inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 7.6

ROAD TRAFFIC NOISE PREDICTION MODEL 'ASJ MODEL 1998' PROPOSED BY THE ACOUSTICAL SOCIETY OF JAPAN - PART 1: ITS STRUCTURE AND THE FLOW OF CALCULATION

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Keywords:
ROAD TRAFFIC NOISE, NOISE PREDICTION MODEL

ABSTRACT
The Acoustical Society of Japan published a new prediction model of road traffic noise, "ASJ Model-1998", in which the equivalent continuous A-weighted sound pressure levels L_{Aeq} in roadside areas can be predicted based on energy-base calculation. This method consists of the models of sound power levels of road vehicles under stable and unstable running conditions, two kinds of sound propagation calculation methods, corrections for ground absorption, meteorological effects, shielding effects of roadside buildings, etc. In this paper, the outline of the model and the main flow of the prediction calculation are introduced.

1 - INTRODUCTION

As the prediction method of road traffic noise in Japan, the Acoustical Society of Japan (ASJ) published a calculation model called "ASJ Model 1975" in 1975. This model is for the calculation of L_{50} of road traffic noise which was used as the noise index of general environmental noises in Japan. From 1987, the ASJ started to develop a prediction model based on L_{Aeq} and published a new model "ASJ Model 1993" in 1994 [1,2].

In September 1998, the "Environmental Quality Standards for Noise" in Japan was revised and the noise index for road traffic noise was changed to L_{Aeq} from L_{50} [3]. To correspond to this change, the ASJ continued the research to improve the "ASJ Model 1993" and published a new model "ASJ Model 1998" last year [4]. The outline of this calculation model is introduced in this congress by a series of reports and the related papers [5-13]. In this paper, the main structure of the model and the calculation flow are presented.

2 - CALCULATION PRINCIPLE

In the prediction calculation of road traffic noise based on L_{Aeq}, it is the point to obtain the "unit pattern", the time history of sound pressure, at the prediction point observed when a road vehicle runs on the road under consideration. By squaring and integrating the unit pattern, the sound pressure exposure is obtained and then by considering the traffic volume and by averaging the total sound exposure, L_{Aeq} can be calculated. The concrete procedure is as follows.

Firstly, the traffic-lane of the road under consideration is properly divided into finite segments [see Fig. 1(a)]. For the i-th segment, the sound propagation from the center point of the segment to the prediction point is calculated. For this calculation, the sound power P_i (or sound power level $L_{W,i}$) of the sound source (vehicle) which is assumed to be an omnidirectional point source on a reflecting plane is provided for each vehicle type and running condition and the sound pressure p_i (or sound pressure level $L_{p,i}$) at the prediction point is calculated.

Next, the sound pressure exposure E_i [Pa^{2}s] at the prediction point over the time interval Δt_i [s] in which the sound source exists within the i-th segment is calculated as follows.

$$E_i = p_i^2 \cdot \Delta t_i = p_i^2 \frac{\Delta \ell_i}{v_i} \qquad (1)$$

where, $\Delta\ell_i$ is the length [m] of the i-th segment, and v_i is the running speed [m/s] of the sound source in the segment. The calculation is made for each segment of the traffic-lane and by adding up these results the total sound pressure exposure E [Pa ^{2}s] over the time interval during which the sound source passes the lane under consideration is obtained as follows [see fig. 1(b)].

$$E = \sum_i E_i = \sum_i p_i^2 \cdot \Delta t_i = \sum_i p_i^2 \cdot \frac{\Delta\ell_i}{v_i} = \sum_i p_i^2 \cdot \frac{3.6\Delta\ell_i}{V_i} \qquad (2)$$

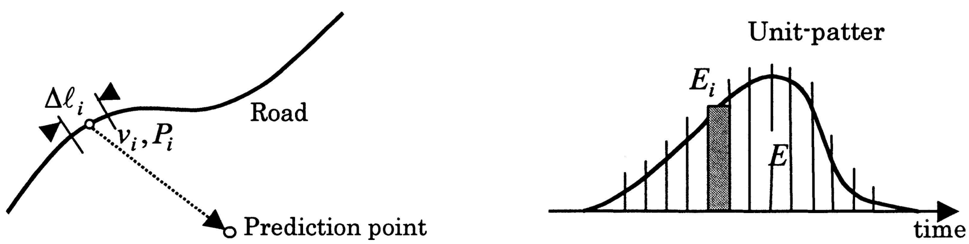
where, V_i is the running speed [km/h] of the sound source in the i-th segment ($v_i = V_i/3.6$).
As expressed by the following equation, the quantity expressed in level (dB) of the total sound pressure exposure E is the "sound pressure exposure level" $L_{p\mathrm{E}}$. (When considering A-weighted sound pressure, $L_{p\mathrm{E}}$ corresponds to "sound exposure level" L_{AE}).

$$L_{p\mathrm{E}} = 10\log_{10}\frac{E}{E_0} \qquad (3)$$

where, $E_0 = 4 \times 10^{-10}$ Pa^{2}s (the reference value of sound pressure exposure).
From the value of $L_{p\mathrm{E}}$ calculated as mentioned above and by considering the traffic volume N [vehicles/h], the "equivalent continuous sound pressure level" $L_{p\mathrm{eq}}$ for 1 hour (3600 s) is obtained as follows. (When considering the A-weighted sound pressure, $L_{p\ \mathrm{eq}}$ corresponds to L_{Aeq}.)

$$L_{p\mathrm{eq}} = 10\log_{10}\left(10^{L_{p\mathrm{E}}/10}\frac{N}{3600}\right) = L_{p\mathrm{E}} + 10\log_{10}N - 35.6 \qquad (4)$$

By making the calculation for all lanes of the road under consideration and for all vehicle types, and by adding up these results on energy-base, $L_{p\mathrm{eq}}$ in each octave or 1/3 octave band at the prediction point is obtained. Finally, L_{Aeq} is obtained by adding up the values of $L_{p\mathrm{eq}}$ in all frequency bands with A-weighting.



(a): A source position and a prediction point on a road.

(b): Unit-pattern.

Figure 1: Calculation principle of road traffic noise in "ASJ Model 1998".

3 - FIELD OF APPLICATION

The calculation conditions and the field of application of the ASJ Model 1998 are as follows.

- Type of road: general roads (flat, bank, cut, and viaduct), special parts (interchange, depressed or semi-underground, vicinity of a tunnel mouth, parts where viaduct and flat road exist together, and double-deck viaduct)
- Traffic volume: unlimited
- Vehicle running speed: 40 to 140 km/h for freeways and urban roads under steady running condition, 10 to 60 km/h for urban roads under unsteady running condition including acceleration and deceleration, and 0 to 80 km/h for the special parts like interchange.
- Prediction area: as far as 200 m in horizontal distance from the road under consideration and up to the height of 12 m from the ground. (Although there is no restriction in the calculation principle, the validity of the model has been examined for the limited areas mentioned above.)
- Meteorological condition: the condition of no wind and no strong temperature inversion is assumed as the standard condition.

4 - SOUND POWER LEVEL AND SPECTRUM FOR EACH VEHICLE TYPE

As reported in Part 2 [5], noise emission of running road vehicles much depends on the difference of vehicle type and running condition. In the ASJ Model 1998, road vehicles are classified into four types; large-sized vehicles, medium-sized vehicles, small-sized vehicles and passenger cars. Besides, two type classification (heavy vehicles and light vehicles) is also prepared for the convenience in actual prediction calculation. For each vehicle type and for each running condition (steady condition and unsteady condition), the sound power level is provided in A-weighted value. In the case where the "A-method" mentioned below is applied, the calculation is made in each octave or 1/3 octave band. For this purpose, the sound power spectrum characteristic of vehicle noise is specified as a function of frequency.
Recently, drainage asphalt pavement is often constructed and its effect of reducing vehicle noise should be considered. Therefore, the method for the correction of sound power level of vehicles is prepared in the model [5], [12].

5 - CALCULATION PROCEDURE

Figure 2 shows the calculation flow of the "ASJ Model 1998". The outline of the calculation procedure is as follows. The concrete calculation methods are presented in Part 3 [6].

- Calculation conditions:
  Geometrical data regarding the road construction and surrounding terrain and building conditions are set.

- Setting of hypothetical traffic-lanes:
  In principle, a hypothetical lane is set on the center line of each traffic-lane of the road under consideration. In almost all cases, it may be sufficient to set two respective lanes representing the up and down lanes.

- Setting of discrete sound source positions:
  Discrete sound source positions are located on the hypothetical lane at an interval less than ℓ (the shortest distance from the prediction point to the lane) over the distance of $\pm 20\ell$ from the center point on the lane.

- Sound propagation calculation from each source position to the prediction point:
  The sound pressure at the prediction point caused by each sound source is calculated by either of the two calculation methods; A-method or B-method. In the A-method (precision method) based on wave acoustics, sound pressure is calculated in complex form at the center frequencies in octave or 1/3 octave bands. In the B-method (engineering method), A-weighted sound pressure level is directly calculated based on geometrical acoustics and using empirical formulas. By performing the calculation mentioned above for all source positions, the unit-pattern at the prediction point is obtained for each lane. From the result, the sound pressure exposure at the prediction point is calculated.

- Calculation of L_{Aeq}:
  By considering the traffic volume in each vehicle type for each lane, the value of L_{Aeq} for each lane is calculated. Then, by adding up the L_{Aeq} values for all lanes on energy-base, the final result of L_{Aeq} at the prediction point caused by the road under consideration is obtained.

- Consideration of the meteorological effects:
  Sound propagation outdoors is seriously influenced by such meteorological effects as wind and temperature gradient in the atmosphere. These phenomena are too complicated to be dealt in simple calculation. In the ASJ Model 1998, therefore, the meteorological condition without strong temperature gradient is assumed as the standard condition and a simple formula for the estimation of the effect of wind is presented as a function of vector wind. In addition, approximate variation range of L_{Aeq} by the wind effect is indicated in tabular form for the propagation distance of 50, 100 and 200 m. Regarding the sound absorption by air, the calculation method is specified based on ISO 9613-1.

- Calculation for special parts:
  In the actual road traffic noise prediction, special parts like interchange have to be dealt with as well as general roads. For this purpose, the following specifications are included.

- Interchange: When dealing with interchange, the change of sound power levels of vehicles due to acceleration, deceleration and stop and sound propagation over complicated road construction and terrain condition have to be considered. In the ASJ Model 1998, acceleration during the transient process for the estimation of the change of vehicle speed, stopping time of vehicles at the toll-gate, and the sound power levels during each of these transient running condition are indicated.
- Depressed and semi-underground roads: For the calculation of noise propagation from depressed and semi-underground roads, the reflection by the side walls has to be considered. For this purpose, the "slit method" is described, in which the reflection surfaces are assumed to be acoustical slits and the reflections are calculated as the diffraction through the slits [6,7].
- Peripheral area of tunnel mouth: In the calculation for the peripheral area from a tunnel mouth, the noise generated from the tunnel mouth is divided into two components; the direct sound from the vehicle in the tunnel and the diffuse sound excluding the direct sound [6], [8].
- Reflection from the back surface of viaduct construction: For a double-deck viaduct road and the parts where a viaduct road and a flat road exist together, the reflection from the back surface of the construction has to be considered. For this purpose, the back surface is simplified as a plain reflection surface and the reflection is calculated by the "slit method". In this calculation, three kinds of propagations (the direct sound, the first-reflection by the back surface of the construction and the reflection between the back surface and the ground surface) are considered.

- Calculation of the sound generated from the back surface of a viaduct structure:
  In the areas near to a viaduct road, the noise generated from the slab of the viaduct structure excited by running vehicles should be considered. To predict this kind of noise, a simple calculation model is indicated, in which a hypothetical moving source with constant sound power level is assumed under the girder of the viaduct structure and the sound propagation is calculated by a simple equation [6].
- Calculation of sound propagation behind buildings:
  The new "Environmental Quality Standards for Noise" in Japan revised in 1998, environmental noise is evaluated not only in roadside areas but also in the areas behind buildings and built-up areas. To deal with such assessments, the methods to estimate the noise behind buildings are described [6], [9].

6 - CONCLUSIONS

As mentioned above, the "ASJ Model 1998" is 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 adopted as the standard prediction method in the Environmental Impact Assessment for road traffic noise in Japan [13]. However, there still exist various kinds of problems that should be developed and improved in the future. The Research Committee of Road Traffic Noise in the Acoustical Society of Japan is continuing these research works.

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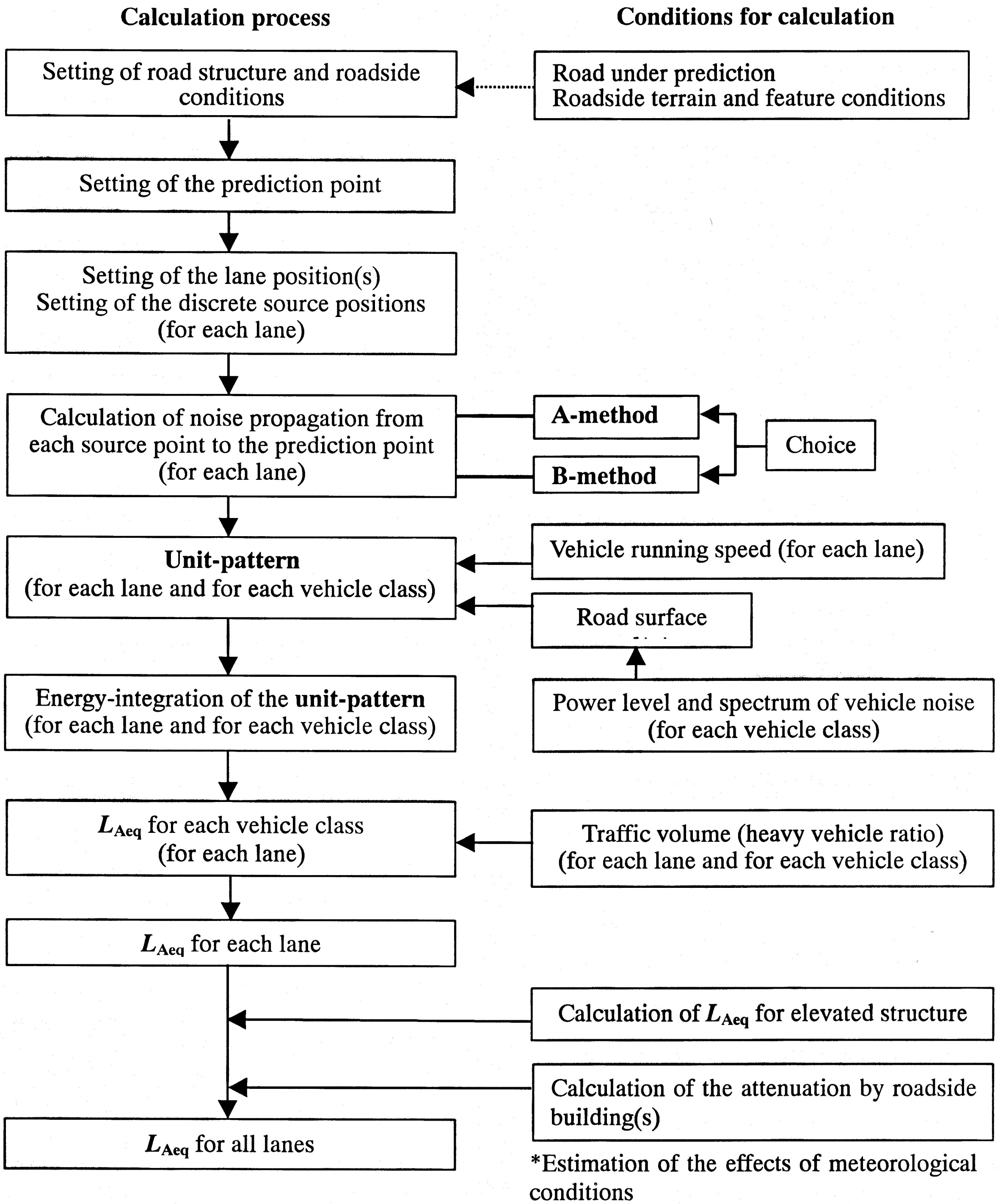

Figure 2: Procedures for the calculation of road traffic noise (ASJ Model 1998).