Large area noise evaluation

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Abstract

A software tool (DRONE) has been developed to evaluate road traffic noise in a large area with the consideration of network dynamic traffic flow and the buildings. For more precise estimation of noise in urban network where vehicles are mainly in stop and go running conditions, vehicle sound power level (for acceleration/deceleration cruising and ideal vehicle) is incorporated in DRONE The calculation performance of DRONE is increased by evaluating the noise in two steps of first estimating the unit noise database and then integrating it with traffic simulation. Details of the process from traffic simulation to contour maps are discussed in the paper and the implementation of DRONE on Tsukuba city is presented.

Introduction

Generally traffic noise is not evaluated in a comprehensive manner i.e., it is limited to road side area with static traffic flow consideration. The effect of buildings especially in built-up area is also not taken into account. For the noise evaluation in a large area with the consideration of network dynamic traffic flow and the buildings (forming the built-up area) a computerized model, DRONE (areawide Dynamic Road traffic NoisE)[1-3], has been developed. This paper elaborates the methodology and structure of

DRONE to estimate noise levels on a large urban area where the vehicles are generally in stop and go running conditions. For computationally efficient noise estimation on a large network, DRONE generates unit noise database for the study area which is then efficiently integrated with traffic simulation.

The structure of paper is as follows: first the general methodology and framework of DRONE is discussed, followed by the discussion on the explicit consideration of acceleration/deceleration in DRONE. Then two step procedures of first generating unit noise database and then areawide noise estimation is discussed. Finally the results from the implementation of DRONE at Tsukuba city, Japan are presented.

General methodology and framework of DRONE

Methodology and Framework of DRONE

The methodology of DRONE is to integrate the time dependent traffic characteristic simulated from the traffic simulation model with the noise estimation model to estimate noise on an areawide region by considering the time dependent variations in traffic flow on the whole network. It is then further linked with GIS to provide visual representation to the estimated noise in the form of time dependent noise contour maps.

In the present research, for traffic simulation, a mesoscopic traffic simulation model AVENUE [4] is used. Standard Japanese road traffic noise estimation model (ASJ Model [5-7]) developed by Acoustic Society of Japan is used for noise estimation. In the model, the building attenuation in the built-up area is estimated by considering the statistical model by Useaka [8]. For detailed discussion about how the buildings and built-up area attenuation is considered for noise estimation in DRONE, refer to [2].

For areawide noise estimation, the study area is divided into a number of receptor points. The road network is also divided into a number of small sections (source sections). For each receptor point, the source sections which contribute noise level at the receptor point are searched. Then for a particular source and receptor point, noise calculations, with appropriate consideration of attenuations such as building, distance etc., are performed based on the time dependent traffic simulation on the network. The process is repeated for all the sources and for all the receptor points to estimate time dependent noise level in the areawide region (Figure 1).

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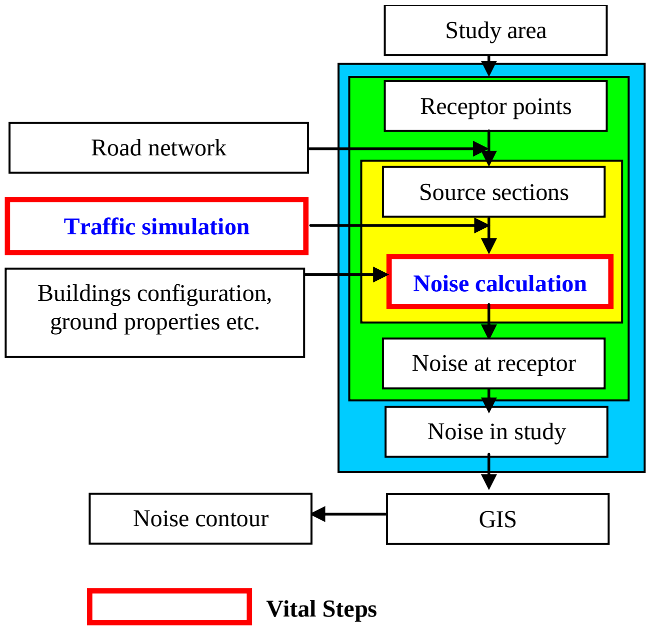

Fig. 1. Framework for noise estimation in DRONE

A brief outline of the noise calculation procedure is as follows: The noise generated from a source section is defined in terms of sound power level (L_{WA},) for a vehicle based on the vehicle type and its running condition (transient or steady). The corresponding sound pressure level (L_{p}, equation 1) at the receptor point is calculated by appropriate consideration of the sound propagation from the vehicle position to the receptor point. The sound propagation from the source to the receptor point is dependent on the number of factors, such as ground properties, buildings, etc., between source and receptor point. These factors contribute to the correction terms to the sound power level (L_{WA}) generated by the source.

$$L_p = L_{WA} + \text{Correction Terms} \qquad (1)$$

Then, the sound pressure exposure (L_{AE}) at the receptor point is estimated based the time during which the vehicle is in the corresponding section. Finally, equivalent continuous sound pressure level (A weighted) L_{AE} is estimated by considering the traffic flow at the corresponding section.

Explicit consideration of acceleration in noise estimation

The last application of DRONE [1]is based on the ASJ Model 1998 which differentiates the vehicle motion in terms of transient and steady running conditions. Vehicle power level for transient running condition is higher than those from steady running condition, which implicitly accounts for the increase in the noise level for accelerating vehicle. However, in an urban environment, the vehicles are in stop and go running condition. For example, at control intersection they decelerate, stop and then accelerate. It has been found that the noise level for an accelerating vehicle can be significantly higher than those from cruising vehicle at the same speed [9]. Hence for more precise and accurate estimation of noise in urban environment it is necessary to consider the more detail driving condition.

In ASJ Model 1998 the sound power level from the source does not explicitly consider the acceleration of the vehicle. So, in order to capture the effect, a detailed relationship between vehicle sound power level and running conditions defined in terms of speed, and rate of change of speed (acceleration/deceleration) is used in DRONE. The required relationship is obtained from the latest research from Japan Automobile Research Institute [10]. The template for the relationship is shown in Table 1. The revised power levels are for acceleration (m s^{-2}) ranging from -1.5 to 1.5 with step of 0.25. The speed (km hr^{-1}) range is from 0 to 120 km hr^{-1}. with zero speed corresponding to an ideal vehicle. In DRONE, Table 1 is a lookup table for the relationship between vehicle type, its running condition and corresponding sound power level. Note in this paper we use the word ‘running condition categories’; these categories are related to column 1 of Table 1.

Table 1. Template for relationship between vehicle running conditions and A-weighted sound power levels

Category	Acceleration (m sec^{-2})	Speed (km hr^{-1})	Sound Power Level dB (A)			
			Passenger Car	Small Size	Medium Size	Large Size
1	0	0 to 5	68.6	80.6	87.0	85.0
2	-1.5	5 to 10	75.3	80.8	82.5	85.1
3	-1.25	5 to 10	75.3	80.8	82.5	85.1
…	…	…	…	…	…	…
155	1	115 to 125	109.3	-	-	-

Unit Noise Database

The sound pressure level (equation 1) at the receptor point depends on the vehicle sound power level (source model) and the correction terms for the sound propagation (propagation model) from source to receptor point. The sound power level depends on the vehicle running condition obtained from the traffic simulation. However, the correction terms are independent of the traffic simulation and depend on the geographical conditions. In a dense urban network, the calculation of correction terms (for building attenuation, etc.) for a grid of large number of receptor points requires considerable computation time. For noise abatement policy evaluation we need to run the noise simulation for different transportation policies to evaluate and implement the cost effective and efficient transportation policy [1]. During different simulation runs for the same area, only traffic conditions in the network changes. Hence, for a large study area, we propose to compute the correction terms for all the sources to respective receptor point only once. And then integrate this with different traffic simulations to generate noise maps in more computationally efficient manner.

The unit noise database is defined in terms of correction terms for each receptor point from different source sections and is visualized in terms of unit noise map. Unit noise is obtained from a hypothetical situation of unit flow on the whole network and for each vehicle running category. The corresponding contour map is unit noise contour map. The physical significance of the unit noise map is that it visualizes the correction terms for sound propagation (effect of buildings, ground and distance) on the whole network.

Traffic simulation provides the flow for each vehicle category type on the network, which is then integrated with unit noise database to obtain the areawide noise map as discussed in the following section.

Areawide noise estimation

Traffic simulation output

The standard traffic simulation output from AVENUE is the flow and speed (mesoscopic characteristics) of vehicles with minimum resolution of one second. For considering the time dependent accelerating and deceleration of the vehicle (microscopic characteristics) individual vehicle trajectory is tracked during traffic simulation from AVENUE (Figure 2) represents an individual vehicle trajectory from AVENUE and its corresponding time dependent information for acceleration, deceleration, cruising and ideal conditions. More precise data for noise estimation is obtained by transforming individual vehicle trajectory into its corresponding running conditions.

Individual vehicle trajectory is time dependent space coordinates of the vehicle. These coordinates are related to the respective sections in the road network. For each section, vehicles are aggregated according to its type and running condition category (defined in column 1 of Table 1). Finally, areawide noise is obtained by integrating the above flow with the pre calculated unit noise database

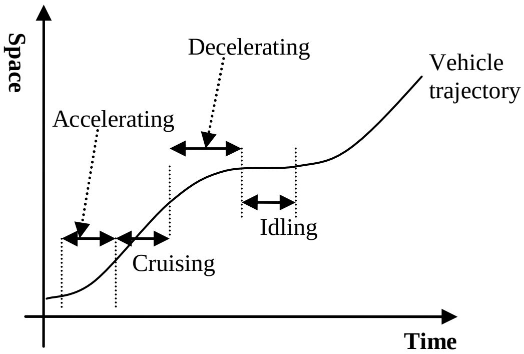

Fig. 2. Individual vehicle trajectory from traffic simulation

The following section discuss about the implementation of the above mentioned procedure on Tsukuba city, Japan

Implementation

Study area

The study area is 1.8 km by 2.3 km in Tsukuba city, Japan. Figure 3 shows the site of the study area where buildings are represented by blocks. Different colours represent different height of the buildings which varies from 4 m to 58 m.

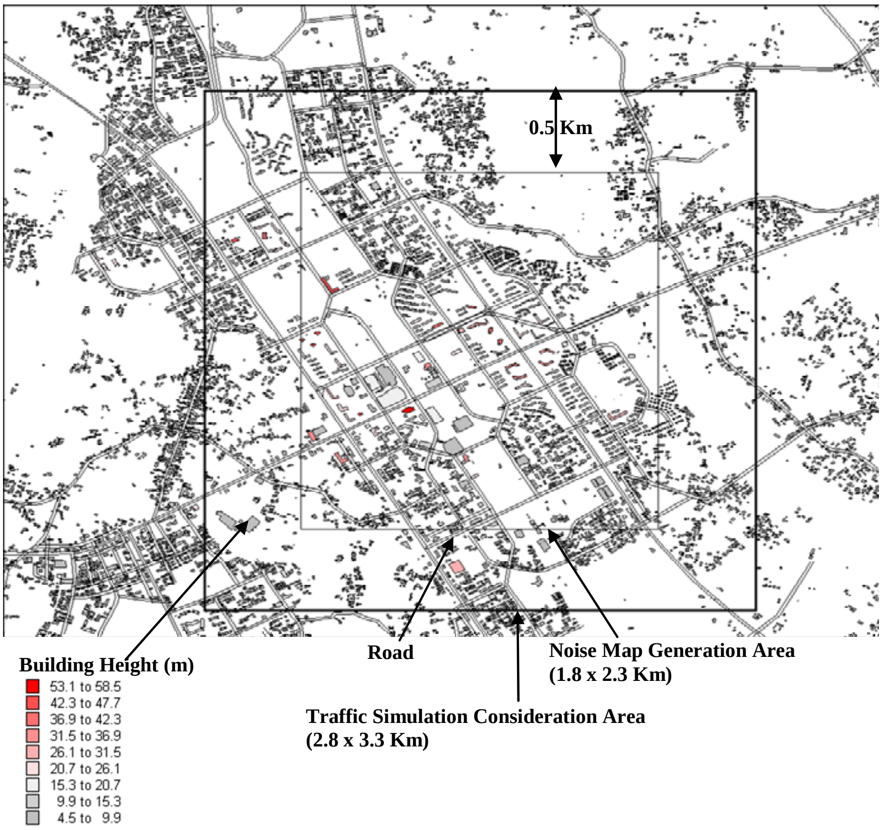

Fig. 3. Study area

To generate noise map for the above mentioned area, we consider a larger area for traffic simulation, which is 2.8 km by 3.3 km as shown in Figure 3. Noise for a receptor point is contributed by all the sources in the network. Farther the source from the receptor point, lesser is the noise contribution. It has been observed that sources beyond 300 m have very little contribution in the noise at the receptor point and beyond 500 m the contribution is negligible 2. For the present application we consider 500 m as a buffer distance for noise estimation at a receptor point i.e., all the sources within 500 m from the receptor point are considered for noise estimation. For estimating noise around boundary points of the study area, we need to consider sources beyond the study area; hence for traffic simulation we consider the area more than 500 m beyond the noise estimation area, which is 2.8 km by 3.3 km area as shown in Figure 3. The entire building infrastructure in the area is considered for noise simulation. Traffic simulation at the morning peak between 7 to 9 am was executed to estimate areawide traffic noise.

In the present application receptor points are spaced at 10 m grid, and the road network is divided into 10 m source sections.

Results

Figure 4 to Figure 6 represent the results of the application of DRONE in the above mentioned area. First, unit noise map database is generated for the area which contains the correction terms for each receptor point and source section. This is visualized by considering the unit flow on the network for each vehicle running category and corresponding unit noise map is presented in Figure 4. In the contour maps different colour represents different noise level. Blue, green, yellow and red represents the increasing intensity of the noise level.

For unit noise map, we assume unit flow (for each vehicle running category) on the whole network, irrespective of the road type. So, each section of the network has a source corresponding to each vehicle running category. This can be seen as intense noise level along the road network in Figure 4. However, during traffic simulation we only have very low flow on the residential roads and high flow on the major roads. The integration of which provides the noise map for the area.

In Figure 5 traffic simulation result is also visualized in terms of hourly flow on the network. The flow on the residential roads is negligible. The diagonal running highway has the major flow, of the order of 1000 vehicles per hour. Noise contour map (Figure 6) for the study area is finally obtained from the integration of the traffic simulation with unit noise database. The traffic simulation output indicates that the diagonal running highway has significant amount of flow, which is reflected in the noise map with more intense noise level along the same road. Similarly, residential roads have negligible flow and corresponding low noise levels in the noise contour map.

The unit noise database for the area is fixed and for further research it can be used for evaluating different transportation policies in computationally efficient manner.

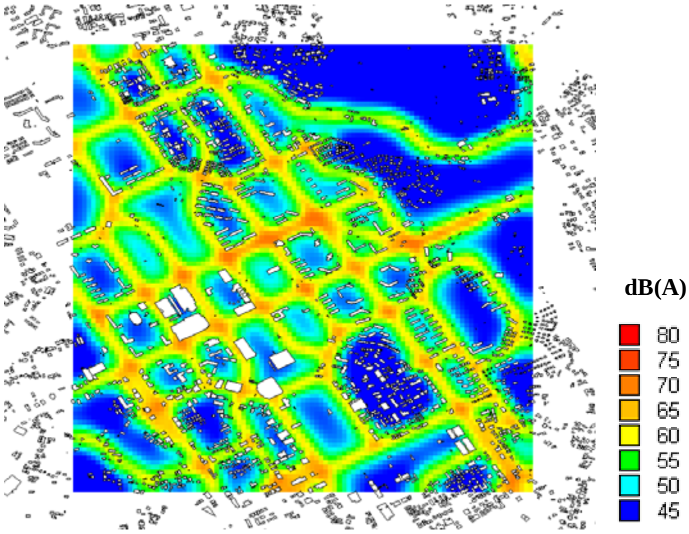

Fig. 4. Unit noise contour database

Fig. 5. Traffic simulation database

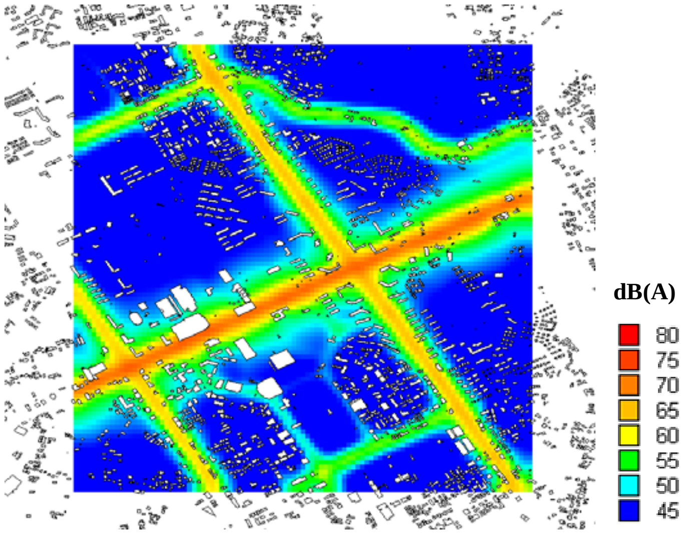

Fig. 6. Noise contour map

Conclusions

A software tool DRONE has been developed by the integration of the dynamic output from a traffic simulation model with the noise estimation model. It can estimate comprehensive areawide noise, considering network time dependent traffic flow and buildings forming built-up area. DRONE considers the state-of-the-art relationship between vehicle sound power level and running conditions along with detailed vehicle trajectory for estimating noise in urban environment.

The calculation performance of DRONE is improved by evaluating the noise in two steps. The two steps procedure is applied on Tsukuba city, Japan and unit noise database is created which can be used for testing different traffic management scenarios on the study area.

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