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A CASE STUDY OF PREDICTION ACCURACY OF "ASJ RTN-MODEL 2023" ON JAPANESE GENERAL ROADS

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ABSTRACT

The Acoustical Society of Japan (ASJ) has recently published a new version of road traffic noise prediction model "ASJ RTN-Model 2023", as the latest development of the research committee on road traffic noise in ASJ for more than 50 years. It is an upgrade version of the previous model. The model is widely used in Japan for the noise assessment in the future, for the noise estimation tool, and for the noise abatement. In this paper, while the outline of the model is introduced, case studies of the prediction accuracy, namely the correspondence between the predicted and measured value using the new model is presented. For the examination on the prediction accuracy, measurement data were provided by Fukuoka City Government, containing simultaneous measurement of the equivalent contentious sound pressure level L_{Aeq} and traffic data. The L_{Aeq} at the measurement points, located just beside the road, were calculated using obtained traffic data. The prediction results using the ASJ RTN-Model 2023 showed good agreement with the measurement values. Moreover, the other measurements were conducted to examine the prediction accuray of the practical calculation method for predicting noise behind dense buildings. The calculated attenuations due to the buildings showed fine agreement with the measured attenuation.

Keywords: *road traffic noise, general road, noise map, prediction model, ASJ RTN-Model*

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1. INTRODUCTION

In Japan, the road traffic noise prediction model had come to play important roles on administrative measures. One is for the prediction tool of the noise assessment in the future environment based on the Environmental Impact Assessment Law (enforced in 1999), and the other is for the noise estimation tool of the regular environmental monitoring based on the Environmental Quality Standards for Noise (enacted in 1971, and revised in 1998). In addition, the prediction model is used as a design tool for noise abatement measures. In consideration of such a situation, the Research Committee on Road Traffic Noise in the Acoustical Society of Japan (ASJ) has been developing a series of the road traffic noise prediction model, named ASJ RTN-Model for more than 50 years.

The latest version named "ASJ RTN-Model 2023" [1] has was published in April 2024, as the result of five years accumulation of examination in the committee after releasing the previous model, ASJ RTN-Model 2018 [2, 3]. It is important to examine the correspondence between the predicted value obtained by the model and the actual measured values, and to consider the factors that influence the goodness of the correspondence. Hereafter, we discuss the prediction accuracy as the goodness of correspondence between the predicted values obtained by the model and the actual measured value on sites, that is, the degree of agreement between the predicted and measured values.

Previously the prediction accuracy of the latest model, ASJ RTN-Model 2023, for Japanese highways and roundabouts has been reported [4]. In this paper, the examinations of the prediction accuracy of the ASJ RTN-Model 2023 on Japanese general roads are provided using governmental survey data. Moreover, the prediction accuracy of the practical calculation method of for predicting noise behind dense buildings are also shown.

2. OUTLINE OF "ASJ RTN-MODEL 2023"

2.1 Scope

The conditions applicable to ASJ RTN-Model 2023 are as follows.

- Types of road: General roads (flat, bank, cut, and viaduct) and special road sections (interchanges, junctions, signalized intersections, roundabouts, tunnels, depressed/semi-underground roads, flat roads with overhead viaducts, and double-deck viaducts).
- Traffic volume: No limitation.
- Vehicle speed: 40 to 140 km/h for steady running conditions on expressways and general roads, 10 to 60 km/h for acceleration/deceleration running conditions in the vicinity of signalized intersections, 0 to 80 km/h for acceleration or deceleration running conditions at interchanges.
- Prediction range: Up to a horizontal distance of 200 m from the target road and up to a height of 12 m above the ground. Note that the validity of the model has been examined for this prediction range; however, the model is applicable without any limitation on the calculation range.
- Meteorological conditions: No wind and no strong temperature profile is assumed as the standard condition.

2.2 General calculation procedure

In the ASJ RTN-Model series, the equivalent continuous A-weighted sound pressure level, $L_{\mathrm{Aeq},T}$, at a prediction point is calculated. It is a basic procedure to obtain the time history of A-weighted sound pressure level, $L_{\mathrm{A},i}$, at a prediction point (referred to as the "unit pattern") for a single vehicle that is considered to be a point source passing along the road, as shown in Figure 1.

First, calculation lane is placed at the height of 0 m at the center of each lane of the object road (lane). It is possible to combine multiple lanes in to a single calculation lane. Then, the calculation lane is divided into some shorter sections, and discrete point sources are distributed on them.

A discrete point source is set at the center point of i-th divided section, and the A-weighted sound power level, $L_{W\mathrm{A},i}$, of the vehicle running at the speed of V_i [km/h] ($v_i = V_i/3.6$ [m/s]) are set. Next, $L_{\mathrm{A},i}$ at the prediction point is calculated according to calculation method of sound propagation.

$$L_{\mathrm{A},i} = L_{W\mathrm{A},i} - 8 - 20\log_{10} l_i\,, \tag{1}$$

where l_i is the distance between i-th point source and prediction point. Then, the single-event sound exposure level, L_{EA}, at that point when a vehicle travels along the entire road is calculated as

$$L_{EA} = 10\log_{10}\sum_i 10^{(L_{\mathrm{A},i}+10\log T_i/T_0)/10}\,, \tag{2}$$

where T_i is the time interval ($= \Delta l_i/v_i$) [s] and T_0 is reference time ($=$ 1 s), as shown in Figure 2. The A-weithted sound power level, $L_{W\mathrm{A},i}$, is dependent on the vehicle category. Two types of vehicle category classification are defined in the model, that is, a three-category and two-category classification. Motorcycles and buses are classified as the other category (Note that the category of buses is utilized only in case of the predicition on highway.)

Therefore, L_{EA} is calculated for each vehicle category, and $L_{\mathrm{Aeq},T}$ is obtained by taking account of the traffic volume for each vehicle type.

$$L_{\mathrm{Aeq},T} = 10\log_{10}\frac{1}{T}\sum_j N_{T,j}10^{L_{EA,j}/10}\,, \tag{3}$$

where T is the total time interval [s], $L_{EA,j}$ is the single-event sound exposure level for vehicle type j calculated by Eq.(2), and $N_{T,j}$ is the traffic volume of vehicle category j during the total time interval T.

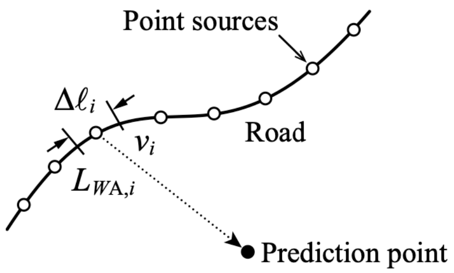

Figure 2. Time history of A-weighted sound pressure level at a prediction point (unit pattern). [1]

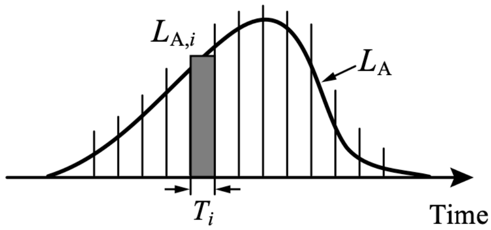

Figure 2. Time history of A-weighted sound pressure level at a prediction point (unit pattern). [1]

2.3 Sound emission of road vehicles

The types of road vehicles are basically classified into the following categories: light, medium-sized, and large-sized vehicles, and motorcycles. These categories are almost identical to the European prediction models such as CNOSSOS-EU. In addition, the equations of L_{WA} are set separately for each pavement type (dense, porous asphalt, and KOKINOU II pavement) and running conditions.

For L_{WA} on dense asphalt pavement, the emission value of a single vehicle is expressed by the vehicle speed V [km/h] and the sum of correction terms C for the change in the power level due to the road gradient ΔL_{grad} [dB], sound radiation directivity ΔL_{dir} [dB], and other factors ΔL_{etc} as follows:

$$L_{WA} = a + b\log_{10} V + C, \tag{4}$$

$$C = \Delta L_{\mathrm{grad}} + \Delta L_{\mathrm{dir}} + \Delta L_{\mathrm{etc}}, \tag{5}$$

where a varies with vehicle type, and b representes the dependence of L_{WA} on speed. Figure 3 shows a schematic of L_{WA} under steady and non-steady running conditions on general roads.

The coefficients a, b for each vehicle type are given in Table 1. These values were determined from pass-by noise measurements on test tracks and actual roads [5]. Also, the power levels at speeds of 50 km/h or more are almost 1 dB lower on average than those in several European emission models, such as CNOSSOS-EU:2021, -NL, -FR, and sonROAD [6].

2.4 Sound Propagation Calculation

An engineering calculation method, by which the A-weighted sound pressure level L_A at a prediction point is obtained directly, is based on the distance attenuation formula with additional attenuations such as the effects of shielding by barriers or buildings, ground surface, sound reflection, air absorption and meteorologi cal conditions, taking into account the frequency characteristics of road traffic noise. Note that the detailed intorduction of the sound propagation calculation was omitted, because the measurement used in this examination in this paper were located without any obstructions in the propagation path.

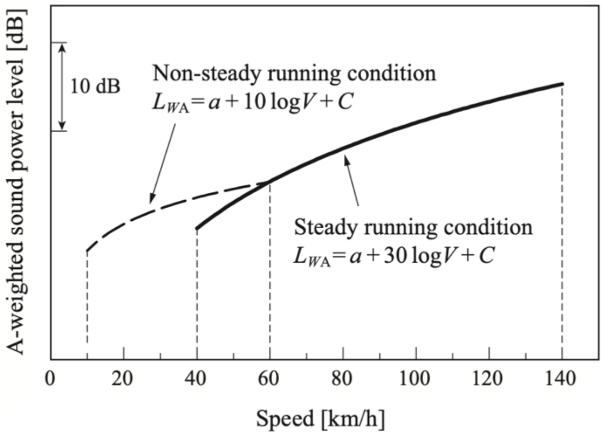

Figure 3. A-weighted sound power level under steady and non-steady running conditions.[1]

2.5 Noise Prediction behind Dense Buidlings

Behind the dense buildings along the roads, the road traffic noise is attenuated by their screening effect. In the ASJ RTN-Model, a practical calculation method is provided for predicting noise behind dense buildings [1].

The noise level $L_{A,i}$ at a prediction point from the i-th source position is calculated as

$$L_{A,i} = L_{WA,i} - 8 - 20\log_{10} r_i + \Delta L_{\mathrm{bldg},j}, \tag{6}$$

where r_i [m] is the direct distance from the i-th source position to the prediction point. $\Delta L_{\mathrm{bldg},j}$ denotes the correction related to the attenuation due to the buildings

Table 1. Coefficients for the equation of A-weighted sound power level on dense asphalt pavement under steady and non-steady running conditions.[1]

Classification	Steady running $40 \leq V \leq 140$ km/h		Non-steady running $10 \leq V \leq 60$ km/h	
	a	b	a	b
Light vehicles	45.8		81.4	
Medium-sized vehicles	51.4	30	87.1	10
Large-sized vehicles	54.4		90.0	
Motorcycles	49.6	30	85.2	10

along the propagation path, which are given using the height of the buildings H [m], the height of the prediction point h_P [m], the ratio of perspective angles ϕ/Φ, and the ratio of the location area of the buildings to the rectangular area (see Figure 4 and 5).

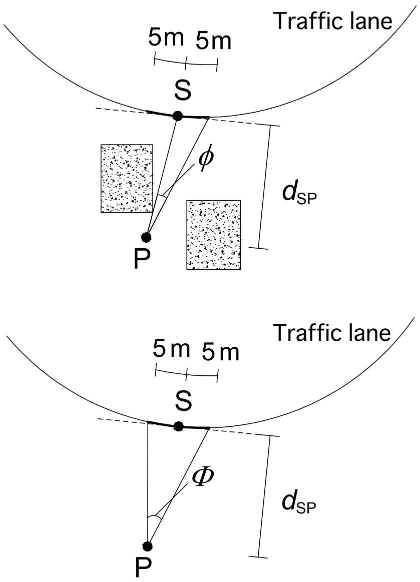

Figure 4. Perspective angle to the road in the case with and without buildings. [1]

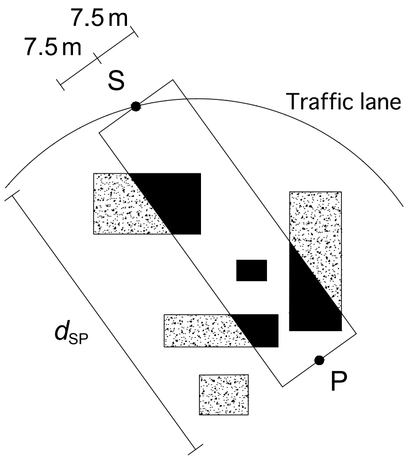

Figure 5. Horizontal distance between source (S) and prediction point (P), d_{SP}, and building density ξ in the area of 15 m width and d_{SP} length.[1]

3. CORRESPONDENCE BETWEEN PREDICTED AND MEASURED VALUES AT GENERAL ROADS

3.1 Measured Data

The measurement data were provided by the Environmental Bureau, Fukuoka City Government. The measurement campaigns were conducted for the continuous monitoring of vehicle noise operated by Japanese Ministry of Environment (MOE). For this study of prediction accuracy, the measurement data at eight road sections (Rd.1–8) were selected. All selected sections were in Fukuoka city, where were at roadside of flat straight road sections, with dense asphalt pavement, without any noise barriers, and without any juxtaposed viaduct roads. The number of lanes was from 4 to 6 (namely, 2 or 3 lanes for each direction).

The measurements were conducted under the instruction defined in the manual of the constant monitoring of road traffic noise by MOE. The measurements were in accordance with JIS Z8731:1999, which is identical to ISO 1996-1:2003.

3.1.1 Noise levels

The equivalent contentious A-weighted sound pressure level L_{Aeq} and N percentage exceedance level L_{AN} (L_{A5}, L_{A10}, L_{A50}, L_{A90}, L_{A95}) were measured in every 10 minutes interval. The measurements were taken every hour from 0 to 10 minutes for 24 hours.

The measurement points were 1.2 m above the ground on a public/private boundary. The selected measurement points were away from traffic signal or road intersections, and without obstructions or glass-ground in the sound propagation path.

3.1.2 Traffic data

Number of traffics were counted simultaneously with the noise level measurement in three-category vehicle classification [1] for each direction. Number of motorcycles were also counted separately. The average speeds of the traffic for each 10 minutes interval were ranged from 30.2 to 73.6 km/h. The measurement data of traffic volume for each 10 minutes interval less than 50 were excluded from the examination, then were volumes ranged from 51 to 411. The ratio of large- and medium-sized vehicles were ranged 0% to 30%.

3.1.3 Summary of measured data

To avoid the influence of background noise, the measurement data with less than 10 dB difference between L_{Aeq} and L_{A95} were excluded from the examination, then 3 to 20 dataset (10 minutes interval) were selected as valid data for the examination. The summary of the measured data is shown in Table 2.

Table 2. Summary of the measured data used for the examination.

Rd.	Date of measurement	Number of valid data	Pavement type	Number of lanes*1	Traffic volume*1	Traffic speed [km/h] *1	Ratio of large- and medium-sized vehicles*1
1	13–14, Dec. 2017	3	Dense	4	83	39.3	6%
2	18–19, Dec. 2017	13	Dense	4	146	46.5	10%
3	13–14, Dec. 2017	13	Dense	4	107	40.4	22%
4	7–8, Nov. 2018	16	Dense	4	154	53.2	4%
5	24–25, Oct. 2018	14	Dense	4	97	52.8	3%
6	11–12, Nov. 2019	20	Dense	5	293	43.0	8%
7	1–2, Nov. 2021	17	Dense	4	166	42.0	10%
8	1–2, Nov. 2021	17	Dense	4	149	37.3	12%

*1 Averaged per 10 minutes interval

3.2 Calculation

The calculation lane positions were set for each direction, combining two or more lanes into a single calculation lane. Discrete point sources were distributed within a range of $\pm 20l$ [m], where l is the shortest distance from the calculation lane to the prediction point. The sound power level, L_{WA}, for each type of vehicle was calculated using Eq.(4) and coefficients shown in Table 1. In the model, steady running condition applies to 40 km/h and above, but coefficients for steady running condition were applied to the dataset below 40 km/h. The correction terms C was set to 0 dB in the calculation.

3.3 Comparison between Predicted and Measured Values

The correspondence between predicted values and actual measurement values are shown in Figure 6. In the scatter diagrams, the line where the predicted and measured value coincide, and its 3 dB range are also shown. The mean difference between predicted and measured values (Δ, predicted L_{Aeq} minus measured values) were -1.3 dB, and 89% of the prediction were included within the ±3 dB range.

In the Figure 7, the correspondence between predicted values and actual measurement values are shown for each measurement road section. The correlations between predicted and measured values are generally high for every measurement, however the mean differences Δ seems to be dependent on the measurement road section. This could suggest the systematic influence of road surface.

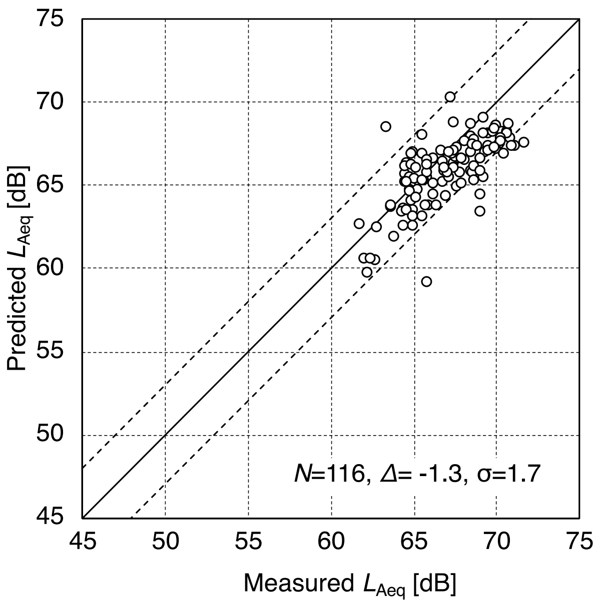

Figure 6. Correspondence between predicted and measured L_{Aeq} at flat and straigt general road section.

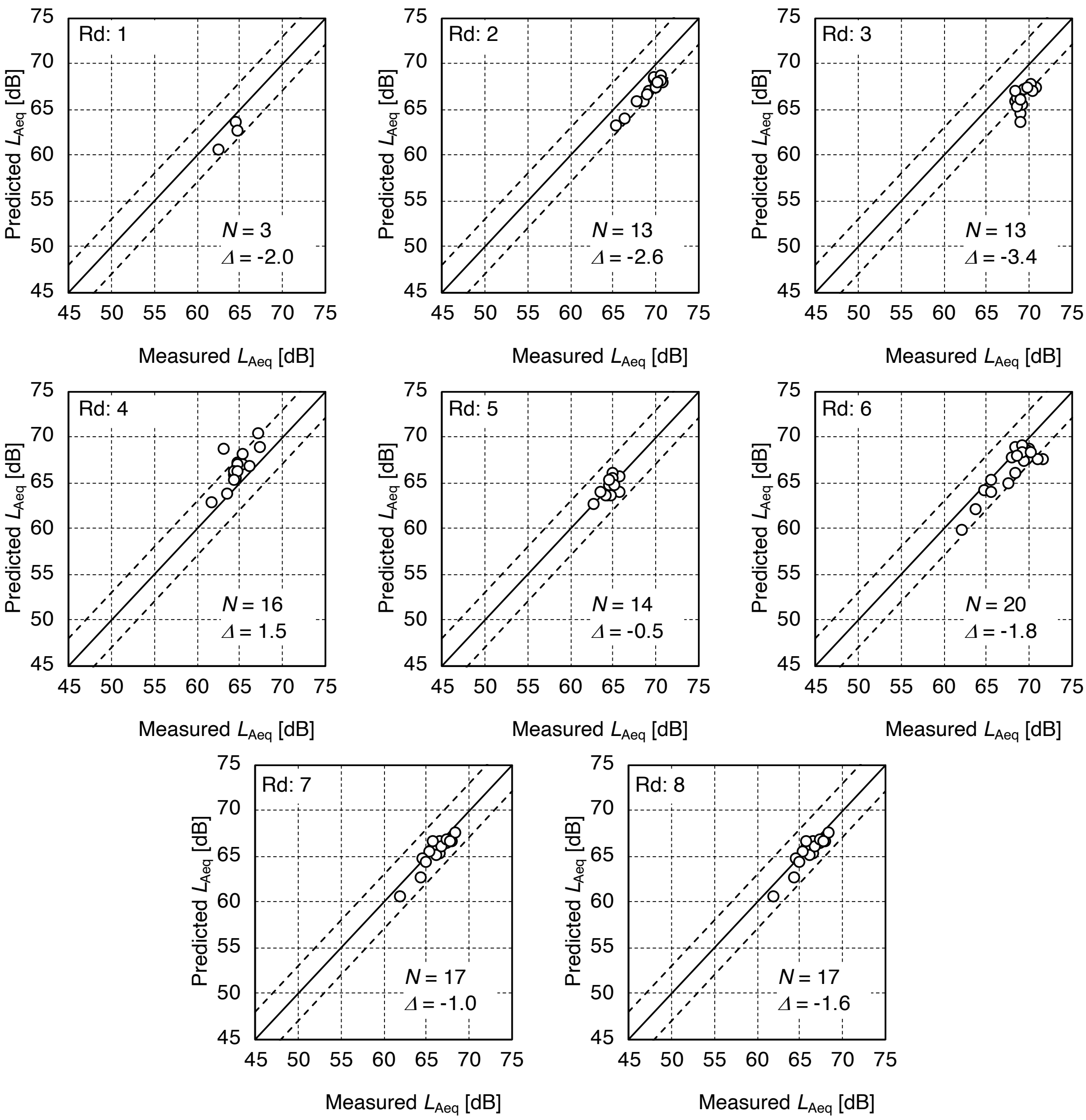

Figure 7. Correspondence between predicted and measured L_{Aeq} for each measurement road section.

4. CORRESPONDENCE BETWEEN PREDICTED AND MEASURED VALUES BEHIND DENSE BUILDINGS

4.1 Measured Data

The measurements were conducted in Fukuoka city and Kurume city in 2023 and 2024, hereafter referred to as site-B and site-C, respectively. Figure 8 shows the arrangement of measurement points for each measurement site, where M00 is the roadside reference point and M01–M08 are the measurement points behind buildings.

The site-B faced to a 4-lane road with dense asphalt pavement. The M01 side was characterized by fields (shaded area in Figure 8), while the M03 side was densely populated with detached houses, and the M04 side was similarly densely populated with detached houses, but there were also a few apartment buildings. The noise levels were measured twice or three times at each point simultaneously with the reference point (M00). The average traffic volume per 10 minutes was 142, and the average traffic speed was 53.9 km/h.

The site-C faced to a 2-lane road with dense asphalt pavement. The M01 side had a mix of 5- to 6-story apartment buildings and 2-story houses. Along the load from M01 to M03, there was a simple wall (dotted line in Figure 8) approximately 2 m height, which the slope was slightly downhill. The open area on the M05 side was a parking lot with concrete pavement, surrounded by 2-story commercial buildings. The average traffic volume per 10 minutes was 211, and the average traffic speed was 31.6 km/h.

4.2 Calculation

The predicted values were obtained using the practical calculation method for predicting noise behind dense buildings (see section 2.5). The calculation lane position was set at the center of the road, combining both directions. Discrete point sources were distributed within a range of $\pm 20l$ [m], where l is the shortest distance from the calculation lane to the prediction point.

The GIS information such as building outline and height were acquired from PLATEAU [7] dataset, provided by Japanese Ministry of Land Infrastructure Transport and Tourism (MLIT). The centerline of the road was acquired from the Conservation GIS-consortium Japan [8]. The prediction points were distributed in a grid with 5 m intervals within 100 m from the roadside, based on the road centerline. The calculated noise level of each prediction point was spline-interpolated at 1 m intervals to create a noise map for an approximately 1 km section of the subject road.

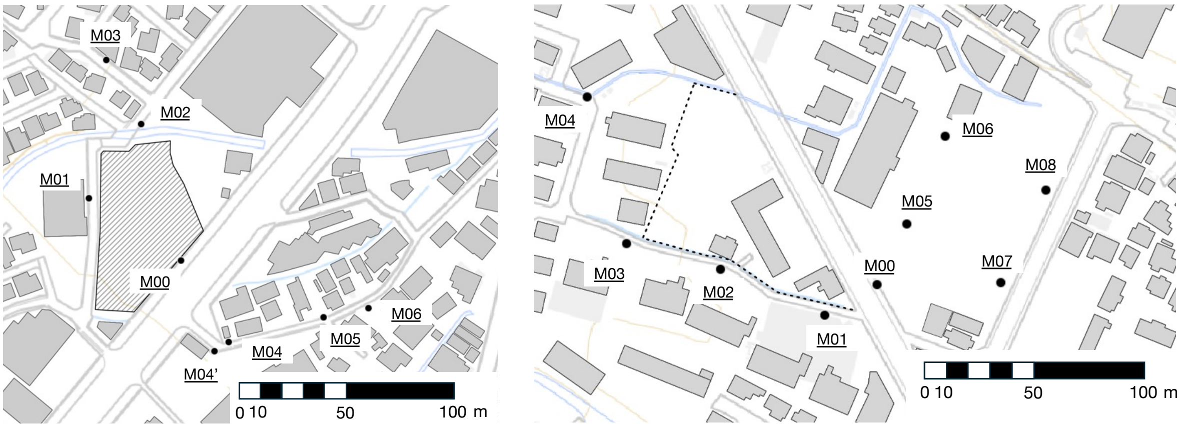

Figure 8. Arrangement of measurement points and building layout for site-B (left) and site-C (right.)

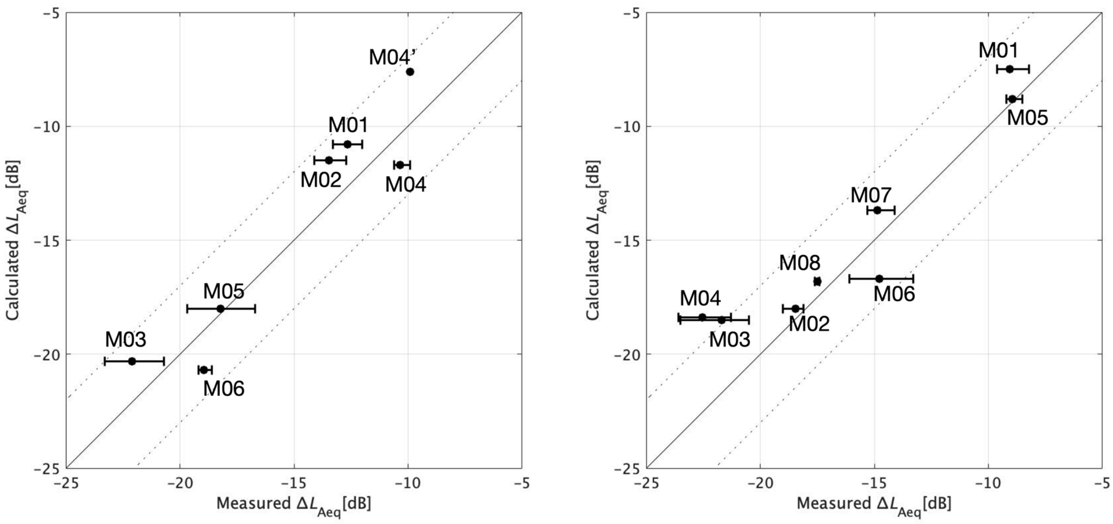

Figure 9. Correspondence between calculated and measured ΔL_{Aeq} for site-B (left) and site-C (right.)

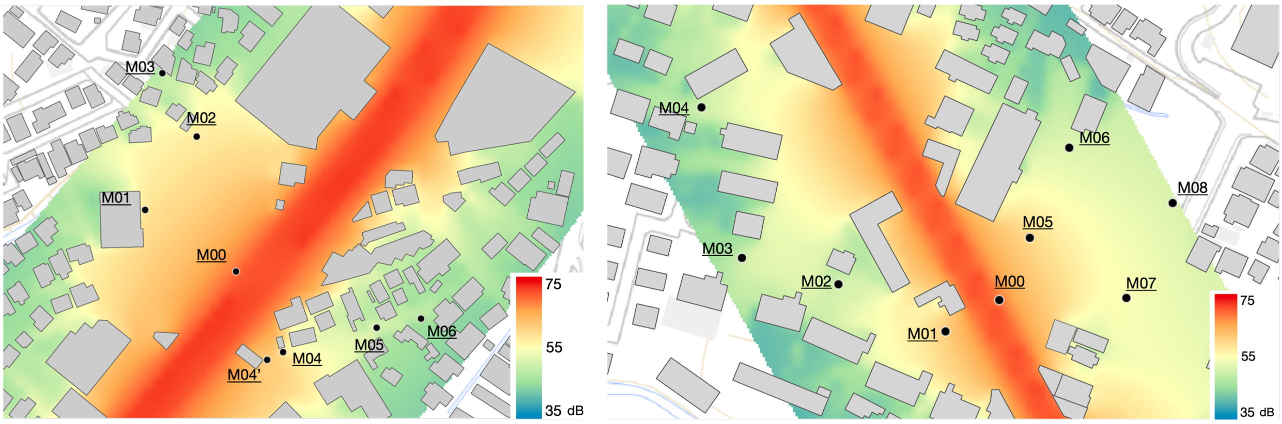

Figure 10. Noise map around the measurement points for site-B (left) and site-C (right.)

4.3 Comparison between Predicted and Measured Values

Subtracting the noise level at refference point $L_{\mathrm{Aeq},0}$ from that at measurent point $L_{\mathrm{Aeq},i}$, the attenuations due to the buildings $\Delta L_{\mathrm{Aeq},i}(= L_{\mathrm{Aeq},i} - L_{\mathrm{Aeq},0})$ were calculated.

Figure 9 show the correspondence between calculated and measured $\Delta L_{\mathrm{Aeq},i}$ for each measurement site. Figure 10 shows a noise map visualizing the distribution of the attenuation based on the calculation results.

The differences between calculated and measured $\Delta L_{\mathrm{Aeq},i}$ were included within the ±3 dB range for both sites. For the site-B, the calculated attenuation values tended to be lower than the measured values for M01 to M03, which were located behind the fields. For the site-C, the calculated attenuation values at M01 to M04 tended to be lower than the measured values, and the average difference was 2.3 dB. The reason for this may be the influence of land conditions, such as the presence of simple walls and slopes.

5. CONCLUSIONS

The latest road traffic noise prediction model ASJ RTN-Model 2023 [1] was published recently from the Acoustical Society of Japan. The model has been developed for more than 50 years, and is still widely used for noise impact assessment or noise abatement measures in Japan. The case studies of prediction accuracy on general roads were reported in this paper. The prediction results using the ASJ RTN-Model 2023 showed good agreement with the measurement values on sites. The Research Committee has a plan to continue its research activities to expand the scope of application of the current version, ASJ RTN-Model 2023.

6. ACKNOWLEDGMENTS

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