APTA 2006 RAIL CONFERENCE

Status: TCRP Project D-12 Ground-Borne Noise and Vibration in Buildings Caused by Rail Transit

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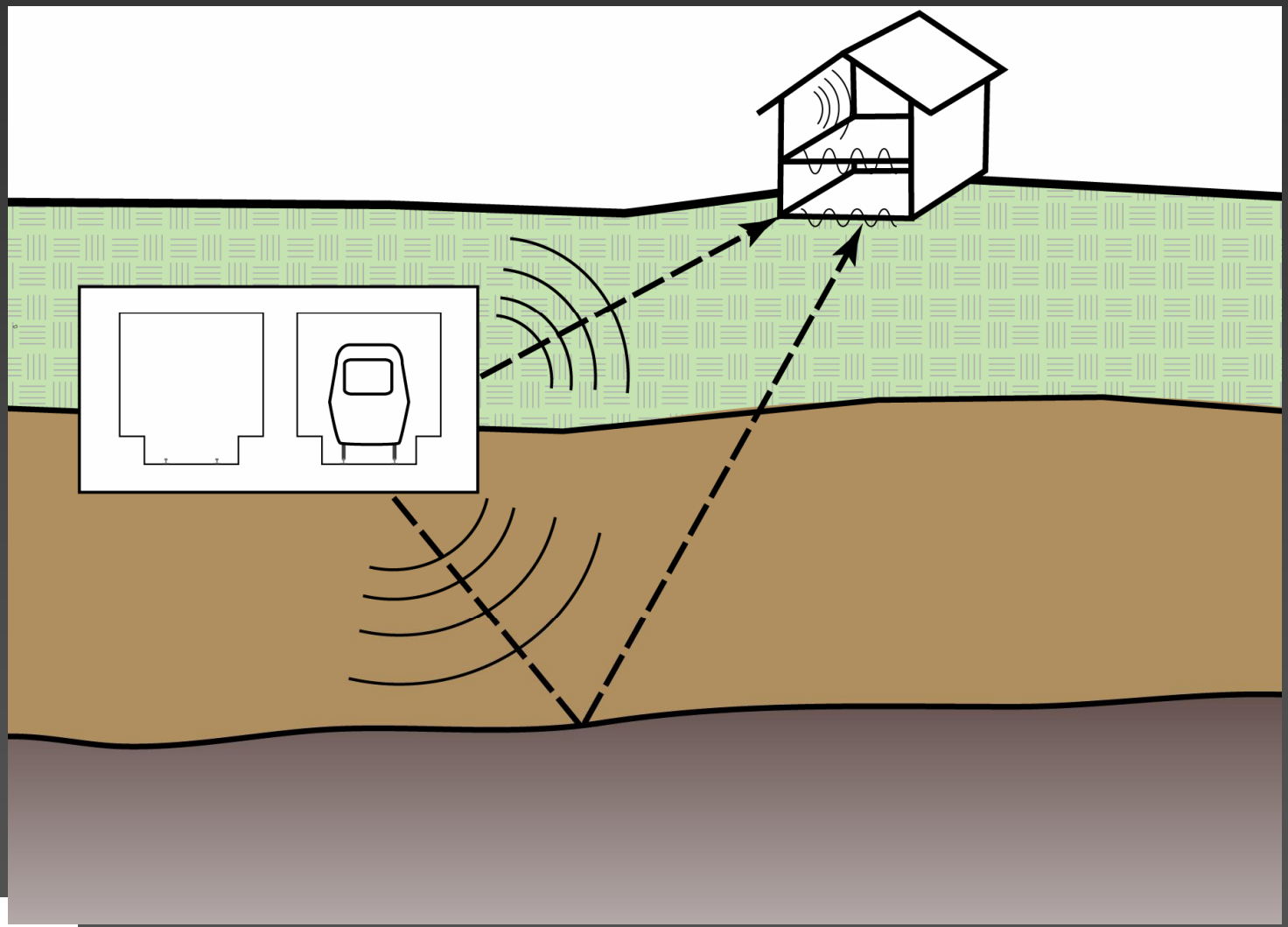
Ground Vibration



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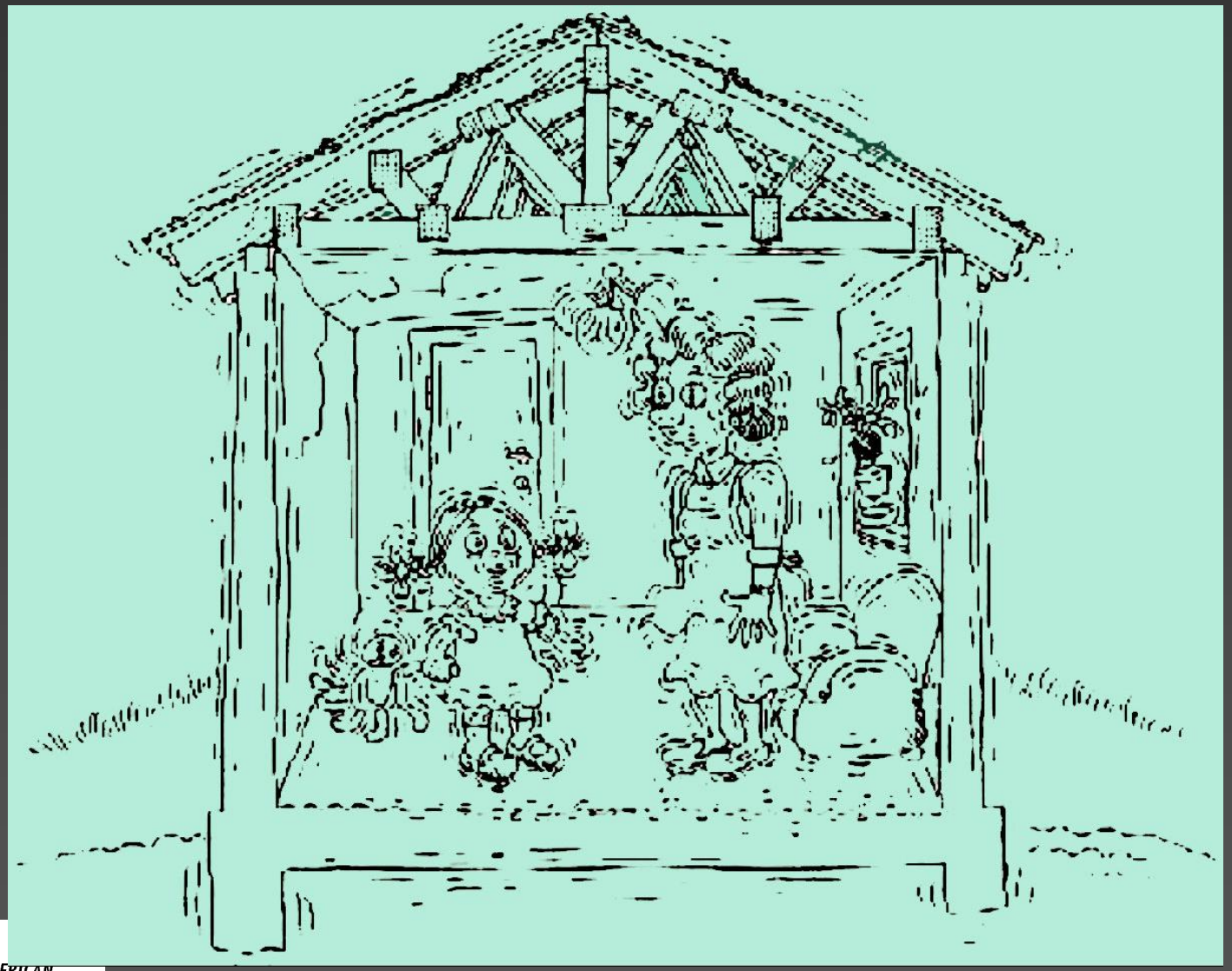
Shake, Rattle, and Rumble

- Perceptible mechanical motion (shaking).
- Noise caused by vibrating items in household (rattling).
- Secondary noise radiated from vibrating room surfaces (rumbling).

Project Issues

- Are we looking at the right things?
- Are we using the right weighting function?
- Are we applying the criteria at the best location?
- How much variation is there in people's response?

How much vibration is too much?



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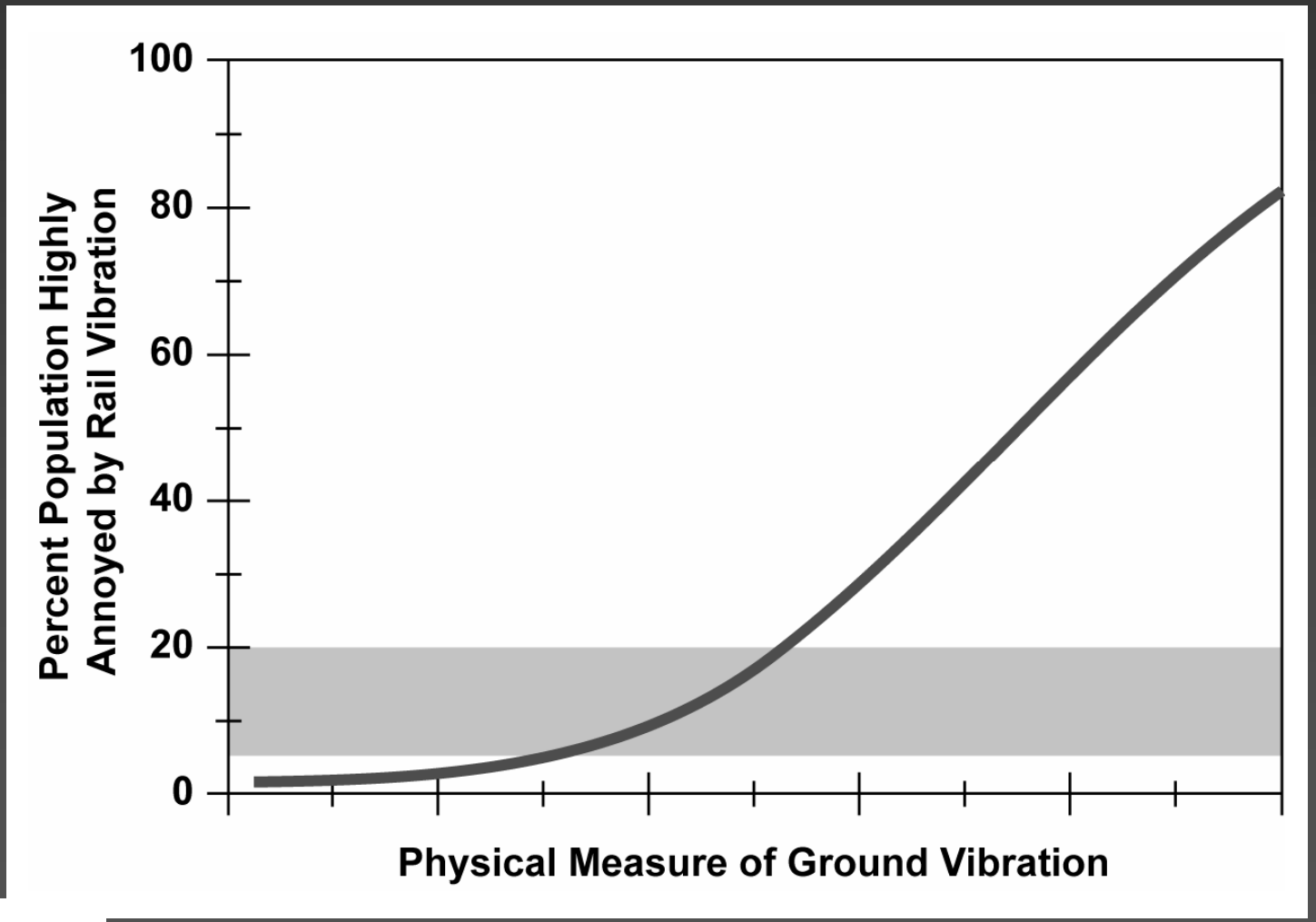
Background

- Prior to 1970's vibration specifications rarely seen.
- Experiences in Toronto in the late 60's and early 70's led to increased concern.
- Early results suggested vibration levels below 75 VdB would generate few complaints.

Dosage-Effect Function



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Project Tasks

PHASE 1

- Literature Review
- Survey North American Rail Transit Systems
- Identify Transit Systems for Field Studies
- Develop Field Survey and Measurement Program

PHASE 2

- Field Tests – Interviews and Measurements
- Develop Human Response Curve

Transit Agencies Survey

- Purpose was to obtain impression of whether vibration is a significant problem.
- Tried to balance amount of information and response rate.
- Contacted APTA members at various agencies first by telephone, then e-mailed survey to appropriate persons.

Survey Results

- Overall response rate 55%.
- 50% reported no problems or complaints at all.
- Only 2 systems reported having major problems.
- Most vibration problems tended to be focused, rather than system-wide.

Survey Results: Complaints

Zero Complaints: **17**

1 to 5 Complaints **10**

6-20 Complaints **2**

50+ Complaints **1**

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Literature Review: Objectives

- Examine International Standards
  - Evaluation Methods
  - Vibration Limits and Guidelines
- Review Published Literature
  - Laboratory Studies
  - Field Work/Social Surveys

Vibration Descriptors in Use

- Root mean square acceleration and velocity (rms)
- Weighted vibration, various weighting curves
- Root mean quad weighted vibration (rmq)
- Fourth power vibration dose ($m/s^{1.75}$)
- Imperial and metric units
- Decibels with different reference values

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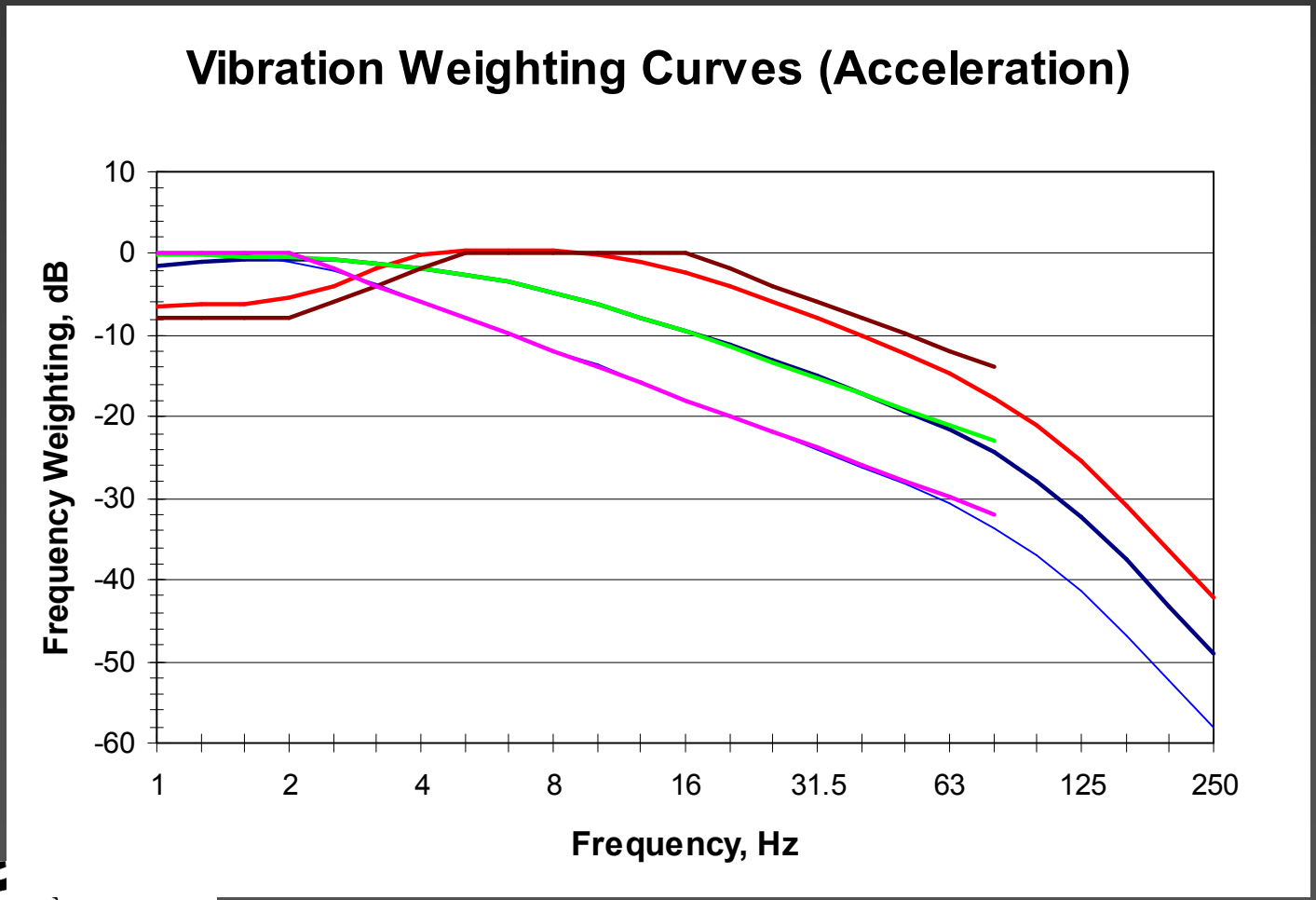
Acceleration Weighting Curves



Wm (KB)

Wk (z)

Wd (xy)

ANSI

BS(z)

BS(xy)

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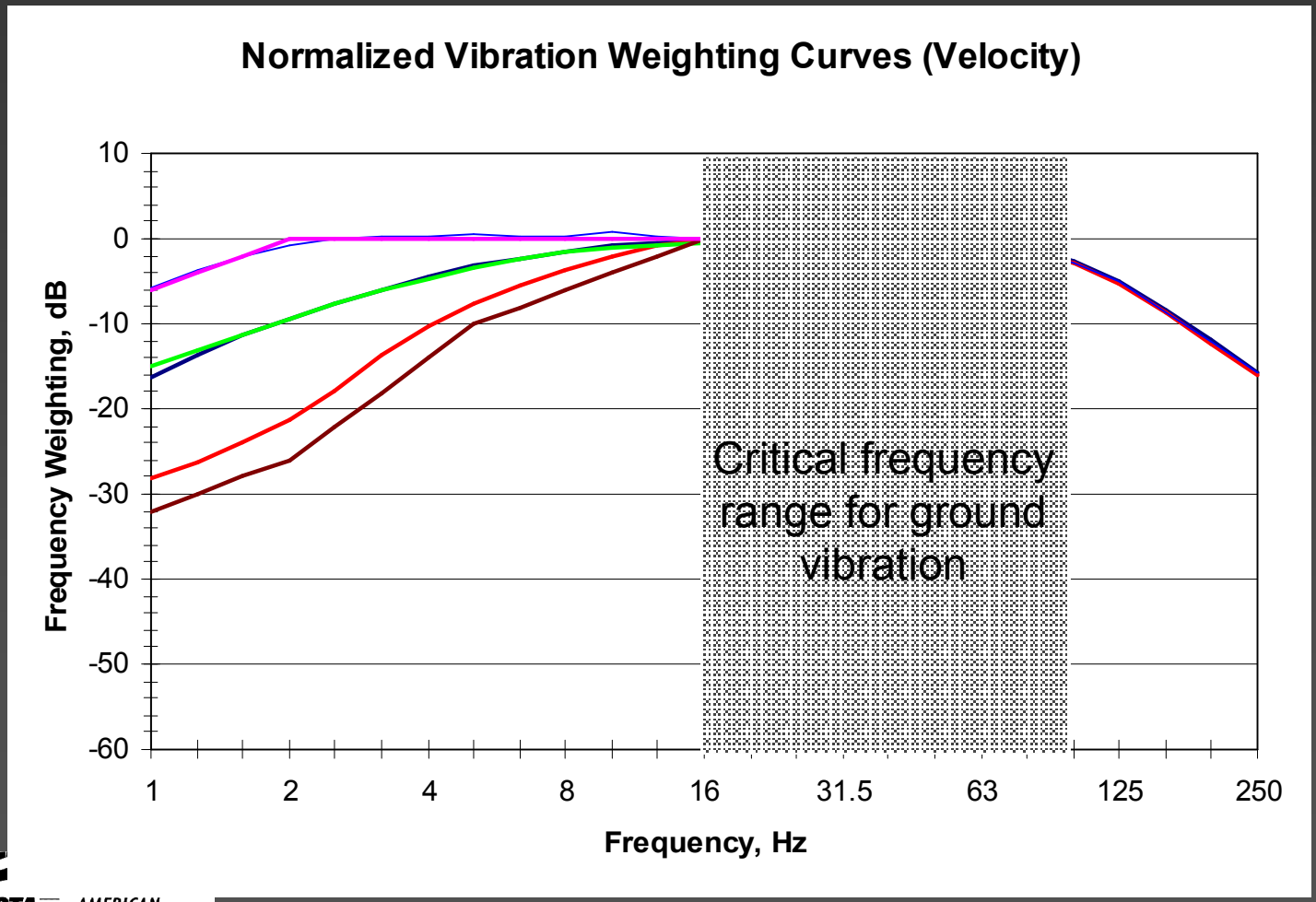
Normalized Velocity Weighting Curves



BS(xy)

Wb(xy)

ANSI

Wm

Wk(z)

BS(z)

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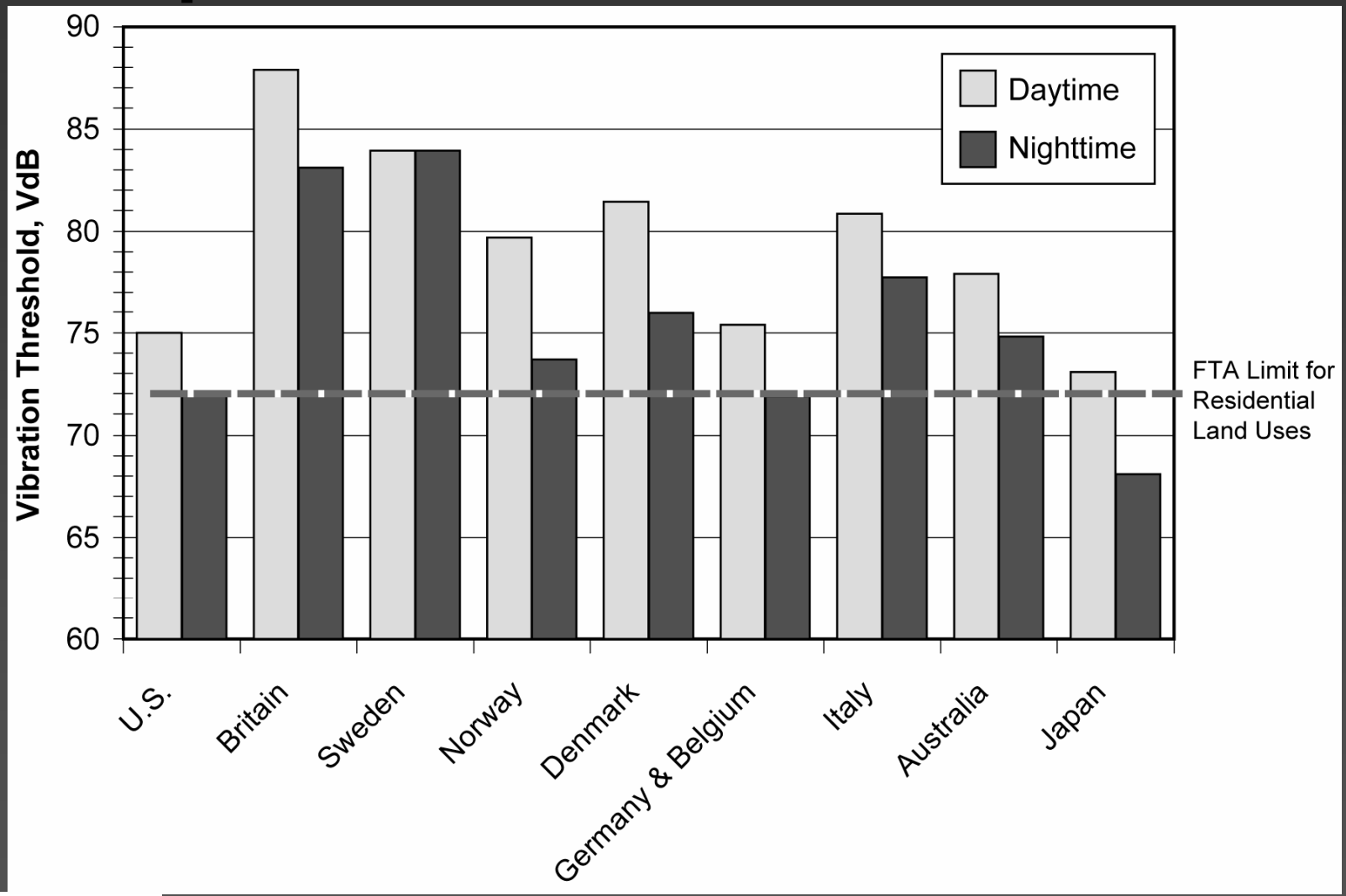
Comparison of Vibration Standards



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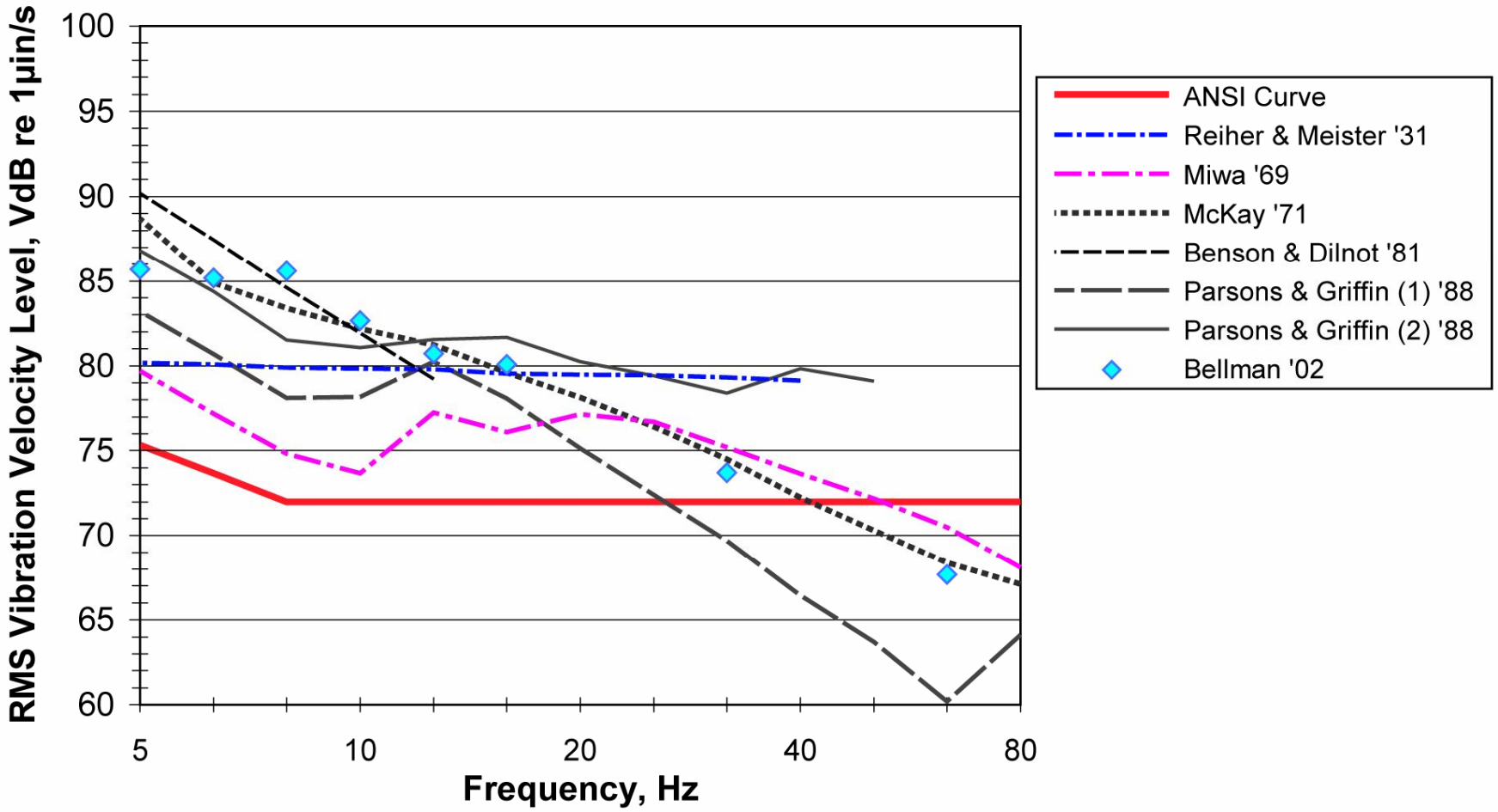
Literature Review: Related Research

- **Laboratory Studies**
  - Thresholds of Perception and Equal Annoyance Contours
  - Annoyance vs. Vibration Levels
  - Combined Effects of Noise and Vibration
- **Social Surveys**

Thresholds of Perception



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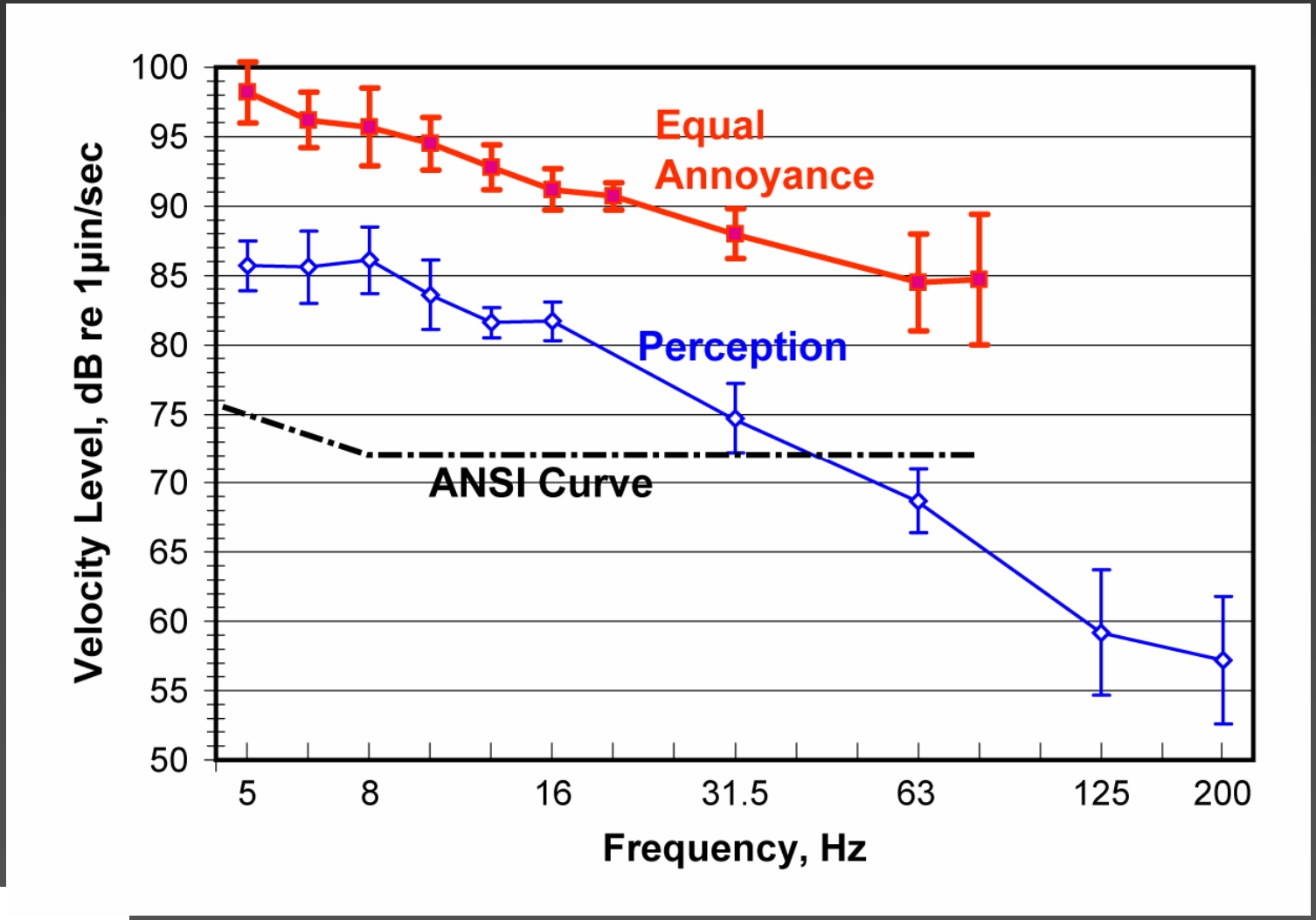
Annoyance vs. Frequency



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Surveys of Community Response 1

Scotland (Woodroof & Griffin, 1986)

- 459 interviews, 160 of whom noticed vibration
- 52 24-hour vibration measurements
- Conclusion: "…vibration is among the least annoying aspects of a railway's presence in a neighborhood."

Surveys of Community Response 2

Sweden (Öhrström, 1997)

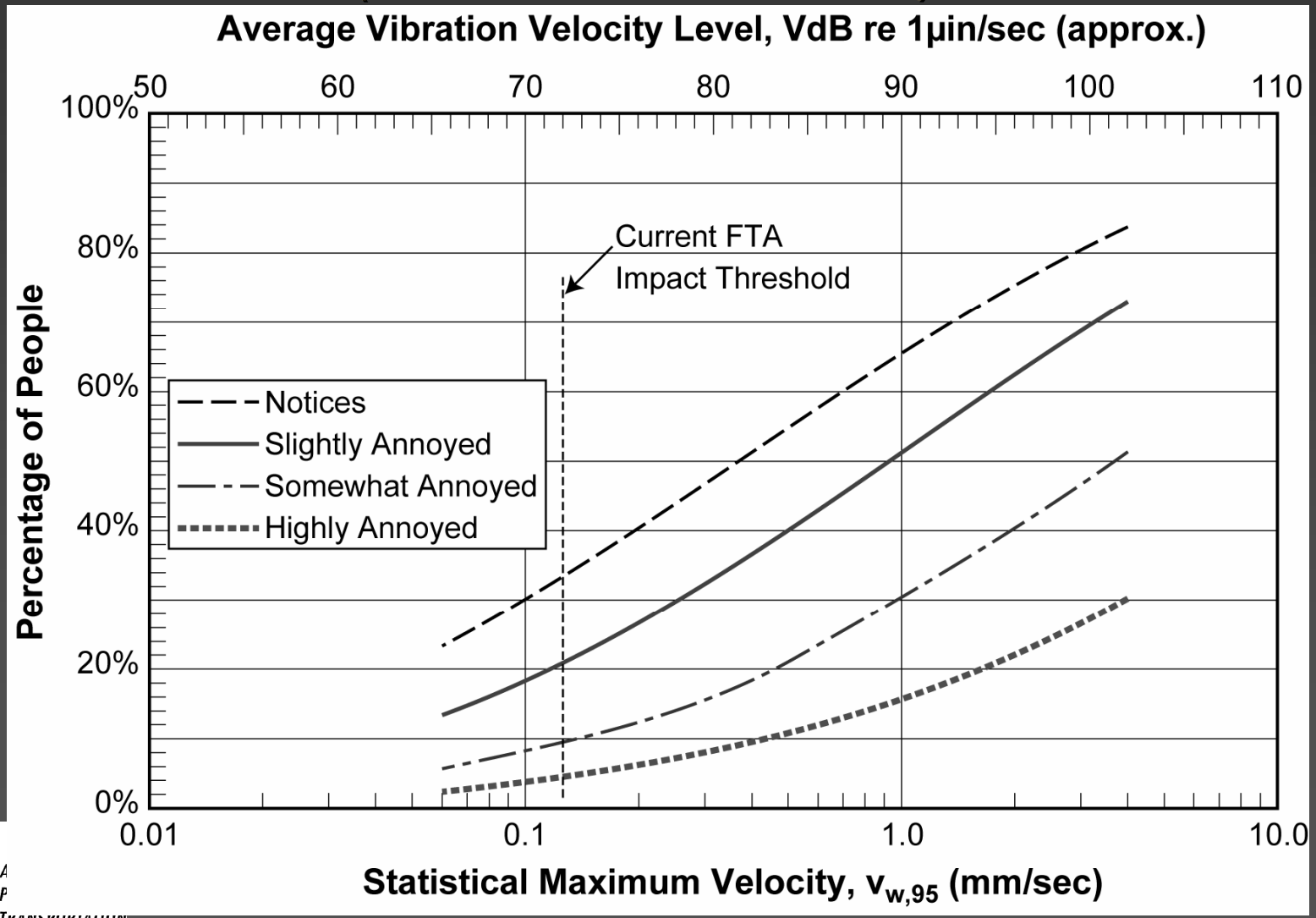
- Obtained from buildings where inhabitants had complained about vibrations
- Much higher vibration levels than in Scotland
- Wide variation in exposure-effect relationships

Surveys of Community Response 3

Norway (Klaeboe et al, 2003)

- 1500 telephone interviews
- Estimates of exposure
- Exposures ranging from below perception to 100 VdB

Annoyance vs. Vibration Level
(Klaeboe et al, 2003)



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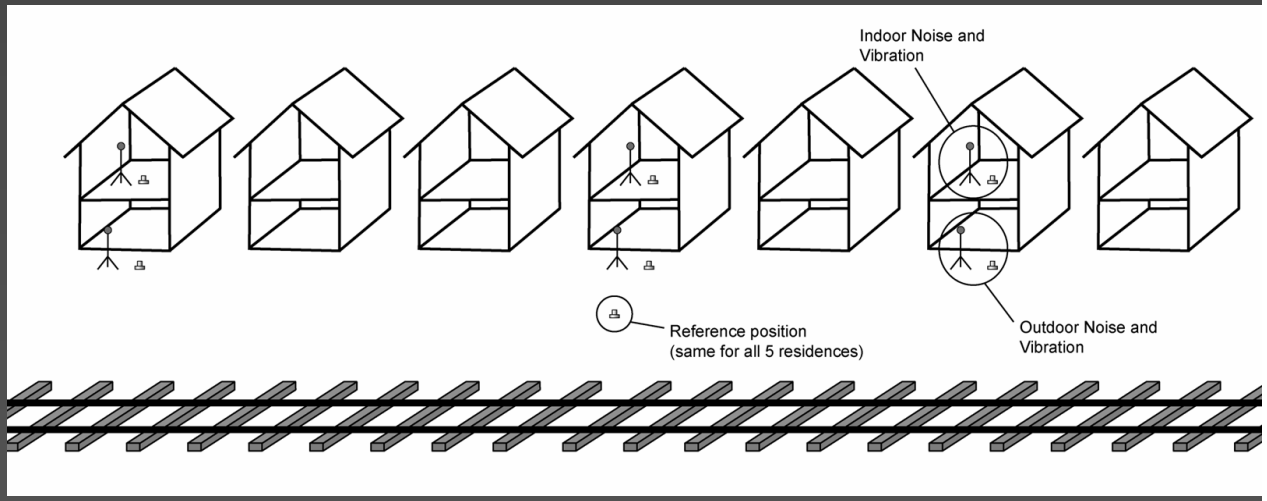
Phase 2 Testing

- Letter to GM requesting assistance
- Target is 2,000 telephone interviews in 20 neighborhoods
- Measurements inside 120 residences
- Standardized field procedures
- Record directly to computer files
- Computerized data analysis
- Results stored directly into database



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Potential Test Systems

Commuter Rail

- Metrolink (LA)
- Caltrain
- Chicago METRA
- MBTA
- Long Island RR
- Metro North
- GO Transit

Light Rail

8. Sacramento
9. LA Blue Line
10. DART (Dallas)
11. **SF MUNI**
12. San Jose
13. Hudson Bergen
14. MBTA Green Line

Rapid Transit

15. BART
16. CTA
17. TTC
18. NYCTA
19. WMATA
20. MBTA
21. SEPTA

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US Standards

Land Use Category	Vibration		Ground-Borne Noise	
	Frequent	In-frequent	Frequent	In-frequent
Category 1: Buildings where low ambient vibration is essential for interior operations.	65 VdB	65 VdB	--	--
Category 2: Residences and buildings where people normally sleep.	72 VdB	80 VdB	35 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use.	75 VdB	83 VdB	40 dBA	48 dBA

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Current Issues

- Standards Currently in Use
- Experience of North American Transit Systems
- Field Survey Procedures
  - Telephone Interviews
  - Where to measure noise/vibration
- How to Analyze Data

Survey Results

Type	Number with Minor Problems	Number with Major Problems
Light Rail	8	1
Heavy Rail	4	1
Commuter Rail	5	0

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