Highway Traffic Noise

Judith L. Rochat

Postal:
6965 Abbottswood Drive
Rancho Palos Verdes,
California 90275
USA

Email:
jrochat@atsconsulting.com

Darlene Reiter

Postal:
504 Autumn Springs Court, #11
Franklin, Tennessee 37067
USA

Email:
dreiter@bowlbyassociates.com

Understanding highway traffic noise sources and how to abate them and addressing health concerns and environmental protection legislation and regulations.

Introduction

More than 45 million people live, work, or attend school within 300 feet of a major transportation facility in the United States alone (http://acousticstoday.org/roadway). These facilities include heavily traveled highways that can cause adverse noise effects. **Figure 1** shows a major highway with adjacent communities. Such geometries with communities in close proximity to highways are not unusual.

***Figure 1.** Aerial view of highway and surrounding community. Image from Google Earth.*

In addition to annoyance and speech interference, recent studies have reported on links between highway traffic noise and health effects. The World Health Organization (WHO) reported on environmental health effects, including heart disease, sleep disturbance, and cognitive impairment in children. WHO states, "… at least one million healthy life years are lost every year from traffic-related noise in the western part of Europe" (WHO, 2011). These human health issues as well as the effects of highway traffic noise on wildlife are a growing concern.

To help minimize the effects of highway traffic noise, researchers and practitioners must understand the noise sources, how the sound propagates to nearby communities, and how to reduce noise levels at the source, during propagation, or at the receiver. Further challenges lie in establishing and implementing highway traffic noise policies. **Figure 2** highlights the major elements of highway traffic noise.

Highway Traffic Noise Sources

Highway traffic noise is caused by tire-pavement interaction, aerodynamic sources (turbulent airflow around and partly through the vehicle), and the vehicle itself (the power-unit noise created by the engine, exhaust, or transmission). At highway speeds, tire-pavement interaction generally is the most dominant source (Sandberg and Ejsmont, 2002).

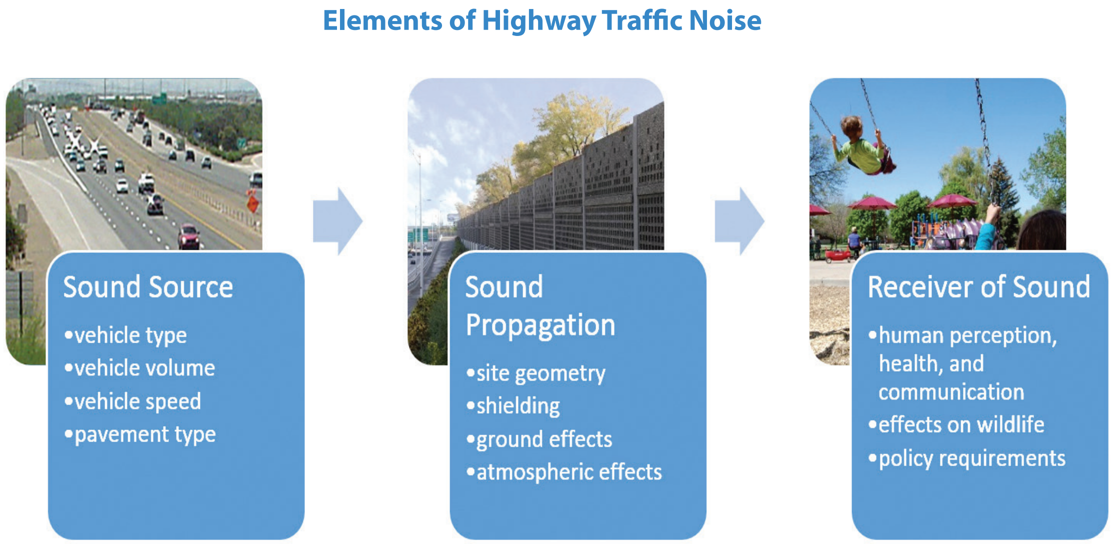


Figure 2. *Elements of highway traffic noise.*

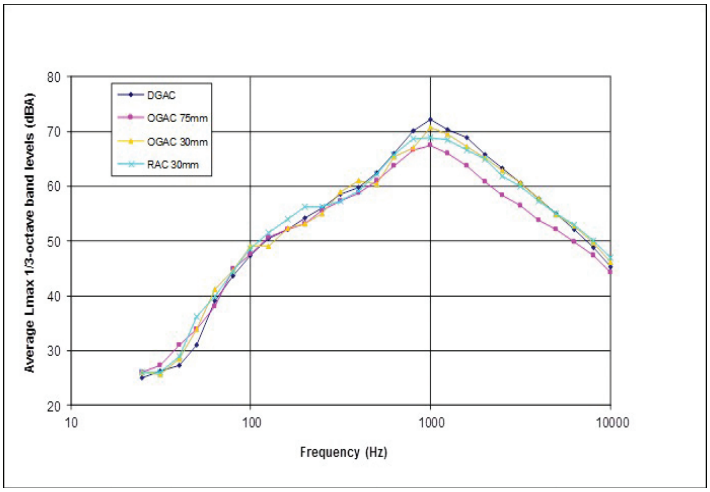
The interaction between tires and pavement is complex. The generated noise level is highly dependent on the road surface, the tire tread pattern, and construction. For the road surface, there are two broad categories of pavement: flexible (asphaltic concrete, aka "asphalt") and rigid (cement concrete, aka "concrete" or "PCC" for Portland cement concrete). Asphalt pavements vary by stone size (aka "aggregate size" or "chipping size") and porosity; smaller stone size and higher porosity produce quieter pavements. Concrete pavements can vary by surface texture; negative and shallow textures produce quieter pavements. **Figure 3** shows an example of a quieter pavement overlay (an asphalt rubberized friction course) on top of a loud pavement base (transversely tined concrete). Besides maintaining proper skid resistance for safety, one of the main challenges is maintaining acoustic durability for quieter pavements, particularly in areas with winter weather concerns. Also, the effectiveness of pavements in reducing noise is influenced by temperature: warmer is quieter. Many researchers and practitioners are working toward recommendations and policies that allow routine use of quieter pavements that are both safe and durable.

Figure 3. *Quieter pavement overlaying louder pavement, Arizona Quiet Pavement Pilot Program. From Donavan et al., 2012.*

Regarding tires, one of the main influential factors is the tread pattern. There are indicators that larger groove width, angled groove, addition of circumferential grooves to a transverse pattern, and tread randomization are tread pattern parameters that result in lower noise levels (Sandberg and Ejsmont, 2002).

The noise levels and spectral content of highway traffic noise are influenced by vehicle type, volume, and speed as well as pavement type. The spectral content for passenger vehicles typically peaks and is dominated by frequencies around 1,000 Hz. Spectral content for heavy trucks typically peaks and is dominated by frequencies from 500 to 1,000 Hz. Trucks are much louder than passenger cars: one truck can be as loud as 10 passenger cars combined! The percentage of heavy trucks in the traffic mix can have a strong effect on sound levels in adjacent communities. The benefit of quieter pavements can be less for heavy trucks than cars, one reason being that the lower frequency content for trucks (e.g., around 500 Hz) is not reduced as effectively as some of the other peak frequencies (e.g., around 1,000 Hz; Rochat and Read, 2009).

Figure 4 shows the spectral content for both cars and heavy trucks, where the most dominant frequencies can be seen. It also shows how the spectral content can change for different types of pavement and different thicknesses of pavement. Dense-graded asphalt (DGAC) is a standard asphalt pavement, and open-graded asphalt (OGAC) and rubberized asphalt (RAC) are quieter asphalt pavements. In **Figure 4**, it can be seen that sound energy at dominant frequencies of 630 Hz and above are effectively reduced by the quieter pavements.



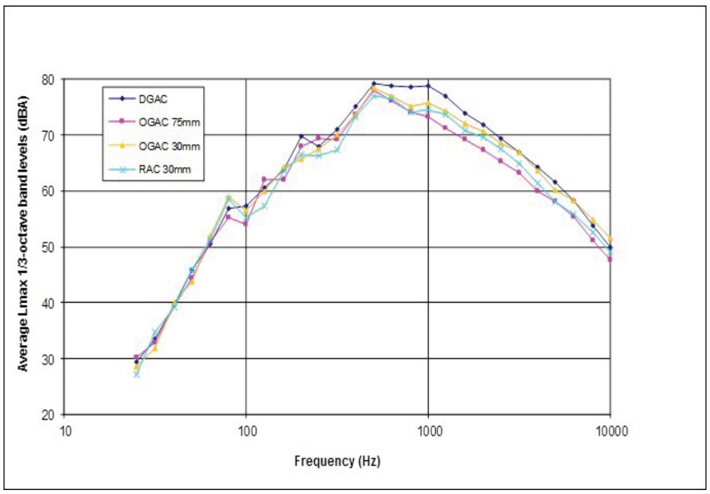


Figure 4. *Car (top) and heavy truck (bottom) one-third octave-band pass-by noise with various pavement types/thicknesses. DGAC, dense-graded asphalt; OGAC, open-graded asphalt; RAC, rubberized asphalt. Results are from Caltrans study (Rochat and Read, 2009).*

Highway Traffic Noise Propagation

As highway traffic noise propagates away from vehicles to nearby homes or other noise-sensitive receptors, the following phenomena affect the received sound levels: geometric divergence, ground effects, atmospheric effects, and shielding and/or scattering by natural and man-made features.

Although individual vehicles are treated as point sources with spherical divergence, highway traffic noise is treated as a line source with cylindrical divergence (multiple moving point sources along a line behave as a line source). So although the sound from individual vehicles passing by decreases at a rate of about 6 dB for each doubling of distance, highway traffic noise decreases at a lower rate of about 3 dB for each doubling of distance. Considering only the cylindrical divergence phenomenon, this means that a highway traffic noise level of 75 dBA at 50 feet will reduce to 72 dBA at 100 feet and 69 dBA at 200 feet, a typical setback for homes adjacent to a highway. Of course, other phenomena will also influence the received sound level. (Highway traffic noise metrics are discussed in **Highway Traffic Noise Metrics and Measurements**.)

The ground between vehicles on a highway and noise-sensitive land uses can have a measurable and often significant influence on received noise. **Figure 5** shows both the direct

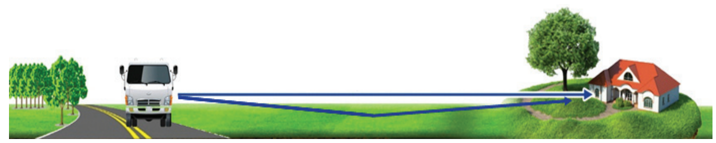


Figure 5. *Highway traffic noise propagation – direct and ground-reflected sound. Illustration modified from Highway Traffic Noise, National Highway Institute (NHI) course 142051.*

and reflected paths as sound propagates away from a vehicle. Sound from both paths can reach the receiver. Grass, loose dirt, and other acoustically soft surfaces can absorb some of the sound as it interacts with the ground, particularly for the shallow angles associated with typical highway/adjacent community geometries. Early highway noise practice applied an additional 1.5 dB reduction per doubling of distance for predictions (beyond cylindrical divergence), but current practice applies greater ground influence with more refined levels based on specific ground types and more sophisticated calculations. Although not considered "soft," ground surfaces such as porous pavement can reduce highway traffic noise at some dominant frequencies. Dense pavements, water, and other acoustically hard surfaces more effectively reflect the sound, which then contributes more to the received sound levels compared with soft surfaces. When measuring and predicting highway traffic noise, all ground surfaces between the source and receiver need to be considered, including the highway traffic lanes and shoulders. In addition, seasonal changes might be considered. For example, powdered snow can be very absorptive and water-saturated grass can be very reflective.

Atmospheric parameters that can affect highway traffic noise propagation include air absorption, humidity, and refraction. As with ground effects, the atmospheric effects need to be considered for both noise predictions and measurements. Air absorption mostly affects frequencies above 2,000 Hz, with a greater effect over longer distances. Humidity affects propagated noise levels but typically to a small degree. Refraction, on the other hand, can exert a strong influence on received highway traffic noise levels. Refraction can be caused by wind shear, which is the change in wind speed with increased height above ground as well as by temperature lapse rate, which is the change in temperature with increased height. A neutral atmosphere with no refraction occurs on a calm cloudy day. For wind shear under upwind conditions (the receiver is upwind from highway), sound levels are quieter near the ground than under neutral conditions. Under downwind conditions, sound levels are louder near the ground. For temperature lapse rate, upward refraction occurs on sunny, calm days, when it is warmer near the ground. Under these conditions, it is quieter near the ground than on a cloudy day. Downward refraction occurs on calm cool nights after sunny days when the ground cools off faster than the air above, and under these conditions, sound is louder near the ground (National Highway Institute [NHI], 2016). Illustrations of the phenomena can be found in **Figure 6**. Research has shown refraction effects to be quite substantial. One example study showed that levels vary generally less than ±5 dB within about 200 ft from a highway and as much at ±10 dB at 1,000 ft. The highest sound levels were measured under temperature inversion conditions at sunrise (Saurenman et al., 2005).

Shielding can have a strong effect on received sound levels and is another phenomenon that needs to be considered for both highway traffic noise measurements and predictions.

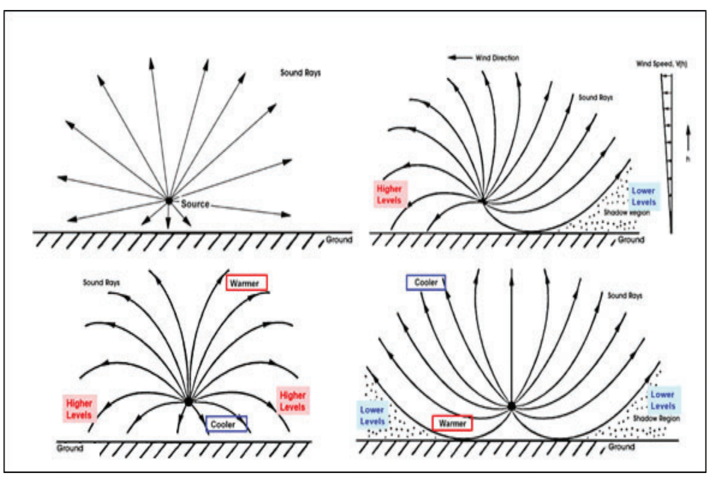


Figure 6. *Various atmospheric conditions and their effect on highway traffic noise.Top left: neutral; top right: upwind (right side) and downwind (left side) conditions; bottom: two temperature profiles - temperature inversion, warmer in air (left) and temperature lapse, warmer at ground (right). Illustration modified from Highway Traffic Noise, NHI course 142051.*

Highway traffic noise propagation is affected by natural or man-made features or objects that fully or partially block the sound path, leading to reduced sound levels. Features that shield sound include natural terrain, densely wooded areas, large buildings, rows of houses, the top edge of a depressed roadway, the edge of a roadway embankment, safety barriers, retaining walls, and noise barriers or berms. There are several paths sound can take when encountering a barrier where each one can affect the received sound level: (1) reflected from the barrier back across the highway (reduces noise behind the barrier but can increase noise on the opposite side of the highway, particularly when an absorptive surface on the barrier is not applied); (2) diffracted over the top of the barrier (reduces noise compared with the direct path, but some of the sound can bend over the top of the barrier, particularly lower frequencies); or (3) transmitted through a barrier (most noise barriers used for noise control provide at least a 30 dB transmission loss, so transmitted sound should not be an issue). Typical highway studies do not consider the scattering of sound; however, scattering can occur from site features such as rough ground surfaces and tree leaves, generally affecting higher frequencies.

Highway Traffic Noise Metrics and Measurements

There are some generally accepted practices for quantifying highway traffic noise. In the United States, for quantifying highway traffic noise in communities, the A-weighted equivalent sound level (L_{AeqT} or LAEQ), the day-night average sound level (L_{dn} or DNL), the community noise equivalent level (L_{den} or CNEL), and the percent exceeded sound level (L_x, e.g., L_{10} for 10%) are commonly applied. For each highway project, the appropriate metrics for measurements and predictions are determined based on local and state noise policies, where the latter are based on federal regulations.

The equivalent sound level represents an average of the sound energy over a specified period of time. For highway projects receiving US federal aid, the worst noise hour (L_{Aeq1h}) is examined to determine potential adverse impacts on nearby communities. Note that the Federal Transit Administration (FTA) also applies L_{Aeq1h} for institutional land uses, which is relevant in cases of multimodal projects (projects that include multiple modes of transportation; Hanson et al., 2006). Another acceptable metric for federal-aid highway projects is when the sound level exceeds 10% of the time for the worst noise hour (L_{10}).

Figure 7. Left: onboard sound intensity (OBSI) measurements. From Pavement Effects Implementation Study (Rochat et al., 2012). Right: wayside noise measurements. Continuous-flow traffic time-integrated measurements from Arizona Quiet Pavement Pilot Program. Available at http://acousticstoday.org/jrochat/.

The L_{dn} and L_{den} metrics are also averages of sound energy, where the period of time is 24 h. For the day-night sound level, there is a +10 dB nighttime sensitivity penalty applied between the hours of 10 p.m. and 7 a.m. For the L_{den} metric, the same nighttime penalty is applied and an additional penalty of +5 dB is applied to evening hours (7–10 p.m.). Some agencies require the use of these metrics, including the FTA for residential land uses (A-weighted L_{dn}) and the Department of Housing and Urban Development (HUD; also A-weighted L_{dn}). California laws require the use of A-weighted L_{den}.

There are several applicable measurement standards and guidance documents for conducting highway traffic noise and related measurements. The guidance documents include:

- *Measurement of Highway-Related Noise.* Report No. FHWA-PD-046, 1996, Federal Highway Administration (FHWA) and Volpe National Transportation Systems Center, US Department of Transportation (DOT); available at http://acousticstoday.org/measure.
- *Methods for Determining the Insertion Loss of Outdoor Noise Barriers*. S12.8, 2013, American National Standards Institute, Acoustical Society of America; available at http://acousticstoday.org/noise.
- *Method for Determining the Acoustic Impedance of Ground Surfaces*. S1.18, 2010, American National Standards Institute, Acoustical Society of America; available at http://acousticstoday.org/impedance.
- *Methods* for determining the effects of pavements include
  - Onboard sound intensity (OBSI), American Association of State Highway and Transportation Officials (AASHTO) T 360; available at http://acousticstoday.org/highway.
  - Statistical isolated pass-by (SIP), AASHTO TP 98; available at http://acousticstoday.org/pass.
  - Continuous-flow traffic time-integrated (CTIM) method, AASHTO TP 99; available at http://acousticstoday.org/traffic.
  - Statistical pass-by (SPB) method, International Organization for Standardization (ISO) 11819-1; available at http://acousticstoday.org/passby.
  - Close proximity (CPX) method, ISO 11819-2; available at http://acousticstoday.org/proximity.

Examples of highway noise measurements are shown in **Figure 7**.

For typical highway projects, measurement methods found in the FHWA's *Measurement of Highway-Related Noise* are applied. This FHWA guidance document contains methods for determining existing noise levels (e.g., for prediction model validation purposes or evaluating the need for a noise barrier), determining barrier insertion loss (e.g., for purposes of determining the effectiveness of a noise barrier), and collecting vehicle noise emission levels (e.g., for inclusion in highway traffic noise prediction models) among other things. This document is currently being updated and will include pavement-related measurement methods as well as a new section providing practitioners with a clear path to applying project-appropriate measurement methodologies.

Regulatory Process

Highway traffic noise regulations vary by country. In the United States, the FHWA Noise Regulation contained in 23 Part Code of Federal Regulations (CFR) 772 (available at http://acousticstoday.org/regs) applies. This regulation requires that state highway agencies (SHAs) conduct noise studies for "Type I" projects during the environmental process. Type I projects generally involve increasing roadway capacity that includes roadway widening or new alignment. The noise studies must identify noise-sensitive land uses that will be impacted by the project and evaluate noise abatement for those impacted uses. Noise studies are also executed for "Type II" projects that involve constructing retrofit noise barriers for existing development with no change to the adjacent highway.

The FHWA Noise Regulation contains noise abatement criteria (NAC) for various land use activity categories. Noise impacts occur when predicted sound levels associated with the project in the design year approach or exceed the NAC for a particular land use category or if the project causes a substantial increase in existing sound levels. The NAC are in terms of the hourly A-weighted equivalent sound levels,

L_{Aeq1h} as well as L_{10}. The NAC for residential uses is an L_{Aeq1h} of 67 dBA or an L_{10} (hours) of 70 dBA. These levels are based on speech interference effects in areas of frequent outdoor human use.

SHAs must develop their highway traffic noise policies in accordance with the FHWA Noise Regulation. SHAs must establish a level to be used when determining a traffic noise impact. That level must be at least 1 dB less than the NAC to meet the “approach or exceed” requirement. Most SHAs define approach as 1 dB (i.e., the limit would be 67 − 1 = 66 dBA for L_{Aeq1h}). SHAs must also define what constitutes a “substantial increase” over existing noise, something that is particularly important for areas with no existing highway. The FHWA Noise Regulation permits values between 5 and 15 dB. The most commonly used value for substantial increase is 10 dB.

Typical highway studies examine noise to distances adequate to identify all impacted noise-sensitive land uses. This distance can vary significantly from project to project. Some SHAs evaluate to 500 ft, which incorporates the first few rows of homes or other uses, and some distance beyond.

At a minimum, SHAs must evaluate noise barriers for impacted land uses. The SHA may also consider the alternative abatement measures listed in the FHWA Noise Regulation that are discussed in **Reducing Highway Traffic Noise**.

The FHWA requires that noise abatement measures that meet both the feasibility and reasonableness criteria in a SHA’s noise policy be incorporated into the project plans. Feasibility means that (1) the construction of an abatement measure would not be anticipated to pose any major design, construction, maintenance, or safety problems and (2) the measure will provide a minimum noise reduction of 5 dB for the majority of the impacted first-row receptors (properties in the row closest to the project roadway).

The determination of reasonableness for an abatement measure is a three-step process. (1) The noise reduction design goal in the SHA’s noise policy must be achieved, (2) the abatement measure must be cost effective per the SHA’s noise policy, and (3) the benefited residents and/or property owners must support the measure.

SHAs have flexibility in determining the noise reduction design goal and the cost-effective criteria as well as establishing procedures for gauging the support of the benefited residents and property owners.

Highway traffic noise can also be an important source for multimodal projects that involve both transit and highway components. The FHWA has stated that the FHWA Noise Regulation applies to multimodal projects even though the term "multimodal" is not defined in the regulation. A proposed transit project that would share an existing highway right-of-way is not necessarily a multimodal project. The FHWA has established a procedure for determining if the project is multimodal in accordance with the regulation that considers the lead agency, project purpose, and funding source (available at http://acousticstoday.org/multimodal).

Highway traffic noise can also be an important source to consider when conducting noise studies for development projects that use funding from the HUD. Federal Regulation 24 CFR Part 51 Subpart B (HUD Noise Regulations) and the *HUD Noise Guidebook* outline the noise study process for such projects (HUD, 2009).

Predicting Highway Traffic Noise

Noise studies for federal projects conducted in accordance with the FHWA Noise Regulation must use the current version of the FHWA Traffic Noise Model (FHWA TNM) computer program (Anderson et al., 1998; Menge et al., 1998). The program calculates worst hour equivalent sound levels for locations representing noise-sensitive land uses in a project area. The FHWA TNM contains the following components:

- Modeling five standard vehicle types, including automobiles, medium trucks, heavy trucks, buses, and motorcycles as well as user-defined vehicles
- Modeling both constant-flow and interrupted-flow traffic using a 1994/1995 field-measured database (database includes over 6,000 isolated vehicle pass-by events!)
- Modeling the effects of different pavement types as well as the effects of graded roadways
- Sound-level computations based on a one-third octave-band database and algorithms
- Graphically interactive noise barrier design and optimization
- Attenuation over/through the rows of buildings and dense vegetation
- Multiple diffraction analysis
- Parallel barrier analysis
- Contour analysis, including sound level contours, barrier insertion loss contours, and sound level difference contours

Figure 8 shows a screen capture for a TNM project. The image shows a plan view with a skew view (cross section) and table of sound level results overlaying the plan view.

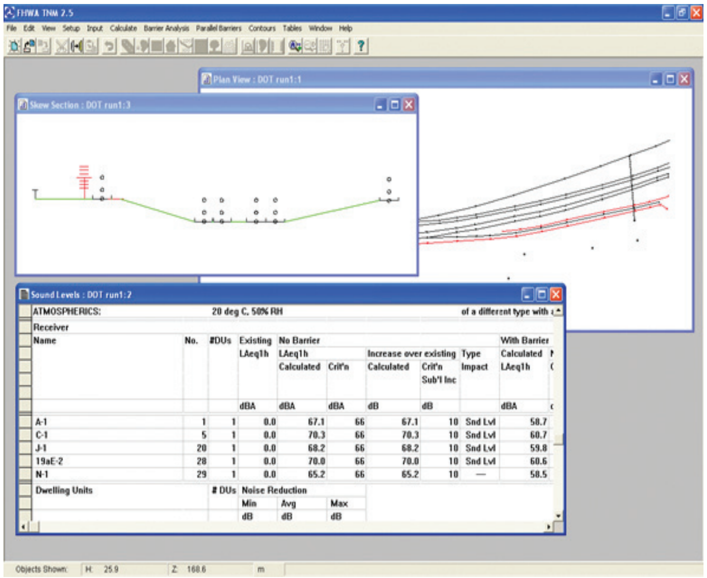


Figure 8. *Examples of Federal Highway Administration Traffic Noise Model (FHWA TNM) views and tables. Top left: skew or cross-sectional view; top right: plan view; bottom: sound level results table.*

Some of the data needed to develop the FHWA TNM models includes project plans, contour/elevation data, development/land use information, traffic data (volumes, vehicle classifications, and speeds), and pavement type. Once the data are collected, an analyst uses seven different TNM objects to aid in developing accurate models: roadways, receivers, barriers, building rows, terrain lines, ground zones, and tree zones. The FHWA TNM includes roadway profile, perspective, and skew (cross-section) views that can be used to check data input and ensure accurate modeling as well as dynamic linking between input tables and graphical views. The quality of the model's output is highly dependent on expertise of the analyst, including his/her knowledge of acoustics and TNM best practices.

The FHWA TNM was validated for accuracy with over 100 h of data collected at 17 highway sites across the United States (Rochat and Fleming, 2002). Comparing measured and predicted data for sites with and without noise barriers, it was concluded that the model performs very well within 500 ft of the highway. It was also demonstrated that considering meteorological, pavement, and ground effects is important to produce good results.

Several other prediction models/software packages are available for predicting highway traffic noise. These include NORD2000, SoundPLAN, and CadnaA, which have more widespread international use. Note that only the FHWA TNM is approved for US federal aid projects.

Reducing Highway Traffic Noise

As previously mentioned, there are several methods for reducing highway traffic noise levels. The most commonly applied abatement measure is a noise barrier. These walls are constructed alongside a highway, blocking the line of sight between vehicles and people in the community. Blocking the line of sight typically reduces the sound by 5 dB, and this is fairly easy to achieve. Achieving a 10 dB reduction is possible; however, reducing the noise by this amount requires removing 90% of the sound energy (which sounds about half as loud), as shown in **Table 1**. This is a challenge and generally requires taller and more expensive noise barriers. A recent survey of US states showed that the average reduction achieved by noise barriers is about 7 dB, the average height is 14 ft, and the average cost per linear mile is about $2.5 million (available at http://www.fhwa.dot.gov/environment/noise/noise_barriers/inventory/). The high cost of noise barriers is one reason accurate modeling and predictions are so important. Another is to make sure targeted reductions in noise are achieved (you want to get what you pay for!).

Table 1. Ease of obtaining noise barrier reduction

Insertion Loss, dB	Degree of Difficulty	Reduction in Sound Energy, %	Relative Reduction in Loudness
5	Simple	68	Readily perceptible
10	Attainable	90	Half as loud
15	Very difficult	97	One-third as loud
20	Nearly impossible	99	One-fourth as loud

In general, increasing insertion loss requires increasing barrier height. From Highway Traffic Noise, NHI course 142051

There are many variations in noise wall material and construction, where considerations are made for the available space, community acceptance, and durability among other items (Knauer et al., 2000). In some cases, noise walls are not feasible or effective. Other considerations include parallel barrier degradation and absorptive surfaces.

Noise barriers are sometimes constructed on opposite sides of a highway to protect communities on both sides. Noise reflections between these parallel barriers, however, can degrade their effectiveness. The reflection effects are a function of the width (distance between barriers) to height (of the barriers) along with geometric relationships between the road, barrier, and receivers. A general rule-of-thumb is to keep the ratio greater than 20:1 to minimize degradation. However, the geometric relationships including the receivers add complexity that warrants site-specific evaluation. It is important to consider adding absorptive material to a barrier surface. Not only does this help reduce parallel barrier degradation, but it can also help in situations where communities are being exposed to single barrier reflections.

SHAs must evaluate noise barriers for impacted land uses. Communities with residences, schools, and parks that meet the criteria for noise abatement are eligible to receive some form of noise control as part of the project. In the United States, the criteria for noise abatement are state specific and follow federal regulations. In addition to noise walls, following federal regulations, SHAs may also consider these other noise-reducing measures:

- Traffic management measures. These include factors such as modified speed limits and vehicle restrictions. These typically do not provide the required noise reductions for the measures to be both feasible and reasonable.
- Alteration of horizontal and vertical alignments. These measures are generally not possible for widening projects, although such shifts could provide the needed noise reductions for projects on new alignments.
- Acquisition of property to serve as a buffer zone. Although SHAs are allowed to acquire property to serve as a buffer, they typically do not do this.
- Noise insulation for land uses such as places of worship and schools. Sound insulation could include air conditioning and new windows and doors. SHAs in some states do not have the authority to insulate buildings, so insulation cannot always be included as part of a highway project.

Although not permitted under federal regulations for use as traffic noise abatement for projects receiving federal aid, quieter pavements can effectively reduce noise. For cases where noise barriers do not meet all the necessary requirements to be built and/or where there are elevated hillside receivers, quieter pavements can provide some reduction in noise. In addition to reducing tire-pavement noise, some pavements can also absorb sound, thereby reducing propagated noise. To maintain their noise-reducing capabilities, quieter pavements require periodic examination to determine the potential need to repave, redo the surface treatment, or clean.

Current Challenges

There are many challenges associated with evaluating highway traffic noise. Some of these are discussed briefly below.

Changing Noise Sources

As noise sources change over time, so must noise predictions. The FHWA TNM currently incorporates a comprehensive vehicle noise emission database collected in the early to mid-1990s. As vehicles get quieter, tires evolve, and there is more understanding of pavement effects, this presents a challenge in updating the TNM database. Obtaining new data is both cost and time intensive, and it is currently being discussed by the Transportation Research Board (TRB) Transportation-Related Noise and Vibration Committee, the FHWA, and state agencies as to how and when this can be accomplished.

Quieter Pavements

From the 1990s to the present, many research studies have focused on the effects of various pavement types on vehicle and traffic noise. Several US states have shifted away from the use of louder pavements (e.g., transversely tined concrete) and/or toward the use of quieter pavements (e.g., open-graded or porous asphalt) as common pavement construction and maintenance practice, based on current findings and understanding. Future research would need to focus on acoustic durability of pavements in order for quieter pavements to be used as a noise abatement measure.

Quieter Rumble Strips

Rumble strips are placed along roadways for safety reasons to warn drivers about unintended lane departure, thus preventing accidents. Unfortunately, due to poor placement and/or traditionally loud designs, numerous accidental rumble strip incursions adversely affect nearby communities. There are only a few high-quality targeted studies that quantify noise emanating from rumble strip incursions. Although some have focused on quieter rumble strip designs, the challenge remains in verification and widespread application of these designs.

Noise-Compatible Land Use Planning

The FHWA advocates that local governments use their regulatory authority to prohibit incompatible development adjacent to highways or require planning, design, and construction of developments that minimize highway traffic noise impacts (FHWA, 2011). Unfortunately, the development of noise-sensitive land uses adjacent to existing heavily traveled roadways continues to be a pervasive problem. SHAs cannot use federal funds to construct noise abatement measures for these new uses, unless changes to the roadway trigger a Type I project that would include a noise impact analysis and noise barrier consideration.

Alternative Project Delivery Methods

Project delivery methods such as design build have become more common and can create additional issues for projects that involve noise abatement measures. Commitments made for noise abatement during the environmental process may be based on preliminary project plans. These plans could change significantly during the project development process, and updated abatement designs may need to be considered.

Effects on Health and Wildlife

Another hot topic identified by the TRB Transportation-Related Noise and Vibration Committee is highway traffic noise-related health effects. Although recognized by the WHO and many European researchers, the United States has done little to verify or build on understanding the adverse health effects related to highway traffic noise. Understanding this would help to inform highway traffic noise decisions and abatement design. A related concern, the adverse effects of highway traffic noise on wildlife, also merits further investigation. There are serious concerns about noise interfering with wildlife communication, migration, and reproduction. Many highway projects travel through wildlife areas, and most practitioners do not have the adequate tools to evaluate related impacts and abatement.

Biosketches

Judy Rochat is a principal consultant at ATS Consulting, Inc., Pasadena, CA, after working as a physical scientist for the US Department of Transportation. She has extensive experience in transportation noise and vibration, including highway-, rail-, and aircraft-related projects. Her experience includes software development, environmental impact assessments, data collection and analysis, mitigation design, and standards development. In addition, she is a certified instructor for the National Highway Institute course "Highway Traffic Noise." Judy held/holds leadership roles on the Transportation Research Board and at the Institute of Noise Control Engineering. She received her PhD and MS in acoustics at The Pennsylvania State University, University Park.

Darlene Reiter is vice president of engineering at Bowlby & Associates, Inc., Franklin, TN, where she has worked for nearly 23 years. She has extensive experience in transportation noise analyses including modeling, abatement design, training, policy development, and research. She has managed large-scale highway traffic noise studies for numerous state highway agencies. She is a certified instructor of the National Highway Institute course "Highway Traffic Noise" and coinstructor of Bowlby & Associates "Traffic Noise Model" and "Traffic Noise Fundamentals" training courses. Darlene received her PhD in civil engineering from Vanderbilt University, Nashville, TN, and her BS and MS in civil engineering from Villanova University, Villanova, PA.

References

Anderson, G. S., Lee, C. S.Y., Fleming, G. G., and Menge, C. W. (1998). *FHWA Traffic Noise Model, Version 1.0 User's Guide*. Report No. FHWA-PD-96-009. 2004 updates for Version 2.5, prepared by the Volpe National Transportation Systems Center, US Department of Transportation, for the Federal Highway Administration, Washington, DC. Available at http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/. Accessed September 1, 2016.

Department of Housing and Urban Development (HUD). (2009). *HUD Noise Guidebook*. Prepared by Environmental Planning Division, Office of Environment and Energy, Department of Housing and Urban Development, Washington, DC. Available at https://www.hudexchange.info/resource/313/hud-noise-guidebook/. Accessed September 1, 2016.

Donavan, P., Reyff, J., and Pommerenck, A. (2012). *Quiet Pavement Pilot Program: Progress Report 3*. Report No. 577, prepared by Illingworth & Rodkin, Inc., Petaluma, CA, for the Arizona Department of Transportation, Phoenix, AZ. Available at http://acousticstoday.org/ntl. Accessed September 5, 2016.

Federal Highway Administration (FHWA) (2011). *Highway Traffic Noise: Analysis and Abatement Guidance*. Report No. FHWA-HEP-10-025, Federal Highway Administration, US Department of Transportation, Washington, DC. Available at http://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/analysis_and_abatement_guidance/. Accessed September 1, 2016.

Hanson, C. E., Towers, D. A., and Meister, L. D. (2006). *Transit Noise and Vibration Impact Assessment*. Report No. FTA-VA-90-1003-06, prepared by Harris Miller Miller & Hanson, Inc., Burlington, MA, for the Federal Transit Administration, Washington, DC. Available at http://acousticstoday.org/manual. Accessed September 1, 2016.

Knauer, H. S., Pedersen, S., Lee, C. S. Y., and Fleming, G. G. (2000). *FHWA Highway Noise Barrier Design Handbook*. Report No. FHWA-EP-00-005, prepared by Environmental Acoustics, Inc., Catseye Services, and Volpe National Transportation Systems Center, US Department of Transportation, for the Federal Highway Administration, Washington, DC. Available at http://acousticstoday.org/design. Accessed September 1, 2016.

Menge, C. W., Rossano, C. F., Anderson, G. S., and Bajdek, C. J. (1998). *FHWA Traffic Noise Model, Version 1.0 Technical Manual.* Report No. FHWA-PD-96-010. 2004 updates available for Version 2.5, prepared by Volpe National Transportation Systems Center, US Department of Transportation, for the Federal Highway Administration, Washington, DC. Available at http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/. Accessed September 1, 2016.

National Highway Institute (NHI). (2016). *Highway Traffic Noise*. Material from course 142051, National Highway Institute, Arlington, VA.

Rochat, J. L., and Fleming, G. G. (2002). *Validation of FHWA's Traffic Noise Model (TNM): Phase 1.* Report No. FHWA-EP-02-031. 2004 updates available for Version 2.5, prepared by Volpe National Transportation Systems Center, US Department of Transportation, for the Federal Highway Administration, Washington, DC. Available at http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/model_validation/. Accessed September 1, 2016.

Rochat, J. L., and Read, D. R. (2009). Noise benefits of asphalt pavements – Trends at ages up to 52 months. *Noise Control Engineering Journal* 57, 104-111. doi: http://dx.doi.org/10.3397/1.3081315.

Rochat, J. L., Hastings, A. L., Read, D. R., and Lau, M. (2012). *FHWA Traffic Noise Model (TNM) – Pavement Effects Implementation Study.* Report No. DOT-VNTSC-FHWA-12-01, prepared by Volpe National Transportation Systems Center, US Department of Transportation, for the Federal Highway Administration, Washington, DC. Available at http://acousticstoday.org/peistudy. Accessed September 5, 2016.

Sandberg, U., and Ejsmont, J. A. (2002). *Tyre/Road Noise Reference Book.* INFORMEX, Kisa, Sweden.

Saurenman, H., Chambers, J., Sutherland, L. C., Bronsdon, R. L., and Forschner, H. (2005). *Atmospheric Effects Associated with Highway Noise Propagation.* Report No. 555, prepared for the Arizona Department of Transportation, Phoenix, AZ.

World Health Organization (WHO). (2011). *Burden of Disease from Environmental Noise – Quantification of Healthy Life Years Lost in Europe.* WHO Regional Office for Europe, Copenhagen, Denmark.

NEWS *from the* Acoustical Society Foundation Fund

ASA Standards Enjoys Support from the Acoustical Society Foundation Through the Robert W. Young Award

The Acoustical Society Foundation provides support to the Acoustical Society of America (ASA) Standards program through the Robert W. Young Travel Award. The objective of this award is to provide financial support to individual experts to participate in international standards meetings. The award was established in honor of the late Robert W. Young, an active participant in standards for many years.

International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO) meetings are typically held in international locations, which may represent a financial burden for some US experts. ASA Standards is an American National Standards Institute (ANSI)-accredited Standards Development Organization and is responsible for developing the US position on all IEC and ISO standards related to acoustics. Therefore, it is critical to have expert representation of the US position at these meetings.

Previous recipients include experienced retired and semiretired standards experts, self-employed individuals, educators, and employees of small firms. Bob Hellweg of Hellweg Acoustics and Vice Chair of the ASA Committee on Standards (ASACOS) was a recent Robert W. Young Award recipient. The stipend enabled him to travel to Milan, Italy, to participate in the meetings of ISO/TC 43 Acoustics and ISO/TC 43/SC 1 Noise.

ASA Standards Manager Neil Stremmel was asked about the recipients: "Given their breadth of knowledge and experience, these experts are an asset to ASA as well as the US and international technical committees they support."

ASA Standards travel awards supported by the ASA Foundation are currently available for international standards meetings in 2017. Details can be found at http://acousticalsociety.org/content/rw-young-travel-award.

A schedule of international standards meetings is available on the ASA Standards site at http://acousticalsociety.org/standards/meetings.

Carl Rosenberg
Chair, Acoustical Society Foundation Board
crosenberg@acentech.com

Mission of the Acoustical Society Foundation Board:
To support the mission of the ASA by developing financial resources for strategic initiatives and special purposes.

ASFF *For more information, contact: Carl Rosenberg at crosenberg@acentech.com*