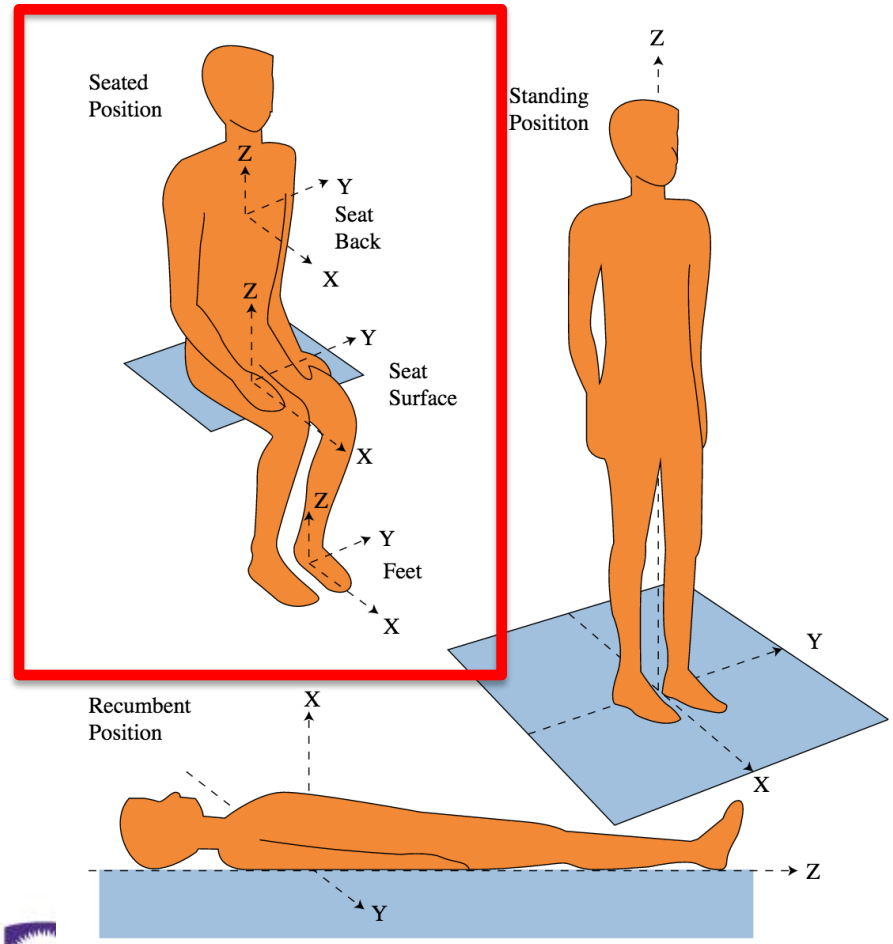
Whole-Body Vibration: What can we do to reduce this known health risk?

IWH Ergonomics/MSD plenary

Dr. Jim Dickey
Western University

October 25, 2016

What is Whole-body Vibration?

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Why
Whole-body Vibration?

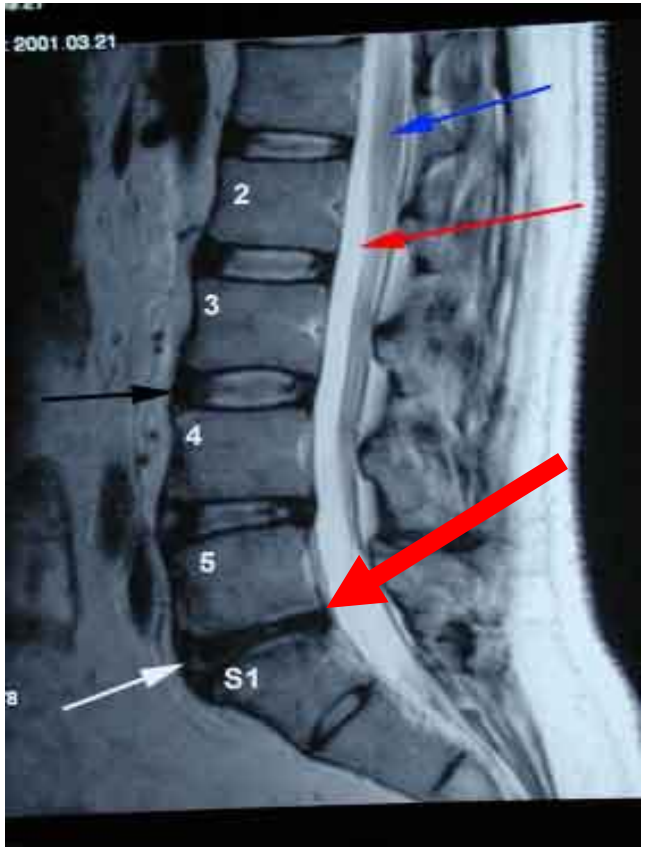
www.sflorg.com/spacenews/images/imsn091206_01_04.jpg

Why
Whole-body Vibration?

- Strong association between LBP and WBV (Bernard, 1997 - NIOSH)
- Dose-response relationship between WBV and driving-related LBP (Tiemessen et al., 2008)
- Between 4% and 7% of the work force in North America and Europe is exposed to potentially harmful levels of whole-body vibration (Bovenzi, 1996; Wasserman et al., 1997)

Mechanism: LBP and Injury

Whole-body Vibration?



www.spinespecialtyinstitute.com/spineinstitute/images/ddd1.jpg

How (to measure) Whole-body Vibration?

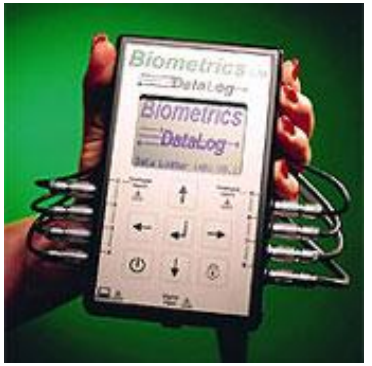
International Standards: ISO 2631-1

Tri-axial accelerometer mounted in rubber seat pad

Seat pad positioned on vehicle seat

Accelerometer on the floor below the seat

Data-logger used to record the vibration data collected in the field



How (to evaluate) Whole-body Vibration?

International Standards: ISO 2631-1

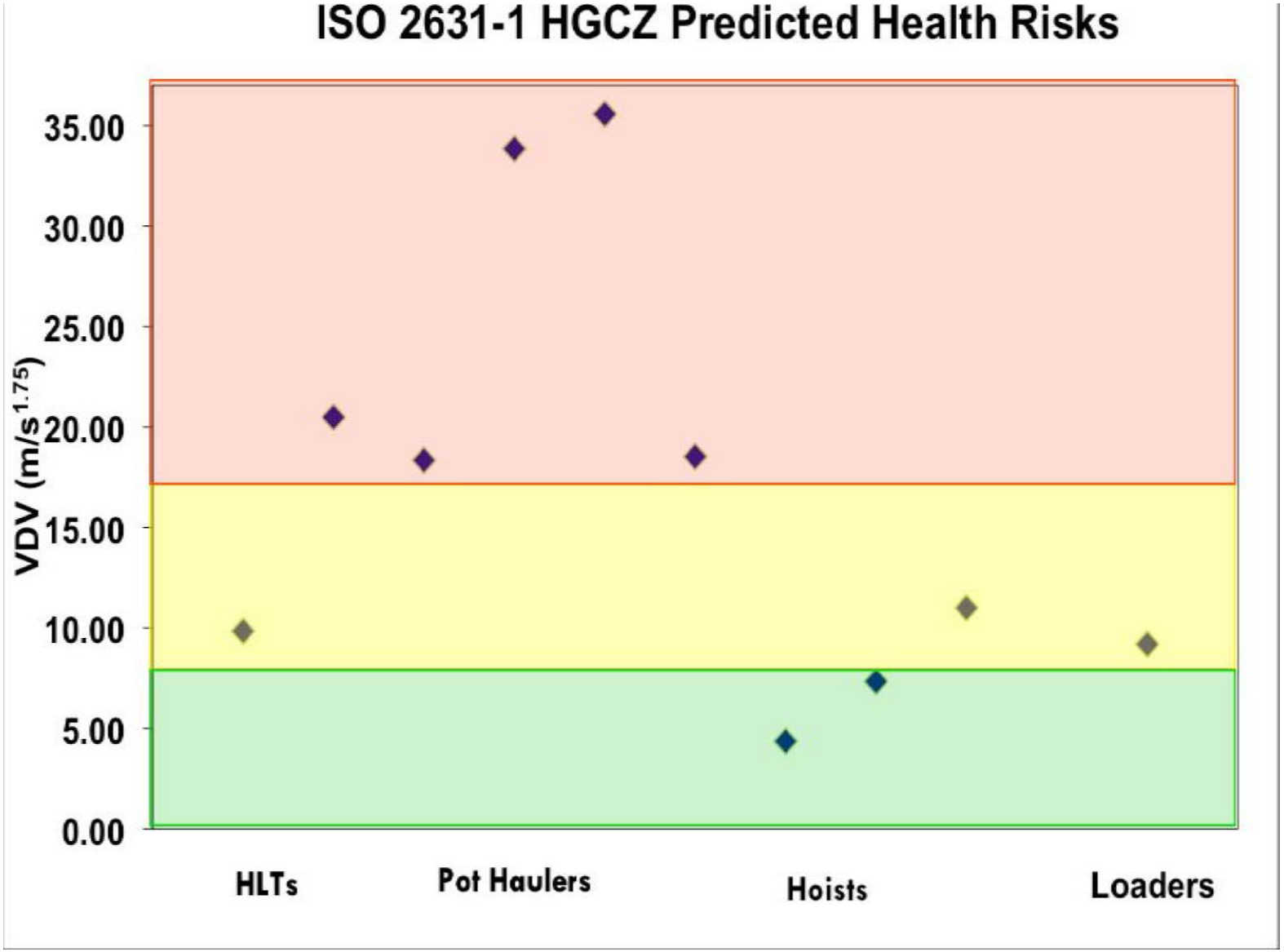
Average

$$A_w = \left[\frac{1}{T} \int_0^T a_w^2(t)\, dt \right]^{\frac{1}{2}}$$

Impulsive

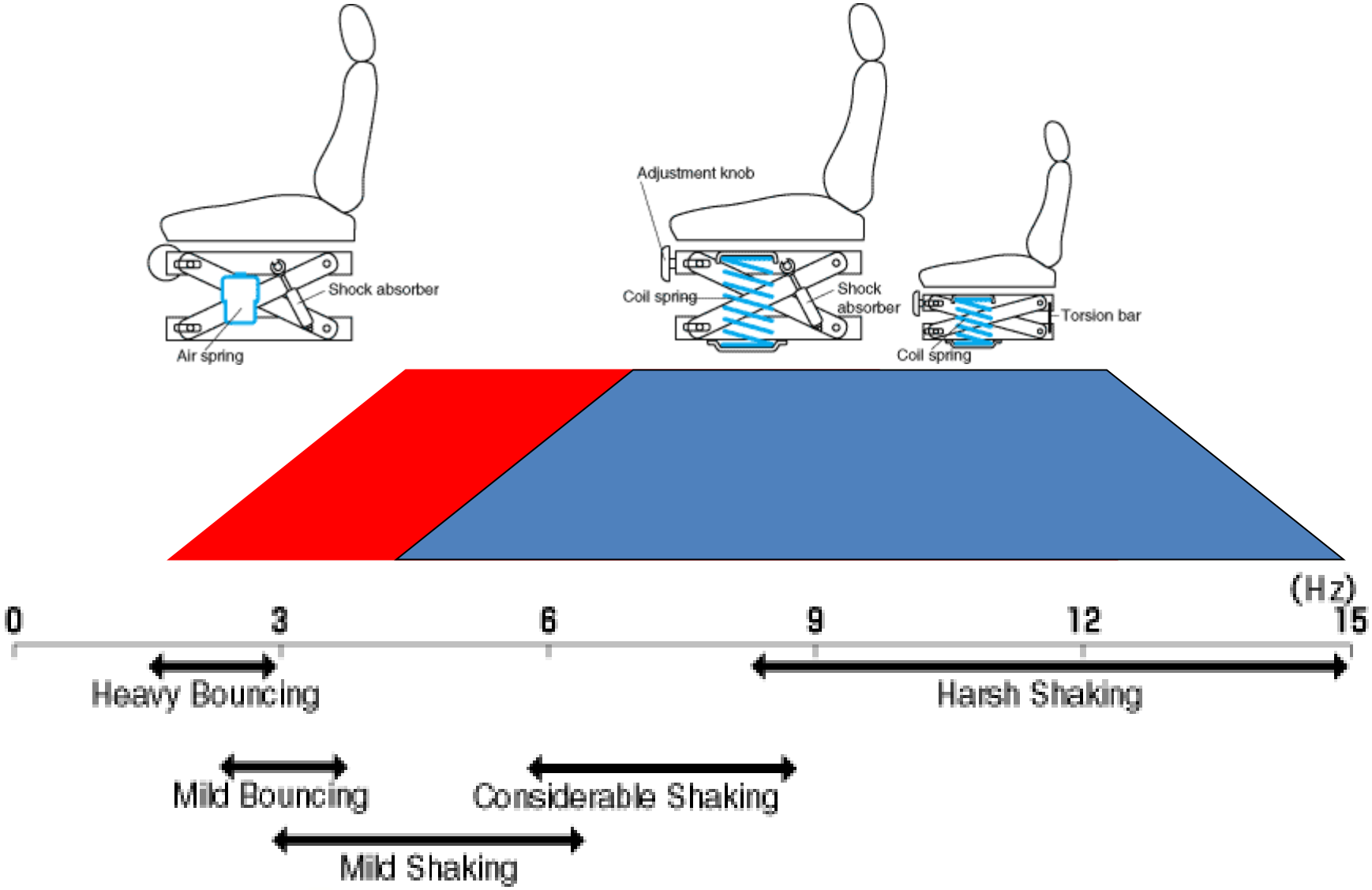
$$\mathrm{VDV} = \left\{ \int_0^T [a_w(t)]^4 \, dt \right\}^{1/4}$$

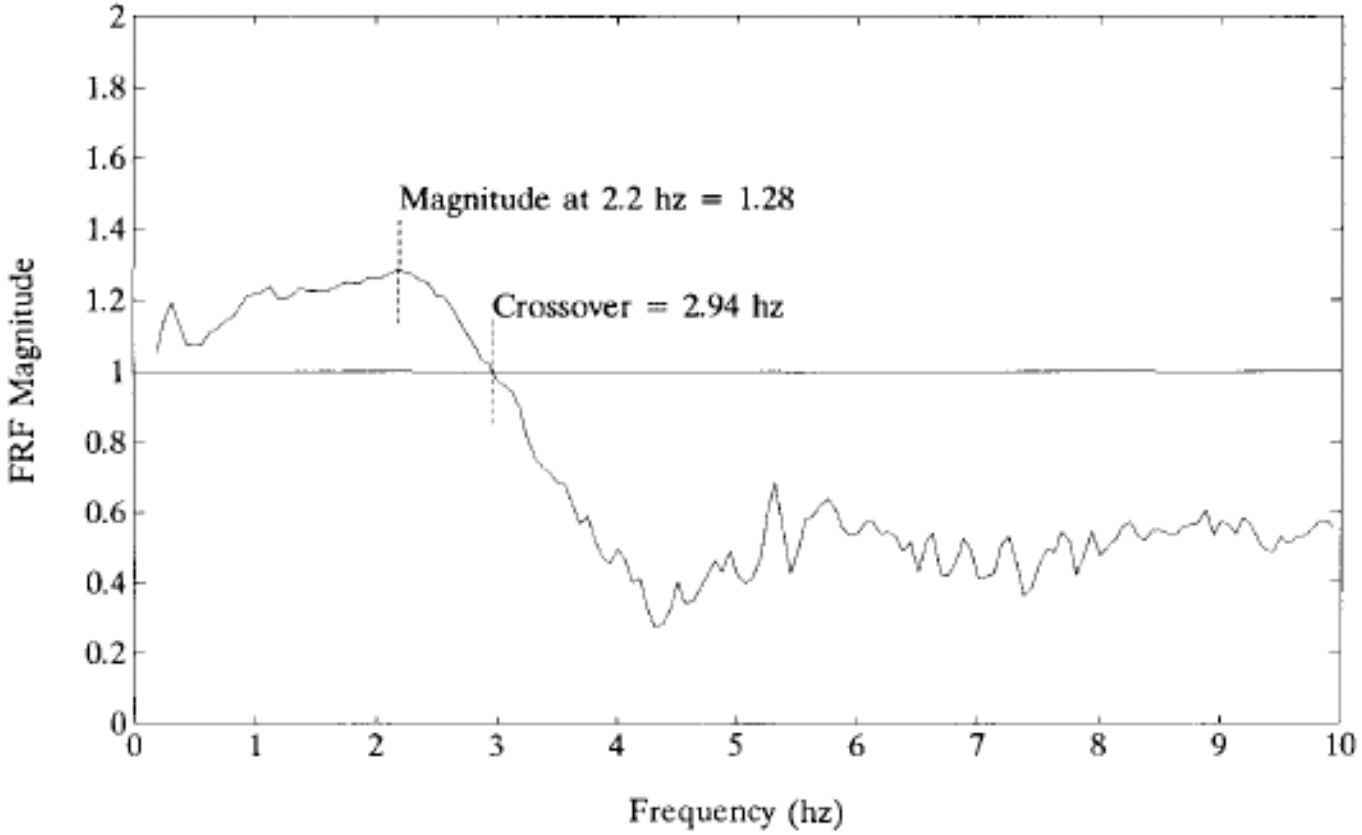
	8 hrs of Exposure	
	Aw (m/s^2)	VDV ($m/s^{1.75}$)
Action	**0.45**	**8.5**
Limit	**0.9**	**17**


ISO 2631-1 HGCZ Predicted Health Risks
VDV (m/s1.75)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
HLTs
Pot Haulers
Hoists
Loaders

How to Reduce Whole-body Vibration?

- **Vehicle Speed**
- **Road Maintenance**
- **Seating**


Shock absorber
Air spring
Adjustment knob
Coil spring
Shock absorber
Torsion bar
Coil spring
(Hz)
0
3
6
9
12
15
Heavy Bouncing
Harsh Shaking
Mild Bouncing
Considerable Shaking
Mild Shaking



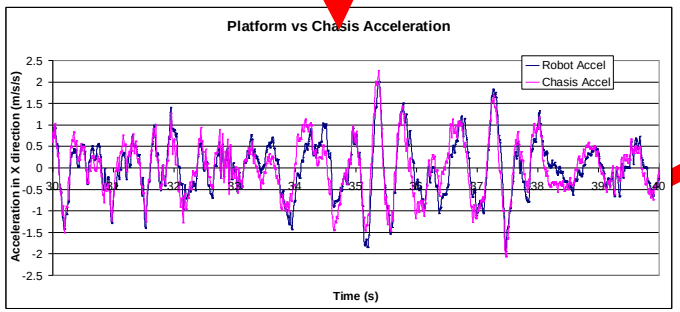
Wegscheid Journal of Forest Engineering 5(2)21-32, 1994

Western

Dr Jim Dickey

WBV & Optimized Seating

First Approach:
Laboratory Testing



A

B

C

D

E

F

G

H

I

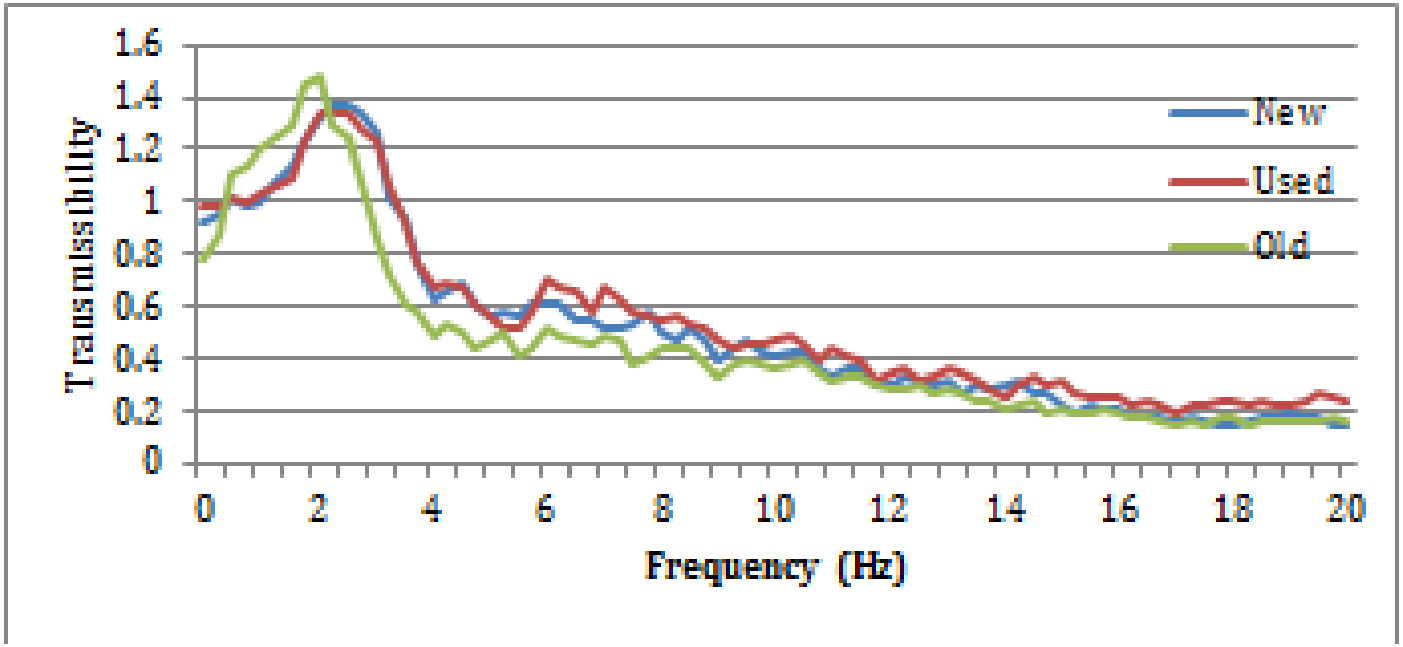


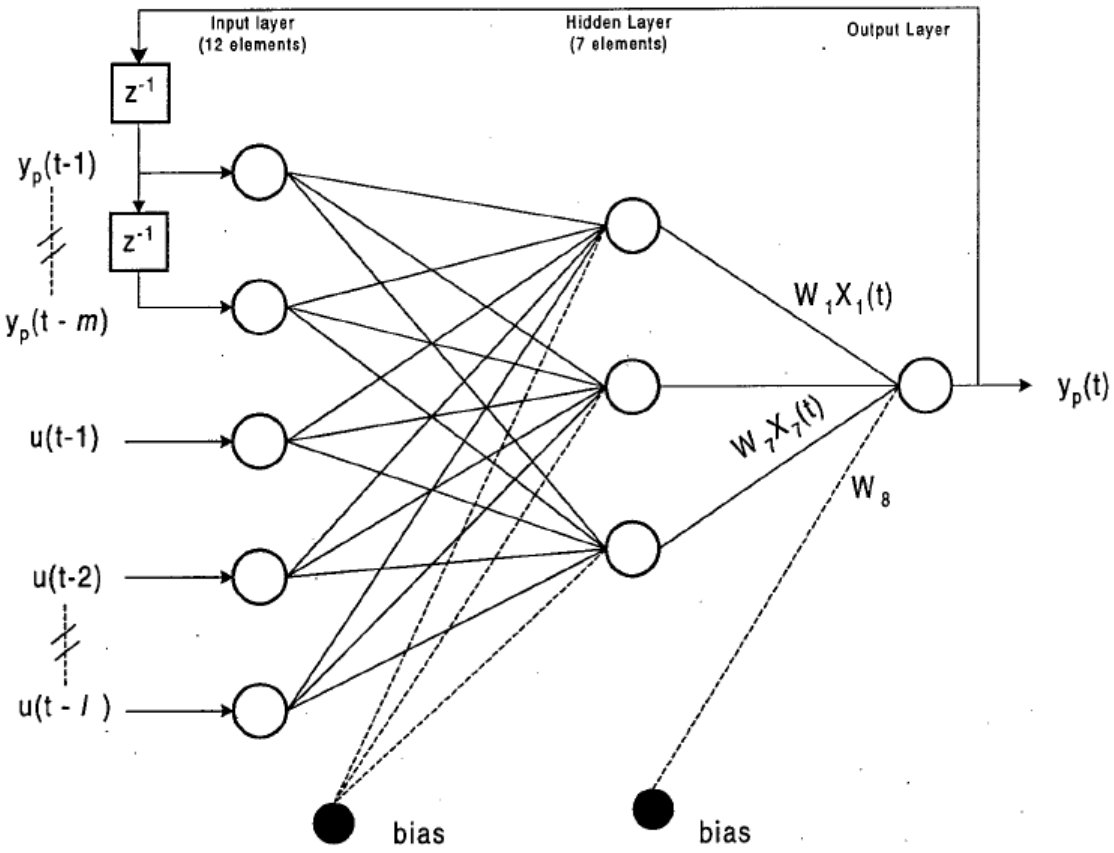
Figure 11 – Transfer functions in the Z-axis for the Access seats (new, used, and old condition). The transfer function for the old condition seat has a higher peak in transmissibility at a lower frequency than the new and used condition seats, and the transmissibility drops more quickly at a lower frequency.

A(8) HGCZ 0.45-0.9 m/s^2

Skidders	A(8) (m/s^2)				
	Access	Amobi	CAT	KAB301	KAB525
S1	**0.76**	0.9	**0.61**	**0.75**	**0.83**
S2	**0.76**	**0.86**	**0.63**	**0.73**	**0.84**
S3	**0.75**	**0.89**	**0.74**	**0.84**	**0.82**
S4	1.3	1.54	0.9	1.32	1.54
S5	1.07	1.24	**0.79**	1.07	1.26
S6	0.99	1.21	**0.62**	1.02	1.17
S7	**0.83**	0.9	**0.69**	**0.78**	0.9
S8	0.9	1.07	**0.59**	0.93	1.04

LHDs	A(8) (m/s^2)				
	Access	Amobi	CAT	KAB301	KAB525
M1	1.1	1.2	1.18	**0.8**	0.96
	1.03	1.04	1.05	**0.7**	**0.89**
M2	0.97	0.99	1.09	**0.69**	**0.85**
M3	1.05	1.07	**0.77**	**0.82**	1.1
M4	**0.53**	**0.53**	**0.39**	**0.56**	**0.62**
M5	1.82	1.73	1.34	1.29	1.78
M6	1.47	1.42	1.27	1.05	1.37
M7	1.63	1.58	1.48	1.18	1.46
M8	1.16	1.14	1.03	**0.77**	1.05
M9	1.76	1.73	1.39	1.43	1.71
M10	1.52	1.54	1.51	1.39	1.44

Ji, X., et al. (2015) and Ji, X., et al. (2016)


Input layer
(12 elements)
Hidden Layer
(7 elements)
Output Layer
z-1
z-1
yp(t-1)
yp(t - m)
u(t-1)
u(t-2)
u(t - l)
W1X1(t)
W7X7(t)
W8
yp(t)
bias
bias

Second Approach:
Field Testing

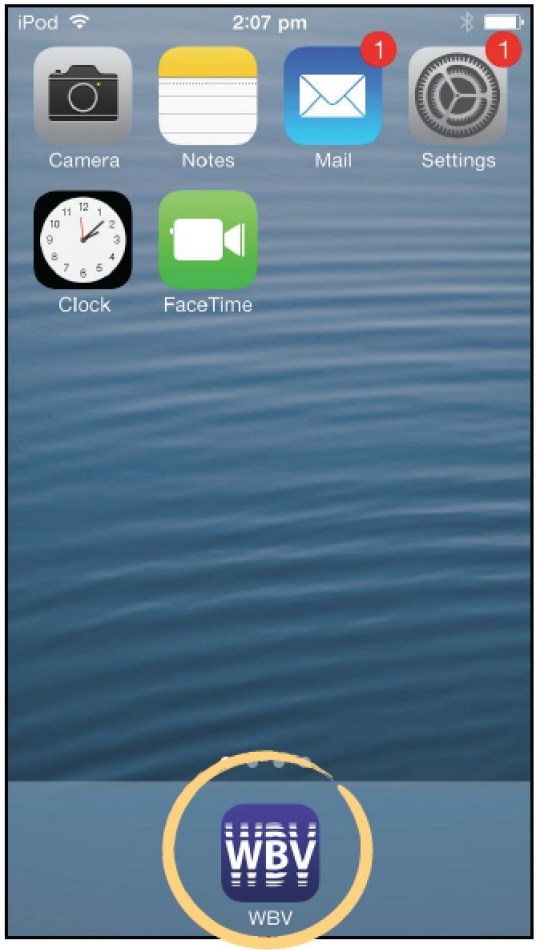
Also in steel making industry:

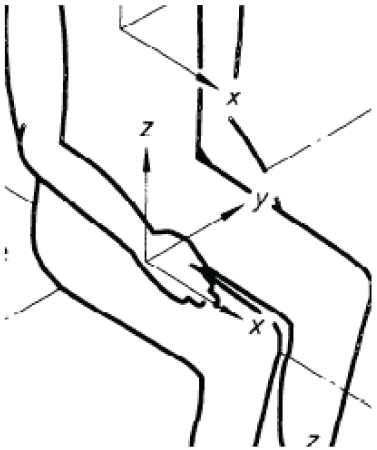
Conrad, L. F., et al. (2014). "Selecting seats for steel industry mobile machines based on seat effective amplitude transmissibility and comfort." Work 47(1): 123-136.

Oliver, M., et al. (2016). "Reducing whole-body vibration through field vibration tested heavy equipment seat retrofitting." Occupational Ergonomics 13(1): 15-22.

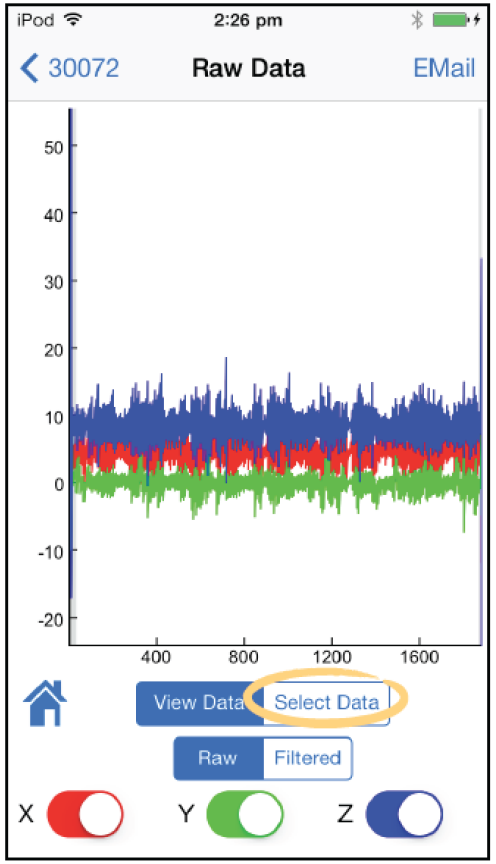
Seatpan Accelerations:

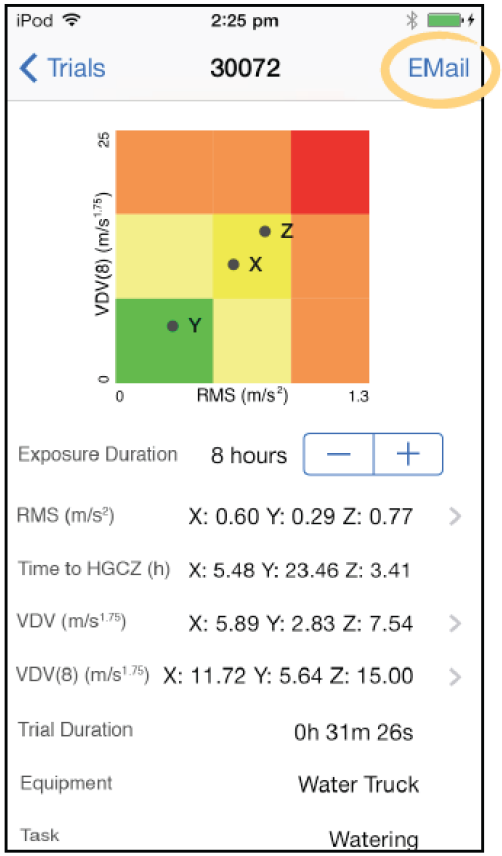
iPod and WBV App:



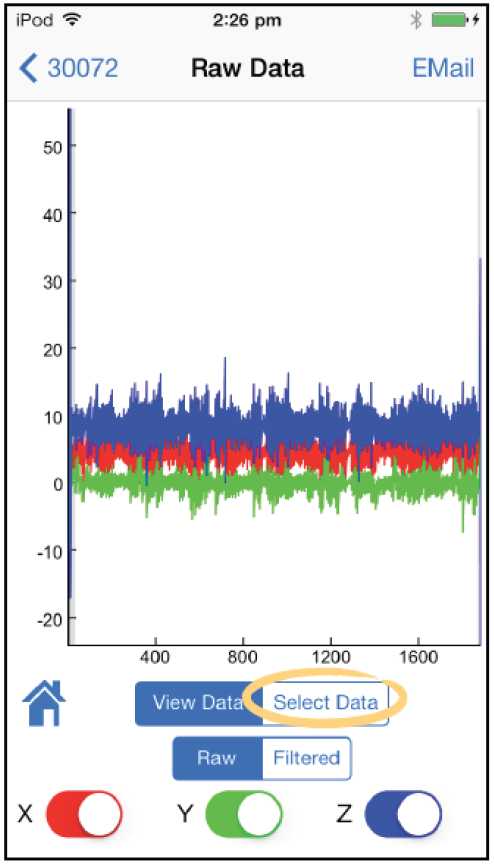


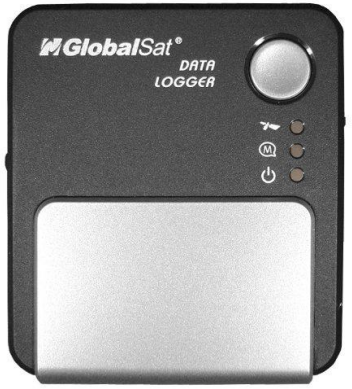
iPod and WBV App:





Instrumentation:

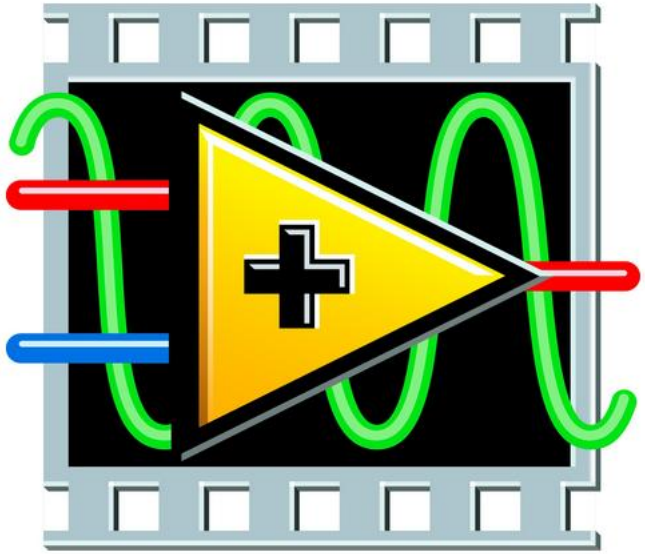




GPS ↓ 5 Hz

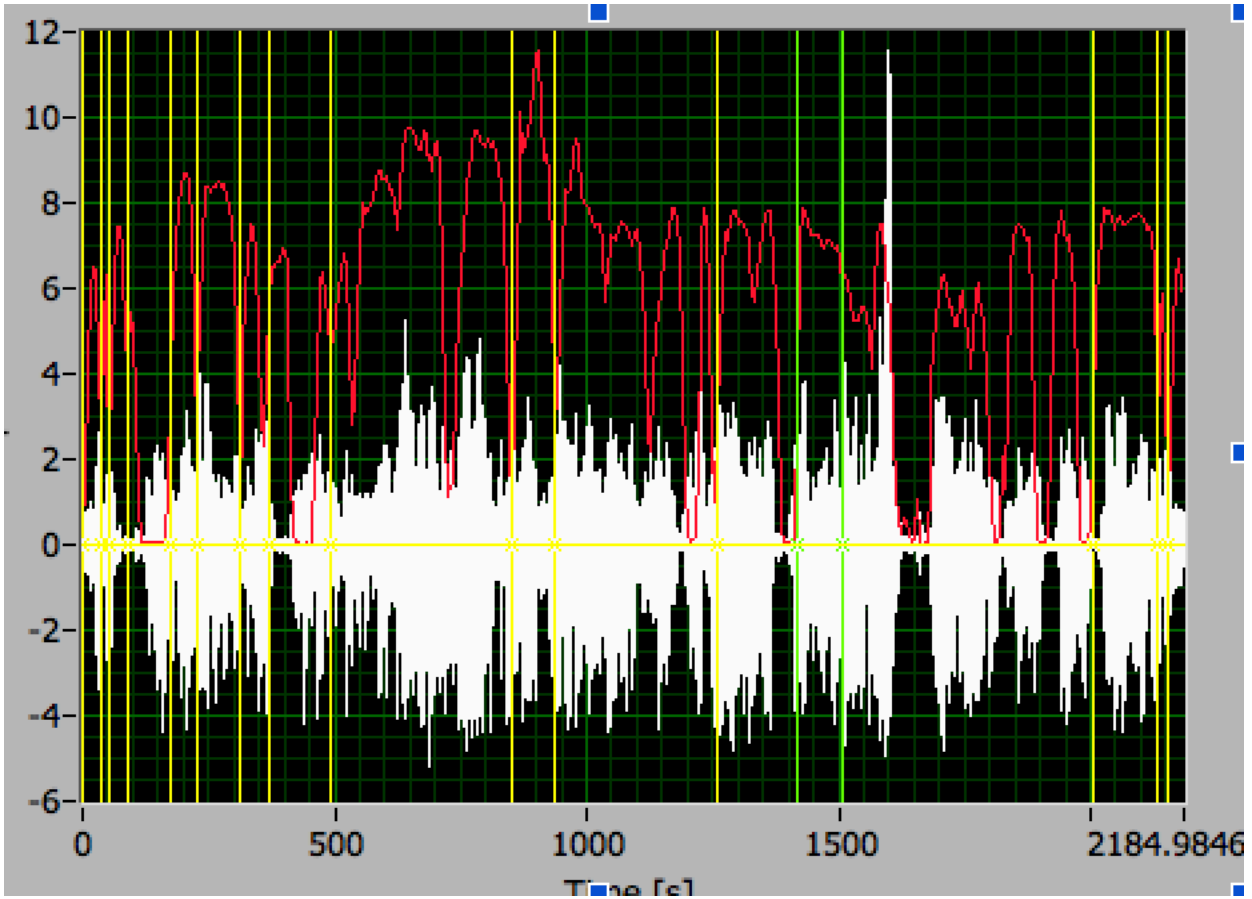
90 Hz →

vibration

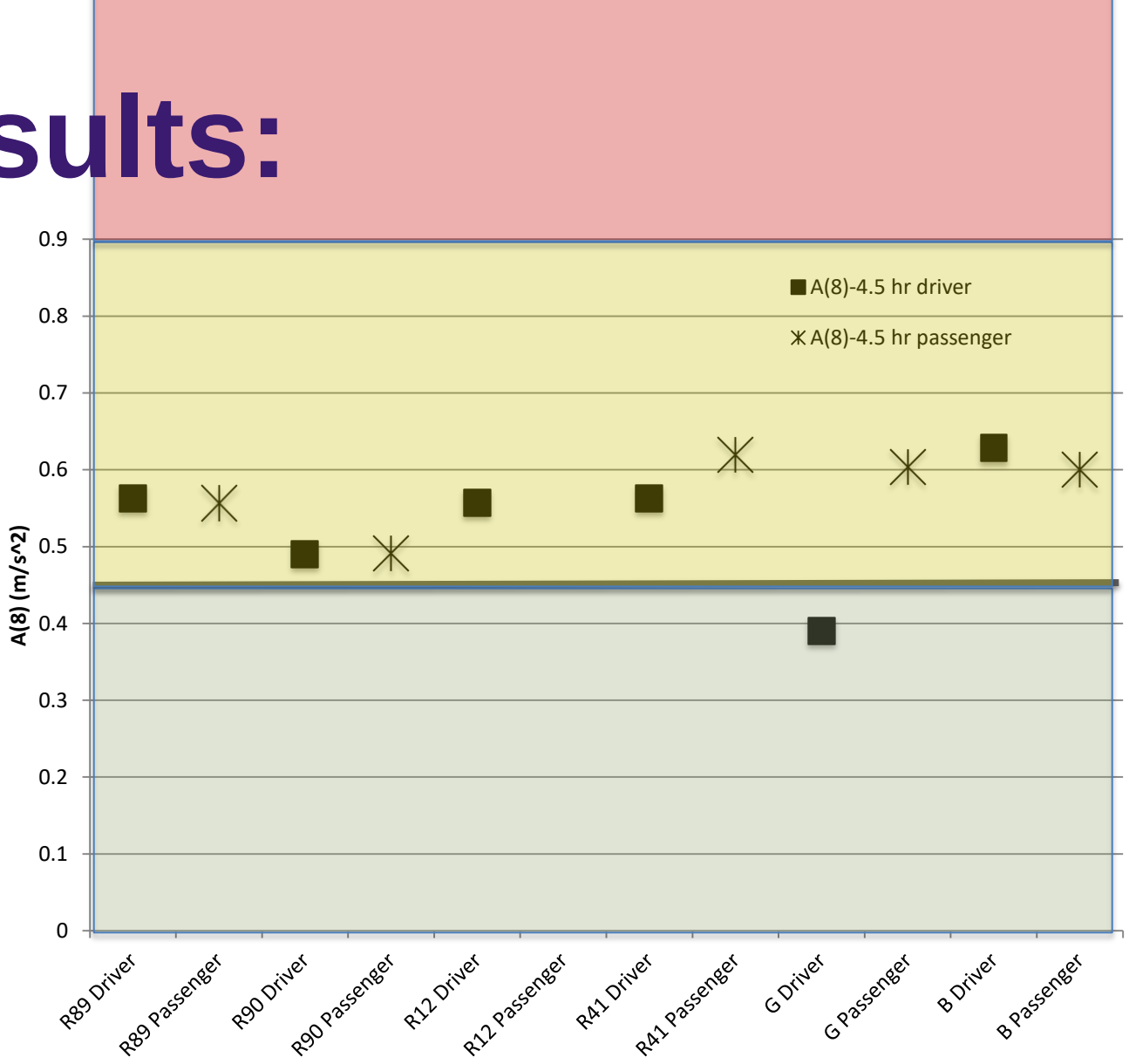


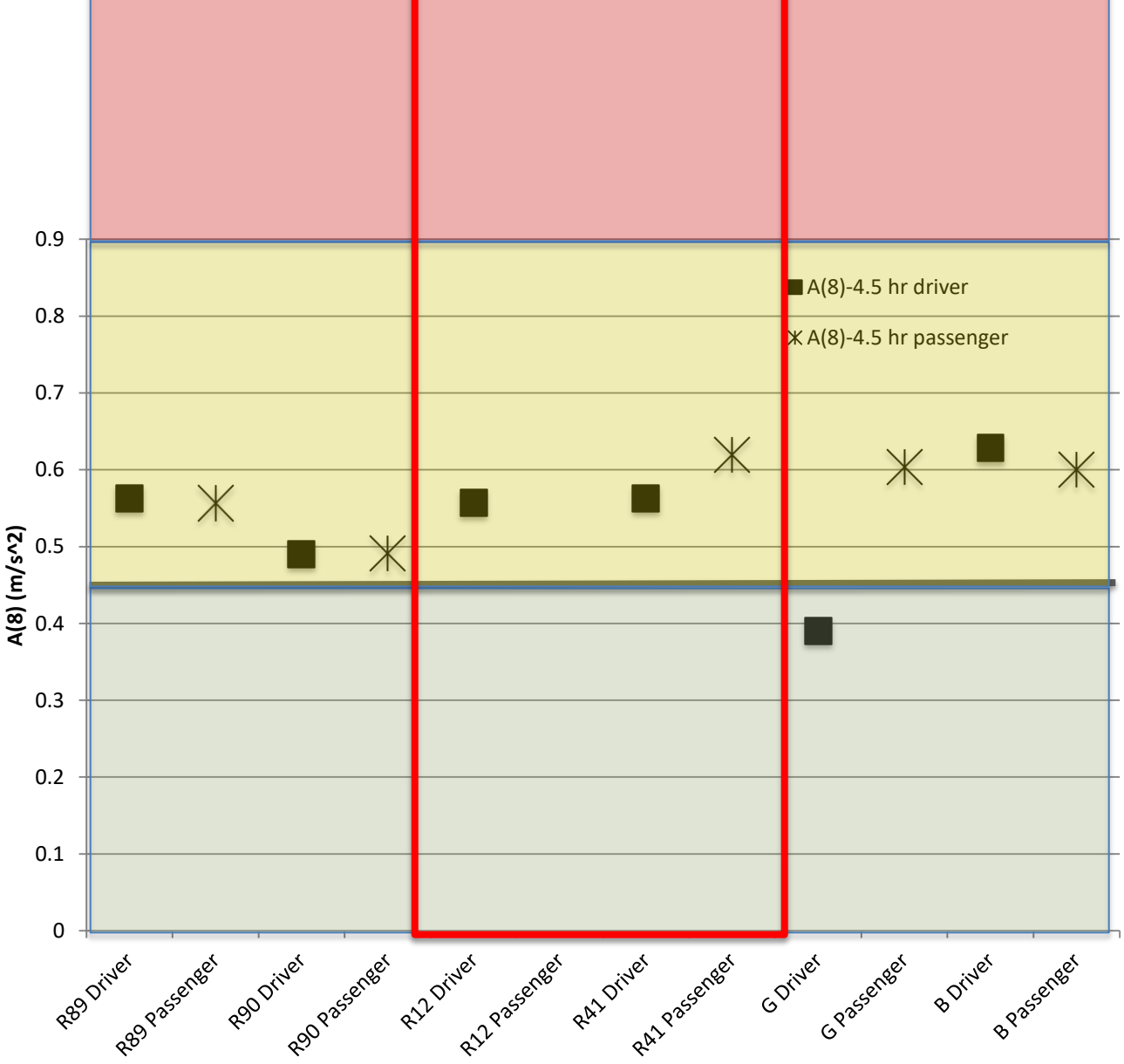
Standard Driving Route:

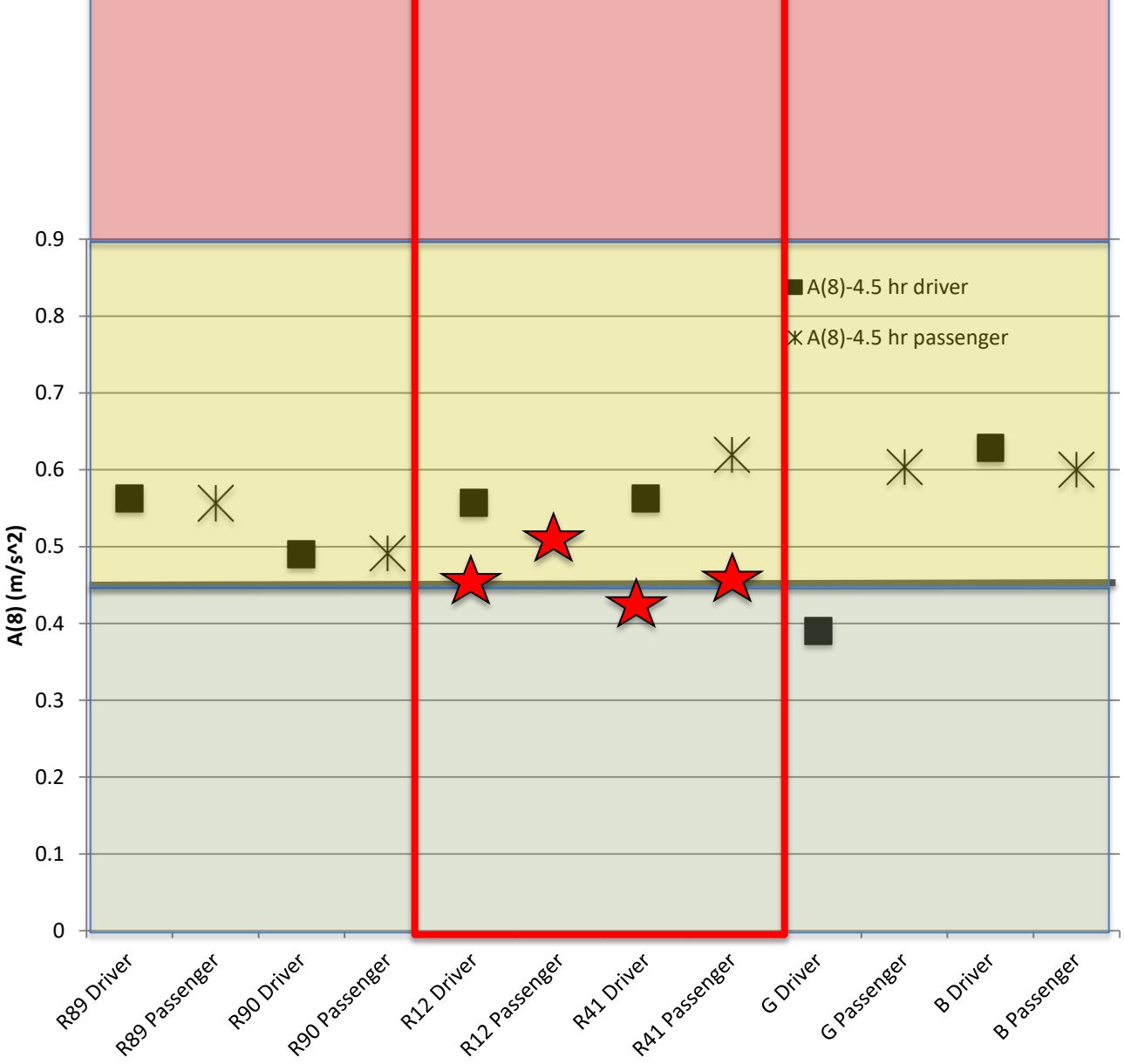
Analysis:

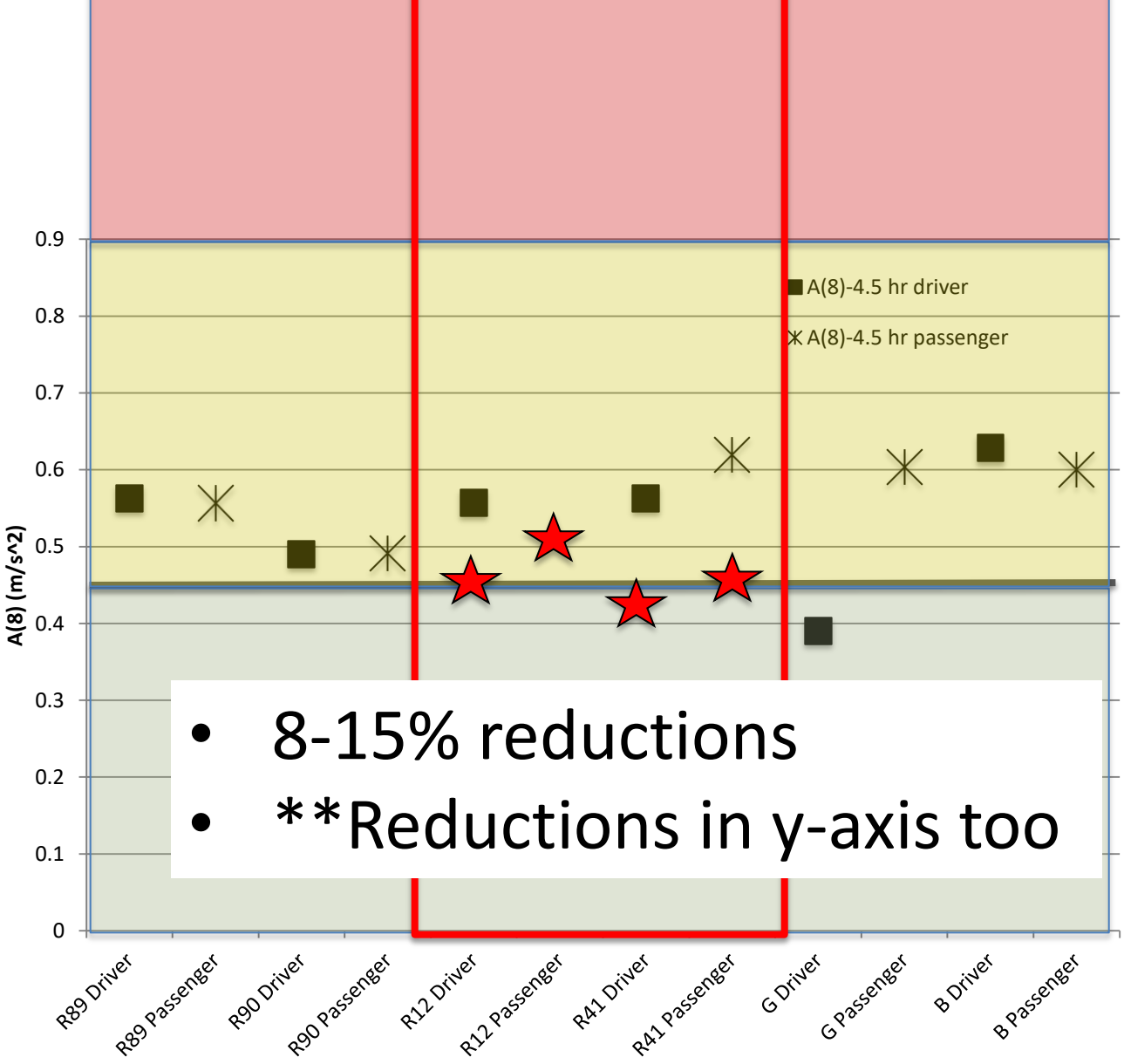


Results:


0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
A(8) (m/s^2)
A(8)-4.5 hr driver
A(8)-4.5 hr passenger
R89 Driver
R89 Passenger
R90 Driver
R90 Passenger
R12 Driver
R12 Passenger
R41 Driver
R41 Passenger
G Driver
G Passenger
B Driver
B Passenger


A(8) (m/s^2)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
A(8)-4.5 hr driver
A(8)-4.5 hr passenger
R89 Driver
R89 Passenger
R90 Driver
R90 Passenger
R12 Driver
R12 Passenger
R41 Driver
R41 Passenger
G Driver
G Passenger
B Driver
B Passenger


A(8) (m/s^2)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
A(8)-4.5 hr driver
A(8)-4.5 hr passenger
R89 Driver
R89 Passenger
R90 Driver
R90 Passenger
R12 Driver
R12 Passenger
R41 Driver
R41 Passenger
G Driver
G Passenger
B Driver
B Passenger



- 8-15% reductions
- **Reductions in y-axis too

Conclusions:

- Seating can reduce vibration exposure
- Seat selection is not straightforward
- WBV App is a powerful assessment tool that is likely suitable for screening

Acknowledgements:

- Collaborators:
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  - Katherine Plewa (MSc)
  - Giselle Delgado (MSc)
  - Derrick Nield (MSc)

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References:

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