Treatments at the Wheel/Rail Interface to Reduce Rail Transit Noise

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Tools for Reducing Wheel/Rail

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Los Angeles Rail Transit in 1930’s
## Current Transit Projects in LA County

<table>
<thead>
<tr>
<th>Project</th>
<th>Cost</th>
<th>Type</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro Orange Line Extension</td>
<td>$182M</td>
<td>BRT</td>
<td>Under construction</td>
</tr>
<tr>
<td>Crenshaw/LAX Transit Corridor</td>
<td>$1.21B</td>
<td>LRT</td>
<td>Design Build RFP stage</td>
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<tr>
<td>Regional Connector Transit Corridor</td>
<td>$1.4B</td>
<td>LRT</td>
<td>Design Build RFP stage</td>
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<tr>
<td>Exposition LRT Project Phase 1</td>
<td>--</td>
<td>LRT</td>
<td>Opened in May 2012</td>
</tr>
<tr>
<td>Exposition LRT Project Phase 2</td>
<td>$925M</td>
<td>LRT</td>
<td>Under construction</td>
</tr>
<tr>
<td>Gold Line Foothill Extension Ph. 1</td>
<td>$735M</td>
<td>LRT</td>
<td>Under construction</td>
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<tr>
<td>Gold Line Foothill Extension Ph. 2</td>
<td>--</td>
<td>LRT</td>
<td>Environmental review</td>
</tr>
<tr>
<td>Eastside Transit Corridor Phase 2</td>
<td>$1.27B</td>
<td>LRT</td>
<td>Environmental review</td>
</tr>
<tr>
<td>Green Line Extension to LAX</td>
<td>$200M</td>
<td>LRT</td>
<td>Alternatives Analysis</td>
</tr>
<tr>
<td>Sepulveda Pass Transit Corridor</td>
<td>$1.08B</td>
<td>RT</td>
<td>Initial Planning</td>
</tr>
<tr>
<td>South Bay Green Line Extension</td>
<td>$272M</td>
<td>LRT</td>
<td>Environmental review</td>
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<tr>
<td>West Santa Ana Transit Corridor</td>
<td>$240M</td>
<td>Undef</td>
<td>Alternatives Analysis</td>
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<tr>
<td>Westside Subway Extension</td>
<td>$4.07B</td>
<td>RT</td>
<td>Preliminary Engineering</td>
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</tbody>
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### Modern Urban Rail Transit Systems*

**Western North America**

<table>
<thead>
<tr>
<th>City/Region</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calgary</td>
<td>Light rail</td>
</tr>
<tr>
<td>Denver</td>
<td>Light rail</td>
</tr>
<tr>
<td>Edmonton</td>
<td>Light rail</td>
</tr>
<tr>
<td>Honolulu</td>
<td>Rapid transit</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>Rapid transit and LRT</td>
</tr>
<tr>
<td>Phoenix</td>
<td>Light rail</td>
</tr>
<tr>
<td>Portland, OR</td>
<td>Light rail</td>
</tr>
<tr>
<td>Sacramento</td>
<td>Light rail</td>
</tr>
<tr>
<td>Salt Lake City</td>
<td>Light rail</td>
</tr>
<tr>
<td>San Diego</td>
<td>Light rail</td>
</tr>
<tr>
<td>San Jose</td>
<td>Light rail</td>
</tr>
<tr>
<td>Seattle</td>
<td>Light rail</td>
</tr>
<tr>
<td>SF Bay Area</td>
<td>Rapid transit and LRT</td>
</tr>
<tr>
<td>Vancouver</td>
<td>Light rail</td>
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</table>

**Eastern North America**

<table>
<thead>
<tr>
<th>City/Region</th>
<th>Type</th>
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<tbody>
<tr>
<td>Atlanta</td>
<td>Rapid transit</td>
</tr>
<tr>
<td>Baltimore</td>
<td>Rapid transit and LRT</td>
</tr>
<tr>
<td>Buffalo</td>
<td>Light rail</td>
</tr>
<tr>
<td>Charlotte</td>
<td>Light rail</td>
</tr>
<tr>
<td>Dallas</td>
<td>Light rail</td>
</tr>
<tr>
<td>Houston</td>
<td>Light rail</td>
</tr>
<tr>
<td>New Jersey</td>
<td>Light rail</td>
</tr>
<tr>
<td>Miami</td>
<td>Rapid transit</td>
</tr>
<tr>
<td>Minneapolis</td>
<td>Light rail</td>
</tr>
<tr>
<td>Norfolk, VA</td>
<td>Light rail</td>
</tr>
<tr>
<td>St. Louis</td>
<td>Light rail</td>
</tr>
<tr>
<td>San Juan</td>
<td>Rapid transit</td>
</tr>
<tr>
<td>Toronto</td>
<td>Rapid transit and LRT</td>
</tr>
<tr>
<td>Wash., DC</td>
<td>Rapid transit</td>
</tr>
</tbody>
</table>

*List is not exhaustive and does not include commuter rail or streetcars!
Clearly noise is an issue for both new and existing systems

Questions are:

• What can be done other than put up sound walls?

• As systems age, will noise increase?

• What tools are available to reduce noise at the wheel/rail interface?
  o Monitoring track and wheel condition
  o Improved maintenance procedures
  o Wheel and track treatments (e.g. tuned vibration dampers)

• How big a difference will treatments make?
Definitions

• Potential wheel/rail noise sources
  o Rolling noise
  o Squeal from slip-stick interaction on rail head, flange/gauge face contact, restraining rail or guard rail contact
  o Impacts at frogs, joints, bad welds, wheel flats

• Roughness
  o Random roughness plus periodic roughness (corrugation)
  o Mathematical models assume:

\[
SPL = \ldots + 10 \log \left[ \left( \frac{\rho c \omega}{p_0} \right) H_{cp}(k) \varphi_{mR}(k) \Delta k \right]
\]

where \( \varphi_{mR}(k) \) is the combined wheel and rail roughness (Remington, et al., 1974).
“Roughness”

Any longitudinal irregularity in rail surface

Random Roughness

\[
\text{frequency} = \frac{\text{speed}}{\text{wavelength}} \\
= 17.9 \times \frac{\text{speed (mph)}}{\text{wavelength (inches)}} \\
= 447 \times \frac{\text{speed (mph)}}{\text{wavelength (mm)}}
\]
“Roughness”
Any longitudinal irregularity in rail surface

Corrugation

frequency \(= \frac{\text{speed}}{\text{wavelength}}\)
\[= 17.9 \times \frac{\text{speed (mph)}}{\text{wavelength (inches)}}\]
\[= 447 \times \frac{\text{speed (mph)}}{\text{wavelength (mm)}}\]
“Roughness”

Any longitudinal irregularity in rail surface

Combined Corrugation and Random

\[
\text{frequency} = \frac{\text{speed}}{\text{wavelength}} = 17.9 \times \frac{\text{speed (mph)}}{\text{wavelength (inches)}} = 447 \times \frac{\text{speed (mph)}}{\text{wavelength (mm)}}
\]
Tools for Evaluating Noise

- On-board noise measurements to identify problem areas
- Detailed measurements at selected sites
  - Community noise
  - Rail roughness
  - Noise at 1m from near rail
  - Rail vibration decay rate
  - Rail Input Impedance
- Wheel input impedance
On-Board Noise Measurements
On-Board Noise Measurement, 2003

In-Car Noise, San Bruno to South San Francisco

A-Weighted Sound Level, dBA

Time, hh:mm:ss

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On-board Noise Measurement
Station to Station

[Graph showing speed and frequency over distance]

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acoustics, transportation + strategy
Area of Interest
“Corrugation” from Rail Grinding
Rail Roughness Measurements
Rail Roughness Measurements

Measure vertical displacement in wear band over a small track section (typically 100 to 300m)
Average Roughness, 1/3 Octave Band Spectra

Roughness on North Bound Track, West Rail

Roughness on South Bound Track, East Rail
Derived Roughness "Coefficient"
Roughness Spectrogram, Site 3
Roughness Spectrogram, Site 4

Duwamish South Southbound East Rail

Roughness (dB re 1um)

Wavelength (mm)

Distance (m)

Wavelength (mm)
Close Proximity (1m) Noise Measurements
Is Noise from Wheel or Rail?

Example 1: Sound Transit Embedded track
Is Noise from Wheel or Rail?

Example 2: Sound Transit Aerial Structure
Conclusion from Close Proximity Measurements:

• Embedded track noise is dominated by noise radiated off of wheel
• Aerial structure noise is dominated by noise radiated off of rail
• Rail dampers may be effective at reducing noise on aerial structure
San Diego Trolley, the Right Way to Reduce Noise

- Environmental studies for Mid-Coast Corridor
- 11 Mile extension to San Diego Trolley from Old Town to University City
- Originally studied in early ‘90s.
- Projected:
  - Start of Construction: 2015
  - Operations: 2018
Noise Testing for Environmental Assessment

- Four locations, three ballast & tie, one aerial structure
- Three vehicle types
  - U2 and SD100 (high floor)
  - S70 (low floor)
  - US-S70 (low floor)
- Measurements:
  - Wayside noise
  - Train speed
  - Rail roughness
Site 2: Riverwalk Golf Course
## Final San Diego Trolley Results

<table>
<thead>
<tr>
<th>Site</th>
<th>Track Type</th>
<th>Lmax, dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>S70/US-70</td>
</tr>
<tr>
<td>1</td>
<td>Ballast &amp; Tie</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>Ballast &amp; Tie</td>
<td>74</td>
</tr>
<tr>
<td>3</td>
<td>Ballast &amp; Tie</td>
<td>73</td>
</tr>
</tbody>
</table>

- Values normalized to 40 mph, 50 ft from track centerline, and 2-car trains.
- FTA suggested reference level: 77 dBA, 40 mph, 50 ft, single car, ballast & tie track.
- Equivalent levels on other LRT systems as high as 83 dBA.
Bottom Line for Mid-Coast Analysis

• Justified using a reference level of 75 dBA
• 2 dB lower than FTA recommendation
• Substantially lower than recently measured on similar LRT systems.
• Amount of noise mitigation (sound walls) substantially reduced.
• Lower reference level might be reasonable.
Overall Conclusions

• Tools are available for analyzing rolling noise
• Relatively simple measurements can lead to insights on where treatments are needed and what treatments will work
• Proper maintenance will result in lower noise levels
  o Specification is needed for rail grinding
  o Problem areas can be identified with on-board measurements
  o Problem wheels need to be identified and trued
• If San Diego Trolley can have low noise levels, why not all other transit systems?