

APTA 2006 RAIL CONFERENCE

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

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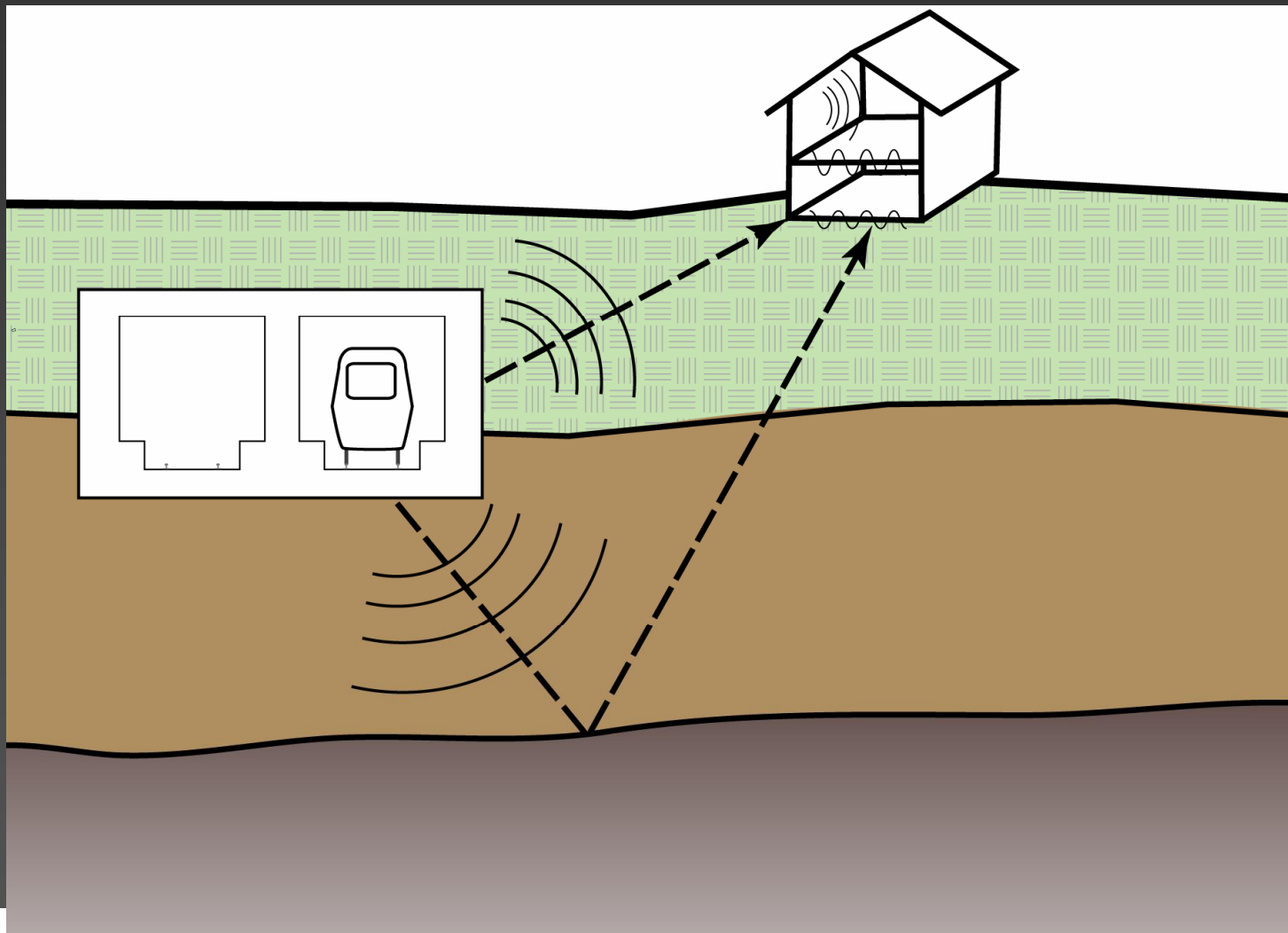
Fidell Associates

Sanford Fidell



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Ground Vibration



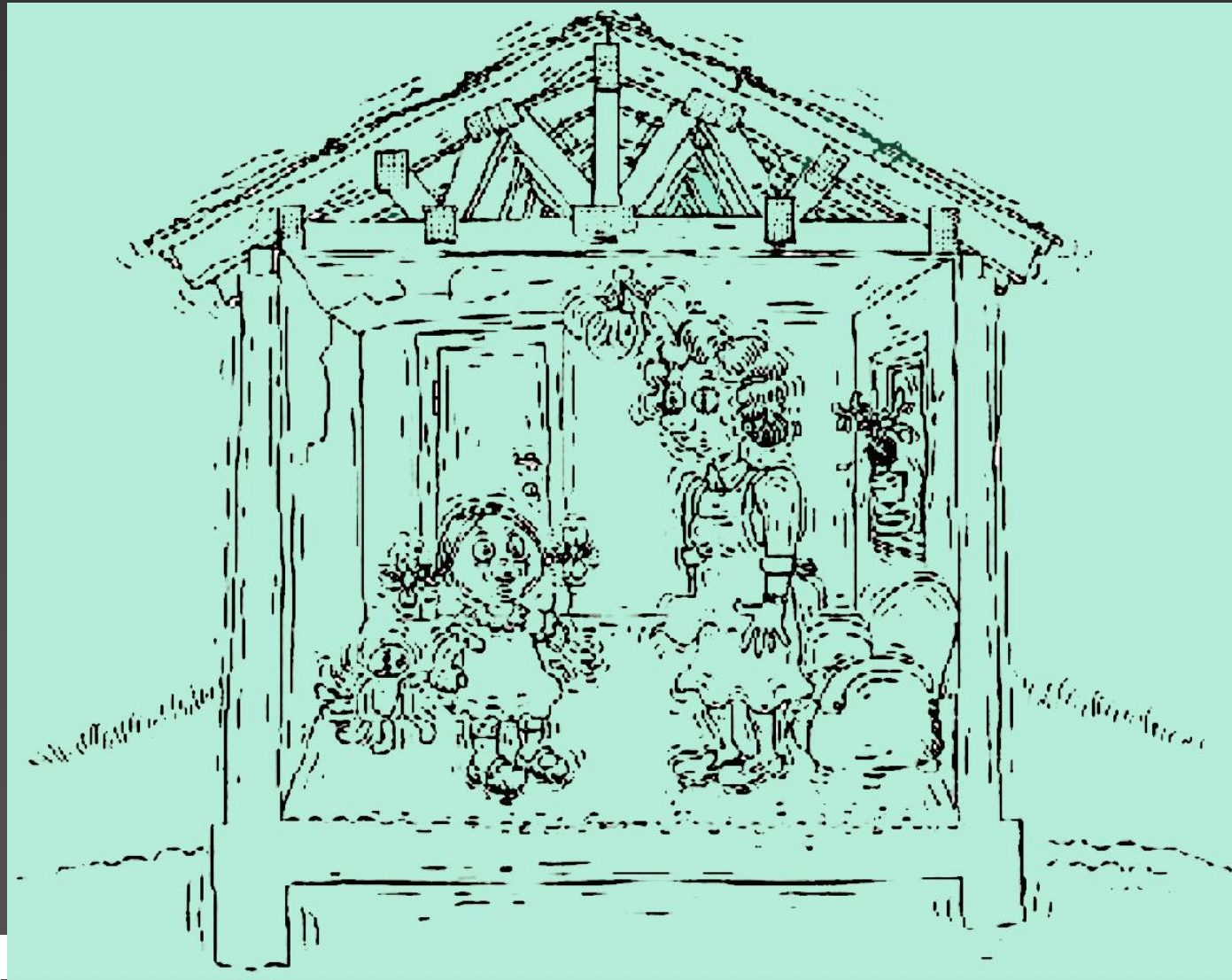
Shake, Rattle, and Rumble

- § 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?

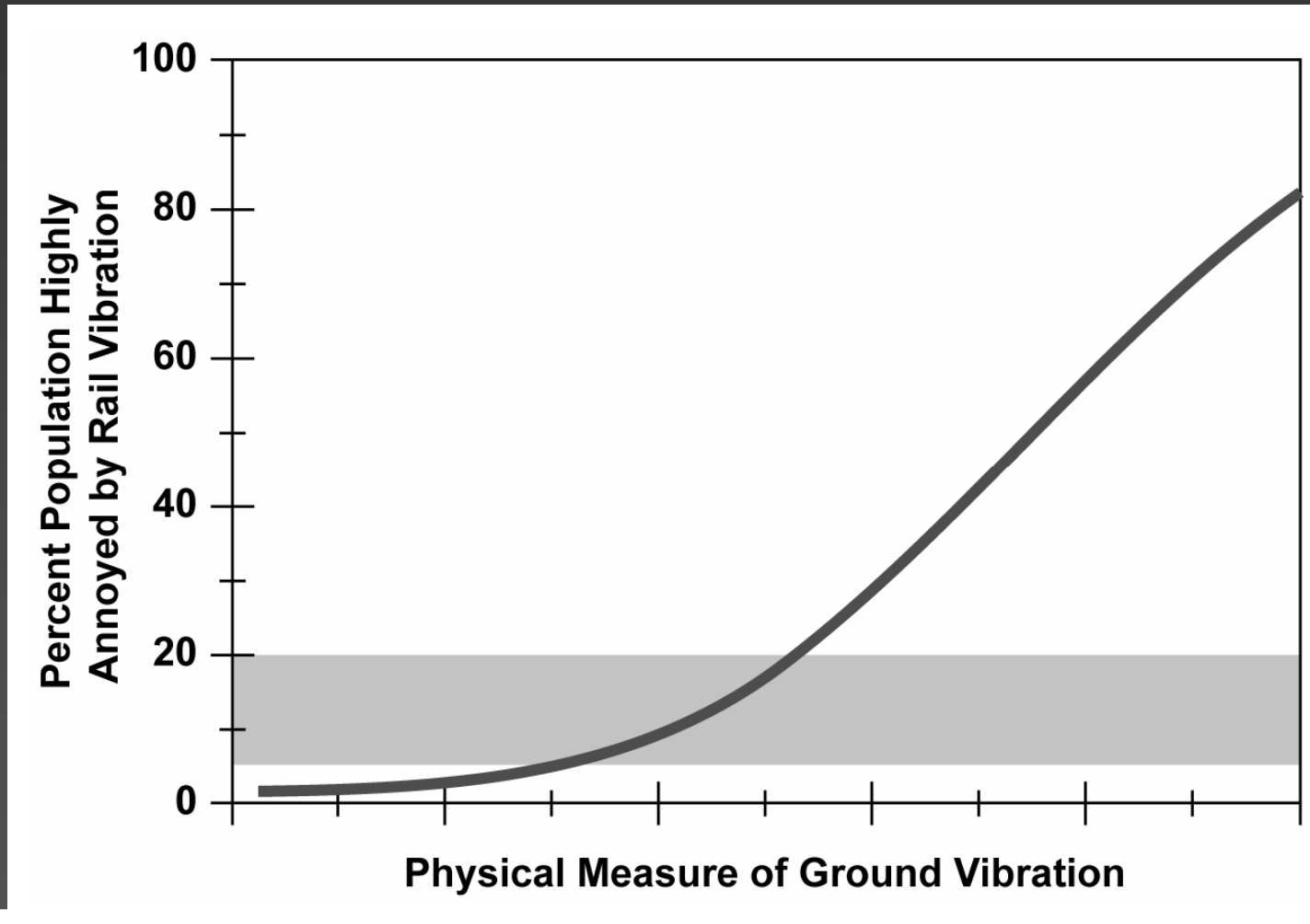


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Background

- § 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



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



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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



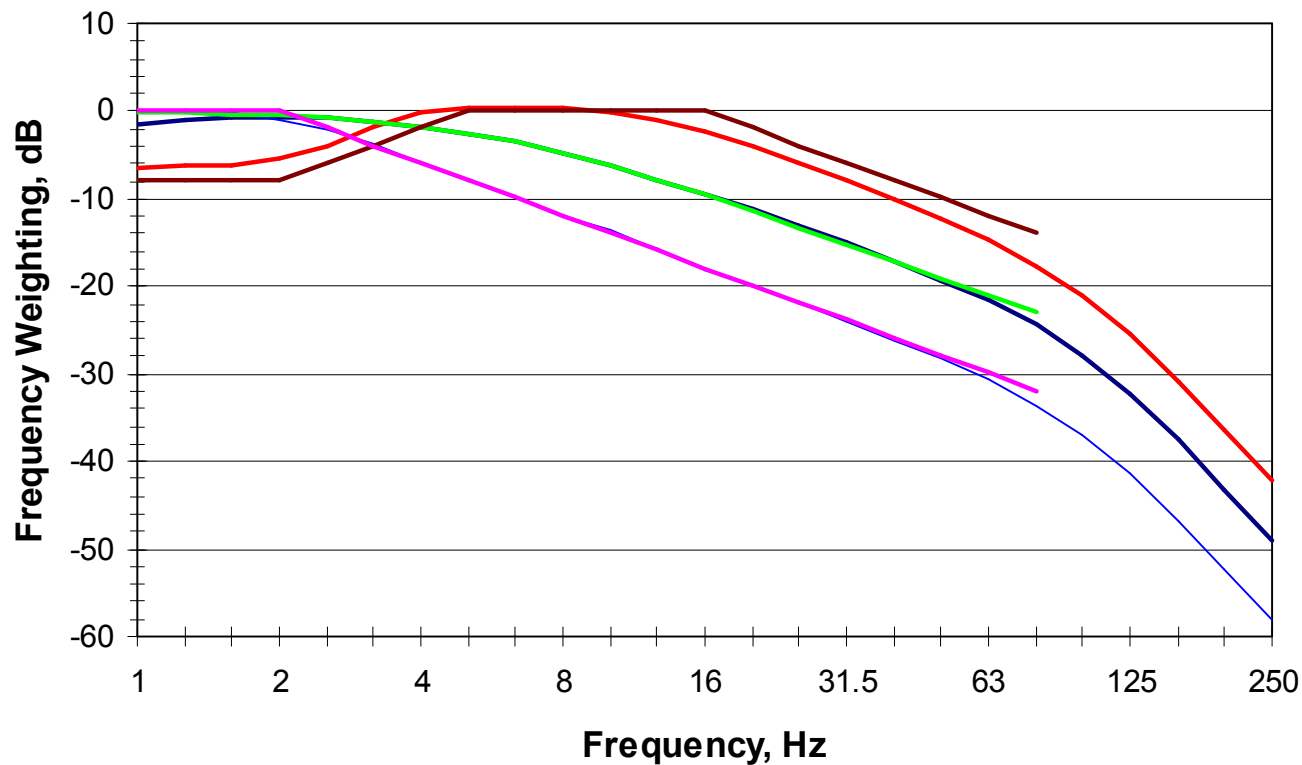
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Vibration Descriptors in Use

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

Acceleration Weighting Curves

Vibration Weighting Curves (Acceleration)



Wm (KB)

Wk (z)

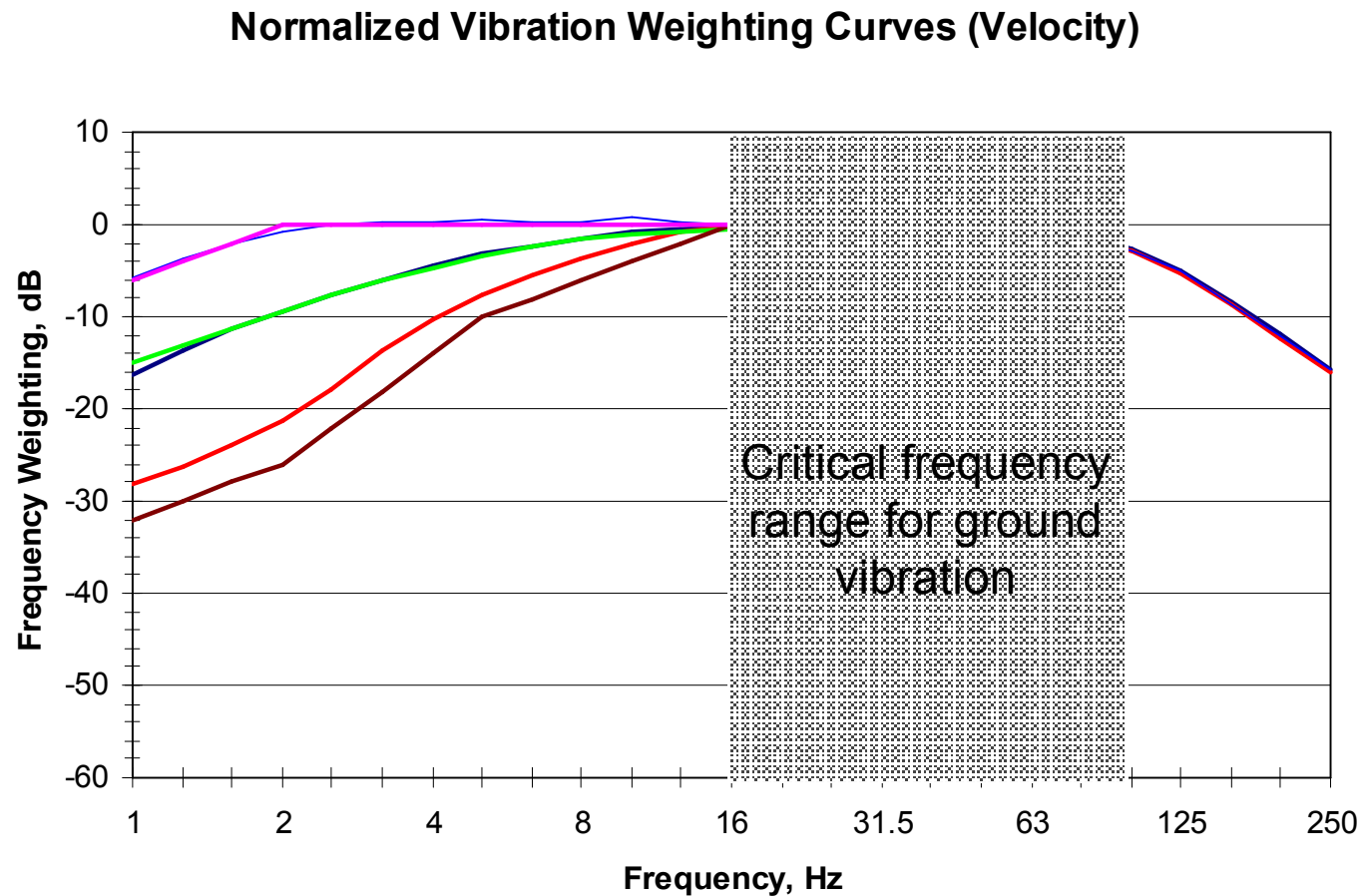
Wd (xy)

ANSI

BS(z)

BS(xy)

Normalized Velocity Weighting Curves



BS(xy)

Wb(xy)

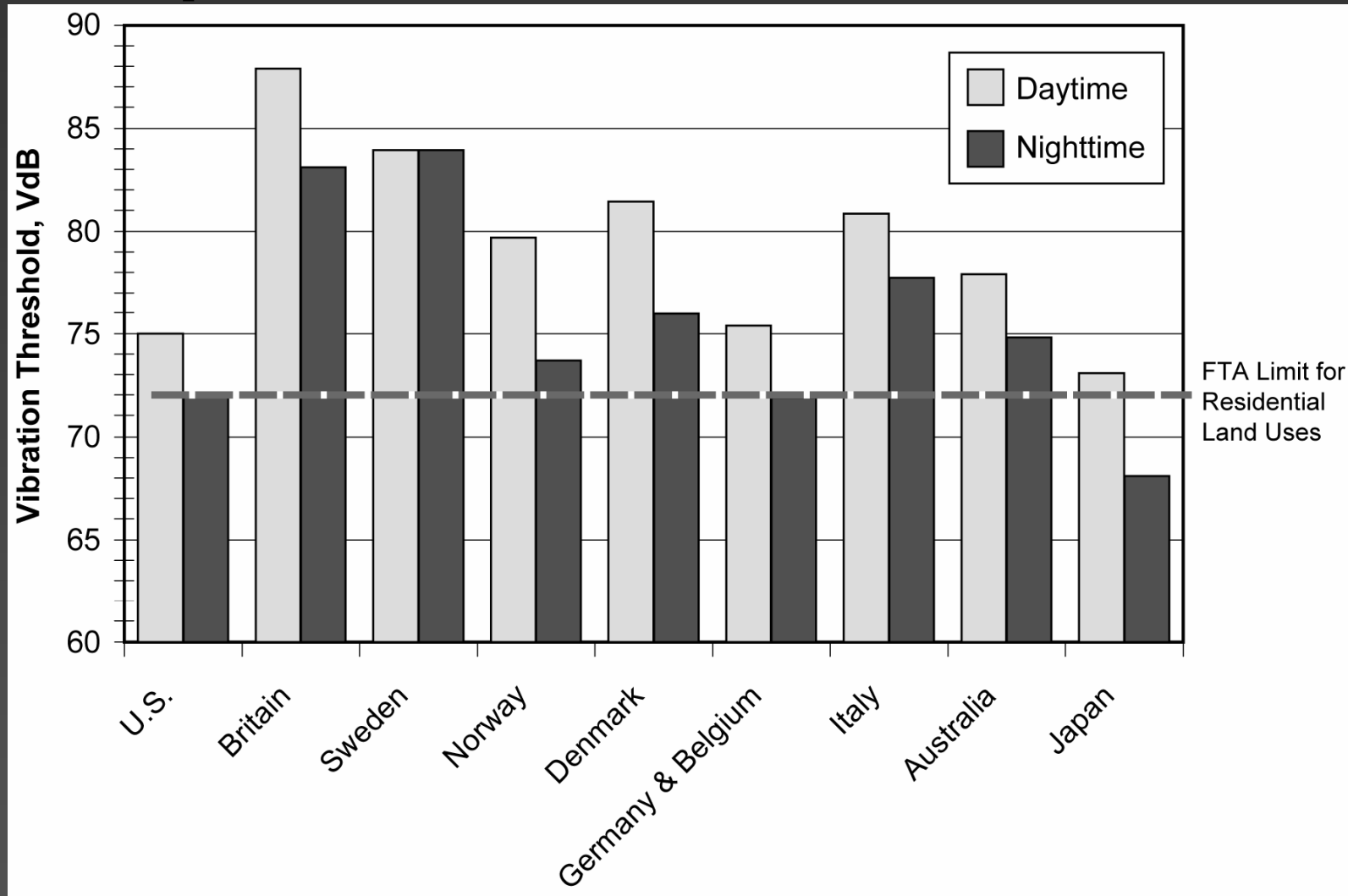
ANSI

Wm

Wk(z)

BS(z)

Comparison of Vibration Standards



Literature Review: Related Research

§ Laboratory Studies

§ Thresholds of Perception and Equal Annoyance Contours

§ Annoyance vs. Vibration Levels

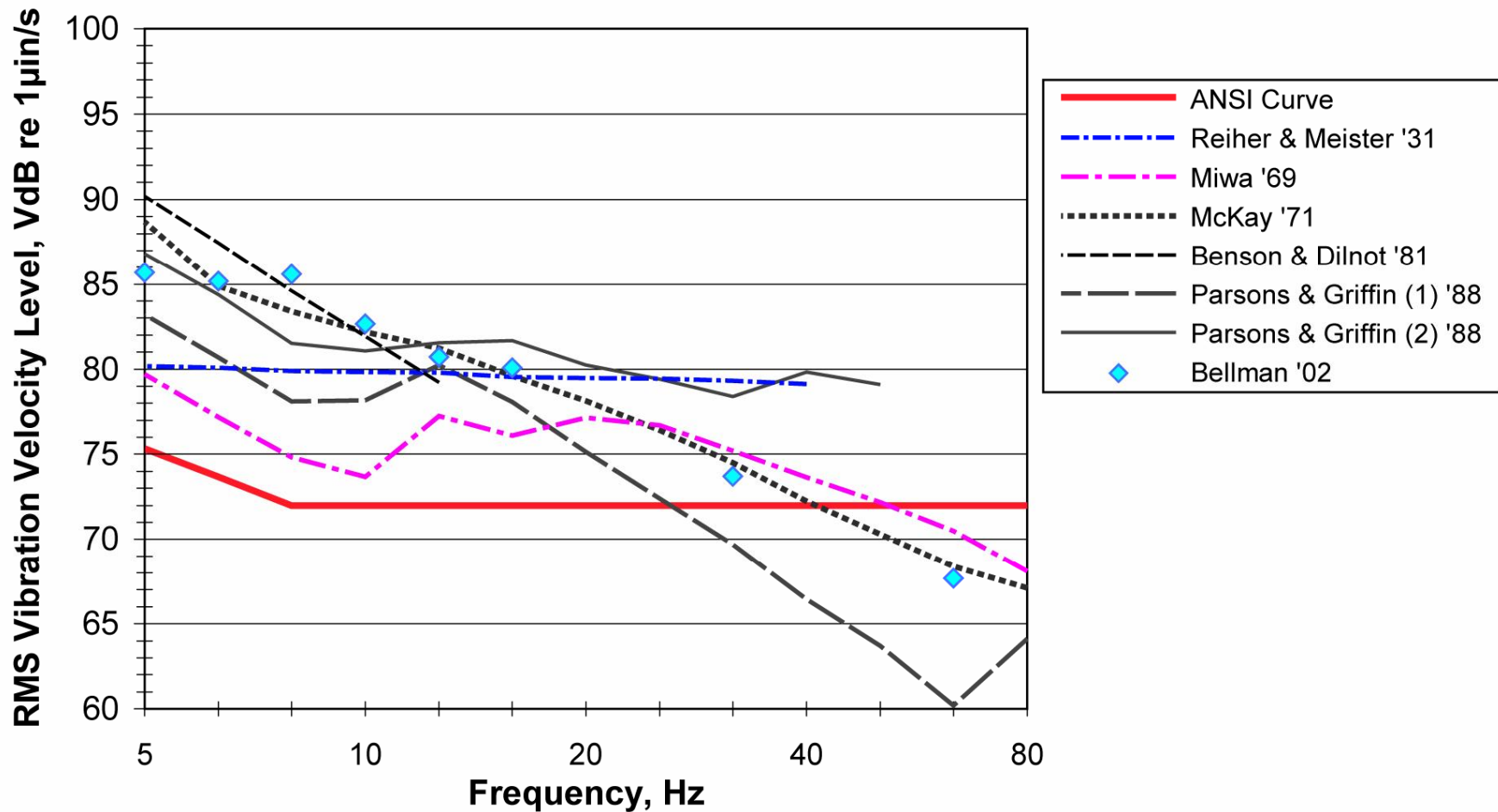
§ Combined Effects of Noise and Vibration

§ Social Surveys

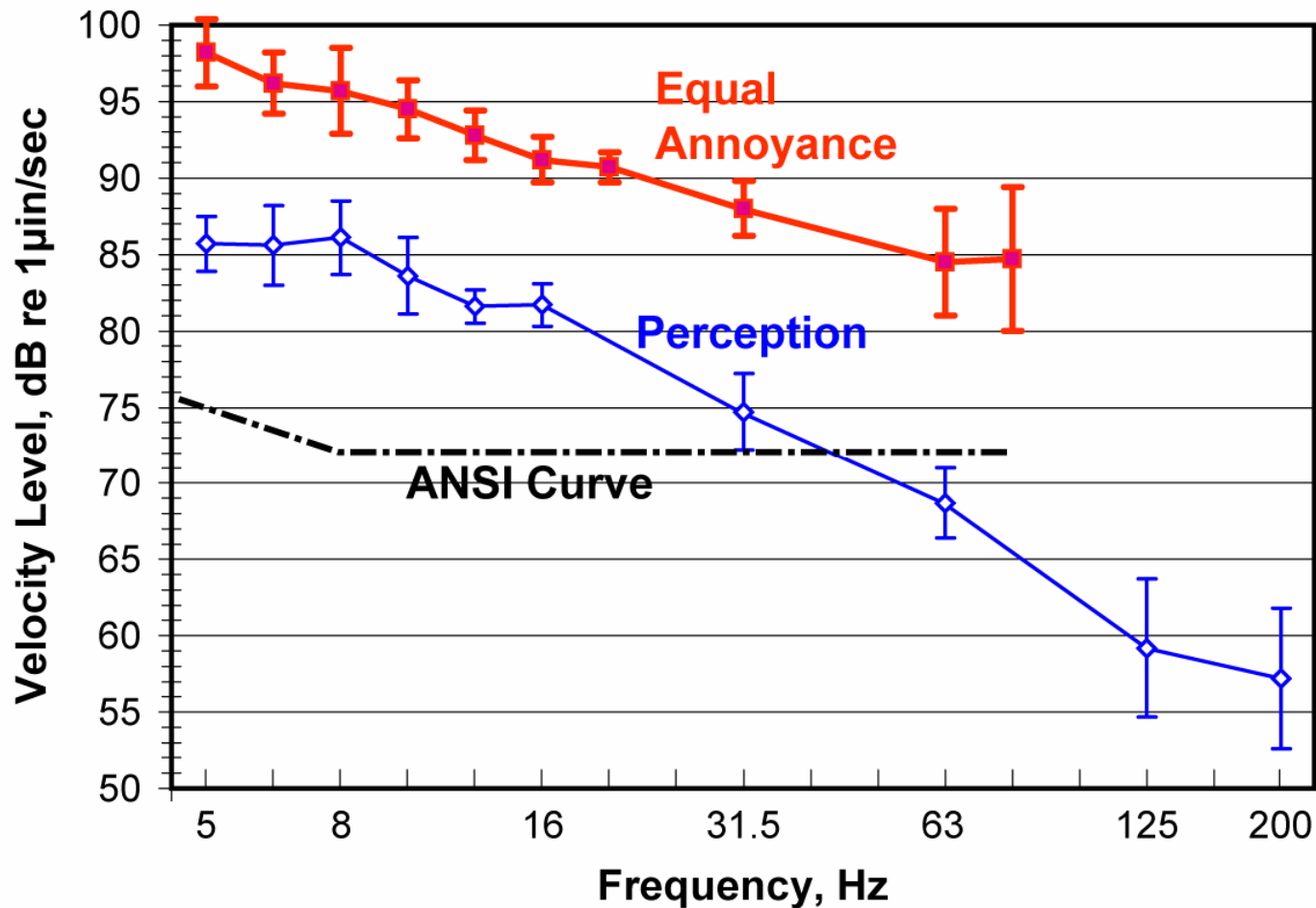


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Thresholds of Perception



Annoyance vs. Frequency



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."



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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

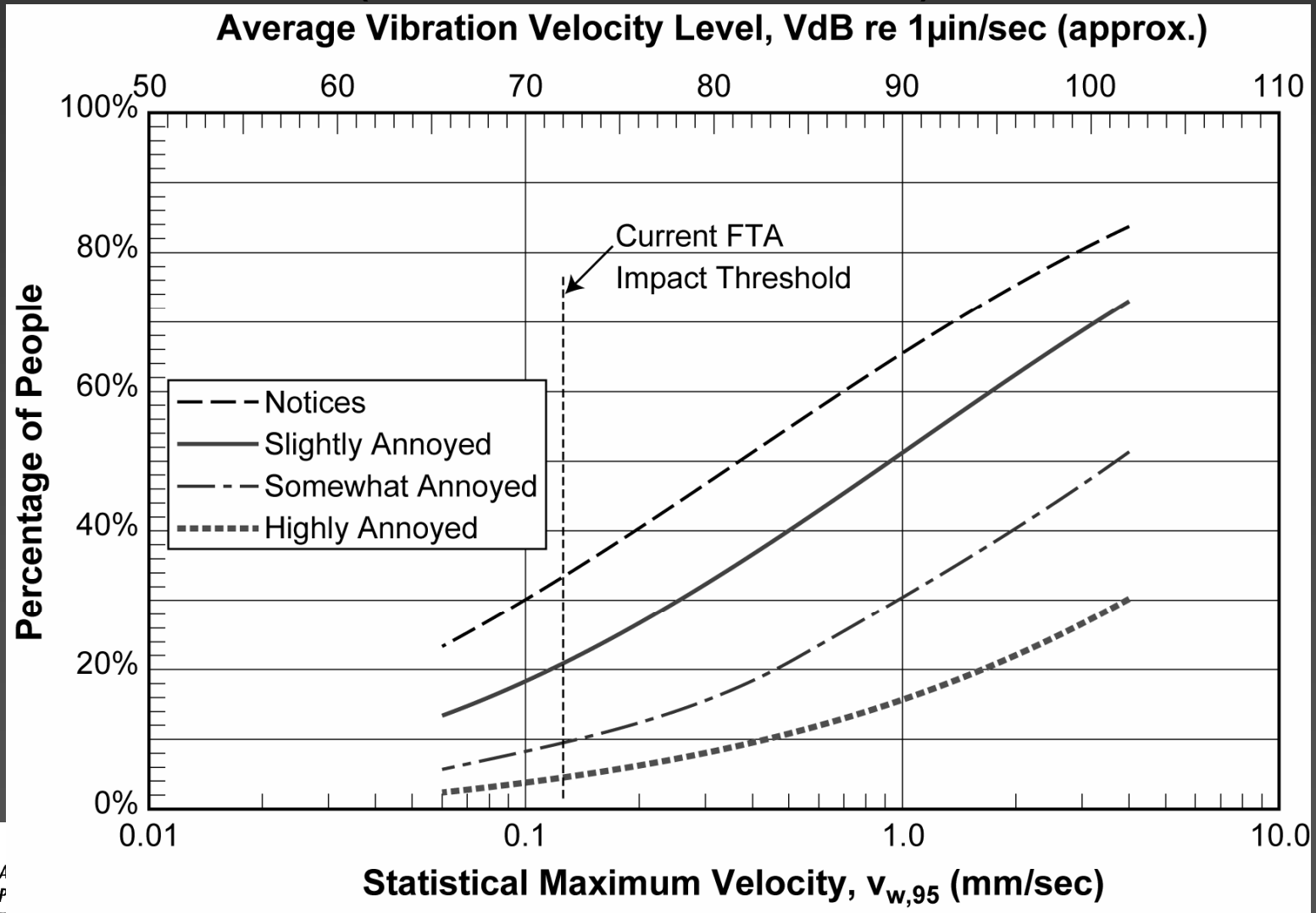
§ Exposures ranging from below
perception to 100 VdB



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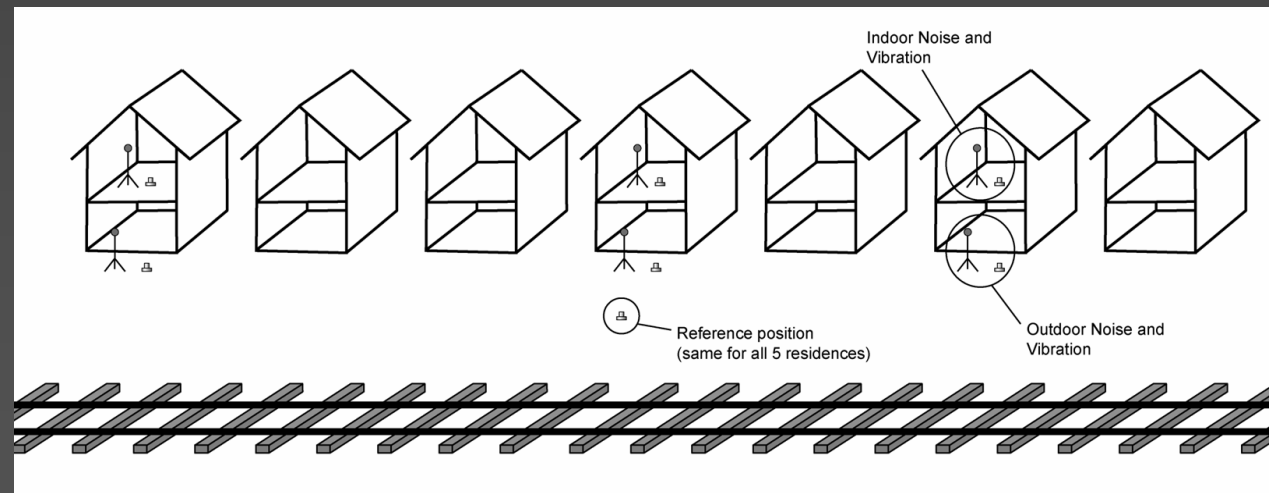
Annoyance vs. Vibration Level

(Klaeboe et al, 2003)



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



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



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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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