Chapter 11

Noise Impacts of Transportation Systems

Kumares Sinha and Samuel Labi
Real Experiences of Transportation Noise

- Highway noise experienced in nearby apartment
  http://www.youtube.com/watch?v=TLiHQtAkUYI

- Sound of a freight train at night passing through a city
  http://www.youtube.com/watch?v=qYCdS8CUVEQ

- Sound in residential areas near airports
  http://www.youtube.com/watch?v=-HfBRPZHAel&mode=related&search=sydney%20airport%20planes%20aeroplanes%20flight%20motion%20sky%20outside%20fast%20engines%20loud%20noise%20air%20pollution
  http://www.youtube.com/watch?v=SwZL9NaFGi0
Topics of this conversation

- Introduction and Fundamental Concepts
- Sources of Transportation Noise
- Factors Affecting Transportation Noise Propagation
- Framework for Noise Impact Estimation
- Application of the Framework (Equations & Software Package)
- Mitigation and Legislation
Introduction

- Definition of Noise: unwanted or excessive sound
- Noise: a widely-experienced environmental impact of transportation systems.
- Effects of excessive transportation noise
  - adversely affects real-estate value
  - causes general nuisance and health problems.
- Tendency for agencies to overlook/underestimate noise pollution problem because:
  - noise generated at a particular time is not affected by previous activity nor does it affect future activities
  - noise leaves no residual effects that are evidential of its unpleasantness.
Fundamental Concepts of Sound
Fundamental Concepts of Sound

- All sound (such as traffic noise) is evaluated by the human ear on the basis of four major criteria:
  - Loudness
  - Frequency
  - Duration
  - Subjectivity.
Loudness of Sound

- Loudness also called “intensity”

- Mechanism of sound transmission:
  - Noise is emitted
  - Results in pressure fluctuations in the air
  - Pressure fluctuations cause contracting of the ear drum and generate the sensation of sound to the receiver

- Hearing extremes:
  - Lowest pressure fluctuation that your ear can sense: $2 \times 10^{-5}$ N/m²
  - Highest: 63 N/m² (causes hearing pain in your ear!)

- Measuring Loudness: What units?
  - Sound pressure (N/mm² or psi)
  - Sound pressure levels (or decibels)
# Loudness of Sound

<table>
<thead>
<tr>
<th>COMMON OUTDOOR NOISES</th>
<th>Sound Pressure (µ Pa)</th>
<th>Sound Pressure Level (dB)</th>
<th>COMMON INDOOR NOISES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet Flyover at 300 m</td>
<td>6,324,555</td>
<td>110</td>
<td>Rock Band at 5 m</td>
</tr>
<tr>
<td>Gas Lawn Mower at 1 m</td>
<td>2,000,000</td>
<td>100</td>
<td>Inside Subway Train (New York)</td>
</tr>
<tr>
<td>Diesel Truck at 15 m Noisy Urban Daytime</td>
<td>632,456</td>
<td>90</td>
<td>Food Blender at 1m</td>
</tr>
<tr>
<td>Gas Lawn Mower at 30 m Commercial Area</td>
<td>63,246</td>
<td>70</td>
<td>Garbage Disposal at 1 m</td>
</tr>
<tr>
<td>Gas Lawn Mower at 30 m Noisy Urban Daytime</td>
<td>200,000</td>
<td>80</td>
<td>Shouting at 1 m</td>
</tr>
<tr>
<td>Gas Lawn Mower at 30 m Noisy Urban Daytime</td>
<td>20,000</td>
<td>60</td>
<td>Vacuum Cleaner at 3 m</td>
</tr>
<tr>
<td>Quiet Urban Daytime</td>
<td>6,325</td>
<td>50</td>
<td>Normal Speech at 1 m</td>
</tr>
<tr>
<td>Quiet Urban Nighttime</td>
<td>2,000</td>
<td>40</td>
<td>Large Business Office</td>
</tr>
<tr>
<td>Quiet Suburban Nighttime</td>
<td>632</td>
<td>30</td>
<td>Dishwasher Next Room</td>
</tr>
<tr>
<td>Quiet Rural Nighttime</td>
<td>200</td>
<td>20</td>
<td>Small Theatre, Large Conference Room (Background)</td>
</tr>
<tr>
<td></td>
<td>63</td>
<td>10</td>
<td>Library</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0</td>
<td>Bedroom at Night, Concert Hall (Background)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Broadcast and Recording Studio</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Threshold of Hearing</td>
</tr>
</tbody>
</table>

**Typical Levels of Noise Loudness**

Source: (Wayson, 2002)
Loudness of Sound: How does it all add up?

\[
SPL_{(\text{total})} = 10 \log_{10} \left( 10^{\frac{SPL_{\text{AUTO}}}{10}} + 10^{\frac{SPL_{\text{VAN}}}{10}} + 10^{\frac{SPL_{\text{TRUCK}}}{10}} \right)
\]
Addition of Sound Loudness - Example

A typical jet flying overhead has a SPL of 105 dB. Find the total SPL of two of such jets flying overhead at that height at the same time.

Solution:

\[
SPL_{(\text{total})} = 10 \log_{10} \left( 10^{\frac{SPL_1}{10}} + 10^{\frac{SPL_2}{10}} \right) \\
= 10 \log_{10} \left( 10^{\frac{105}{10}} + 10^{\frac{105}{10}} \right) \\
= 108 \text{ dB}
\]
Frequency of sound

- Definition: change in the rate of pressure fluctuations in the air.
- Units: Nr. of oscillations (pressure changes) per second or hertz (Hz)
- Frequencies that can be heard by human ear: 20 Hz to 20,000 Hz.
- Ear identifies a sound by its frequency and not its loudness. (example, braking sound vs. horn sound)
- Human ear does not hear well sounds at following frequencies
  - Less than 500 Hz or
  - Higher than 10,000 Hz
- Therefore, loudness not sufficient to describe a sound. Frequency also needed.
Difference between sound loudness and sound frequency

Loudness = maximum amplitude = 1.0 N/mm$^2$

Frequency = 1 cycle per 0.25 seconds = 4 cycles per second
Noise duration

- Together with loudness and frequency, duration helps us to describe a noise more completely.

- Consider these extremes:
  - Collision between two vehicles: very loud, but very short duration
  - Noise from a nearby freeway: not very loud, but is continual.

- Variation of traffic noise with time is considered important for noise assessment.
Noise duration

- $L_{\text{max}}$: the maximum noise level occurring during a definite time period

- $L_{xx}$: The subscript $xx$ indicates the percentage of time that the listed level is exceeded.
  - $L_{15}$ is the sound level that is exceeded 15% of the time
  - $L_{50}$ is the sound level that is exceeded 50% of the time
  - $L_{90}$ is the sound level that is exceeded 90% of the time
Statistical Descriptors of Sound Duration - Illustration

Consider noise received by tenants of apartment near a certain urban freeway:

\[ a + b + c = 15\% \]

This chart means that:
\[ a + b + c = 15\% \]
Subjectivity of Noise

- Individuals have different responses to various sounds.
- A sound type that is pleasing to an individual may be a nuisance (noise) to another.
- Degree of noise unpleasantness may be influenced by the time or place at which it occurs.
  - For example, flow of truck traffic through a residential area may be more offensive at night than on a weekday afternoon.
Effects of Noise

- **Transportation construction:**
  - several individual loud noises
  - can result in acute hearing loss

- **Transportation operations:**
  - chronic in nature,
  - In short term – causes irritation or annoyance
  - In long term - may result in reduced hearing ability

- **Transportation noise can lead to**
  - problems in emotional well-being
  - discomfort by sleep interference
  - disruption in the daily lives of humans.

- Specifically, research as found that noise **indeed does** …
  - prevents deep sleep cycles considered necessary for complete refreshment,
  - causes tension due to continual intrusion,
  - affects communication, and decreases the learning abilities of students class sessions are interrupted by noise events (Wayson, 2002)
Sources of Transportation Noise

Factors affecting Transportation Noise Levels
Sources of Transportation Noise
Sources of Transportation Noise

- Horn
- Engine
- Wind-Body interaction
- Exhaust
- Brakes
- Tire-pavement interaction
Sources of Transportation Noise

- **Vehicle/air interaction**: In motion, friction between vehicle body and surrounding air induces a gradient in air pressure field thus generating noise.

- **Tire/pavement interaction**: A direct result of friction and small impacts that occur as tires roll along guide-way surface.

- **Vehicle engines**: Greater noise when cars/trucks/planes/trains, accelerate. Also, greater noise at higher speeds.

- **Vehicle exhaust systems**: Faulty exhaust systems lead to higher noise levels, especially in cases of malfunctioning noise-control devices (mufflers).

- **Vehicle horns**: Constitute significant and irritating source of urban traffic noise,

- **Vehicle Brakes**: also constitute a significant noise source particularly for large trucks.
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Factors affecting the Level of Transportation Noise

Noise source

medium

receiver
Factors affecting the Level of Transportation Noise

- **Type and size of vehicles** (reference energy mean emission level)
- Length of guideway exposed to the receiver
- Nature of the **traffic stream** (speed, volume, etc.)
- **Distance** b/n noise source and receiver
- Nature of the **media** b/n noise source and receiver
  - land is the primary consideration
  - air temperature gradients, winds, and atmospheric absorption (normally not considered in noise analysis)
- Existence and nature of any **shielding features** between noise source and receiver
Type and size of vehicles

- **Reference energy mean noise emission level** (REMEL) is the noise emitted by each single unit of a given vehicle type.

- For each vehicle class, REMEL is found as follows:
  - **Automobiles (A)**: \((L_0)_{E} = 38.1 \log_{10}(S) - 2.4\)
  - **Medium trucks (MT)**: \((L_0)_{E} = 33.9 \log_{10}(S) + 16.4\)
  - **Heavy trucks (HT)**: \((L_0)_{E} = 24.6 \log_{10}(S) + 38.5\)

  where \(S\) is the average vehicle speed in km/hr. of each vehicle type.

- Note: due to variation in vehicle characteristics, roadway and other conditions across regions, it may be necessary for you to adjust these equations or to develop new REMEL values for your specific area under consideration.
Traffic flow characteristics

- Typically, transportation noise emanates from a continuous stream of vehicles and not a single vehicle.
- Therefore, the noise effect of this situation is as follows:

\[
10 \log_{10} \left[ \left( \frac{N_i \pi D_0}{S_i T} \right) \right]
\]

- \( N_i \) = number of class \( i \) vehicles passing a specified point during time \( T \) (1hr)
- \( S_i \) = average speed for the \( i^{th} \) vehicle class, km. per hr
- \( T \) = time period over which \( L_{eq} \) is sought, in hours (typically 1 hr.)
- \( D \) = perpendicular distance traffic lane centerline to receptor
- \( D_0 \) is the reference distance at which the emission levels are measured. In the FHWA model, \( D_0 \) is 15 meters
Distance between Noise Source and Receiver and Other Factors

- Height of the noise source
- Height of the receptor
- Height of the ground (hard or soft)
- Nature of the ground
- Height of the line of sight
- Distance
- Distance
- Reflect
- Incident
- Transmitted
- Reflected
- Direct
- Diffracted
- Shadow zone
- Receiver
- Barrier
Distance between Noise Source and Receiver and other Factors

- The distance adjustment is generally referred to as the *drop-off rate*
- The distance adjustment factor is:

\[ 10 \log_{10} \left( \frac{D_0}{D} \right)^{1+\alpha} \]

- \( \alpha = 0 \ldots \)
  - If the noise source or receptor is located >3m above the ground irrespective of ground hardness, or
  - If the line-of-sight (a direct line between the noise source and the receptor) averages > 3 m above the ground, or
  - If the top of the noise barrier (if any) is >3 m in height irrespective of source or receptor height or ground hardness
  - If the height of the line-of-sight is < 3 m but there is a clear (unobstructed) view of the highway, the ground is hard, and there are no intervening structures.

- \( \alpha = 0.5 \ldots \)
  - If the view of the roadway is interrupted by isolated buildings, clumps of bushes, scattered trees, or
  - If the intervening ground is soft or covered with vegetation.
Effect of finite length roadways

- Noise level also influenced by “how much section of the roadway is visible to the receptor”
- Useful to separate a roadway into sections to account for changes in topography, traffic flows, shielding, etc.
- Some possible positions of receptor relative to roadway segment:
Effect of finite length roadways (ground shielding effect)

- The nature of ground affects noise propagation
- Adjustment factor is
  \[ 10 \log_{10} \left( \psi \alpha \left( \phi_1, \phi_2 \right) / \pi \right) \]

where

\[ \psi \alpha \left( \phi_1, \phi_2 \right) \] is a factor related to the finite length of roadway,
\[ \phi_1, \phi_2 \] are the angles defined in previous slide, and
\[ \alpha \] is the ground hardness parameter.

- For a terrain with hard (perfectly reflective) ground, \( \alpha = 0 \), and the adjustment factor becomes
  \[ 10 \log_{10} \left( \Delta \phi / \pi \right) \]

- For terrains with soft (absorptive) ground, the adjustment term reduces to a complex function that yields a family of curves that are used to obtain the values of the adjustment factor.
Adjustment Factors for Finite Length Roadways and Ground Effects

*(Barry and Reagan, 1978)*
Effect of Any Existing Noise Shield

- Noise level reaching receiver can be affected by physical object located between the noise source road and the receiver.

- Such “barriers” interfere with sound wave propagation, create “acoustic shadow zone” and reduce noise level reaching receptor.

- May be natural or man-made, intentional (earth berms, noise barriers, walls, etc.) or unintentional (large buildings, rows of houses, dense woods, hills, etc.).

- “Field insertion loss” is the difference in the noise levels at the same location with and without the shield.

- When a shield is specifically constructed (i.e., noise barriers), elements of design include barrier attenuation, barrier shape, and field insertion loss.
Effect of Any Existing Noise Shield (cont’d)

- Accounts for noise-reducing effect of barrier orientation and its shape
- $\Delta_{B_i}$, the change in noise levels (attenuation) provided by the barrier for the $i$th class of vehicles is given by:

$$\Delta_{B_i} = 10\log \left[ \frac{1}{\phi_R - \phi_L} \int_{\phi_L}^{\phi_R} 10^{-\frac{\Delta_i}{10}} d\phi \right]$$

Where:

$\phi_R$ and $\phi_L$ are angles that establish the relationship (position) between the barrier and the receptor.

Case 1

Case 2

Case 3
Effect of Any Existing Noise Shield (cont’d)

\( \Delta_i \) is the point source attenuation for the \( i \)th class of vehicles and is given by:

\[
\Delta_i = \begin{cases} 
0 & N_i \leq -0.1916 - 0.0635 \varepsilon \\
5(1 + 0.6 \varepsilon) + 20 \log \frac{\sqrt{2 \pi |N_o|_i \cos \phi}}{\tan \sqrt{2 \pi |N_o|_i \cos \phi}} & (-0.1916 - 0.0635 \varepsilon) \leq N_i \leq 0 \\
5(1 + 0.6 \varepsilon) + 20 \log \frac{\sqrt{2 \pi (N_o)_i \cos \phi}}{\tanh \sqrt{2 \pi (N_o)_i \cos \phi}} & 0 \leq N_i \leq 5.03 \\
20 (1 + 0.15 \varepsilon) & N_i \geq 5.03 
\end{cases}
\]

\( N_i = (N_0)_i \cos \phi \); \( \varepsilon \) (a barrier shape parameter) = 0 for a freestanding wall, = 1 for an earth berm.

\( N_0 \) is the Fresnel nr. determined along the perpendicular line between the source and receptor.

\( (N_0)_i \) is the Fresnel nr. of the \( i \)th class of vehicles determined along the perpendicular line b/n the source and receptor.

Mathematically, the Fresnel number is defined as follows:

\[
N_o = 2 \left( \frac{\delta_o}{\lambda} \right)
\]

Where \( \delta_o \) is the path length difference measured along the perpendicular line between the source and receptor,

\( \lambda \) is the wavelength of the sound radiated by the source.
Path Length Difference, $\delta_0 = A_0 + B_0 - C_0$

Barrier Attenuation vs. Fresnel Number for Noise Barriers of Infinite Length
The Overall Equation …

\[ L_{eq}(h)_i = (L_o)_{E,i} + 10 \log_{10} \left( \frac{N_i \pi D_0}{S_i T} \right) + 10 \log_{10} \left( \frac{D_0}{D} \right)^{1+\alpha} + 10 \log \left( \frac{\psi \alpha(\phi_1, \phi_2)}{\pi} \right) + \Delta_s \]

Where:

- \( L_{eq}(h)_i \) = hourly equivalent sound level for the \( i \)th vehicle class
- \((L_0)_{E,i}\) = reference energy mean emission level for vehicle class \( i \), (see Eqn 11-5 below)
- \( N_i \) = number of class \( i \) vehicles passing a specified point during time \( T \) (1hr)
- \( S_i \) = average speed for the \( i \)th vehicle class, km. per hr
- \( T \) = time period over which \( L_{eq} \) is sought, in hours (typically 1 hr.)
- \( D \) = perpendicular distance traffic lane centerline to receptor
- \( D_0 \) is the reference distance at which the emission levels are measured. In the FHWA model, \( D_0 \) is 15 meters
- \( \alpha \) = site condition parameter reflecting hardness or softness of terrain surface
- \( \psi \) = an adjustment for finite length roadways
- \( \Delta_s \) = shielding attenuation parameter due to noise barriers, rows of houses, densely wooded area, etc., in dBA
Summing up for all noise sources

- In a typical traffic stream, there are several different vehicles classes.
- Need, therefore, to combine noise levels from the different noise sources into an equivalent noise level

\[
L_{eq}(h) = 10 \log \left[ 10 \frac{leq(h)_A}{10} + 10 \frac{leq(h)_{MT}}{10} + 10 \frac{leq(h)_{HT}}{10} \right]
\]
Summary of Steps for Noise Impact Estimation

1. **DETERMINE TRAFFIC FLOW PARAMETERS**
   - Estimate the Volume and Average Speed of: Automobiles, Medium Trucks and Heavy Trucks

2. **APPLY TRAFFIC FLOW ADJUSTMENT**

3. **DETERMINE UNSHIELDED NOISE LEVELS**
   - Estimate the unshielded noise levels at Receptor position, for each vehicle class

4. **APPLY DISTANCE ADJUSTMENT**

5. **DETERMINE UNSHIELDED NOISE LEVELS AT OBSERVER’S POSITION**
   - Estimate the shielded noise levels at Observer’s position, for each vehicle class

6. **APPLY SHIELDING ADJUSTMENT**
   - Estimate Shielding Adjustment for each vehicle class, $\Delta_s$

7. **DETERMINE SHIELDED NOISE LEVELS AT OBSERVER’S POSITION**

8. **COMPARE EXPECTED NOISE LEVEL AND MAXIMUM NOISE LEVEL**

9. **DETERMINE REFERENCE ENERGY MEAN EMISSION LEVEL**
   - i.e., UNADJUSTED NOISE LEVELS, $(L_0)_E$

10. **DETERMINE DISTANCE PARAMETERS**

11. **DETERMINE SHIELDING (BARRIER) PARAMETERS**
    - from Figure 11-7 and Table 11-1
    - Estimate Line-of-Sight distance, $L/S$
    - Determine Barrier Position, $P$
    - Determine Barrier Break, $B$
    - Determine Subtension of Angle, $\theta$

12. **DETERMINE MAXIMUM NOISE LEVEL**

13. **DETERMINE MAXIMUM NOISE LEVEL**
    - Estimate Reference Energy Mean Emission Level, $(L_0)_E$
Example

Example 11.3 in Text

Traffic Operating Data for Baylor Freeway

Automobiles = 7,800 vph @ 55 mph (90km/hr)
Medium trucks = 520 vph @ 50 mph (80km/hr)
Heavy trucks = 650 vph @ 50 mph (80km/hr)

Roadway Configuration = Depressed
Length of highway segment = 1000 ft
Pavement width = 12 ft
Ground elevation of roadway = 80 ft
Location of receiver = 250 ft from road centerline 500 ft from the beginning of segment
Height of the receiver: 5 ft.

Compute noise levels at the receptor (a) without noise barrier (b) with noise barrier
Software Package for Noise Impact Estimation

The Traffic Noise Model (TNM)

- Developed by FHWA (1998)
- Designed to eventually replace the FHWA's prior pair of computer programs, STAMINA 2.0 and OPTIMA.
- Microsoft Windows interface
- Ability to model both constant and interrupted traffic flows
- Ability to import Stamina 2.0/Optima files, as well as roadway design files saved in other formats
TNM considers …

- Traffic speed and hourly traffic volumes, including percentages of automobiles, medium trucks and heavy trucks.
- Highway alignment and grade (curves, hills, depressed, elevated, etc.)
- Surrounding terrain features
- Locations of activity areas likely to be impacted by the associated traffic noise.
TNM Features

Input data on vehicle volume and speed, for each vehicle class

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Veh/hr</th>
<th>Speed [mph]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>7800</td>
<td>55.00</td>
</tr>
<tr>
<td>Medium Truck</td>
<td>520</td>
<td>50.00</td>
</tr>
<tr>
<td>Heavy Truck</td>
<td>650</td>
<td>50.00</td>
</tr>
</tbody>
</table>

Input data on highway segment boundary coordinates and pavement

<table>
<thead>
<tr>
<th>Pnt.Name</th>
<th>Pnt.No</th>
<th>X [ft]</th>
<th>Y [ft]</th>
<th>Z[pavement] [ft]</th>
<th>Pavment Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>HW 1+00</td>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
<td>80.00</td>
<td>Average</td>
</tr>
<tr>
<td>HW 11+00</td>
<td>2</td>
<td>1,000.0</td>
<td>0.0</td>
<td>80.00</td>
<td>Average</td>
</tr>
</tbody>
</table>
TNM Features

Input data on receptor coordinates and characteristics

Input data on barrier coordinates and characteristics
## TNM Features

Output data: noise levels at receptor positions with and without barrier

<table>
<thead>
<tr>
<th>Receiver Name</th>
<th>No.</th>
<th># DU's</th>
<th>Existing L_{Aeq} 1h</th>
<th>No Barrier L_{Aeq} 1h</th>
<th>Increase over existing with barrier</th>
<th>Type Impact</th>
<th>Calculated Noise Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>dB</td>
<td>dB</td>
<td>Calculated</td>
<td>dB</td>
<td>dBA</td>
</tr>
<tr>
<td>Receptor</td>
<td>2</td>
<td>1</td>
<td>73.0</td>
<td>73.2</td>
<td>66</td>
<td>0.2</td>
<td>10</td>
</tr>
<tr>
<td>Dwelling Units</td>
<td></td>
<td></td>
<td>Noise Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>dB</td>
<td>dB</td>
<td>dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Selected</td>
<td>1</td>
<td>1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Impacted</td>
<td>1</td>
<td>1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All that meet the goal</td>
<td>1</td>
<td>1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td>6</td>
<td>0.1</td>
</tr>
</tbody>
</table>
TNM Demonstration
Traffic Noise Mitigation

- Categories of techniques for noise mitigation:
  - At the noise source
  - At the path (medium) of noise propagation, or/and
  - At the receptor.
Traffic Noise Mitigation – Some specific techniques

- Contra-noise – installing speakers in engine compartment to cancel out engine noise or electronic mufflers for exhaust noise.
- Open–graded asphalt pavement material for tire noise reduction
- Speed limit reduction in certain neighborhoods
- Banning truck operation at certain urban streets.
- Enforcing sufficient right-of-way distances.
- Establishing “greenbelt buffer zones” to reduce noise levels at receptor locations.
- Changes in vertical or horizontal alignment, so that the transportation facility avoids noise sensitive areas.
- Special materials and fittings for walls and windows of residences, hospitals, schools, etc. to reduce noise
- Noise barriers
Traffic Noise Mitigation – Noise Barriers
Traffic Noise Mitigation – Noise Barriers
Traffic Noise Mitigation – Cost of Noise Barriers

Cost/km versus Length of Barrier

\[ y = -0.2677 \ln(x) + 1.7878 \]

\[ R^2 = 0.8421 \]
## Traffic Noise Mitigation – Cost of Noise Barriers

### Noise Barrier Construction Material Average Unit Cost by Height (2005$/sq.ft.)

<table>
<thead>
<tr>
<th>Height</th>
<th>Concrete</th>
<th>Block</th>
<th>Wood</th>
<th>Metal</th>
<th>Berm</th>
<th>Brick</th>
<th>Combination</th>
<th>Absorptive</th>
<th>All Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;=30 Feet</td>
<td>26.26</td>
<td>7.16</td>
<td>5.97</td>
<td>-</td>
<td>1.19</td>
<td>-</td>
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*Source: Adapted from FHWA (2002)*
Traffic Noise Legislation

- U.S. federal legislation for noise pollution:
  - passed in 1960s and 1970s
  - still in effect.

- Noise Control Act of 1972,
  - Reinforced the Housing and Urban Development Act of 1965
  - mandated the control of urban noise.

- Quiet Communities Act of 1978
  - better defined and added to the requirements of the Noise Control Act
  - required noise pollution to be considered for all modes of transportation
  - Led to the development of methodologies for noise measurement, assessment, and evaluation.

- The Control and Abatement of Aircraft Noise and Sonic Boom Act of 1968
  - mandated noise emission limits on aircrafts beginning in 1970.
Questions?