EFFECTS OF TRAFFIC DENSITY ON MEASURED SOUND LEVELS – A CASE STUDY

Ian Matthew, M.Sc., P.Eng. *, Anthony Amarra, M.Sc. †
Valcoustics Canada Ltd., 30 Wertheim Court, Unit 25, Richmond Hill, Ontario, L4B 1B9

1 Background

Consultants are frequently required to predict sound levels based on input data regarding road traffic. These assessments are used to design mitigation for new roadways or new noise-sensitive developments in the vicinity of existing roadways. It is typically assumed that the sound level is a function of (among other variables) the vehicular speed and the vehicle volume. As the volume of vehicles increases for a given speed, the sound level is assumed to increase.

2 Sound Level Relationships

2.1 Vehicle Volume and Sound Level

All models for transportation noise sources include a relationship between vehicle volume and predicted sound level. In Ontario, the mandated model is ORNAMENT[1] which uses the following equation :

$$L_{eq,i} = L_{0,i} + 10\log_{10} V - 10\log_{10} S + 10\log_{10} D_{ref} - 25 + other\ adjustments$$

Where $L_{eq,i}$ is the one-hour equivalent sound level for a specific vehicle type (automobiles, medium trucks, or heavy trucks), $L_{0,i}$ is the reference emission level for vehicle type i at a distance of 15 m, V is the hourly volume, S is the speed (in km/hr), and the "other adjustments" refers to terms accounting for distance, screening and angle of exposure, etc.

TNM (developed by the FHWA for use in the United States) uses the following relationship:

$$L_{eq,i} = 10\log_{10} E_{emis,i} + 10\log_{10} V - 10\log_{10} S - 13 + other\ adjustments$$

Where $E_{emis,i}$ is the reference emission energy of each vehicle type i.

In both cases, the dependence of sound level on volume is an adjustment equal to ten times the logarithm (base 10) of volume. The relationship is presented graphically in Figure 1.

2.2 Vehicle Speed and Sound Level

Similar to the above, models also assume/utilize a relationship between speed and predicted sound level. For both ORNAMENT and TNM, the vehicle speed factors into both the reference sound levels (which vary by vehicle type) as well as a direct speed adjustments shown in Equations (1) and (2). The relationships are presented graphically in Figure 2. In both cases, an arbitrary 1000 vehicles per hour has been used, split into 80% automobiles, 15% heavy trucks, and 5% medium trucks.

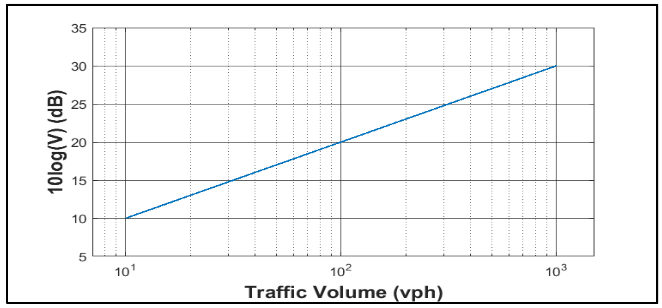

Figure 1: Relationship between Vehicle Volume and Sound Level

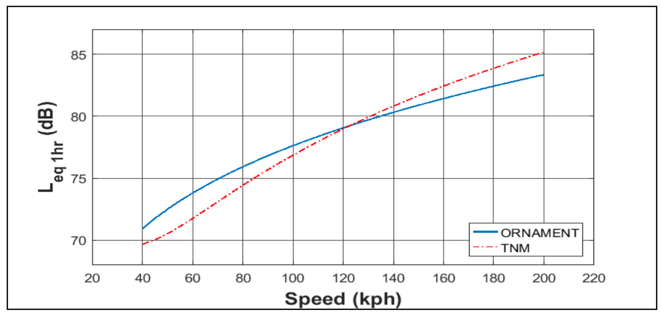

Figure 2: Relationship between Vehicle Speed and Sound Level

3 Case Study Measurements

3.1 Measurement Method

72-hour sound level measurements were done at 4 locations adjacent to the Don Valley Parkway in the City of Toronto. The measurement locations varied in setback distance relative to the highway as well as intervening topography. As the specific receptor sound level is not the focus of this study, the investigation will focus on one location which had a direct line of site to the highway (approximately 50 m from the roadway). The microphone was approximately 1.5m above grade. At the measurement location, the highway is divided with 3 lanes of traffic in each direction (northbound and southbound) and there are no access points in the vicinity of either set of lanes. Thus, flow should be essentially uninterrupted up to the critical vehicular density.

The sound level meters were set to measure 1 minute L_{eq} values for the full measurement duration. Road traffic counts were conducted concurrently with the sound level measurements.

It should be noted that the measurements were done during the spring season (prior to the end of the school year).

3.2 Results

Typically, sound levels resulting from road traffic on well travelled roadways follows a common pattern. See Figure 3. If it is assumed that the speed remains constant, then the measured sound level will increase with increasing vehicular volume. This results in two characteristic peaks – one during

* ian@valcoustics.com
† anthony@valcoustics.com

the morning rush, and one during the evening rush – followed by a significant decrease during the nighttime period.

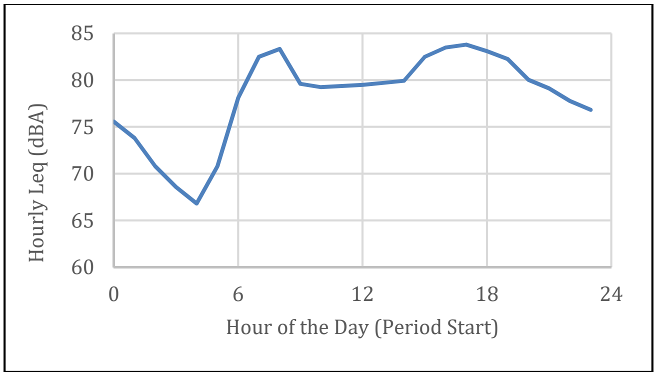

Figure 3: Typical Fluctuation of Sound Level vs Time of Day for a Well-Travelled Road

In this case study, there is a significant dip in measured sound level during the 0800 to 0900 hour (based on hourly Leq data). This dip was seen consistently in each of the three morning periods which were included in the measurements (see Figure 4). Road traffic volumes are also plotted in Figure 4.

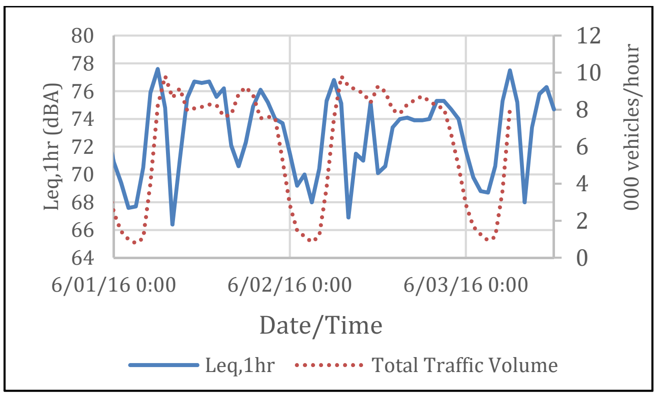

Figure 4: Measured Sound Level Time History

3.3 Discussion

It is clear from the measured data that although the sound level decreased significantly each day between 0800 and 0900 hours, a similar decrease in traffic volume was not observed. Thus, the decrease in measured sound level is not the result of a significant decrease in traffic flow. This is intuitive as the time period in question (0800 to 0900 hours) lies well within the typical AM Peak period ('rush hour').

Based on observations at the time of the measurements, the decrease in sound level was likely attributed to a significant decrease in vehicle speed resulting from an overall increase in vehicle density.

4 Relationship Between Vehicle Density, Flow, and Speed

The Traffic Engineering Handbook[2] provides the basic relationships between speed, density, and flow for uninterrupted traffic. Based on the traffic data presented above, specific interest is given to the relationship between flow (vehicles/hour) and speed (km/hour). See Figure 5.

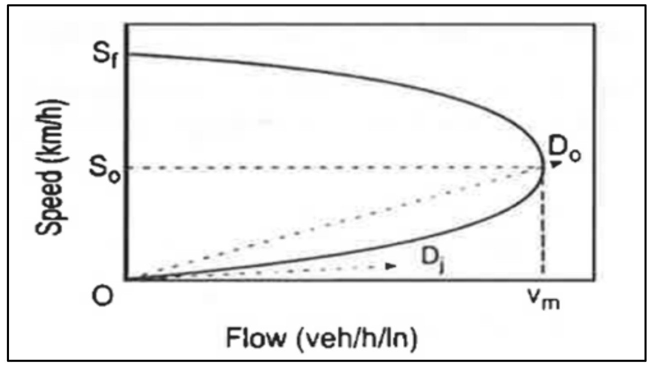

Figure 5: Conceptual Relationship Between Speed and Flow

For a roadway which operates in the vicinity of optimum density (D_0), large changes in speed can result in only small changes in flow rate (above or below speed S_0). This is consistent with the measured sound data which showed only small changes in flow (volume) but showed a remarkable decrease in measured sound level between 0800 and 0900 hours.

5 Effect on Sound Level for Increasing Vehicular Density

As noted above, the sharp decrease in measured sound level is not correlated to a significant change in traffic flow during the measurement period. Although the predicted sound level will decrease with the observed decrease in vehicle flow, the decrease in sound level far outpaces that of the volume decrease. Rather, it is related to a decrease in speed which results when the vehicular density exceeds the critical density for the roadway.

This decrease in speed produces a well understood decrease in emitted sound level for the vehicles on the source roadway.

6 Conclusions

It is clear from the above case study that the typical application of road traffic noise models (ie using static speed throughout the full time period) may not accurately predict hourly sound levels for a roadway which may exceed the critical density. Rather, when the density exceeds the critical density, a significant decrease in speed is possible without a corresponding decrease in flow (vehicles per hour). The speed reduction become the controlling variable in the sound emission level for the roadway and as such the emitted sound energy from the roadway decreases significantly.

References

[1] Ontario Ministry of the Environment. *Ontario Road Noise Analysis Method for Environment and Transportation (ORNAMENT)*, October 1989.

[2] J Pline. *Traffic Engineering Handbook*, 5th Ed., Institute of Traffic Engineers, 1999