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Minimum measurement time interval to estimate a reliable sound pressure level of road traffic noise using two types of dynamic statistics

Mitsunobu Maruyama [a,*], Kazuhiro Kuno [b], Toshio Sone [c]

[a] Acoustical Science Laboratory, 6-5-5-105, Jousuihon-cho, Kodaira City 187-0022, Japan
[b] Department of Electrical Engineering, Aichi Institute of Technology, 1247 Yachigusa, Yakusa-cho, Toyota City 470-0392, Japan
[c] Tohoku University, 4-9-5 Midorigaoka, Taihaku-ku, Sendai City 982-0021, Japan

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ABSTRACT

A new method to determine the minimum measurement time interval needed to obtain the equivalent continuous A-weighted sound pressure level with a designated reliability is presented. This method considers variations in the noise emission from passing vehicles. To verify the validity and availability, simulation experiments based on our dynamic model are examined under various traffic conditions. A statistic quantity, the mean time interval between two maximum sound pressure levels consecutively observed during the reference measurement time interval, is introduced in the experimental analysis. Additionally, the theoretical analysis includes another statistic quantity corresponding to the mean time interval, the mean recurrence time of the maximum sound pressure level, when the transition probability, rate of heavy vehicles, and probability distribution of vehicles passing the observation point during the reference measurement time interval are known.

1. Introduction

The minimum time measurement interval (T) should be conclusively determined to obtain a reliable equivalent continuous A-weighted sound pressure level (L_{AeqT}) on a truck road from the viewpoints of an environmental standard and new highway planning. Skarlatos and Drakatos have proposed a probabilistic method to select T to determine a reliable L_{Aeq} if the probability density function of the noise level is well defined theoretically or experimentally [1–4]. Similarly, de Donato has discussed T necessary to measure the hourly L_{Aeq} of road traffic noise with a designated measurement uncertainty (ΔL_{Aeq}), and has shown that T can be obtained from the expression of error associated with L_{Aeq} when traffic conditions (traffic volume (Q) [vehicles/h], rate of heavy vehicles (Q_t), average vehicle speed ($\overline{V}$) [km/h]) and the probability distribution related to running vehicles are known; regardless of the Q distribution, ΔL_{Aeq} is within 2.5 dB [5,6,7–12]. However, for most actual measurement sites, these factors are unknown.

Previously, we suggested a method to select T to obtain reliable and effective L_{AeqT}'s, even if the above information is unavailable, and conducted simulation experiments to validate the effectiveness of the proposed dynamic model. If the probability distribution of the number of vehicles passing by an observation point (P) is assumed to obey a Poisson distribution and T is the time required for about 70 vehicles to successively pass P, the measured L_{AeqT}'s should fall within an error of ±1 dB with a reliability of 75% or more [13–16].

ISO 1996-Part 2 provides the following descriptions to select T for L_{Aeq} as well as the maximum A-weighted sound pressure level (L_{AFmax}). "Select the measurement time interval to cover all significant variations in noise emission and propagation. If the noise displays periodicity, the measurement time interval should cover an integer number of at least three periods. If continuous measurements over such a period cannot be made, measurement time intervals shall be chosen so that each represents a part of the cycle and so that, together, they represent the complete cycle" [17,18]. Taking these descriptions into consideration, many simulation experiments have been performed with an emphasis on the time interval between two measured L_{AFmax}'s when one or two successive heavy vehicles pass P during the reference measurement time interval ($T_{reference}$) of 1 h. On the other hand, if the probability distribution of the number of vehicles passing P, transition probability, and rate of heavy vehicles are available, the mean recurrence time ($\widetilde{\Theta}$) of L_{AFmax}, which corresponds to the mean time interval

* Corresponding author. Tel.: +81 8055322887.
E-mail addresses: nru34444@nifty.com (M. Maruyama), quno@aitech.ac.jp (K. Kuno), tsone0021@ybb.ne.jp (T. Sone).

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($\bar{t}$) of its appearance obtained from the experiment, can be estimated [19–21]. Thus, a new method is discussed herein to select T required to obtain stable L_{AeqT}'s while considering significant variations in the noise emission from the vehicle groups in relation to the two dynamic statistical quantities of $\bar{t}$ and $\widetilde{\Theta}$ [22–26].

2. Mean time interval ($\bar{t}$) between two successive maximum A-weighted sound pressure levels (L_{AFmax}'s)

This section considers the number of significant variations in the noise level at the observation point (P) during the measurement time interval (T) and the duration of the interval between two successive maximum sound pressure levels (L_{AFmax}'s) from the viewpoint of traffic flow with an emphasis on passing heavy vehicles.

Simulation experiments based on our dynamic model were executed with the Monte Carlo method for a variety of traffic conditions (traffic volume (Q) [vehicles/h], rate of heavy vehicles (Q_t), and average vehicle speed ($\overline{V}$) [km/h]) [16,24,25]. The observation point was placed at d_0 = 50 m from the road $\bar{t}$ between two successive L_{AFmax}'s was introduced as a dynamic statistic quantity that varied with time. It was assumed that the three traffic conditions (Q, Q_t, and $\overline{V}$) remained steady during the reference measurement time interval ($T_{reference}$).

Fig. 1 schematically diagrams the traffic flow on a road divided into 25 sections of equal length. All vehicles run from left to right along the X-axis over time. Each section along the horizontal axis in the figure has a length of $\Delta X = d_0/2$ m, and the section along the vertical axis indicates the average time for sound energy integration at P (i.e., $d_0/2v$ [s]). v[m/s] is the running speed of the vehicles. An open circle (○), black closed circle (●), and a cross (×) represent a passenger car, heavy vehicle, and no vehicles in the relevant section, respectively.

Fig. 2 shows six typical vehicle arrangements when L_{AFmax}'s are observed at P during $T_{reference}$ (1 h). In the figure, D_{min} represents the minimum allowable distance between two successive cars; namely, if a car runs at $\overline{V} = 80,\ 100$, or 120 km/h, then D_{min} = 80, 100, or 120 m, respectively. For Case (1), one heavy vehicle passes P and t_1 [s] later another heavy vehicle follows. For Case (2), one heavy vehicle and one passenger car pass P at an interval of D_{min} and t_2 [s] later the same sequence passes P. For Case (3), two heavy vehicles pass P at an interval of D_{min}, and t_3 [s] later the same sequence passes P. In Case (4), one passenger car, one heavy vehicle, and another passenger car pass P while maintaining D_{min} between successive vehicles and t_4 [s] later the same sequence of vehicles passes P. In Case (5), one passenger car followed by two heavy vehicles pass P while maintaining D_{min} between successive vehicles and t_5 [s] later the same sequence of vehicles passes P. For Case (6), three heavy vehicles pass P successively while maintaining the interval of D_{min} and t_6 [s] later the same sequence of heavy vehicles passes P. For Cases (1)–(5) discrete L_{AFmax}'s may

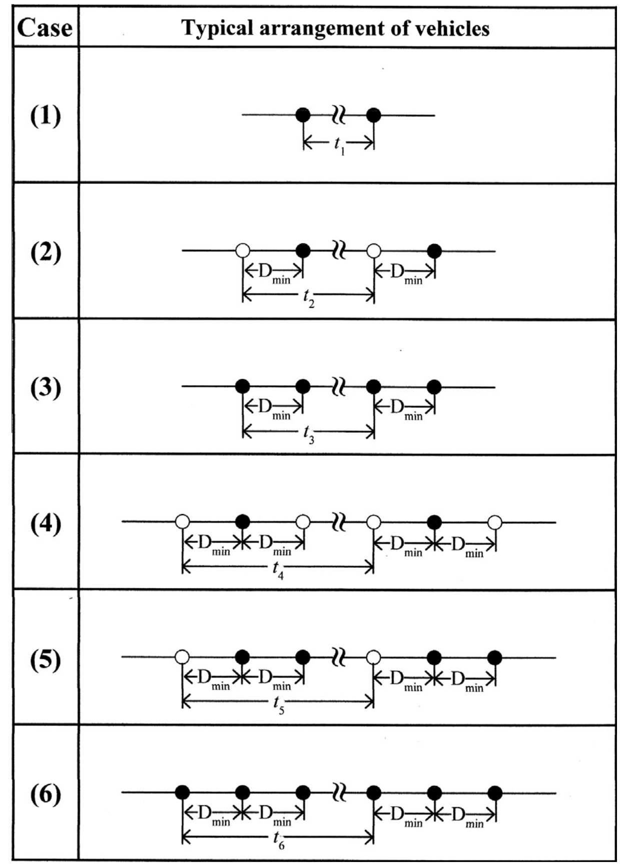

Fig. 2. Six typical arrangements of vehicles when L_{AFmax}'s are observed at the observation point.

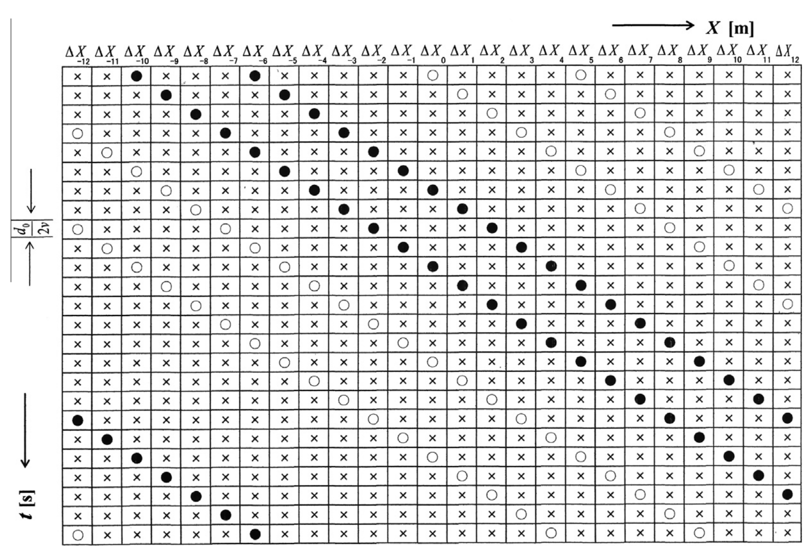

Fig. 1. Schematic diagram of traffic flow on a road divided into 25 equal sections.