups through hierarchical cluster analysis (cluster method: Ward’s method, similarity measure: Euclidean distance). Table 1 shows the types of sounds listed in descending order of Po by the three groups recently defined. The 9 sounds of group1 represent mainly natural sounds, such as 33) the twittering of birds or 36) the murmurs of water streams, which people rated as (F) or (N). The 18 sounds of group2 represent miscellaneous sounds heard by residents, the so-called daily life sounds, indicated mostly by (N), with a ratio of 10 - 20% annoying. The 12 sounds of group3 relate to 1) large automobiles, 17) stores,
Table 1. Outdoor Sounds Observed in Respondents’ Houses and the Attitude of the Inhabitants Towards the Sounds Whether Favorable or Not Favorable (Yokohama-city, 1991)

<table>
<thead>
<tr>
<th>Group</th>
<th>Types of Sounds</th>
<th>Po</th>
<th>Pf</th>
<th>Pn</th>
<th>Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>33 Twittering</td>
<td>75.5</td>
<td>72.6</td>
<td>26.4</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>32 Chirping of insects in autumn, Croaking of frogs and droning of cicadas</td>
<td>72.9</td>
<td>59.6</td>
<td>37.8</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>30 Festivals, fireworks and Bon festival dance</td>
<td>52.6</td>
<td>29.4</td>
<td>63.1</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>35 Whispers of leaves of trees and grasses</td>
<td>41.3</td>
<td>43.6</td>
<td>55.6</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>31 Wind-bells</td>
<td>29.9</td>
<td>55.0</td>
<td>41.2</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>39 Bells of temples and churches</td>
<td>17.7</td>
<td>49.4</td>
<td>45.3</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>38 Whistles of ships</td>
<td>12.1</td>
<td>47.3</td>
<td>48.7</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>36 Murmurs of water streams</td>
<td>6.9</td>
<td>57.0</td>
<td>39.5</td>
<td>3.5</td>
</tr>
<tr>
<td>G1</td>
<td>37 Sea waves</td>
<td>83.1</td>
<td>1.0</td>
<td>81.8</td>
<td>17.2</td>
</tr>
<tr>
<td>G2</td>
<td>1 Collection of garbage</td>
<td>70.2</td>
<td>6.4</td>
<td>89.9</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>34 Cawing of crows</td>
<td>59.7</td>
<td>5.7</td>
<td>68.3</td>
<td>26.0</td>
</tr>
<tr>
<td></td>
<td>20 Voices of children</td>
<td>58.4</td>
<td>5.7</td>
<td>79.9</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td>19 Chats at standing</td>
<td>42.8</td>
<td>0.9</td>
<td>82.9</td>
<td>16.2</td>
</tr>
<tr>
<td></td>
<td>29 Parking lots</td>
<td>35.8</td>
<td>0.0</td>
<td>80.6</td>
<td>19.4</td>
</tr>
<tr>
<td></td>
<td>25 Water supply and drainage in bathrooms</td>
<td>35.2</td>
<td>0.9</td>
<td>83.5</td>
<td>15.6</td>
</tr>
<tr>
<td>G2</td>
<td>23 Musical instruments such as pianos</td>
<td>34.8</td>
<td>9.3</td>
<td>79.9</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>21 Cries of babies</td>
<td>32.0</td>
<td>4.3</td>
<td>84.8</td>
<td>10.9</td>
</tr>
<tr>
<td></td>
<td>26 Upper floors</td>
<td>29.8</td>
<td>0.5</td>
<td>73.7</td>
<td>25.8</td>
</tr>
<tr>
<td></td>
<td>13 Schools and kindergartens</td>
<td>28.5</td>
<td>6.8</td>
<td>82.2</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>24 TV and stereos</td>
<td>25.7</td>
<td>6.3</td>
<td>75.8</td>
<td>17.9</td>
</tr>
<tr>
<td></td>
<td>8 Railroads</td>
<td>21.9</td>
<td>4.4</td>
<td>76.1</td>
<td>19.5</td>
</tr>
<tr>
<td></td>
<td>22 Air-conditioners and boilers</td>
<td>21.6</td>
<td>0.4</td>
<td>80.9</td>
<td>18.7</td>
</tr>
<tr>
<td>G2</td>
<td>7 New inter-city trains</td>
<td>8.3</td>
<td>3.9</td>
<td>78.6</td>
<td>17.5</td>
</tr>
<tr>
<td></td>
<td>9 Alarm signals of railroad crossings</td>
<td>6.9</td>
<td>2.3</td>
<td>85.1</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td>14 Alarm signals of pedestrian crossings</td>
<td>6.6</td>
<td>3.7</td>
<td>91.4</td>
<td>4.9</td>
</tr>
<tr>
<td>G3</td>
<td>3 Motorcycles</td>
<td>90.9</td>
<td>1.2</td>
<td>32.9</td>
<td>65.9</td>
</tr>
<tr>
<td></td>
<td>1 Large automobiles</td>
<td>66.0</td>
<td>0.6</td>
<td>65.3</td>
<td>34.1</td>
</tr>
<tr>
<td>G3</td>
<td>10 Airplanes and helicopters</td>
<td>62.0</td>
<td>0.8</td>
<td>61.9</td>
<td>37.3</td>
</tr>
<tr>
<td></td>
<td>5 Horns of passenger cars and motorcycles</td>
<td>61.8</td>
<td>0.4</td>
<td>54.8</td>
<td>44.8</td>
</tr>
<tr>
<td>G3</td>
<td>15 Loud speakers of advertising cars</td>
<td>55.6</td>
<td>0.6</td>
<td>50.0</td>
<td>49.4</td>
</tr>
<tr>
<td></td>
<td>4 Horns of large automobiles</td>
<td>51.9</td>
<td>0.3</td>
<td>57.9</td>
<td>41.8</td>
</tr>
<tr>
<td></td>
<td>28 Idling engines</td>
<td>40.6</td>
<td>0.4</td>
<td>37.9</td>
<td>61.7</td>
</tr>
<tr>
<td></td>
<td>27 Cries of pets</td>
<td>39.4</td>
<td>1.6</td>
<td>65.4</td>
<td>33.0</td>
</tr>
<tr>
<td></td>
<td>12 Constructions and public works</td>
<td>22.3</td>
<td>0.4</td>
<td>42.2</td>
<td>57.4</td>
</tr>
<tr>
<td></td>
<td>17 Loud speakers of stores</td>
<td>15.2</td>
<td>2.1</td>
<td>66.5</td>
<td>31.4</td>
</tr>
<tr>
<td></td>
<td>11 Factories and workshops</td>
<td>12.9</td>
<td>1.9</td>
<td>57.4</td>
<td>40.7</td>
</tr>
<tr>
<td>G3</td>
<td>18 Karaoke restaurants</td>
<td>8.2</td>
<td>1.0</td>
<td>51.9</td>
<td>47.1</td>
</tr>
</tbody>
</table>

Po (observed rate in %) = 100(O/T).
Pf (favorable rate in %)=100(F/O).
PN (neither favorable nor annoyed rate in %)=100(N/O), and
Pa (annoyed rate in %)=100(A/O).
T: total number of valid respondents,
O: the number of respondents who heard a particular sound,
F: the number of respondents who heard a particular sound and felt favorable,
N: the number of respondents who heard a particular sound and felt neither favorable nor annoyed, and
A: the number of respondents who heard a particular sound and felt annoyed.
11) factories and 12) construction work, indicated by (N) or (A).

Large cars, motorbikes, and car horns had a high observation rate and showed the highest annoyance rate. Moreover, respondents rated favorably the twittering of birds, the sounds of sea waves, and the sounds of brooks. Although the observed rates of daily life sounds were not so high, neither favorable nor annoying rates were high, and most of those favorable rates fell below the rates observed for annoying. The increased rate of complaints for these sounds suggests to us an understanding of the meaning of complaints and the need for improving the sound environments of cities.

A similar survey was carried out at Muscat city (Oman) in April 1996 (Al-harthy & Tamura, 1999). In this survey, the Azan sound, i.e. the prayer religious call, had the highest observed and favorable rates. In Yokohama, 39) bells of temples and churches as religious calling devices were rarely heard, due to the fact that they are not frequently used. Religious sounds differ from one culture to another. The observed rate and the favorable rate minus the annoyance rate for water supply engines were 84.3% and -44.1%, respectively, in Muscat. As a water supply network has yet to be installed in Muscat, the use of cistern trucks to carry drinking water is still the preferred delivery system. About 50-85% of the people in Yokohama but only about 30% of the people in Muscat heard the sounds of 6) sirens of patrol cars and ambulances and 15) the loudspeakers of advertising cars. Sirens of patrol cars and ambulances are widely used in Yokohama. Although they do exist in Muscat, they are rarely heard. Loudspeaker cars for advertising purposes are commonly used in Yokohama but are not used at all in Muscat.

**Classification of 1240 Respondents**

The classification reflects the feelings of respondents to their individual sound environment in terms of how they perceive the three sound groups. For this purpose, 6 variables, i.e. 1f, 1na, 2fn, 2a, 3fn, and 3a, are introduced as follows:

1f: the ratio of the number of sounds rated (F) to the 9 sounds of group1 in %,
1na: the ratio of the number of sounds rated (N) or (A) to the 9 sounds of group1 in %,
2fn: the ratio of the sounds rated (F) or (N) to the 18 sounds of group2 in %,
2a: the ratio of sounds rated (A) to the 18 sounds of group2 in %,
3fn: the ratio of sounds rated (F) or (N) to the 12 sounds of group3 in %, and
3a: the ratio of sounds rated (A) to the 12 sounds of group3 in %.

People rarely rated the 9 sounds of group1 as (A), the 18 sounds of group2 as (F), and the 12 sounds of group3 as (F). That is to say that the response level of (N) was closer to (A) than to (F) in the case of group1, and the response level of (N) was closer to response (F) than to (A) in the case of group2 and 3. So the perceptions of group1 sounds were recategorized into (F) and (N + A), and perceptions of group2 sounds and group3 sounds were recategorized into (F + N) and (A).

By using the 6 variables 1f, 1na, 2fn, 2a, 3fn, and 3a, the 1240 respondents were classified into 5 sound recognition clusters, i.e. SRC1, SRC2, SRC3, SRC4, and SRC5, through k-means cluster analysis that can handle large numbers of cases (see Fig. 1). The mean perception, i.e. mean values of 1f, 1n, 2n, 2a, 3n, and 3a, and the rate of respondents belonging to each cluster are shown as follows.

![Fig. 1. Mean Values of 1f, 1na, 2fn, 2a, 3fn, and 3a of 5 Sound Recognition Clusters](image-url)

**Sound recognition clusters**

<table>
<thead>
<tr>
<th>SRC</th>
<th>Recognition level toward sound groups (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRC1</td>
<td>34%: low recognition level for every sound,</td>
</tr>
<tr>
<td>SRC2</td>
<td>22%: recognized group1 sounds favorably and has a high ratio of feeling neither good nor annoyed by group2 and 3 sounds,</td>
</tr>
<tr>
<td>SRC3</td>
<td>14%: recognized every sound well but feels neither good nor annoyed,</td>
</tr>
<tr>
<td>SRC4</td>
<td>13%: feels neither good nor annoyed if recognizing group1 and2 sounds, but feels annoyed by group3 sounds at a high level, and</td>
</tr>
<tr>
<td>SRC5</td>
<td>18%: rarely recognizes group1 and 2 sounds, but feels annoyed by group 3 sounds at an extremely high level.</td>
</tr>
</tbody>
</table>

Sound recognition clusters, i.e. SRCs, perceived by the inhabitants together indicate the quantitative and qualitative recognition level of them towards the sound conditions in their surroundings. Their perceptions to their sound environments are well...
reflected by SRCs.

The distribution of SRCs of the inhabitants in an area shows the reproduction of the sound environment made by the recognition of their long-term memories and the summary of the sound environment in the area.

SRC1 has a low recognition ratio for every sound. SRC2, SRC3, and SRC4 recognize group 1, 2, and 3 sounds well but have different attitudes toward sounds. Those in the SRC5 category cannot recognize group 1 and 2 sounds well, but are annoyed by group 3 sounds at an extremely high rate. While SRC2 recognizes the natural sounds of group 1 well occupying 22%, SRC4 and SRC5 who are annoyed by group 3 sounds generated by automobiles or construction work, make up a higher rate of 31%.

By using the responses for other questions related to the satisfaction of the 10 environmental issues except quietness, the respondents were classified into 5 environmental attitude clusters, i.e. EAC1, EAC2, EAC3, EAC4, and EAC5, through k-means cluster analysis (see Fig. 2). A total of 10 issues were identified as "walking ability areas", "clean air", "amount of greenery", "collecting garbage", "convenience of shopping", "convenience of transportation", "relation between your neighborhood", "the safety of surrounding roads", "sunshine in your house", and "ventilation in your house".

![Environment attitude clusters](image)

**Fig.2. Mean Dissatisfaction Scores of “clean air”, “amount of greenery”, “convenience of shopping”, “convenience of transportation”, “sunshine in your house”, and “ventilation in your house” of the 5 Environmental Attitude Clusters**

EAC1 (26%): satisfied with both natural, indoor environments and convenience,
EAC2 (22%): satisfied with both natural and indoor environments but dissatisfied with convenience,
EAC3 (23%): slightly satisfied with natural and indoor environments but slightly dissatisfied with convenience,
EAC4 (20%): dissatisfied with natural environment but satisfied with indoor environments and convenience, and
EAC5 (9%): dissatisfied with both natural and indoor environments but satisfied with convenience.

Group EAC1, which was fully satisfied with all items, occupies 26%. As the number of clusters increases starting from 2, the dissatisfaction with the natural environment increases while the satisfaction with convenience increases.

Demographic variables (hours in the home, composition of the family, building type of residence, length of residence) were coded from the answers to the questionnaires. Land use zoning, the distance from main roads (national highway, express way, or major local road) and that from the nearest station were decided upon based on the locations of the residences where the respondents were dwelling. The whole population, the number of whole employees, and the ratio of employees to the population per mesh where each respondent was dwelling were coded from the mesh data of 250m x 250m. This was carried out based on the results of the national census taken in 1990. The 3 variables that indicate the main features, i.e. land use, road condition, and population, of the locations of the dwelling residences, are listed as follows.

**Land use zoning (at the time)**
- z1 (5%): restricted urbanization district,
- z2 (39%): exclusive residential district classes 1,
- z3 (20%): exclusive residential district classes 2,
- z4 (21%): residential district,
- z5 (6%): neighborhood commercial district,
- z6 (5%): commercial district, and
- z7 (4%): quasi-industrial district.

**The distance from main roads (national highway, express way, or major local road)**
- d1 (5%): less than 10m,
- d2 (6%): 10m-30m,
- d3 (6%): 30m-50m,
- d4 (15%): 50m-100m,
- d5 (19%): 100m-200m, and
- d6 (49%): more than 200m.

**The ratio of employees to population per mesh (250m x 250m)**
- jr1 (28%): less than 0.05,
- jr2 (18%): 0.05-0.1,
- jr3 (20%): 0.1-0.2,
- jr4 (16%): 0.2-0.4,
- jr5 (11%): 0.4-0.8, and
- jr6 (7%): more than 0.8
Discussion

By using $\chi^2$ tests of independence in cross tables, distributions of SRCs were either not significant or of low significance for gender, age, hours in home, composition of the family, building type of residence, length of residence, distance from the nearest station, and whole population per mesh, but were highly significant ($p<0.001$) for land use zoning, distance from main roads, the number of whole employees per mesh, and the ratio of employees to the population per mesh (employee: people who work and live in an area or work in the area but live in other area, population: number of people who live in the area). As a whole, the relationship is weak between the perceptions of the sound environment, namely sound recognition, and personal attributes, but is strong between perception and the conditions of the residential locations. Based on the balance of the evidence from 464 findings drawn from 136 surveys, Fields (1993) summarized the same conclusions that annoyance is not affected to a significant extent by ambient noise levels, the amount of time residents are at home, the type of interviewing method, or any of the nine demographic variables (age, sex, social status, income, education, home ownership, type of dwelling, length of residence, or the receipt of benefits from the noise source).

The rate of respondents belonging to the SRC2 group decreases in the order of the land use zoning clusters from restricted urbanization district, exclusive residential district classes 1 and 2, residential district, neighborhood commercial district, commercial district, while the rate of SRC5 increases. The rate of SRC1 shows no difference between districts. The rate of SRC3, i.e. those that recognize every sound well but feel neither good nor annoyed by the sounds, decreases in commercial and semi-industrial districts having scarce daily living.

As the distance to major roads increases, the rate of SRC5 decreases, while the rate of SRC2 and 3 increases. The rate of SRC4, i.e. those that feel neither good nor annoyed by the sounds, decreases in commercial and semi-industrial districts having scarce daily living.

As can be seen above, the increases and decreases in the rates of SRC5 and SRC2, respectively, depend strongly on the characteristics of the residential area.

Hence, a log-10 transformation of the ratio of the subjects belonging to SRC5 to the subjects belonging to SRC2 was developed as an index of sound recognition, represented by LSRC5/2. The index reflects the combined recognition to the ambiguous sound environment.

In the restricted urbanization district, exclusive residential district classes 1 and 2 and residential districts, the LSRC5/2 count for less than 0.0. In the neighborhood commercial district and the quasi-industrial district, it counts for more than 0.0. In the commercial district, it counts for 0.9 or more; where the ratio of the SRC5 to the SRC2 is larger than 8 to 1 (see Fig. 3).

![Fig.3. Log-10 Transformation of Ratios of Subjects Belonging to the SRC5 to Subjects Belonging to the SRC2 in Cases of Land Use Zoning, Distance from Main Roads, and the Employees to the Population per Mesh.](image)

In the close vicinity of major roads, it counts for 0.5, within 100m of the major road it counts for 0.0 or more, while for distances over 100m, it counts for -0.3.

When the employees per mesh stays below 40% of the residential population, it counts for around -0.3, but when it exceeds 40%, it counts for more than 0.3.

The relationship between the values of the LSRC5/2 in areas having various features and the ratios of both the EAC4 and EAC5, whose attitude to the natural environment is dissatisfied, relative to the total number of subjects of the same areas are indicated in Fig. 4.

The correlation coefficient exceeds 0.85, showing a good relationship. At the LSRC5/2 of -0.3, namely at the group where participants of the SRC5 is half that of the SRC2, about 1/4 of the respondents of the area belong to EAC4 or EAC5, i.e. clusters dissatisfied with the natural environment in their residential areas. At the LSRC5/2 of 0.0, namely at the area where the SRC2 mostly equals the SRC5, about 1/3 of the respondents of the area belong to the clusters, and at the LSRC5/2 of 0.3, namely at the area where the SRC5 is twice the SRC2, about 1/2 of the respondents of the area belong to the clusters.

The index of sound recognition, i.e. LSRC5/2, which is calculated from the distribution of SRCs of the inhabitants in an area, reflects the living area features of the area and closely relates to the attitude of the inhabitants to their natural environment.
1) 4 variables, i.e. Po, Pf, Pn and Pa, were introduced as predictors of quantitative and qualitative components of each sound, and 39 sounds were classified into 3 groups using Pf, Pn and Pa. The 9 sounds of group1 represent mainly natural sounds, such as the twittering of birds or the murmurs of water streams, which people rate as “Favorable”, or “Neither favorable nor annoying”. The 18 sounds of group2 represent miscellaneous sounds heard by residents, the so-called daily life sounds, indicated mostly by “Neither favorable nor annoying”, with a ratio of 10 - 20% “Annoying”. The 12 sounds of group3 relate to automobiles, stores, factories and construction work, indicated by “Neither favorable nor annoying” or “Annoying”.

2) 6 new variables, i.e. 1f, 1na, 2a, 3fn and 3a, were presented as indicators of individual recognition to the levels of the 3 sound groups, and 1240 respondents were classified into 5 sound recognition clusters, i.e. SRC1, SRC2, SRC3, SRC4, and SRC5, using 6 variables. The increases and decreases in the rates of SRC5 and SRC2, respectively, are strongly related to the characteristics of the living area.

3) A newly developed index of sound recognition for various areas, i.e. LSRC5/2, was developed, which consisted of a log-10 transformation of the ratio of subjects belonging to SRC5 in each area to subjects belonging to SRC2. The index reflects the living area features of the area and closely relates to the attitude of the inhabitants in the area to their natural environment.

4) The index indicates the level of the total sound environment. The index will become a useful target for land use planning, travel demand management, living enjoyment, and so on.

Conclusions

A matrix that consisted of 1240 respondents placed in rows and the responses to the 39 sounds in columns was arranged based on a question asked in a survey carried out in Yokohama city that was reinvestigated. This reanalyzing showed the following:

1) 4 variables, i.e. Po, Pf, Pn and Pa, were introduced as predictors of quantitative and qualitative aspects of the environment. The index of sound recognition, i.e. LSRC5/2, is a reproduction from the trail of ambiguous sound environments in residential areas based not on physical measurements but on the recognition of the long-term memories of residents. It indicates quantitative and qualitative levels of the total sound environment. By further accumulating knowledge of the relationships between the index and living area features, the index will become a useful target for land use planning, travel demand management, living enjoyment, and so on.

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