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# PSYCHOLOGICAL EVALUATION ON TRANSMISSION LOSS OF BUILDING MATERIALS BY ROAD VEHICLE NOISE SIMULATOR

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**ABSTRACT**
A vehicle noise simulator was proposed in the previous paper [1] (inter-noise 99) on the model of a house facing a national road in an anechoic room. The psychological evaluation on the effect of various physical conditions (vehicle noise sources, traffic conditions, barrier and building materials) was adopted with the following terms: annoyance, the subjective effect on transmission loss and the subjective impression of considering all the factors. From the results of the psychological experiment, if average sound insulation of roadside houses is about 33dB, the subjects evaluated as follows: $L_{\mathrm{Aeq(5min)}}$ (about 37dB) corresponds to "not too bothersome", the transmission loss is "effective" and the subjective impression of considering all the factors is "good". As a conclusion, it can be said that the simulator proposed is effective for the selection of building materials.

## 1 - INTRODUCTION

Road traffic is the most widespread source of noise in all countries and the primary reason for annoyance and interference with human activities. In Japan, it is difficult to reduce noise in area where houses are directly exposed to high-level traffic noise. For such limited areas adjacent to trunk roads, exceptional standard values (70dB or less for daytime, 65dB or less for nighttime) should be considered in order to promote measures to reduce noise. Compliance of these values means that guidelines of indoor noise for roadside area (45dB or less for daytime, 40dB or less for nighttime) of these values means that roadside houses have average sound insulation (closed-window: 25dB) and their windows are closed all day. Generally speaking, it is only necessary for these concepts to be understood by key people such as noise control officers, acoustical consultants and regulatory officers. However, to minimize the impact of road traffic on the quality of life of surrounding communities, anyone interested in housing (residents, buyers, builders and researchers) will need to understand the above concepts to make housing more comfortable and individually suitable. As a noise prevention method, if the planner and residents can realistically experience and psychologically evaluate the effect of transmission loss with building materials in the planning stage of houses, it can be said that they can appropriately and economically choose those materials for sound insulation efficiency. In the previous paper [1], we constructed road vehicle noise simulator in an anechoic room based on the sensory characteristics of sight and hearing.
This paper discusses whether this simulator is effective for an evaluation and enlightenment on noise prevention technique and fosters a better understanding of housing design.

## 2 - VEHICLE NOISE SIMULATOR

From the aspect of virtual reality system, the vehicle noise simulator was constructed audio-visual system in an anechoic room (see Fig. 1) based on the intersensory and integration effects across sight and hearing.

The main characteristics in the previous paper [1] so far are as follows:

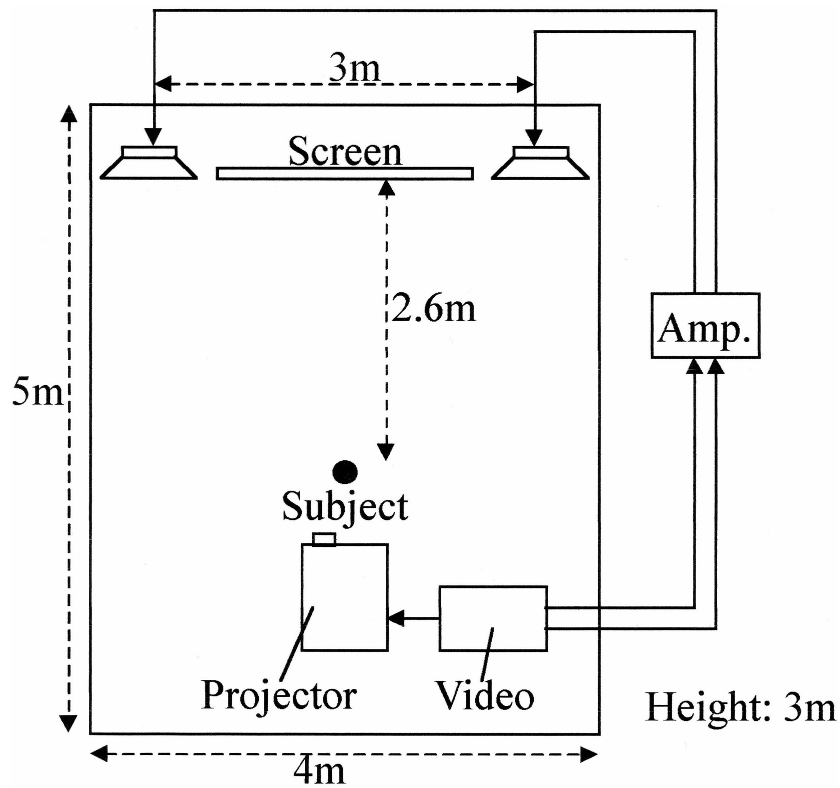


**Figure 1:** Arrangement plan of the vehicle noise simulator.

- One can suppose the noise condition of the field imaged by the projector-watching. As the image size is larger, the results (480 data / one image size) of 12 subjects were adjusted louder. The optimum image size is about 60inches.
- From the integration of simulated sound and motion picture videotaped, the two-point noise sources model to correspond each wheelbase of two kinds of vehicles is more effective than the one point noise source model.
- The relation between the mean annoyance scores and $L_{AE}$ of each passing vehicle in the case of this simulator corresponds to the relation in the case of a field experiment. The relation between "annoying" and about 82dB of $L_{AE}$ is an effective index for noise sources control.

This road traffic noise simulator by computational methods can change immediately the various kinds of conditions on environmental noise, and link each technique of prediction, measurement, control and evaluation to solve some noise problems.

## 3 - PSYCHOLOGICAL EXPERIMENT

| Test No. | Condition of place and subjects | Stereophonic noise sound reproducing method (Loudspeakers: ONKYO D-77 FX) | Picture on the projector (ELMO EDP-2000) screen (60 inches) | Traffic conditions | | | $L_{Aeq(5min)}$ [dB] at hearing point |
|---|---|---|---|---|---|---|---|
| | | | | Average flow: [vehicles/hour] | Mean speed: [km/jour] | Large vehicles mixed at: [%] | |
| 1 A group | An anechoic room 4×5×3 m in size of Shinshu University | Simulated sound by level difference method for two-point noise sources model proposed [1] | Nothing | 1200<br><br>750<br><br>400 | 40<br><br>60<br><br>60 | 15<br>30<br>15<br>30<br>15<br>30 | 70.2<br>71.5<br>70.5<br>71.2<br>67.7<br>69.0 |
| 2 B group | Brightness: 50 lx White Mean temperature: about 20°C | Stereophonic recording method (distance from a near traffic line to the recording point: 9m) at the side (steady moving vehicles) of National Route 19 in Nagano City | Outdoor image: At the same time the scene recorded on video (SONY DCR-VX1000) tape Indoor image: (see Table 2) | 648 | 37.3 | 27.8 | 72.8<br>70.0<br>69.5 |
| 3 B group | 26 subjects: A group (male: 9 and female: 2) B group (male: 13 and female: 2) | Stereophonic recording method (distance from a near traffic line to the recording point: 9m) at the side (an intersection with traffic lights) of National Route 19 in Nagano City | Outdoor image: At the same time the scene recorded on video (SONY DCR-VX1000) tape Indoor image: (see Table 2) | 1248 Traffic lights turned 2 minutes 10 seconds interval | 0∼about 40 | 15.4 | 72.9<br>70.3<br>69.6 |

**Table 1:** Experimental outdoor conditions by vehicle noise simulator.

As the outdoor conditions by our vehicle noise simulator, the details are listed in Table 1.

| Case No. | Simulated condition by FIR digital filter (Sampling frequency: 48kHz and 4096 taps) and pictures designed | Insertion or transmission loss [dB(A)] | |
|---|---|---|---|
| 1 | Outdoor image<br>Hearing point: 9m from traffic line. Height: 1.2m<br>Noise barriers (h=1m∼2m) at 5m from traffic line (noise source) | 7.2<br>12.0<br>13.3 | 7.8<br>13.0<br>14.0 |
| 2 | Indoor image: a house model (4.2×6.0×2.3 m)<br>Hearing point: 9m from traffic line. Height: 1.2m<br>Wall: the composition of wooden, mortar and glass wool<br>A glass window (1.15×1.6 m) with aluminum sash: single (thickness = 3mm∼6mm)<br>An Aluminum door (0.9×2.1 m) | 27.0<br>30.0<br>32.0<br>34.0 | 28.0<br>31.0<br>33.0 |
| 3 | Indoor image: a house model (4.2×6.0×2.3 m)<br>Hearing point: 9m from traffic line. Height: 1.2m<br>Wall: the composition of wooden, mortar and glass wool | 35.0<br>36.2 | 36.0 |
| 4 | Indoor image: a house model (4.2×6.0×2.3 m)<br>Hearing point: 9m from traffic line. Height: 1.2m<br>Wall: the composition of wooden, mortar and glass wool<br>A glass window (1.15×1.6 m) with aluminum sash: double (thickness = 5mm)<br>An Aluminum door (0.9×2.1 m) | 36.0<br>37.5 | 37.0 |

**Table 2:** Simulated conditions (insertion or transmission loss) by FIR digital filter and pictures designed.

| Annoyance scale [2], [3] | Effect of transmission loss | Subjective impression of considering all the factors |
|---|---|---|
| 3.19: Extremely annoying<br>2.06: Very annoying<br>1.15: Annoying<br>0: A little annoying<br>-0.91: Not too bothersome<br>-1.81: Not bothersome<br>-3.06: Not at all bothersome | 7: Extremely effective<br>6: Very effective<br>5: Effective<br>4: A little effective<br>3: Not too effective<br>2: Not effective<br>1: Not at all effective | 8: Extremely good<br>7: Very good<br>6: Good<br>5: A little good<br>4: A little bad<br>3: Bad<br>2: Very bad<br>1: Extremely bad |

**Table 3:** Psychological scales.

Table 2 shows the simulated conditions of a house model by FIR digital filter and a picture designed by computational method.
The evaluation of the effects of psychological impression used three psychological scales in shown Table 3.

## 4 - TEST RESULTS

The annoyance score ($A$), the effect score ($E$) of transmission loss and the subjective impression score ($S$) of considering all the factors are investigated by fitting coefficients in the following linear model through simple regression analysis:

$$A = \alpha + \beta \left( L_{\mathrm{Aeq(\ 5min)}} / 10 \right) \tag{1}$$

$$E = \alpha + \beta \left( TL \right) \tag{2}$$

$$S = \alpha + \beta \left( TL \right) \tag{3}$$

where $L_{\mathrm{Aeq(5min)}}$ [dB] is the equivalent continuous A-weighted sound pressure level; $TL$[dB(A)] is transmission (or insertion) loss; $\alpha$ is the constant (intercept); and $\beta$ is the slope.
Table 4 gives the correlation coefficient for model (1), (2) and (3), the regression coefficients (constant and slope), each lower and upper limit of the 95%-confidence interval, and the standard deviation of residual. The 95%-confidence interval of the regression coefficients can test for the significant difference between our standard noise-rating scale [2], [3] and each noise-rating scale obtained under the conditions shown in Table 1 and Table 2. An asterisk (*) indicates that a difference is significant at the level of p<0.05, and (**): at the level of p<0.01.

| Psychological scale | Test No. (see Table 1) | Correlation coefficient | Constant: $\alpha$ Confidence limits (Lower limit, Upper limit) at level 95% | Slope: $\beta$ Confidence limits (Lower limit, Upper limit) at level 95% | Standard deviation of residual |
|---|---|---|---|---|---|
| Annoyance scale A | Field tests [2], [3] | 0.792 | -4.96 (-5.25, -4.67) | 0.95 (0.90, 1.00) | 0.98 |
| | Laboratory tests | 0.849 | -4.83 (-5.04, -4.62) | 0.95 (0.91, 0.98) | 0.83 |
| | Test No.1 | 0.834 | -3.73 (-3.92, -3.53)** | 0.80 (0.76, 0.84)** | 0.79 |
| | Test No.2 | 0.853 | -4.53 (-4.87, -4.19) | 0.96 (0.89, 1.02) | 0.84 |
| | Test No.3 | 0.894 | -5.25 (-5.56, -4.93)* | 1.08 (1.02, 1.15)** | 0.78 |
| Effect of transmission loss E | Test No.1 | 0.779 | 1.71 (1.48, 1.94)* | 0.104 (0.097, 0.111)* | 0.83 |
| | Test No.2 | 0.629 | 2.25 (1.85, 2.63) | 0.084 (0.071, 0.097) | 1.05 |
| | Test No.3 | 0.752 | 1.90 (1.55, 2.24)* | 0.103 (0.092, 0.115)* | 0.92 |
| Subjective impression S | Test No.1 | 0.757 | 1.83 (1.55, 2.10)** | 0.116 (0.108, 0.125)* | 0.99 |
| | Test No.2 | 0.582 | 2.76 (2.29, 3.25) | 0.091 (0.075, 0.107) | 1.29 |
| | Test No.3 | 0.737 | 2.17 (1.76, 2.57)* | 0.117 (0.103, 0.130)* | 1.08 |

**Table 4:** The correlation coefficient, the regression coefficients (constant and slope), each lower and upper limit of the 95%-confidence interval, and the standard deviation of residual for simple regression model (*: statistical significance at the level of p<0.05, **: statistical significance at the level of p<0.01).

## 5 - CONCLUSIONS

From the experimental results on psychological effects of aural information only or aural and visual information for transmission loss with building materials in the planning stage of houses by the vehicle noise simulator, several conclusions can be given in following.
(1) The effect of visual information on the transmission loss with building materials can soothe (annoyance) from 2.5dB to 4.7dB. On the contrary, the effect of visual information on the high-level traffic noise can create a perception of a more noise from 3.8dB to 4.7dB.
(2) "Effective" of the transmission loss corresponds to 31.6dB(A) for aural information only, 32.7dB(A) (steady moving vehicles) and 30.1dB(A) (intersection with traffic lights) for aural and visual information.
(3) "Good" of the subjective impression of considering all the factors corresponds to 35.8dB(A) for aural information only, 35.5dB(A) (steady moving vehicles) and 32.9dB(A) (intersection with traffic lights) for aural and visual information.

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