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Road Traffic Noise Prediction Model "ASJ RTN-Model 2018" Proposed by The Acoustical Society of Japan – Part 5: Study on prediction accuracy

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ABSTRACT

This paper introduces the study on prediction accuracy of the ASJ RTN-Model 2018, as a part of the series of five papers which has same main title in this congress, on behalf of the research committee on road traffic noise in the Acoustical Society of Japan. It is very important to examine the prediction accuracy of the new model, because some assumptions are included in modeling the source power level of each type of vehicles and in simplifying the calculation of noise propagation. Some examination of the correspondence between the predicted values and measured traffic noise levels are introduced in this paper. The accuracy of the method of prediction for noise behind building complex are also examined. The measured values were obtained recently in Japan on flat and strait section of general roads and on expressways. This paper also introduces the examination on assumed causes of errors that are thought to be important in considering prediction accuracy, such as the condition setting of hypothetical traffic lanes, vehicle type classification, and some typical causes of uncertainty on actual measurement.

Keywords: Road Traffic Noise, Prediction Model, ASJ RTN-Model 2018, Prediction Accuracy

1. INTRODUCTION

The Technical Committee on Road Traffic Noise in the Acoustical Society of Japan has developed a series of the road traffic noise prediction model, named ASJ RTN-Model. After releasing the previous model, ASJ RTN-Model 2013 (1) published in 2014, the research committee has been working to improve the prediction model on the basis of the latest data and knowledge for five years, and the latest version named "ASJ RTN-Model 2018" was published April 2019. The updates are introduced in the series of papers (2–5). The calculation models of sound power levels of road vehicles and calculation methods of sound propagation were updated so that the calculated value becomes more accurate to the measured road traffic noise. It is necessary to examine the prediction accuracy of the latest model.

In this paper, the examinations of the prediction accuracy of the latest model, ASJ RTN-Model 2018, are provided by the comparison between the predicted and actual measured values. The examinations were performed for the measurement data obtained on general road and expressway. The prediction accuracy of the practical method for areas behind buildings in urban districts is also examined and described in the other publication (5). In addition, it is necessary to note that several types of uncertainty are included in the actual measurement values. We also examine the causes of errors that are likely to be significant when considering the prediction accuracy of the ASJ RTN-Model 2018.

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2. CORRESPONDENCE BETWEEN PREDICTED AND MEASURED VALUES AT GENERAL ROAD SECTION

In the ASJ RTN-Model 2018, the calculation model of sound emission of read vehicles was updated. On the dense asphalt pavement, which is common for general road in Japan, the A-weighted sound power level $L_{W\mathrm{A}}$ of road vehicles is given by

$$L_{W\mathrm{A}} = a + b\log_{10} V + C \tag{1}$$

where V is the vehicle running speed [km/h], a and b are regression coefficients, and C is the correction term. The term a was changed for each vehicle category based on accumulated data in last decade. In this section, the correspondence between the predicted values and measured traffic noise levels is examined.

2.1 Measured Data

The actual measurement data were obtained at straight sections of general roads in fiscal year 2013 based on the manual of constant monitoring of motor vehicle traffic noise (6) by the Ministry of Environmental Government of Japan. The measurements were in accordance with JIS Z8731:1999, which is almost identical to ISO 1996-1:2003. The measurement conditions of these data are as follows.

(1) Noise levels considered

L_{Aeq} and $L_{\mathrm{A}N}$ (L_{A5}, L_{A10}, L_{A50}, L_{A90}, L_{A95}). Measurement duration was 10 minutes, and multiple measurement were performed over 24 hours at each location.

(2) Measurement point

1.2 m above the ground on a public/private boundary. The selected measurement points were away from juxtaposed roads or road intersections, and without obstructions or glass-ground in the sound propagation path. The number of lanes was from 1 to 4.

(3) Traffic conditions

Number of traffics were counted in three-category or two-category vehicle classification for each direction. Number of motorcycles were also counted separately. Since it will be assumed the steady traffic flow section in the prediction, the measurement data of traffic flow with running speed less than 40 km/h were excluded from the examination. The traffic volumes of the target roads were less than 4,500 per hour, and the ratio of heavy vehicles were varied widely (from 0% to 100%).

2.2 Calculation

The predicted values were obtained using the simple method for estimation L_{Aeq} described in the ASJ RTN-Model 2018. In the case of simple road conditions and steady traffic flow, the $L_{\mathrm{Aeq},T}$ can be calculated using the following formula involving the single-event sound exposure level $L_{\mathrm{A}E}$ [dB] and the traffic volume N_T [number of vehicles] passing a prediction point during the time T [s]:

$$L_{\mathrm{Aeq},T} = L_{\mathrm{A}E} + 10\log_{10}\frac{N_T}{T} \tag{2}$$

When and omni-directional point source with the A-weighted sound power level $L_{W\mathrm{A}}$ [dB] moves along a straight road of infinite length at the constant speed V [km/h], $L_{\mathrm{A}E}$ at the distance l from the lance can be analytically derived from the following formula obtained by applying the inverse-square low in a hemi-free field and integrating over time up infinity:

$$L_{\mathrm{A}E} = L_{W\mathrm{A}} + 10\log_{10}\frac{3.6}{2lV} \tag{3}$$

To simplify the calculations, multiple lanes of traffic traveling in the same direction were combined into a hypothetical single lane at the center of the traffic stream. The correction term C was set to 0 dB in this examination.

2.3 Comparison between Predicted and Measured Values

The correspondence between predicted values and actual measurement values for daytime (6:00–22:00) and night (22:00–6:00) are shown in Figure 1. In the scatter diagrams, the line where the predicted and measured value coincide and its 3 dB range are also shown. The correlation coefficients were 0.81 for daytime and 0.85 for night. The mean difference between predicted and measured values (Δ, predicted L_{Aeq} minus actual measurement values) were +0.4 dB and -0.8 dB for daytime and night, respectively, indicating excellent agreement of two values. For daytime, 87% of the prediction were included within the ±3 dB range, where 78% were included for night.

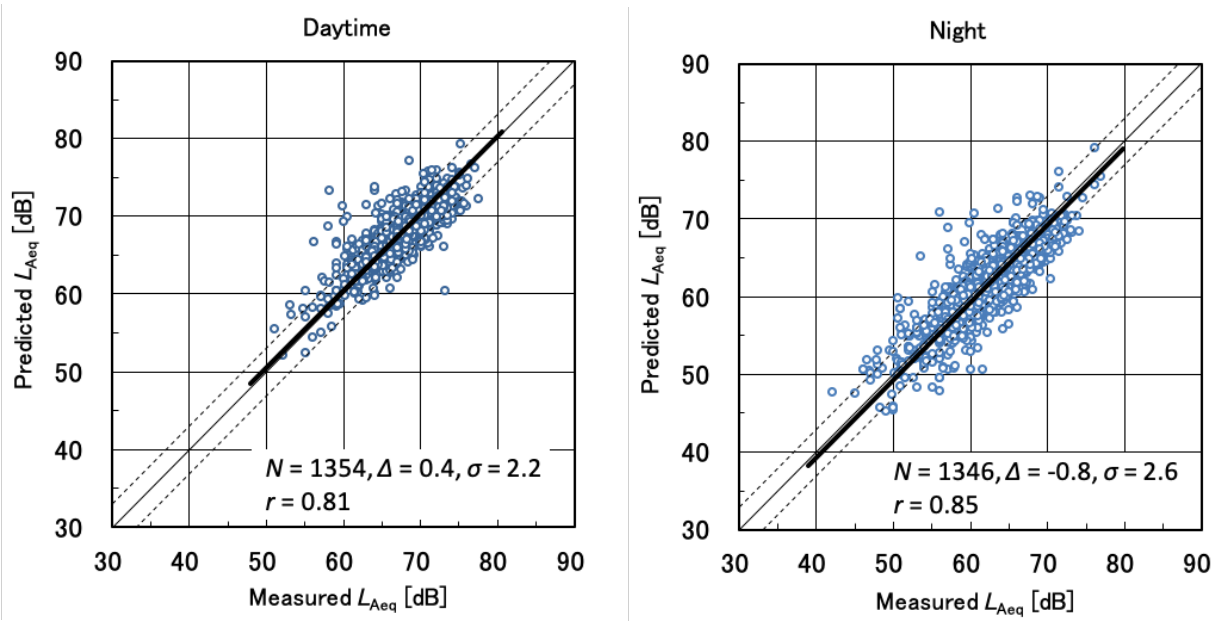


Figure 1 – Correspondence between predicted and measured L_{Aeq} at flat and straight general road section.

3. CORRESPONDENCE BETWEEN PREDICTED AND MEASURED VALUES ON THE ROADSIDE OF EXPRESSWAY

3.1 Measured Data

The actual measurement data were obtained at the expressway with bank and cut road structure in fiscal year from 2014 to 2018. The summary of selected 7 measured point are shown in Table 1.

Table 1 – Summary of the measured data used for the examination

	Structure type	Pavement		Number of measurement points		Noise barriers
		Type	Age	Reference	Roadside	
1	bank	porous	8.0	1	1	none
2	bank	porous	6.3	1	1	none
3	bank	porous	7.3	1	1	none
4	bank	porous	8.3	1	1	none
5	bank	porous	0.5	1	1	none
6	bank	KOUKINOU II	1.3	1	1	none
7	cut	porous	3.0	1	2	2 m height

(1) Noise levels considered

L_{Aeq} and L_{A95} (the lower limit of the 90% percentile range). Measurement duration was 2 hours, while only for the road 7 the duration was 15 minutes.

(2) Measurement point

The reference measurement points for bank roads were 1.2–2.0 m height above the road surface at 7.5 m away from the center of the closest cruising lane. For the cut road, the reference point was 3.0 m above the 2.0 m height noise barrier on the top of slope (5.0 m height above the road surface). The road side measurement points were 25 to 66 m away from the center of the road, and the heights were 1.2 m above the ground surface. The pavement types were porous asphalt or gap-graded asphalt mixture that is referred as "KOUKINOU II".

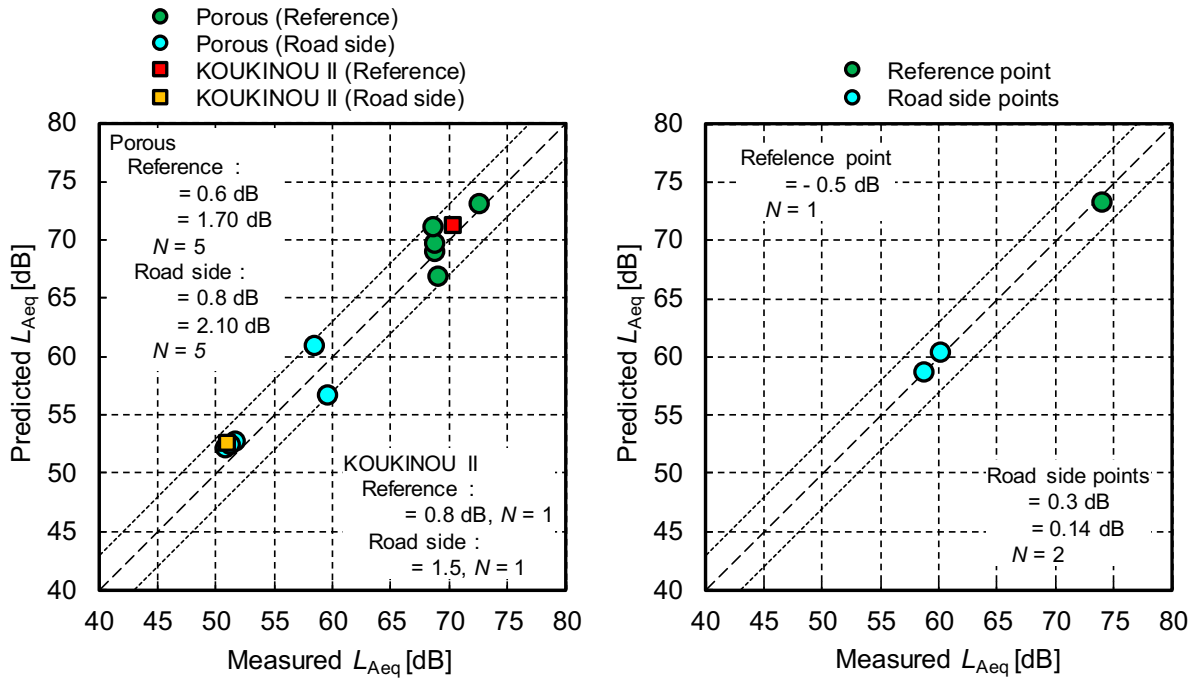
(3) Traffic conditions

Number of traffics were counted for three-category vehicle classifications for each direction. Buses and motorcycles were separately counted. The traffic volumes of the target roads were from 800 to 4,000 per hour, and the ratio of heavy vehicles were varied from 17% to 32%. The traffics were steady, and their mean traffic speed were from 80 to 110 km/h.

3.2 Calculation

The predicted values were obtained using the ASJ RTN-Model 2018. Regarding the porous asphalt and KOUKINOU II pavement, the sound power level L_{WA} for each type of road vehicles is given as functions of the running speed and the age of the pavement after construction.

In the propagation calculation, the correction for diffraction due to acoustical obstacles such as noise barriers is involved. The correction for the diffraction on the top of slope of the bank structures were calculated by the method for the wedge with an opening angle, which were newly developed in the model. The correction for the noise barrier was calculated by the method for the knife-wedge. The correction for the absorptive barrier was also involved. Regarding the correction of ground effect for the slope surface, the coefficients for loose soil were used, while the correction was set to 0 dB for the ground of measurement side since the surfaces were covered by asphalt pavement. The correction for atmospheric absorption was also involved.



(a). Bank road (b). Cut road

Figure 2 – Correspondence between predicted and measured L_{Aeq} on the roadside of expressways

3.3 Comparison between Predicted and Measured Values

The correspondence between predicted values and actual measurement values for each road structure are shown in Figure 2. Since the measured L_{Aeq} were higher than 10 dB than L_{A95}, which is assumed to be equivalent to the background noise level, the correction of background noise was not performed.

For the bank roads, the predicted values corresponded to within 3 dB of the measured values. With regard to the porous asphalt pavements, the mean differences between predicted and measured values (Δ, predicted L_{Aeq} minus actual measurement values) were +0.6 dB and +0.8 dB at reference and roadside points, respectively. The mean differences for KOUKINOU II pavement were +0.8 dB at the reference, and +1.5 dB at the roadside points.

For the road 7 (cut road), the mean difference between prediction and measurement at the roadside point, where was behind the noise barrier, was +0.3 dB.

4. CAUSES OF ERRORS IN ASJ RTN-MODEL 2018

Since many assumptions are included in setting the power level of running-vehicle noise and in simplifying the calculation of noise propagation in the prediction model, it is necessary to examine the causes of errors that are likely to be significant when considering the prediction accuracy of the model. In the ASJ RTN-Model 2018, as a part of references, several investigations on the effect of the error factors are provided.

4.1 Setting of Hypothetical Traffic Lanes

In the model, it is allowed to combine two or more lanes into a single hypothetical lane for simplicity of the calculation. According to the previous investigation (7), the difference in L_{Aeq} caused by combining the lanes into single was less than 1 dB even in the case of a road with eight lanes, if the distance from the center of the nearest lane to the receiver was 5 m or more. However, the error increases drastically when the distance to the receiver is less than 5 m. Thus, when noise is predicted in the vicinity of roads with multiple lanes, it is recommended to increase the number of hypothetical lanes.

4.2 Road Traffic Conditions

The classification of road vehicle has been changed from the conventional model. In the ASJ RTN-Model 2018, three-category classification (large-sized, medium-sized and light vehicles) which is recommended from an acoustical viewpoint, while two-category classification (heavy and light vehicles) is also provided as an alternative considering practicality. As the result of the investigation, the prediction error caused by replacing three-category with two-category classification was less than 1 dB, if the ratio of medium-sized vehicles to heavy vehicles ranged 10 to 80%.

In the prediction model, the sound power level of a road vehicle is calculated under the assumption that all vehicles classified in each category run at the same speed (*i.e.*, at the mean speed of all vehicles). According to the results of examination from a stochastic viewpoint (8), the change in L_{Aeq} due to the variation of running speed is extremely small. Furthermore, the change in L_{Aeq} is 1 dB or less if the standard deviation of the power level is 3 dB or less.

4.3 Range of Unit Pattern Calculation

In the general calculation procedure of the model, point sources are discretely set on lanes to obtain the unit pattern at the receiver, and then L_{Aeq} is calculated. In this case, it is necessary to determine the range over which the point sources must be arranged, the range of the unit pattern calculation in other words. According to the previous examination (7), it was found that the difference in L_{Aeq} caused by removing low-level portions 10 dB below the maximum were approximately 1 dB or less for flat roads and for interchange sections. Those were also less than 1 dB for the areas surrounding a tunnel portal when the low-level portions 15 dB below the maximum were removed.

However, since L_{Aeq} strongly depends on the energy integration over the entire unit pattern, it is necessary to be noted that a significant error may occur owing to the lack of consecutive portions of the unit pattern. Hence, it is necessary to avoid the excessive removal of portions, even if the A-weighted sound pressure levels are sufficiently smaller than the maximum.

4.4 Problems encountered in actual measurements

In addition to considering problems in the prediction calculation, it is necessary to consider the causes of uncertainties in the actual measurements of road traffic noise. Typical causes of uncertainties are discussed below. It is also necessary to consider the measurement duration necessary to stabilize the values of L_{Aeq} statistically.

(1) Influences of meteorological factors

When sounds propagate outdoors, the influences of the temperature profile and wind in the atmosphere appear as propagation distance increases. Attenuation may also occur owing to atmospheric absorption, which depends on atmospheric temperature and humidity. Among these influences, the wind and temperature profiles are extremely complicated phenomena, and it is still difficult to take these influences into account in practical noise prediction. Thus, only the variation of road traffic noise as influenced by wind, which is based on actual measurement results, is introduced in the model. Sound propagation may also be influenced by the temperature gradient, however, its influence can be ignored for propagation distances of up to approximately 200 m, unless extreme temperature inversion occurs. For attenuation caused by atmospheric absorption, a comparatively precise calculation is available in the model.

(2) Influence of background noise

In the measurement of road traffic noise, other types of noise (background noise) always influence the measurement results to some extent. In particular, the influence of background noise is larger when the receivers are far from the road or noise reduction measures such as noise barriers are provided. Although several methods of estimating the degree of background noise have already been investigated, an approximate background noise level can be estimated by simultaneously measuring the percentile level, L_{A90} or L_{A95}, along with L_{Aeq}.

(3) Influence of other factors

Since road traffic noise may be measured under circumstances that are not taken into account in the prediction, not only the causes described above but also various other causes of errors must be considered, for instance, errors caused by traffic flow conditions that are different from those set in the prediction or a difference in the performance of noise reduction measures such as noise barriers due to their installation condition. For drainage asphalt pavement, although the noise reduction effect and its change with time after the installation are taken into account in the model, the deterioration of its performance caused by the blockage of air pores may significantly depend on its location. In the case of a viaduct, not only structure-borne noise, which is already taken into consideration in the model, but also noise from the expansion joints of the road may often be included in actual measurement values.

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