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Road Traffic Noise Prediction Model "ASJ RTN-Model 2018" Proposed by The Acoustical Society of Japan – Part 1: Outline of the calculation model

Shinichi SAKAMOTO[1]; Yasuaki OKADA[2]; Akinori FUKUSHIMA[3];
Toshio MATSUMOTO[4]; Terutoshi TAJIKA[5]

[1] Institute of Industrial Science, The University of Tokyo, Japan

[2] Faculty of Science and Technology, Meijo University, Japan

[3] NEWS Environmental Design Inc., Japan

[4] Kobayasi Institute of Physical Research, Japan

[5] Environmental Technical Laboratory Ltd., Japan

ABSTRACT

The Acoustical Society of Japan (ASJ) has published a new version of road traffic noise prediction method "ASJ RTN-Model 2018" this April. The technical committee on road traffic noise in the Acoustical Society of Japan had been working for structuring the road traffic noise prediction models in conformity with the times for decades, and "ASJ RTN-Model 2018" is an up-grade version of the previous model, "ASJ RTN-Model 2013", published in 2014. In developing the new version, existing knowledge is widely taken into account, in particular, specification of sound power levels of vehicles and calculation methods for sound propagation are improved in wide range. This new model is introduced in five papers with the same main title in this congress. In this paper, the framework of the model, the calculation principle, the general procedure of prediction calculation, the outline of the revision, are described.

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

1. INTRODUCTION

Road traffic noise is one of the most representative environmental issues worldwide. In Japan, the Acoustical Society of Japan organized the Technical Committee on Road Traffic Noise and the committee has continued researches on the road traffic noise issues of Japan for over 40 years. As a result of the research activity, a series of the prediction model of road traffic noise named ASJ Model (up to the Model 1998) and ASJ RTN-Model (Model 2003 and later) has been published (1-7). In Japan, the models have played important roles on noise assessment in the future environment (based on the Environmental impact Assessment Law) and noise estimation in regular environmental monitoring (based on the Noise Regulation Law). As a result, they have considerably contributed to realization of the quiet society in Japan. After release of ASJ RTN-Model 2013 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 this April. This new model is introduced in five papers with the same main title in this congress. In this paper (Part 1), the calculation principle, the general procedure of the prediction calculation and the outline of the revision are described. The calculation models of sound power levels of road vehicles and calculation methods of sound propagation are introduced in Part 2 (8) and Part 3 (9), respectively. In addition, accuracy verification of the calculation method of noise in

[1] sakamo@iis.u-tokyo.ac.jp
[2] okada@meijo-u.ac.jp
[3] fuku-new@wonder.ocn.ne.jp
[4] matsumoto@kobayasi-riken.or.jp

build-up areas is introduced in Part 4 (10). Finally, the prediction accuracy of this model is shown in Part 5 (11).

2. SCOPE

The conditions applicable to ASJ RTN-Model 2018 are as follows.
(1) **Types of road**: General roads (flat, bank, cut and viaduct) and special road sections (interchanges, junctions, signalized intersections, road tunnels, depressed/semi-underground roads, flat roads with overhead viaducts and double-deck viaducts).
(2) **Traffic volume**: No limitation.
(3) **Running speed of vehicles**: 40 to 140 km/h for sections of steady traffic flow on expressways and general roads, 0 to 60 km/h for sections of non-steady traffic flow section on general roads, 0 to 80 km/h for acceleration/deceleration sections on expressways such as interchanges, 0 to 60 km/h for acceleration/deceleration sections on general roads such as in the vicinity of signalized intersections.
(4) **Prediction range**: Up to a horizontal distance of 200 m from the road under consideration and up to a height of 12 m above the ground. The validity of the model has been examined for this prediction range; however, the model is applicable without any limitation on the calculation range.
(5) **Meteorological conditions**: conditions of no wind and no strong temperature profile are assumed as the standard condition.

3. GENERAL PROCEDURE AND BASIC FORMULAE

3.1 Principle and basic formulae

In ASJ RTN-Model, the equivalent continuous A-weighted sound pressure level, $L_{\mathrm{Aeq},T}$, at a prediction point is calculated. As the first step to calculate $L_{\mathrm{Aeq},T}$, the "unit pattern", a time history of A-weighted sound pressure level at a prediction point for a single vehicle that is considered to be a point source passing along the road under consideration is obtained, and the sound pressure exposure level, $L_{\mathrm{A}E}$, for the single vehicle is calculated. By taking account of the traffic conditions (traffic volume, vehicle type composition, etc.) in the above results, the time-averaged value of the noise at a prediction point in terms of energy is calculated. The concrete procedure is as follows.

First, the objective road (lane) is divided into several sections as shown in Fig. 1. Here, running speed v_i [m/s] and sound power level $L_{W\mathrm{A},i}$ of the running vehicle at i-th divided section should be regarded as constant. One of the sections is selected and a representative point (source point) is set at the center point of the section, and the A-weighted sound power level, $L_{W\mathrm{A},i}$, is set. Next, sound pressure level, $L_{\mathrm{A},i}$, at the prediction point is calculated according to calculation method of sound propagation. Sound pressure exposure level for the i-th section, $L_{\mathrm{AE},T_i,i}$, during the interval T_i in which the vehicle exists in the i-th section is calculated as follows (see Fig. 2).

$$L_{\mathrm{AE},T_i,i} = L_{\mathrm{A},i} + 10\lg\frac{T_i}{T_0} \tag{1}$$

where T_0 = 1 s (the reference time). The above calculation is performed for every section. Then, the single event sound exposure level $L_{\mathrm{A}E}$ [dB] at the prediction point when a vehicle travels along the entire road (lane) is calculated as

$$L_{\mathrm{A}E} = 10\lg\sum_i 10^{\frac{L_{\mathrm{A}E,T_i,i}}{10}} \tag{2}$$

Sound power level is dependent on the vehicle type. Therefore, the single event sound exposure level L_{AE} is calculated for each vehicle type, and the equivalent continuous A-weighted sound pressure level $L_{\mathrm{Aeq},T}$ is calculated by taking into consideration of the traffic volume for the vehicle type.

$$L_{\mathrm{Aeq},T} = 10\lg\frac{\sum_i N_{T,j}10^{\frac{L_{\mathrm{A}E,i}}{10}}}{T} \tag{3}$$

where T [s] is the total time interval, $L_{\mathrm{A}E,j}$ [dB] is a single event sound exposure level for vehicle type j calculated by Eq. (2), $N_{T,j}$ is the traffic volume (number of vehicles) of the vehicle type j during the time interval T.

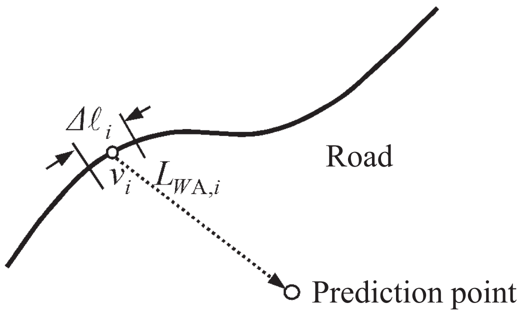

Figure 1 – Sound propagation from a sound source to a prediction point.

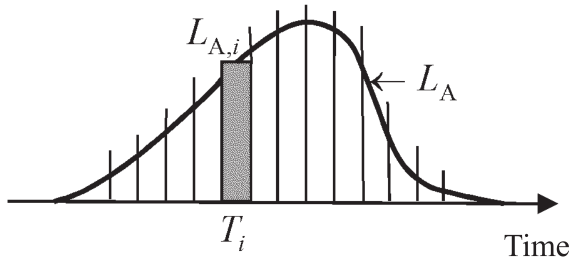

Figure 2 – Unit pattern

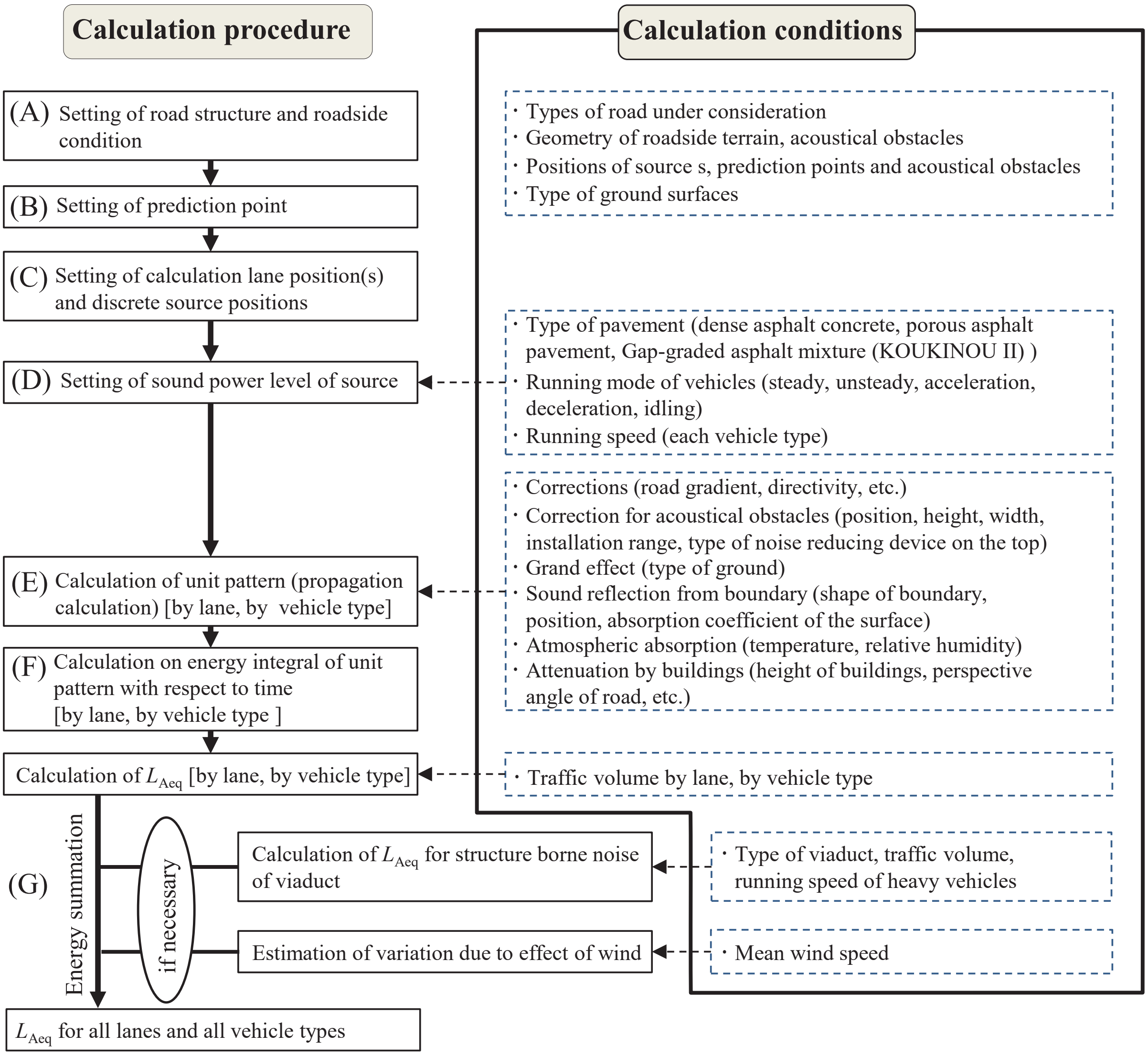

Figure 3 — Calculation procedure for predicting road traffic noise

3.2 General calculation procedure

A flow showing the general procedure for calculating road traffic noise based on this model is shown in Fig. 3. The outline of the calculation procedure is as follows.

(A) Setting road structures, roadside conditions and prediction point

The first step of the procedure includes setting the road structure, the positions of the source, the prediction point, and the acoustical obstacles, the ground surface conditions along the propagation path and so on.

(B) Setting positions of lanes

The calculation position for each lane is located at the center of the lane. For simplicity of the calculation, it is possible to combine two or more lanes into a single hypothetical lane. For instance, a hypothetical lane can be located along the centerline between two lanes of traffic traveling in opposite directions.

(C) Setting discrete source positions

Discrete source positions are generally located within a range of $\pm 20l$ (l: shortest distance from the calculation lane to the prediction point) from the point of intersection of lines representing the lane and the perpendicular from the prediction point on the lane. They are located with an interval of l or less. On the other hand, in the cases where vehicle running speed varies by acceleration-deceleration as seen in special road sections or where the propagation property rapidly changes with the arrangement of the sound source, the prediction point and other acoustical factors, it may be necessary to shorten the intervals of the discrete sources in order to capture the maximum level of the unit pattern correctly, and in order to obtain accurate value of single event sound exposure level of the unit pattern, the point sources should be set in the range where the sound pressure level goes down to -10 dB or less than the maximum level.

(D) Setting the power level of the source

L_{WA} is set considering the type of pavement of the road surface, the running condition of the vehicle (steady flow, non-steady flow, acceleration, deceleration and idling while at rest), running speed and corrections (power-level change due to the type of pavement, road gradient, directivity and other factors).

(E) Calculation of the unit pattern

The unit pattern $L_{A;i}$ at the prediction point is calculated when a single vehicle runs alone along the objective road. The unit pattern is calculated separately by lane and by vehicle type.

(F) Calculation of the energy integration of the unit pattern and L_{Aeq}

Single event sound exposure level L_{AE} for respective vehicle type by Eq. (2). Taking into consideration of traffic volume N_T during the evaluation time T [s], equivalent continuous A-weighted sound pressure level $L_{Aeq,T}$ is obtained by Eq. (3).

(G) Calculation of total noise level

When the road has multiple lanes exist, $L_{Aeq,T}$ for all of the lanes is calculated by the energy summation of the obtained results for respective driving lanes. In the case of noise prediction around a viaduct road, the structure-borne noise of the viaduct is taken into consideration in addition to vehicle noise. If a viaduct has a structure separated by a gap between lanes, the noise is calculated by considering that each set of lanes exists independently. Sound attenuation caused by the variation of sound due to the effect of wind can also be calculated when required.

Finally, $L_{Aeq,T}$ for the entire road is obtained.

4. OUTLINE OF REVISIONS

The present model is developed based on the previous version, ASJ RTN-Model 2013 (7), and the following points are revised to the previous version.

(1)Sound source characteristics

- The classification of road vehicle from an acoustical viewpoint was reviewed and it was changed from the conventional four-category classification (large-sized vehicles, medium-sized vehicles, small-sized vehicles and passenger cars) to the three-category classification (large-sized vehicles, medium-sized vehicles and light vehicles).
- Based on the latest knowledge regarding the sound power levels of recent vehicles, values of the coefficients for the calculation formulae of the A-weighted sound power levels of vehicles were updated.
- In the previous versions of ASJ RTN-Model, the calculation formulae of the A-weighted sound power levels of vehicles was basically given for dense asphalt concrete road, and correction terms were applied for porous power levels of vehicles were given for respective types of the road pavement.
- In the types of road pavement, gap-graded asphalt mixture (referred to as "KOUKINOU II"), which is often used in cold snowy regions in Japan due to its high durability, was newly included.
- Based on the latest data on recent road vehicles, sound power spectra of vehicle noise were

updated.

- The latest knowledge on the A-weighted sound power levels of hybrid vehicles (HVs) and electric vehicles (EVs) are given.

(2) Propagation calculation

- The corrections due to sound attenuation by diffraction and reflection were reviewed and a part of calculation formulae and values of coefficients were updated.
- For correction for diffraction, sound diffraction over knife wedge (assuming a barrier) and that over right-angled wedge (assuming an embankment or a building) were discriminated and formulae for respective fundamental correction terms were given.
- According to update of sound power spectra of vehicles and addition of gap-graded asphalt mixture to road pavement type, values of the coefficients for calculation formulae on correction terms on diffraction were updated.
- According to the introduction of fundamental term on right-angled wedge diffraction, the calculation method of thick barrier was changed.
- In addition, applying the calculation method of the thick barrier, calculation method for overhung barrier was also changed. Noise shielding effects of overhung barriers were modeled as summation of the noise shielding effect of a hypothetical thick barrier with the same diffraction point as the objective overhung barrier and the specific shielding effect to the type of the overhung barrier, and the calculation method based on such a modeling was given.
- For ground effect, calculation method for ground effect over porous asphalt pavement was newly added.
- For scattered reflection method included in calculation method of sound reflection, method of setting of the calculation condition was described.
- On the basis of numerical investigation of meteorological effect on sound propagation of road traffic noise, upper limit of attenuation effect due to diffraction and ground effect was determined.
- Calculation method of frequency-dependent propagation was updated to generalized energy-base method.

(3) Special road sections

- Calculation method of noise around road tunnel was changed to the method taking into consideration of directivity characteristics of sound radiation from tunnel mouth.
- For noise around flat/overhead roads and double-deck viaduct, calculation method of scattered reflection was simplified.

(4) Noise behind a single building and in build-up areas

- For road traffic noise in build-up areas, calculation method based on a point source model given in the previous model was simplified from an engineering viewpoint and the content was updated.
- The detailed calculation method based on a point source model was described in Appendix in order to meet the necessity in which detailed unit patterns should be calculated.

5. CONCLUSIONS

As mentioned above, ASJ RTN-Model 2018 is basically an energy-base calculation method based on L_{Aeq} and can be applied to almost all types of roads, in principle. This prediction model will be effectively used for the environmental impact assessment and regular environmental monitoring in Japan. At the same time, this model can be applied to noise mapping of existing environment. However, there still exist various kinds of problems that should be solved in the future. For this aim, the Research Committee on Road Traffic Noise in the Acoustical Society of Japan will continue the research work.

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