

Noise, Vibration and EMI from Modern Streetcars

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What is a modern streetcar?

- Shared ROW with vehicular traffic
- Easy on/easy off for passengers
- Urban areas
- Low speed operation
- Lightweight vehicles



Examples

- Modern Systems
 - n Portland
 - n Tacoma
 - n Paris
- Older Systems
 - n Toronto Transit
 - n SF Muni
 - n SEPTA Surface/Subway Trolley
- New systems considered or under study for Tucson, Albuquerque, Sacramento, Madison, WI, Miami, and many other cities

Modern vs. Historic Streetcar



- PCC* vehicle on left, relatively low vibration levels
- Milan streetcar on right, relatively high vibration
- Impacts vary widely with historic vehicles
- Modern vehicles are low floor for faster loading/unloading

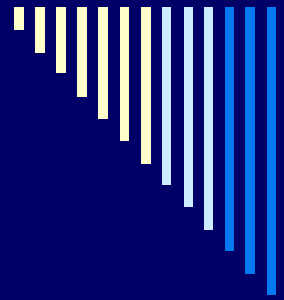


*Presidents' Conference Committee car introduced in the 1930's.



Advantages

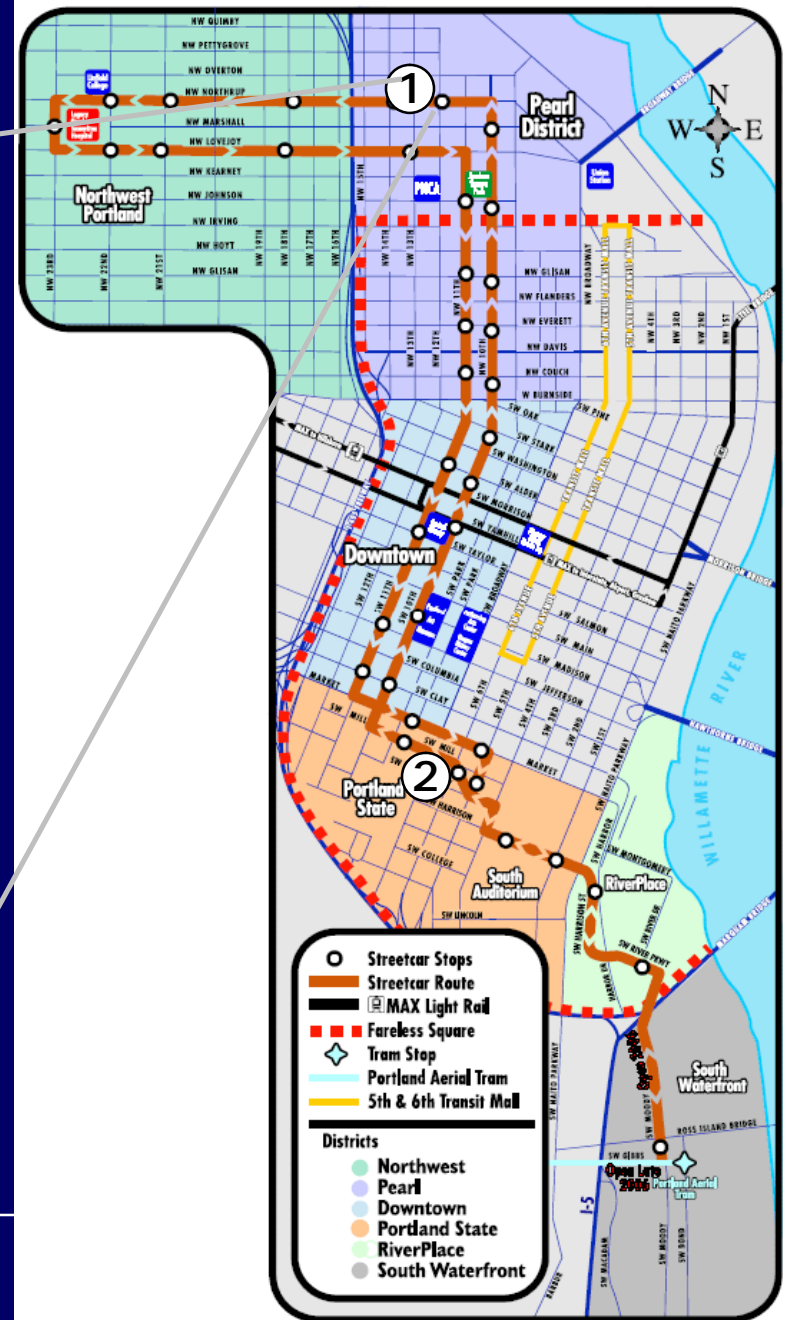
- Inexpensive
- Straightforward construction
- Existing roadways
- Minimal environmental impact???
- EMI



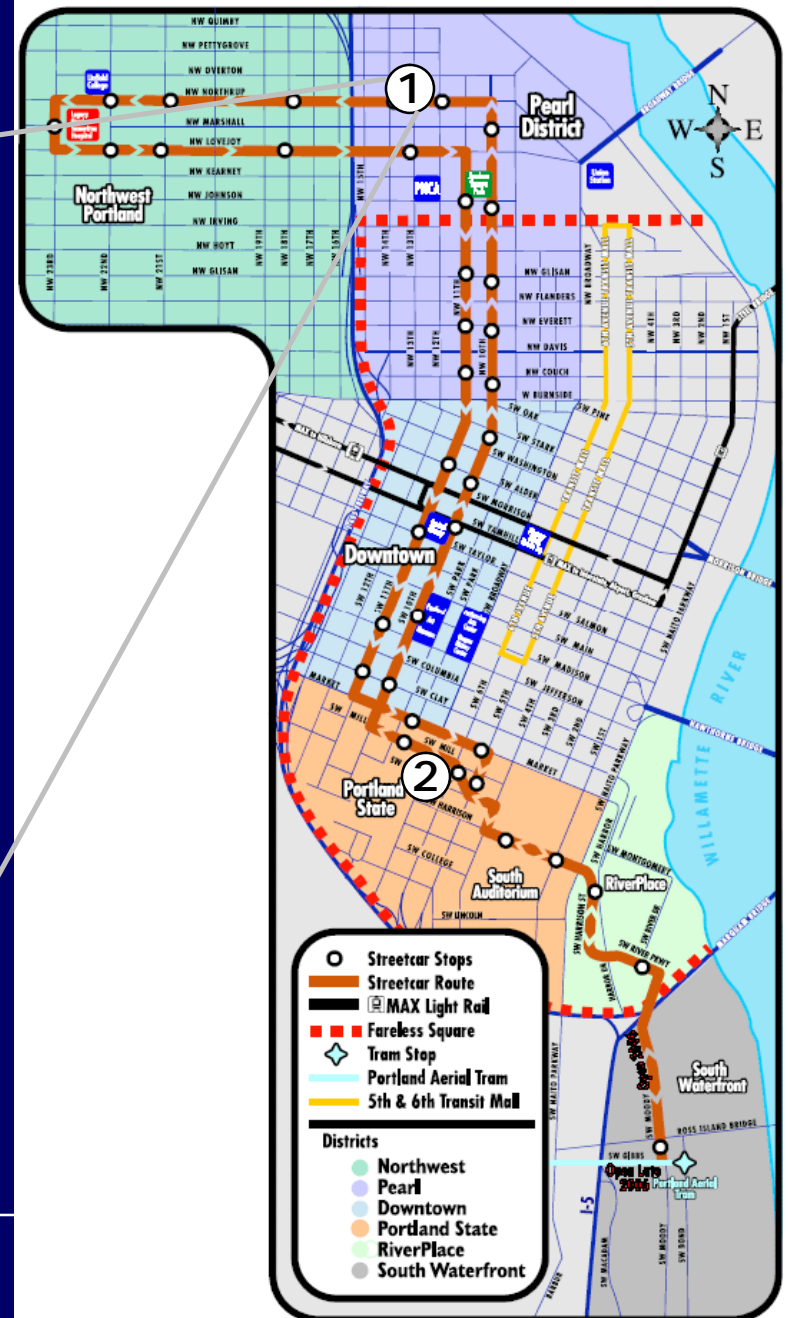
Characterizing Noise and Vibration

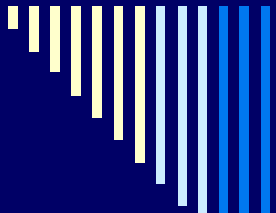
- Test of Škoda Vehicle (Portland, OR)
 - n Passby Noise
 - n Passby Vibration
- Vibration Propagation
 - n Portland
 - n Tucson

Portland Streetcar Test Sites

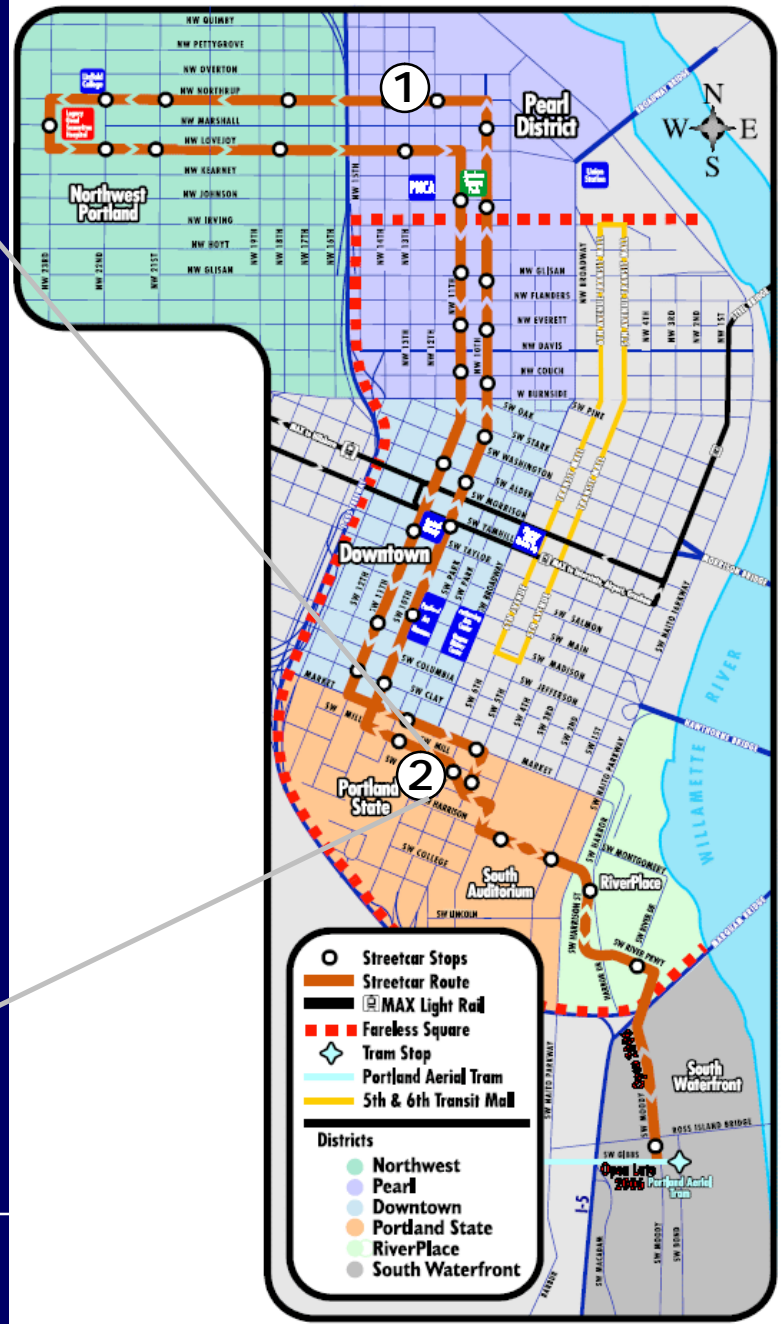


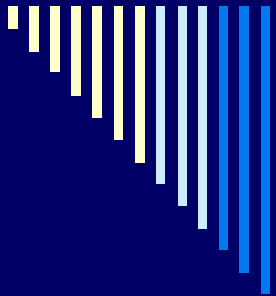
Portland Streetcar Test Sites



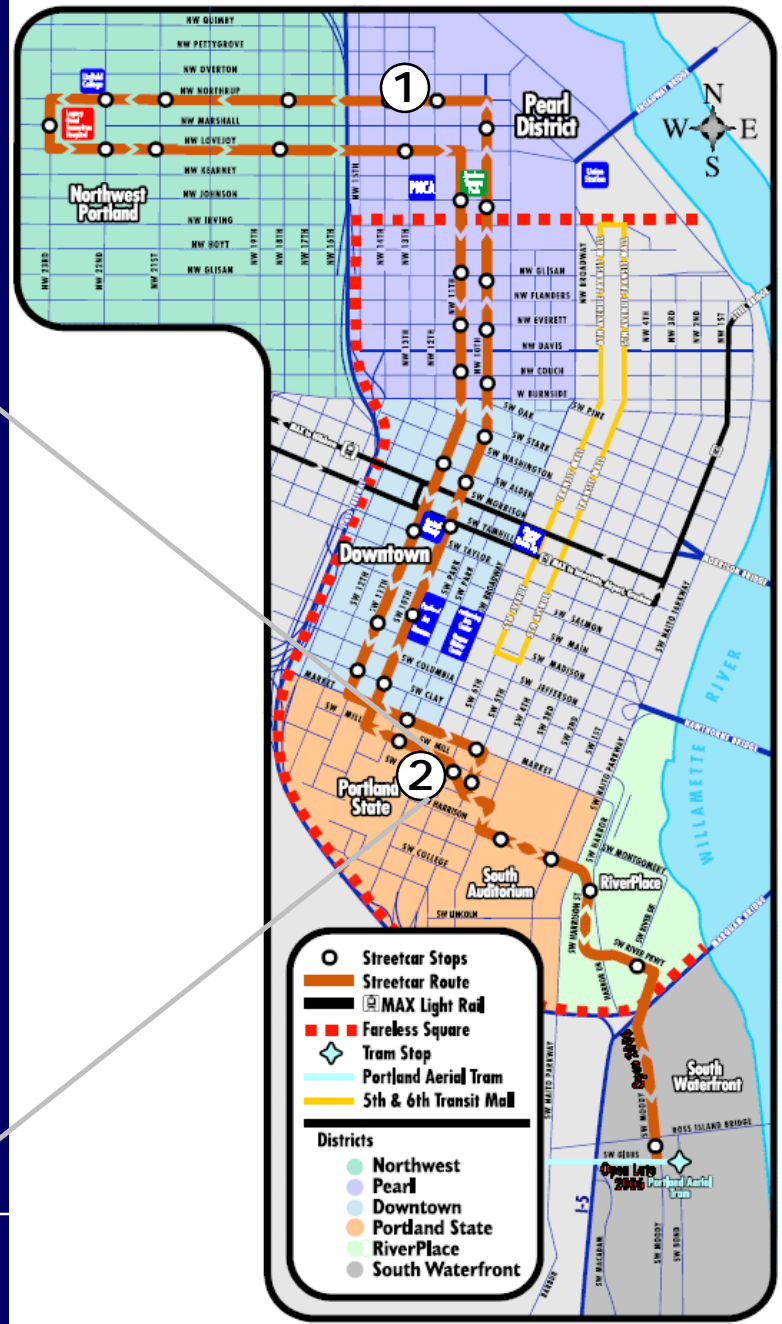


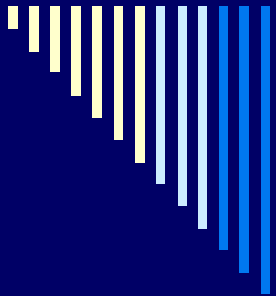
Portland Streetcar Test Sites





Portland Streetcar Test Sites





Test Results, Noise Time History

Average Leq*

Site 1 (20 mph): 76.7 dBA

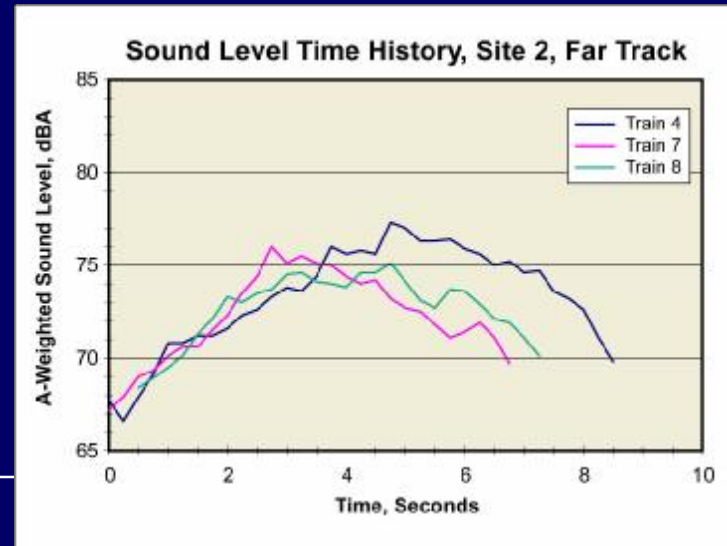
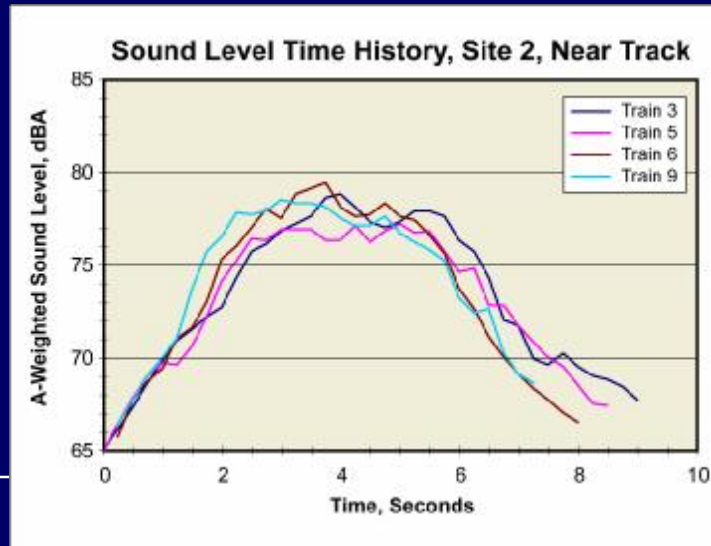
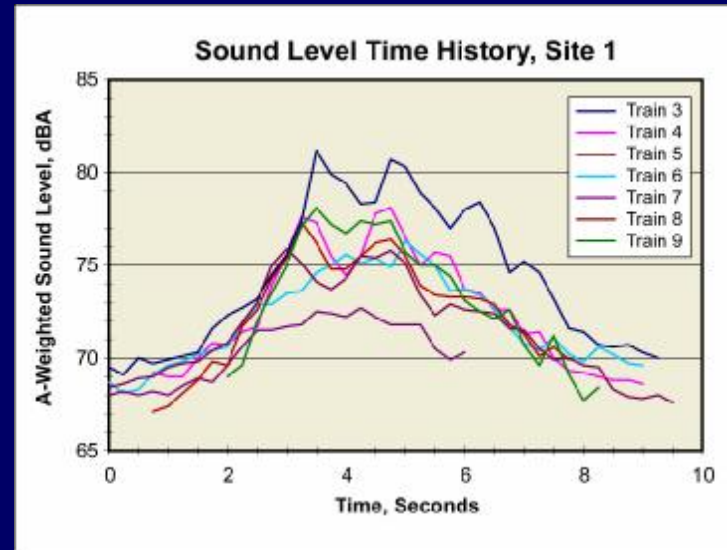
Site 2:

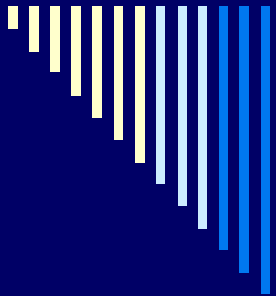
Near (20 mph) 77.6 dBA

Far (16 mph) 75.2 dBA

*averaged over passby time

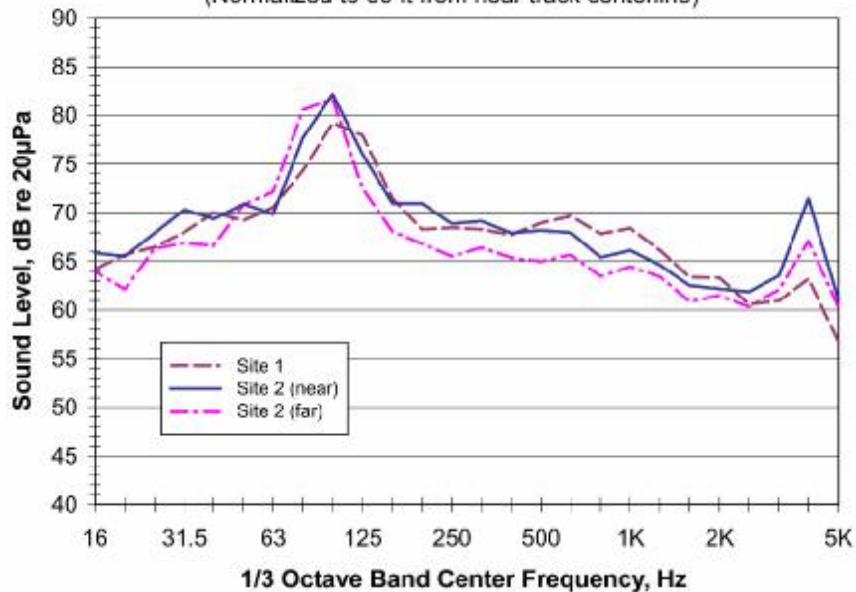
Site 1: 50 ft, Site 2: 50 ft near track and 60 ft far track



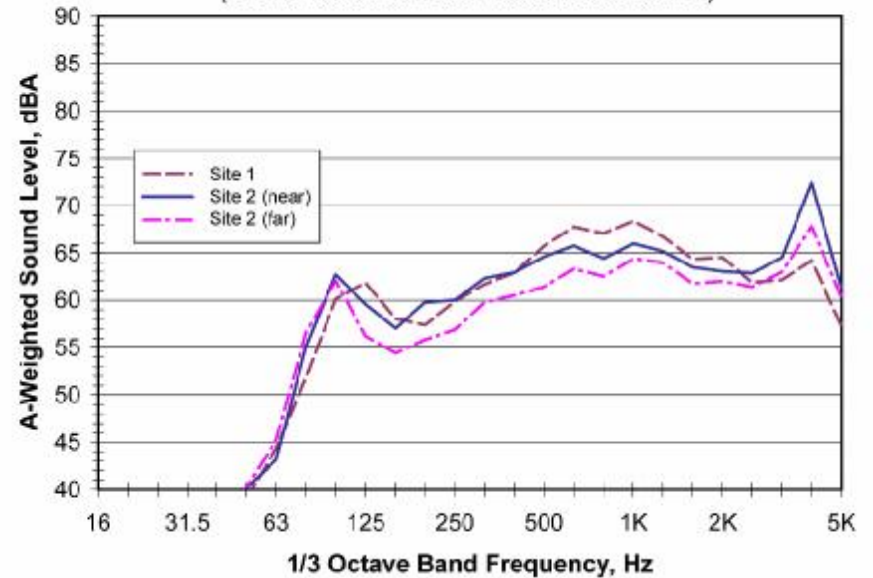


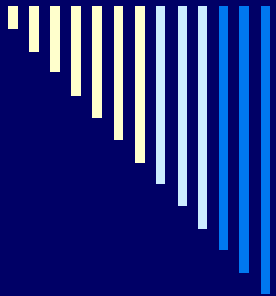
Test Results, Noise Spectrum

Average Spectra, Portland Streetcar Noise
(Normalized to 50 ft from near track centerline)



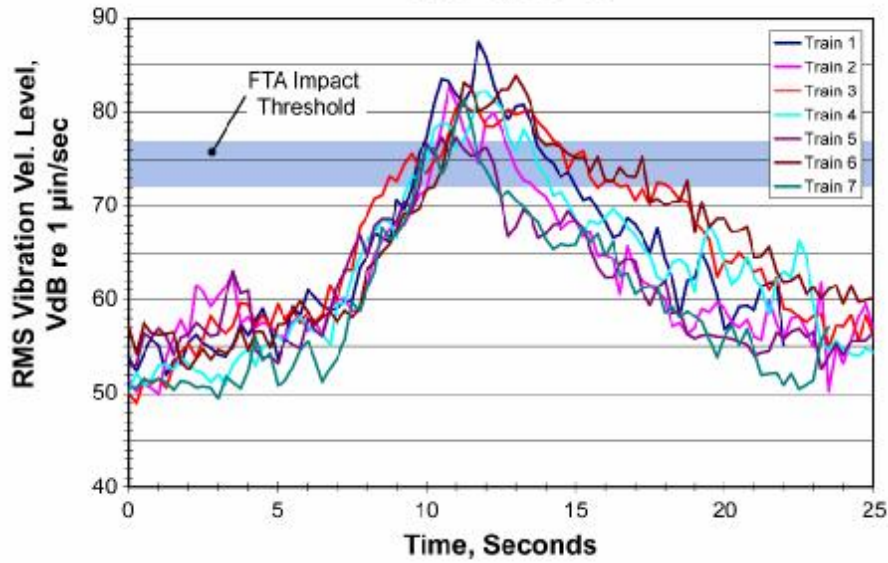
Average A-Weighted Spectra, Portland Streetcar Noise
(Normalized to 50 ft from near track centerline)



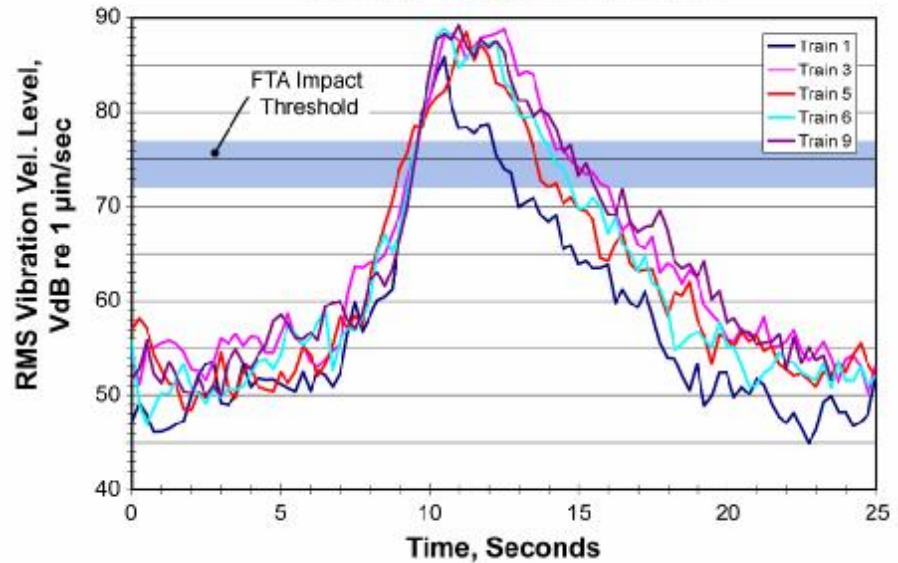


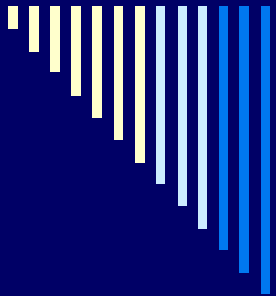
Test Results, Vibration at 25 ft

Site 1, 25 ft



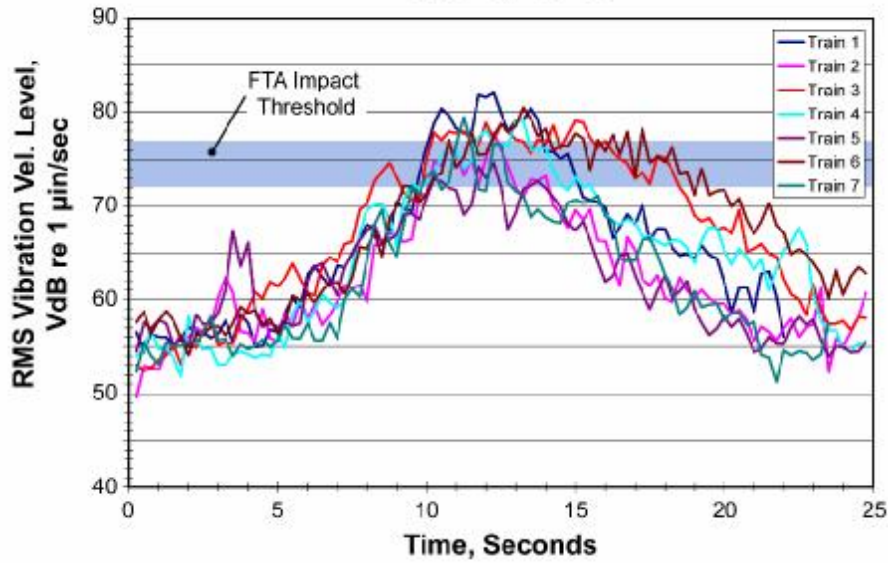
Site 2, 25 ft, Near Track



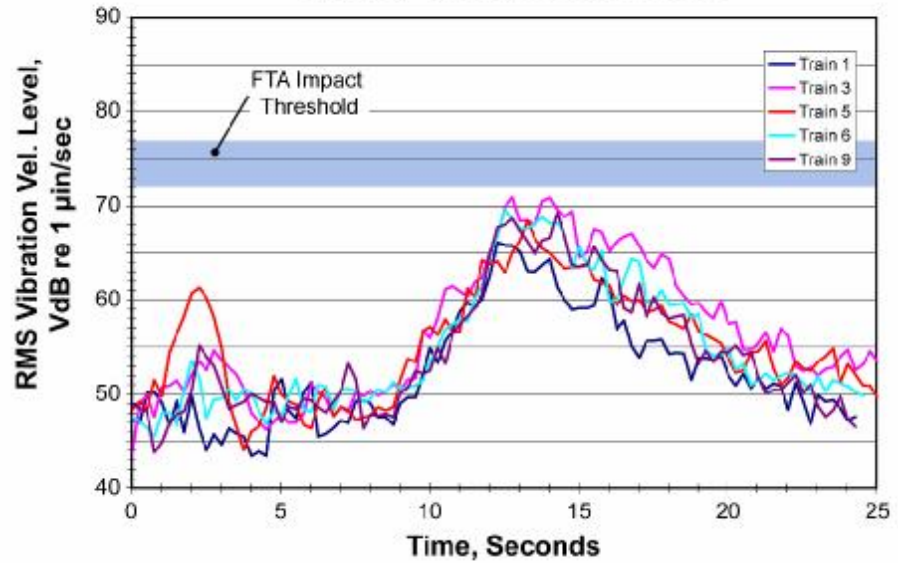


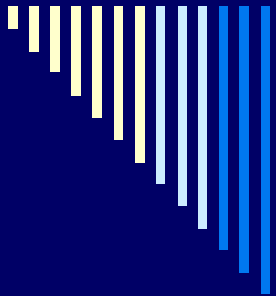
Test Results, Vibration at 50 ft

Site 1, 50 ft



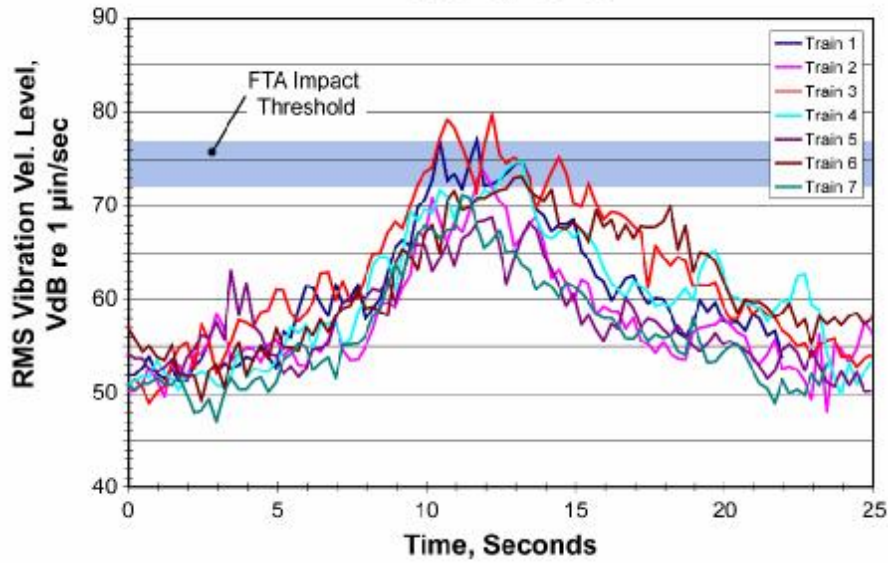
Site 2, 50 ft, Near Track



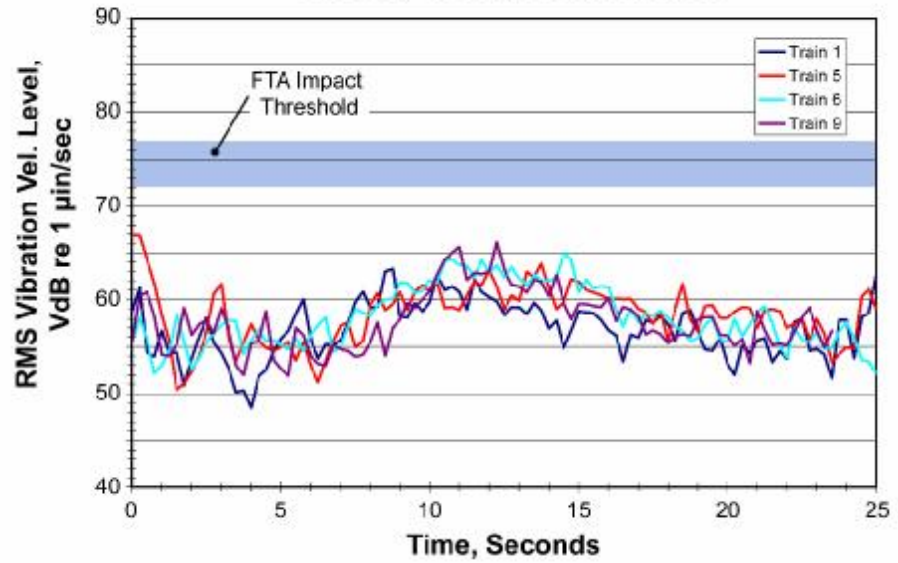


Test Results, Vibration at 75 ft

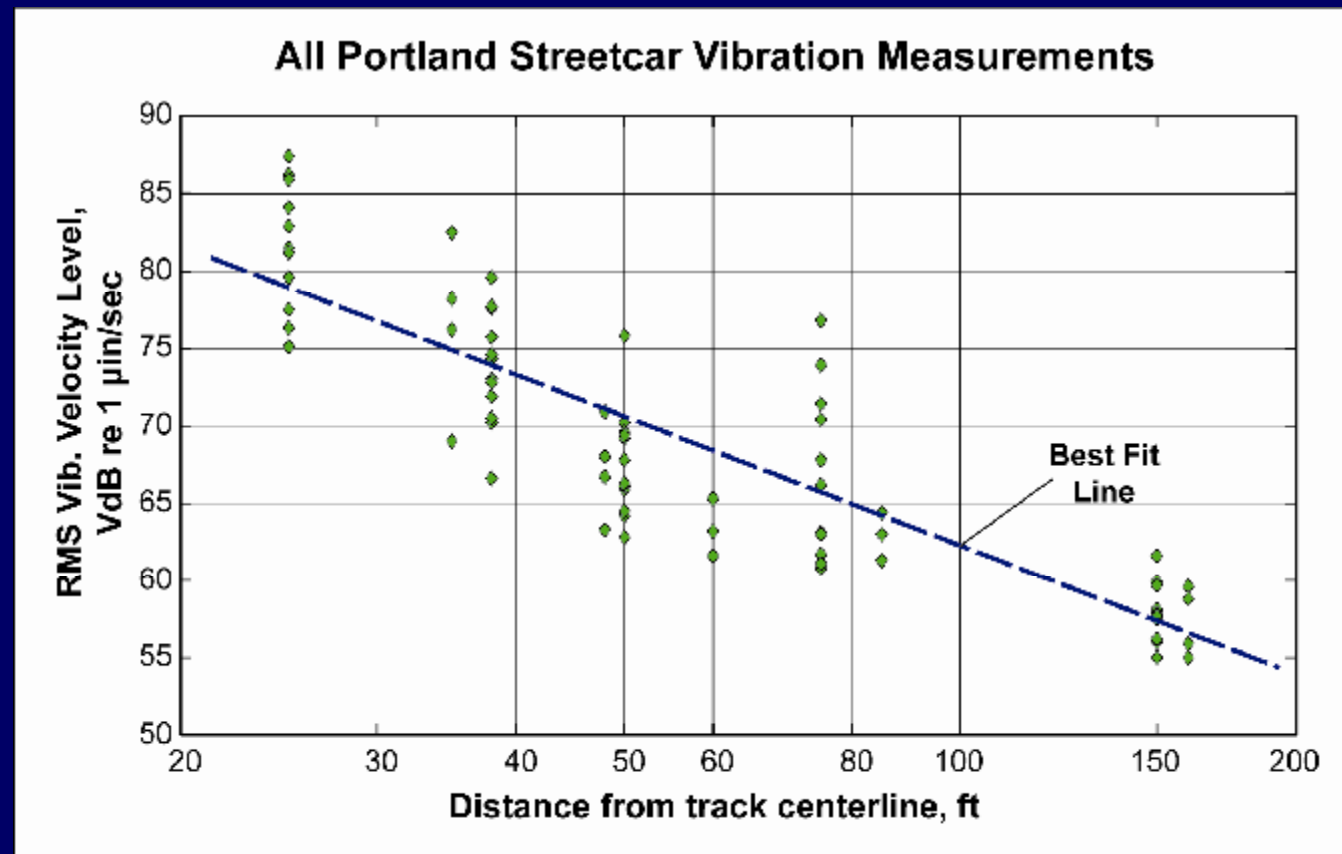
Site 1, 75 ft



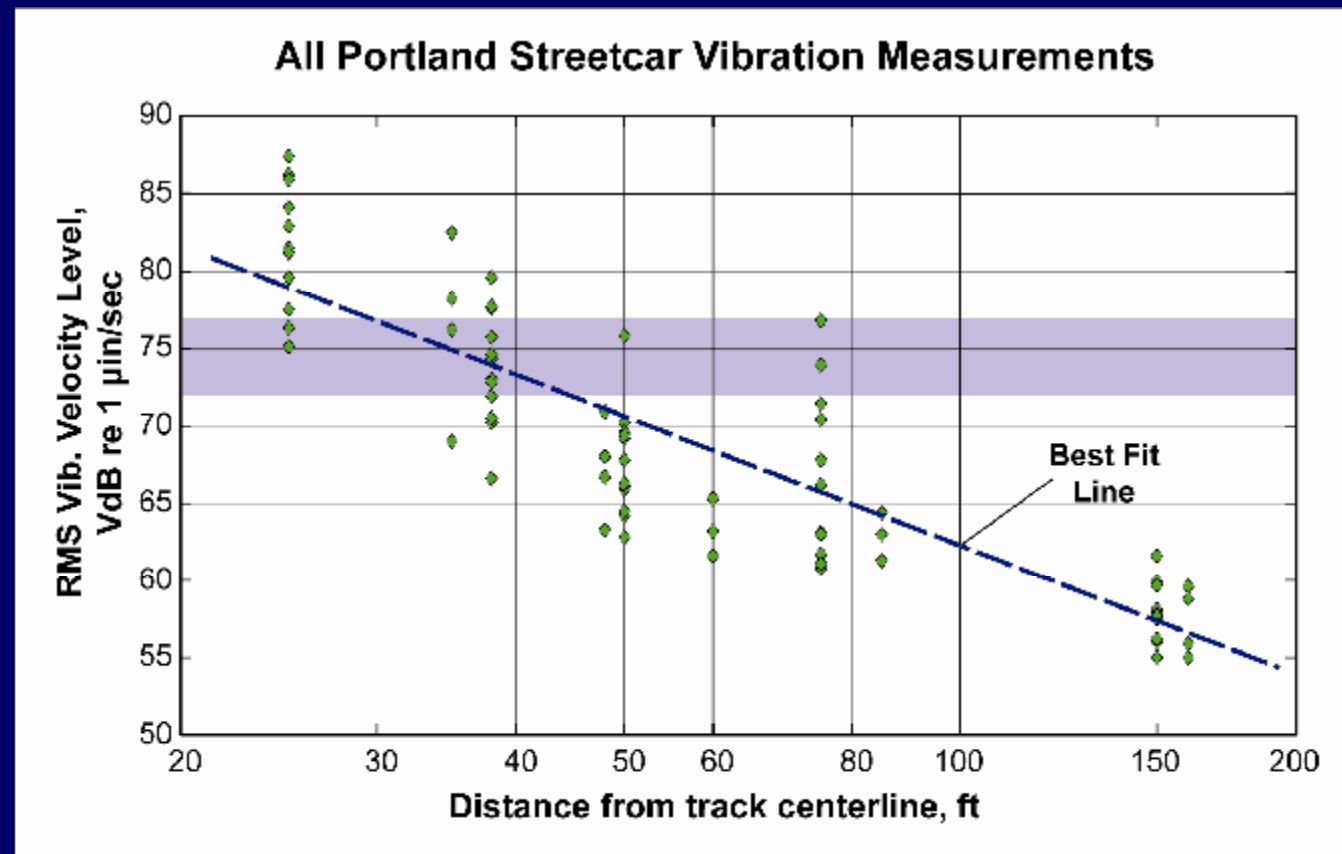
Site 2, 75 ft, Near Track



Overall Vibration Levels

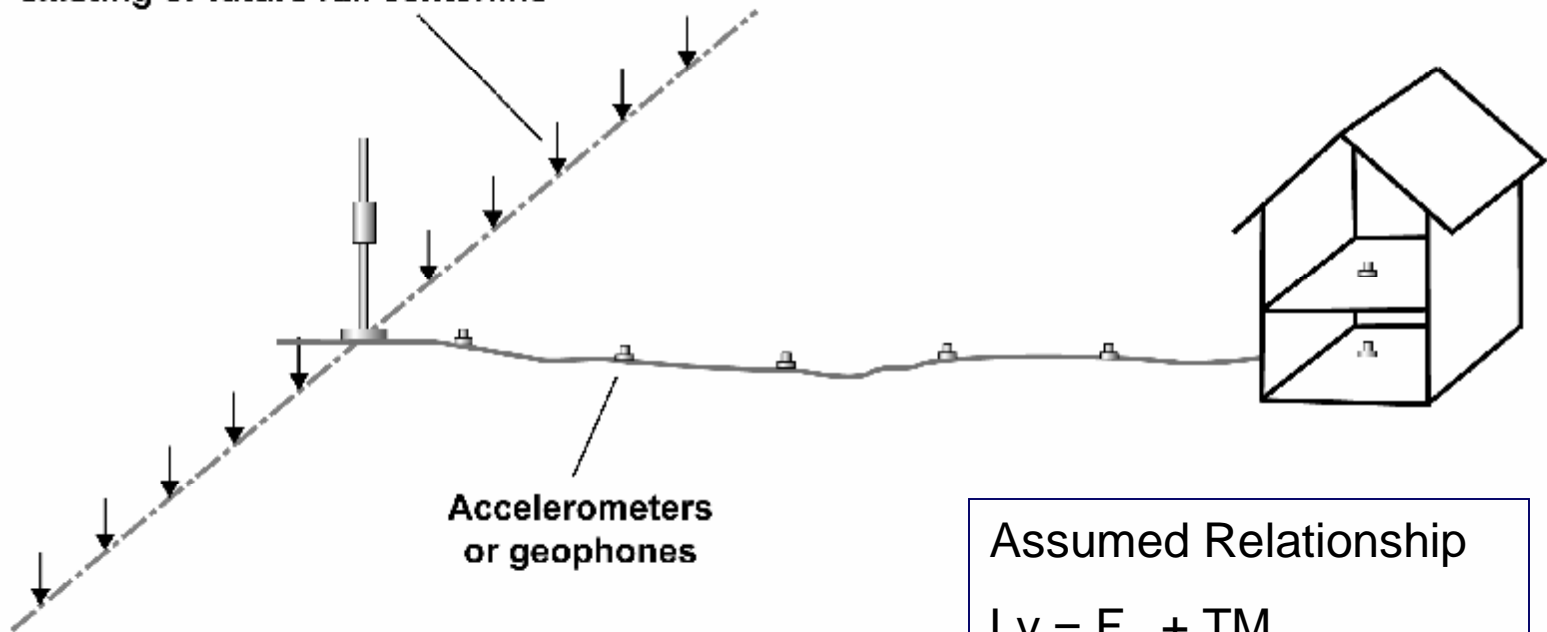


Overall Vibration Levels



Vibration Propagation Test Procedure

Line of impact locations along existing or future rail centerline

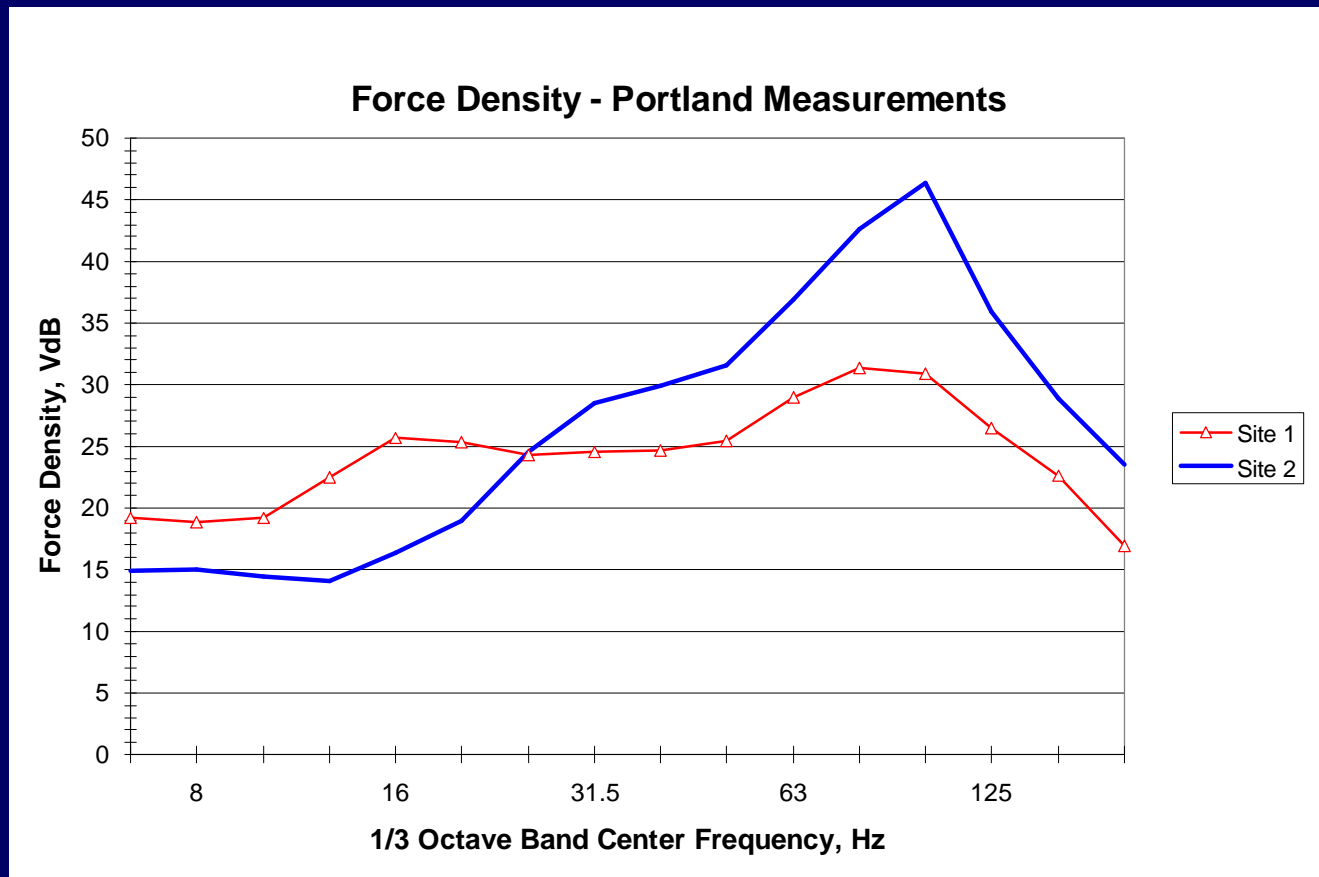


Assumed Relationship

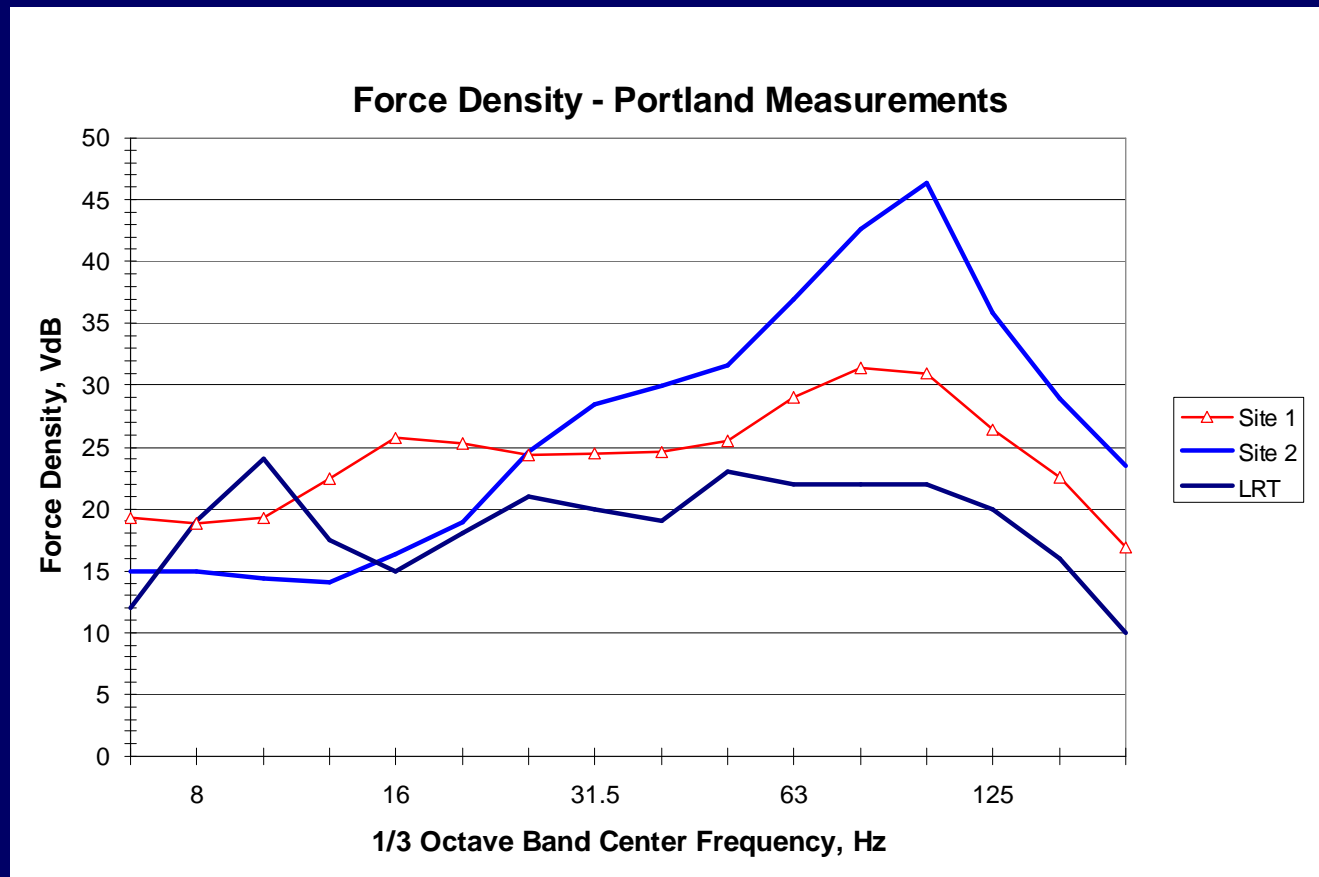
$$L_v = F_D + TM_{Line}$$



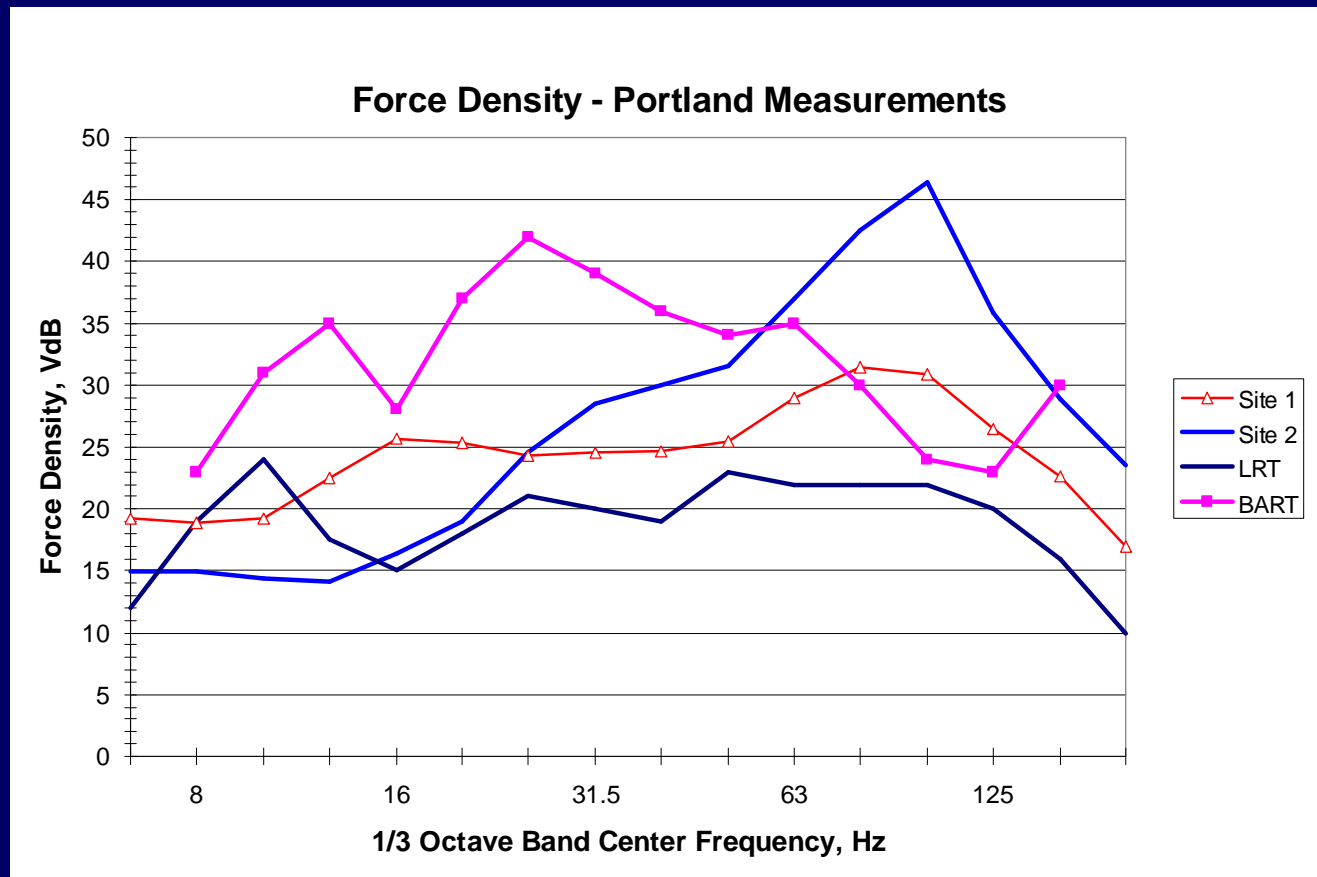
Derived Streetcar Force Densities



Derived Streetcar Force Densities



Derived Streetcar Force Densities



Vibration Predictions, Indoor

