Relationship Between IRI and Vehicle Dynamic Response to Road Roughness

Steven M. Karamihas
University of Michigan Transportation Research Institute

National Pavement Preservation Conference
nppc23
IMPACTS AND BENEFITS FROM PAVEMENT PRESERVATION
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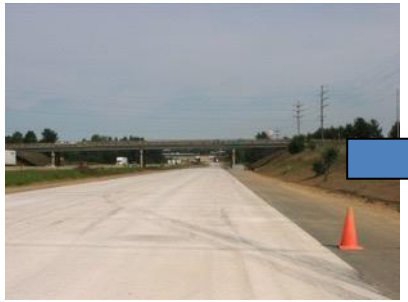
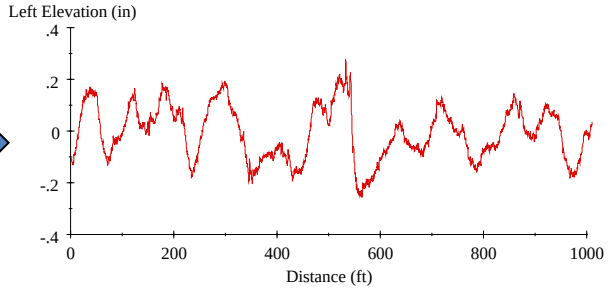
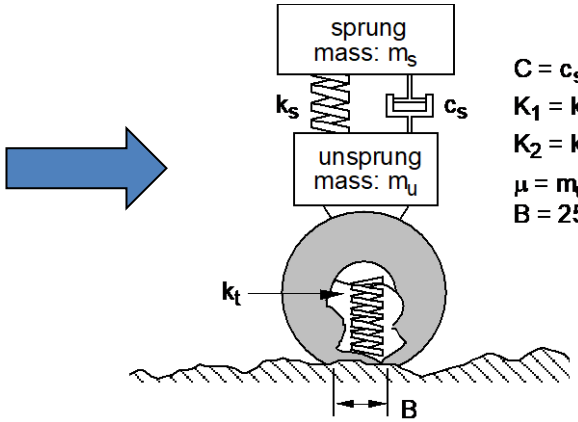
MICHIGAN STATE UNIVERSITY

Road Profiles and Road Roughness







$C = c_s/m_s = 6.0\ sec^{-1}$

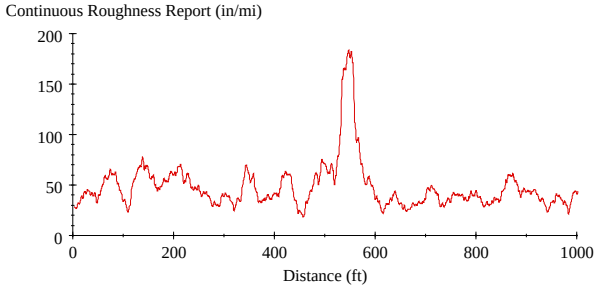
$K_1 = k_t/m_s = 653\ sec^{-2}$

$K_2 = k_s/m_s = 63.3\ sec^{-2}$

$\mu = m_u/m_s = 0.15$

$B = 250\ mm$

IRI



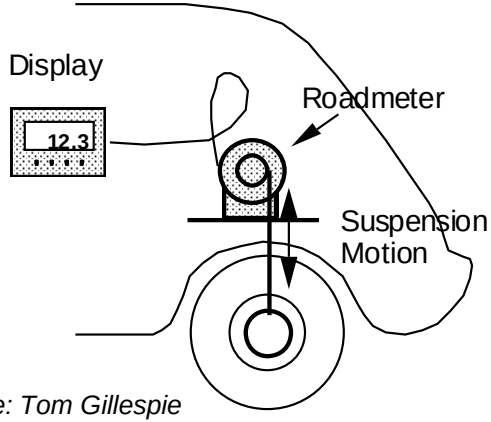
Outline

- IRI and vehicle vibration response.
- Localized roughness and ride quality.
- Research topics:
  - Travel speed versus simulation speed.
  - Roughness thresholds.
  - Texture sensitivity.

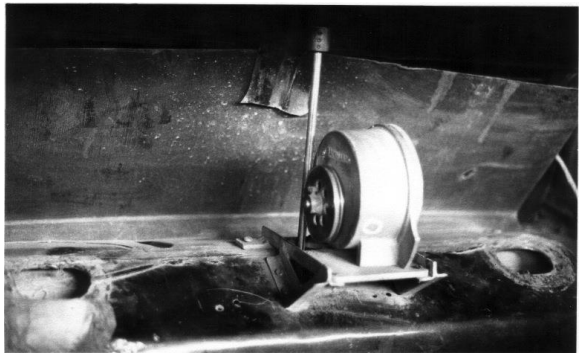
IRI Origins: Response-Type Systems

Sayers, M.W., et al., “The International Road Roughness Experiment.” *World Bank Technical Paper Number 45* (1986) 453 p.

Gillespie, T.D., et al., “Calibration of Response-Type Road Roughness Measuring Systems.” National Cooperative Highway Research Program Report 228 (1980) 81 p.



Source: Tom Gillespie



Source: Mike Sayers

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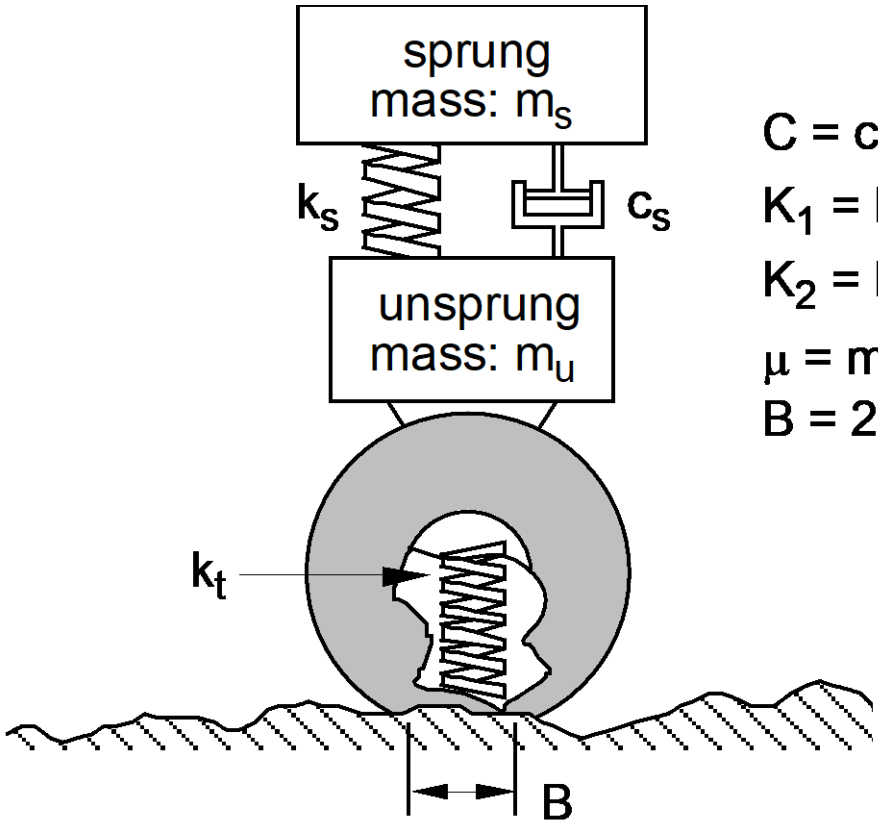
Golden Car Model



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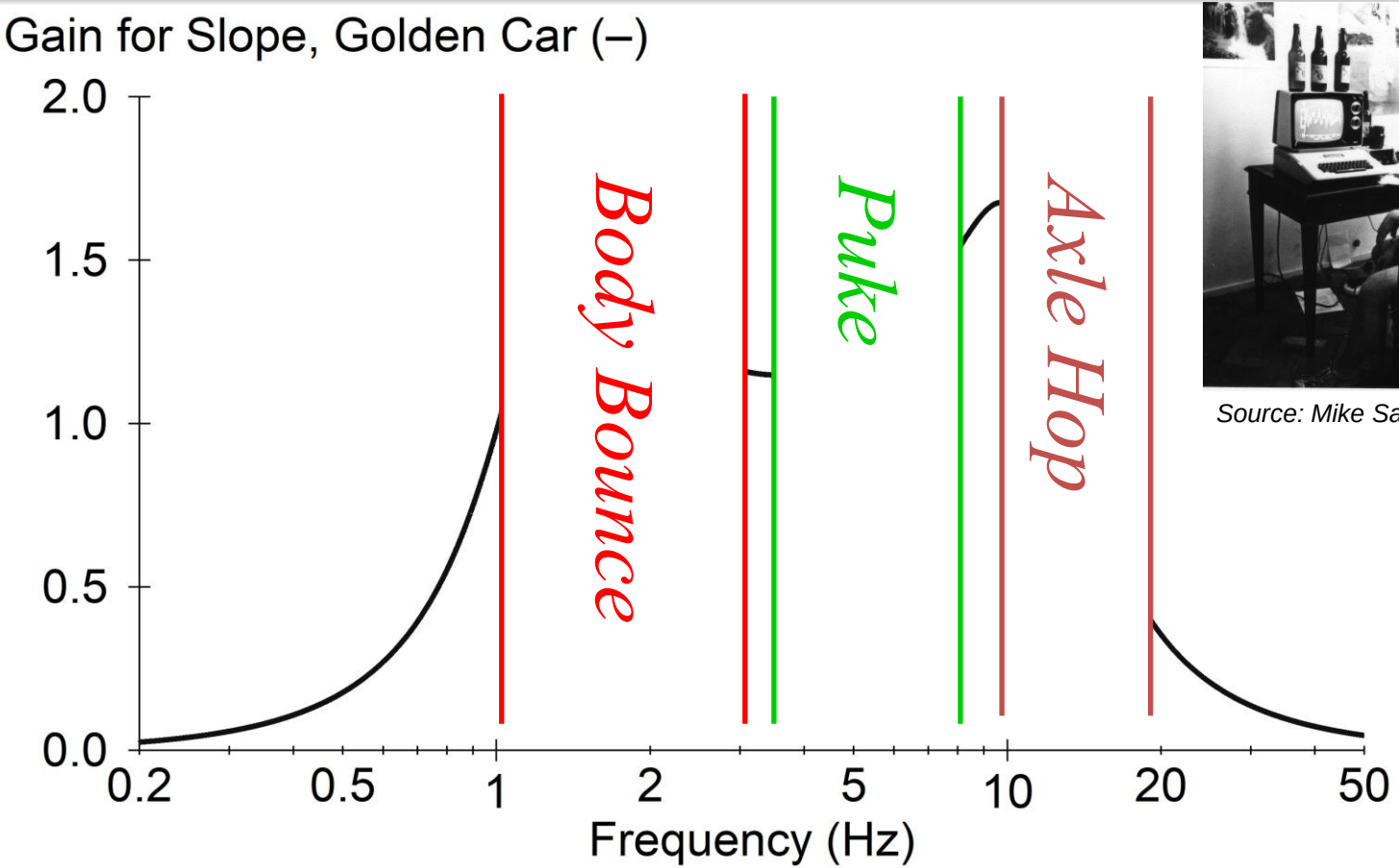
Sayers, M.W., "On the Calculation of International Roughness Index from Longitudinal Road Profile." *Transportation Research Record 1501* (1995).

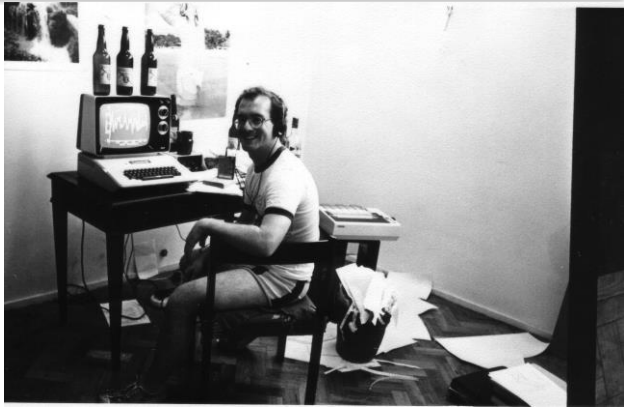
Body Bounce

Axle Hop

Golden-Car Model Response

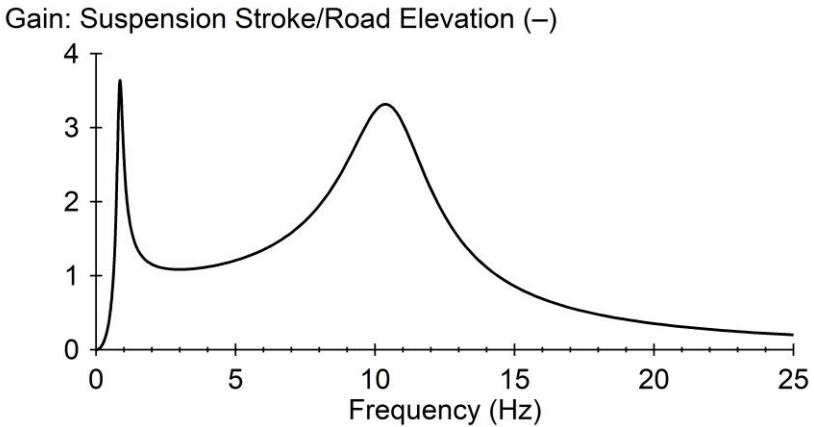


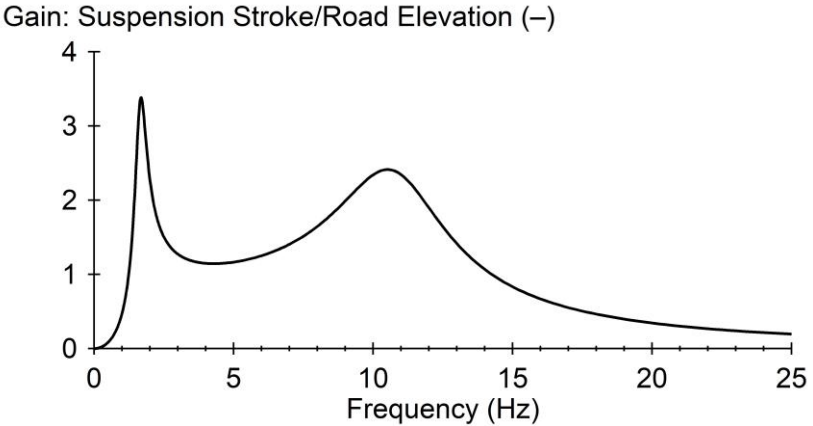
Source: Steve Karamihas



Source: Mike Sayers

Roughness Meter Simulations



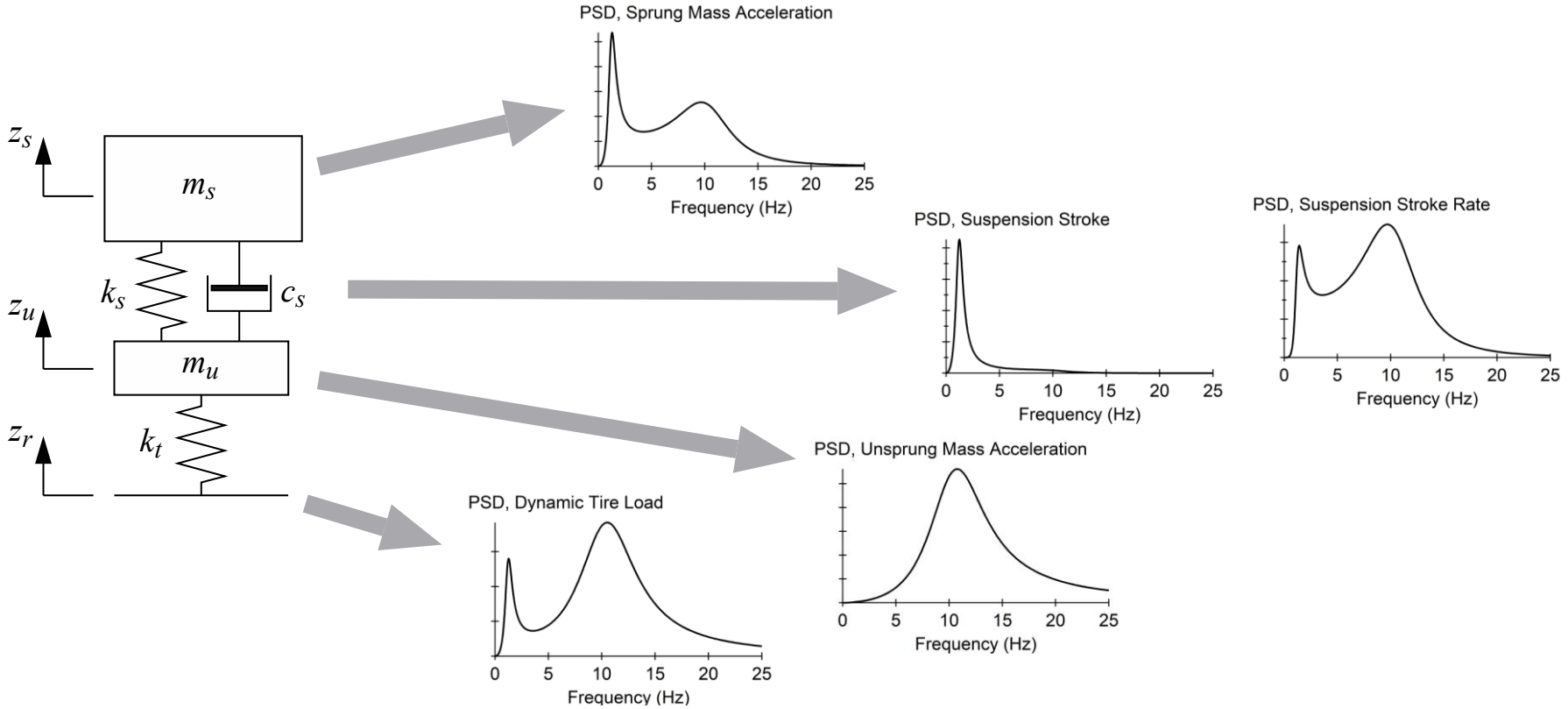


Source: Richard Wix

Source: U.S. Highway Research Board

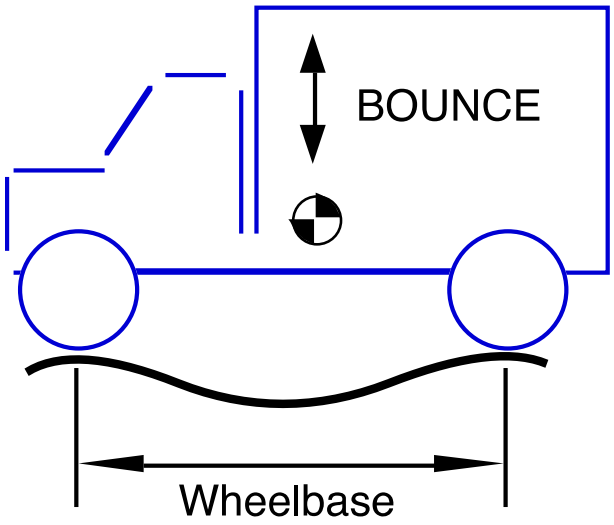
Gillespie, T.D., et al., “Calibration of Response-Type Road Roughness Measuring Systems.” *NCHRP Report 228* (1980).

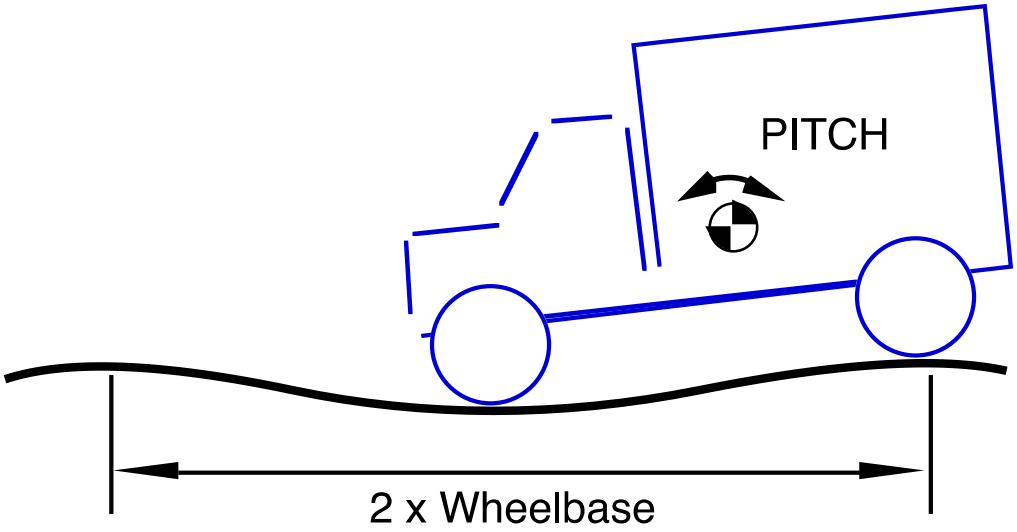
IRI Generality/Other Responses



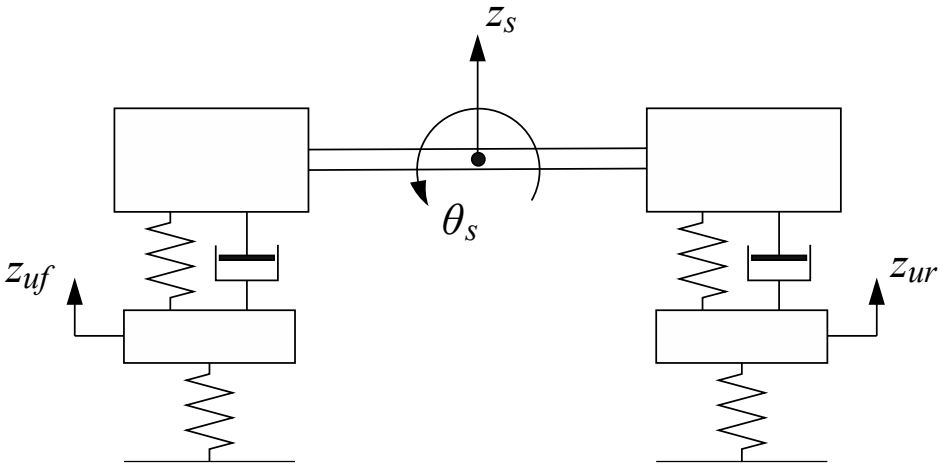
Karamihas, S.M., et al., "Measuring, Characterizing, and Reporting Roughness of Low-Speed and Urban Roads." *NCHRP Report 914* (2019).

Wheelbase Filtering





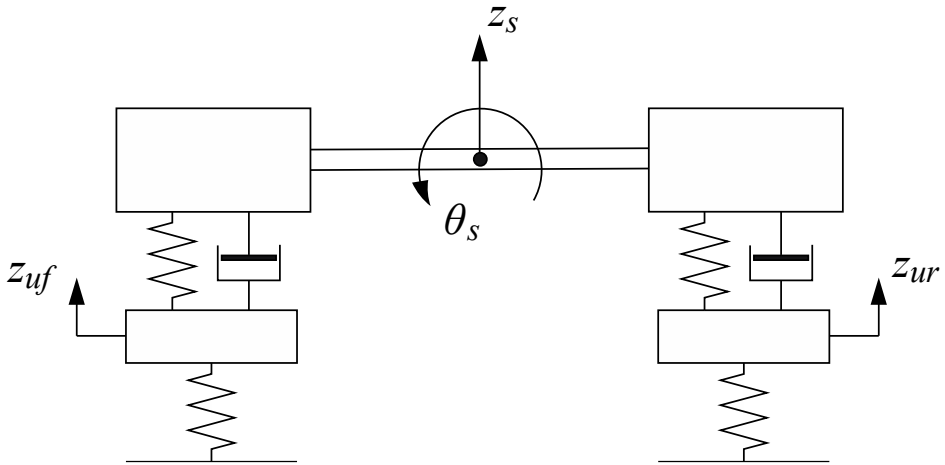
IRI Generality/Wheelbase Filtering



Pitch Plane Model

It matters where you are within the wheelbase.

IRI Generality/Wheelbase Filtering



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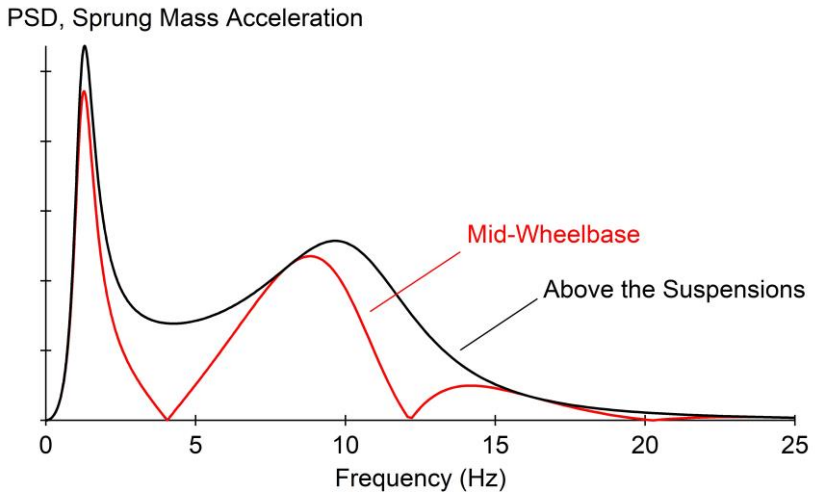
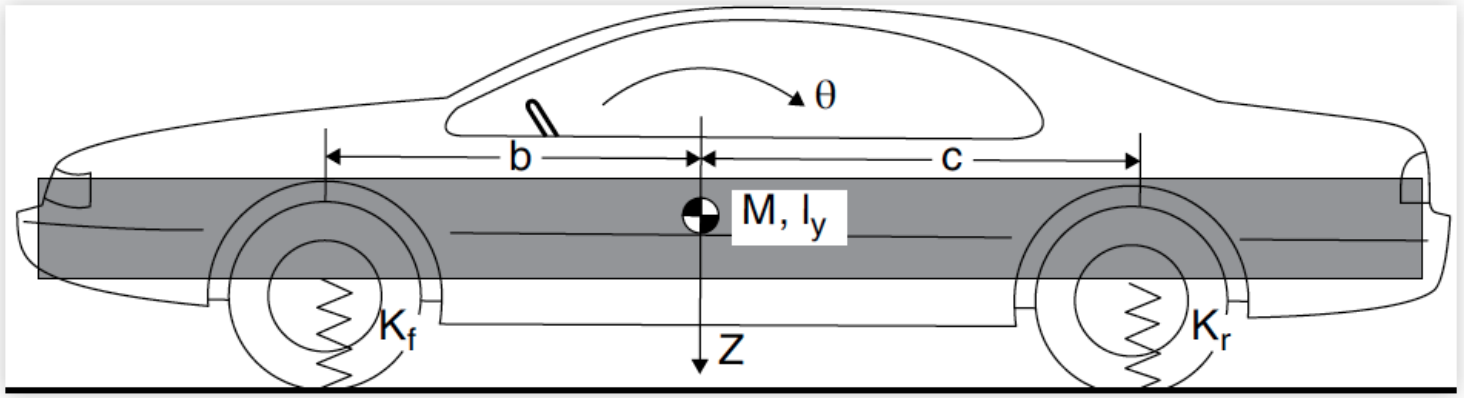
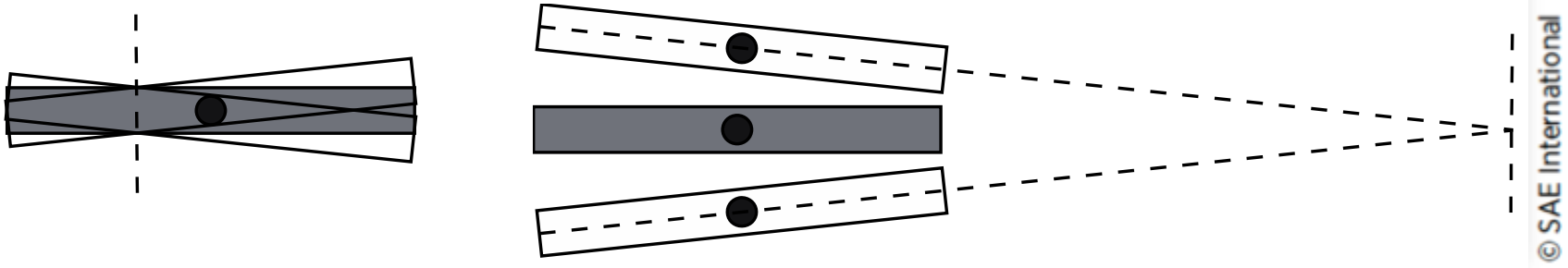


Acceleration Response

Wheelbase = 9 feet; Speed = 50 mi/hr; First notch at Speed/(2 x Wheelbase)

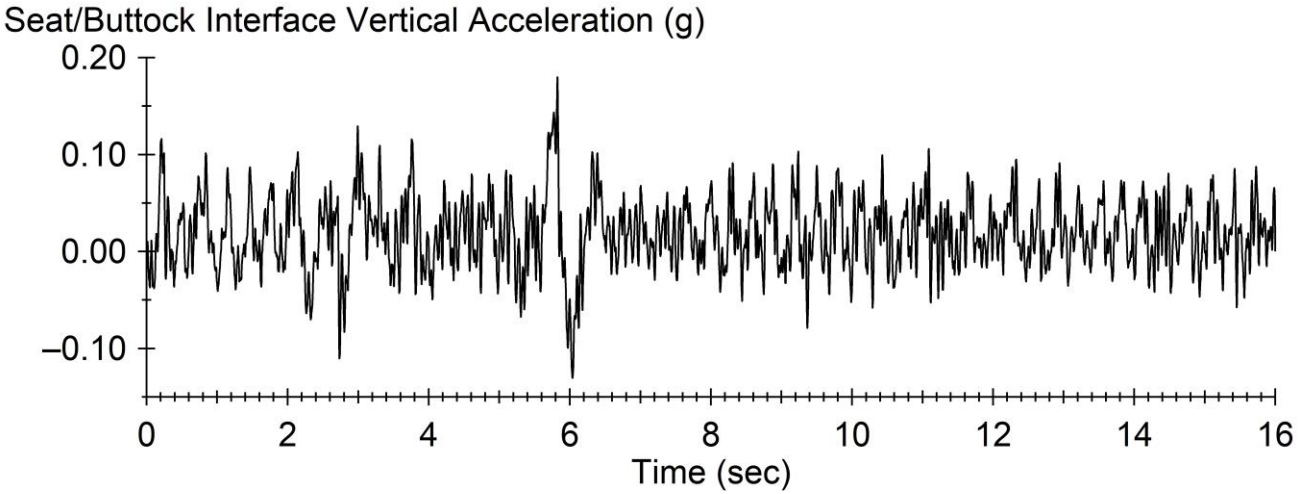
Suspension Design/Olley Criteria





Gillespie, T.D., *Fundamentals of Vehicle Dynamics, Revised Edition*. SAE International, Warrendale, PA (2021).

Acceleration Measurements

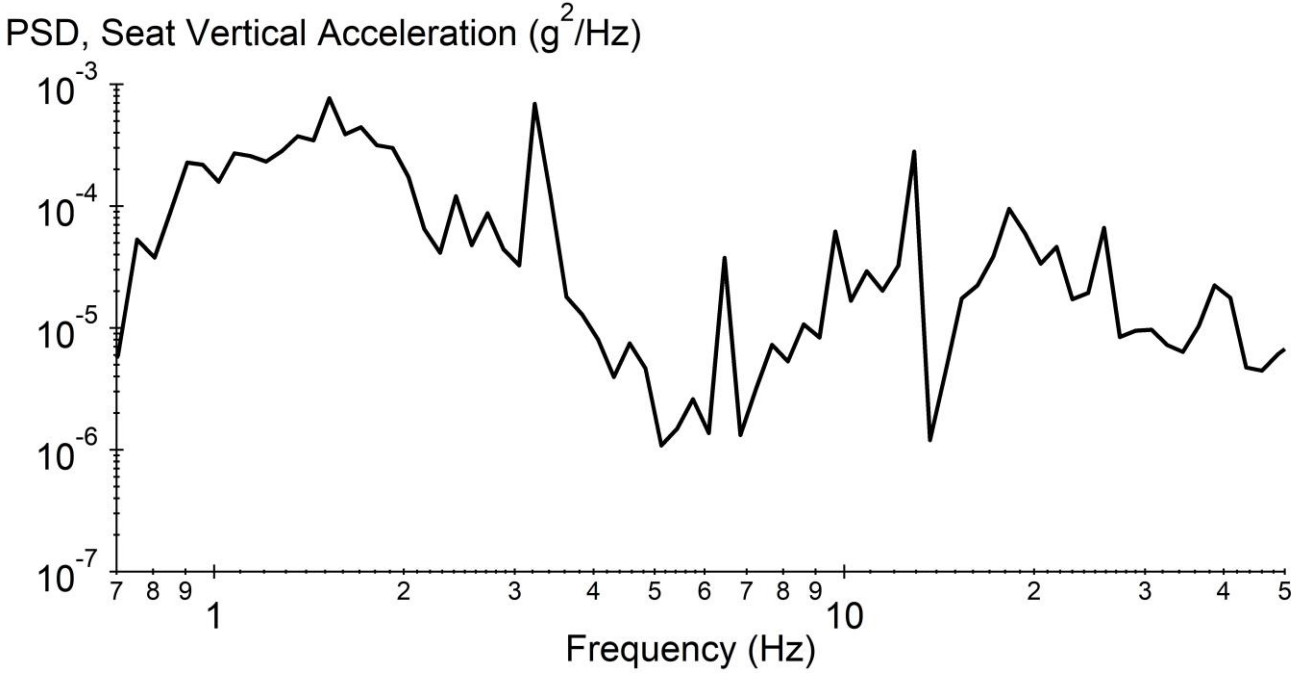


Per ISO 2631:

- Measure acceleration at vehicle/occupant interfaces.
- Apply frequency weighting for human sensitivity.
- Combine RMS values.

Karamihas, S.M., “Ride Quality of Jointed Concrete Pavements.” *University of Michigan Transportation Research Institute Report UMTRI-2010-24*.

Acceleration Measurements



Travel speed: 59 mph
Wheelbase: 9.2 ft

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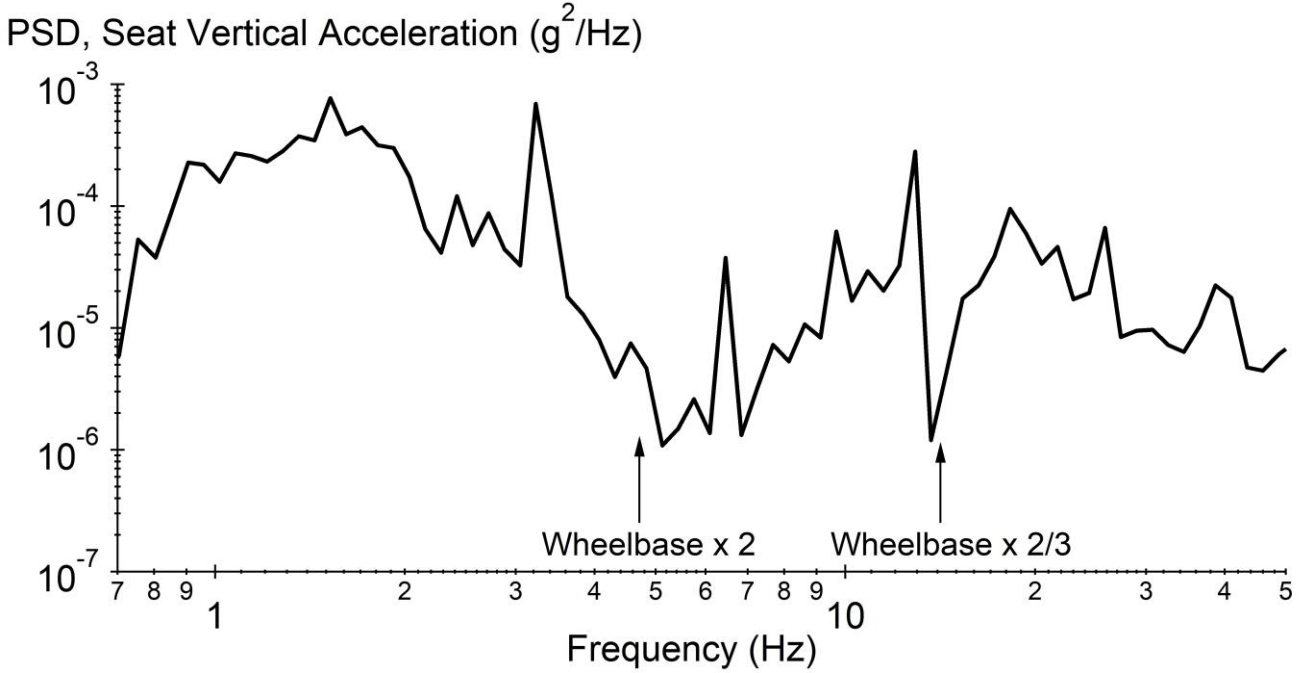

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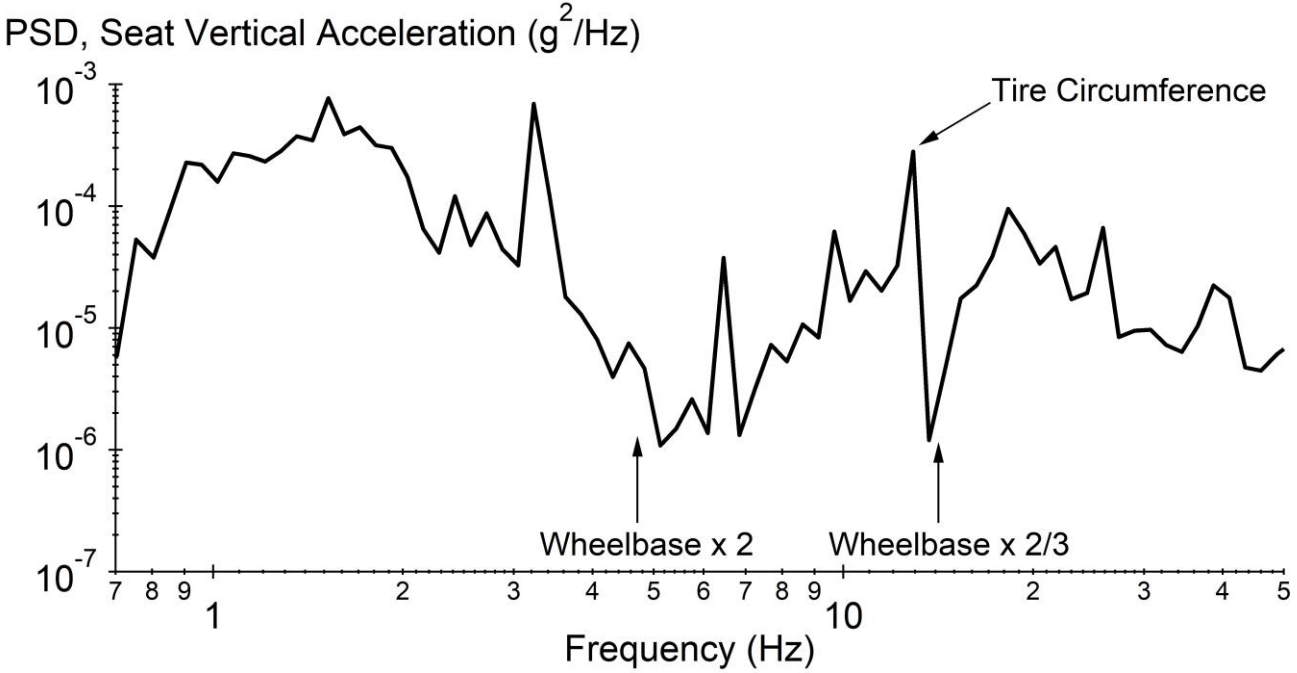

Travel speed: 59 mph
Wheelbase: 9.2 ft
Tire radius: 1.03 ft

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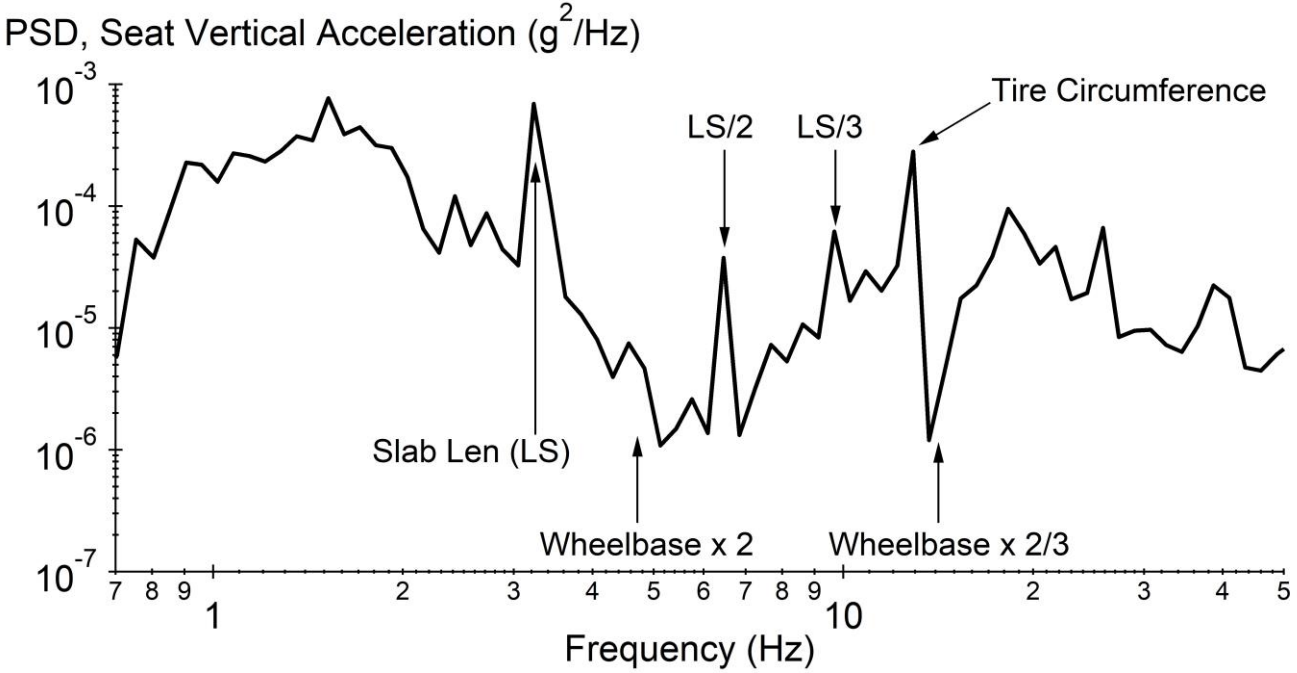
Acceleration Measurements



Travel speed: 59 mph
Wheelbase: 9.2 ft
Tire radius: 1.03 ft
Slab length: 26.7 ft

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Outline

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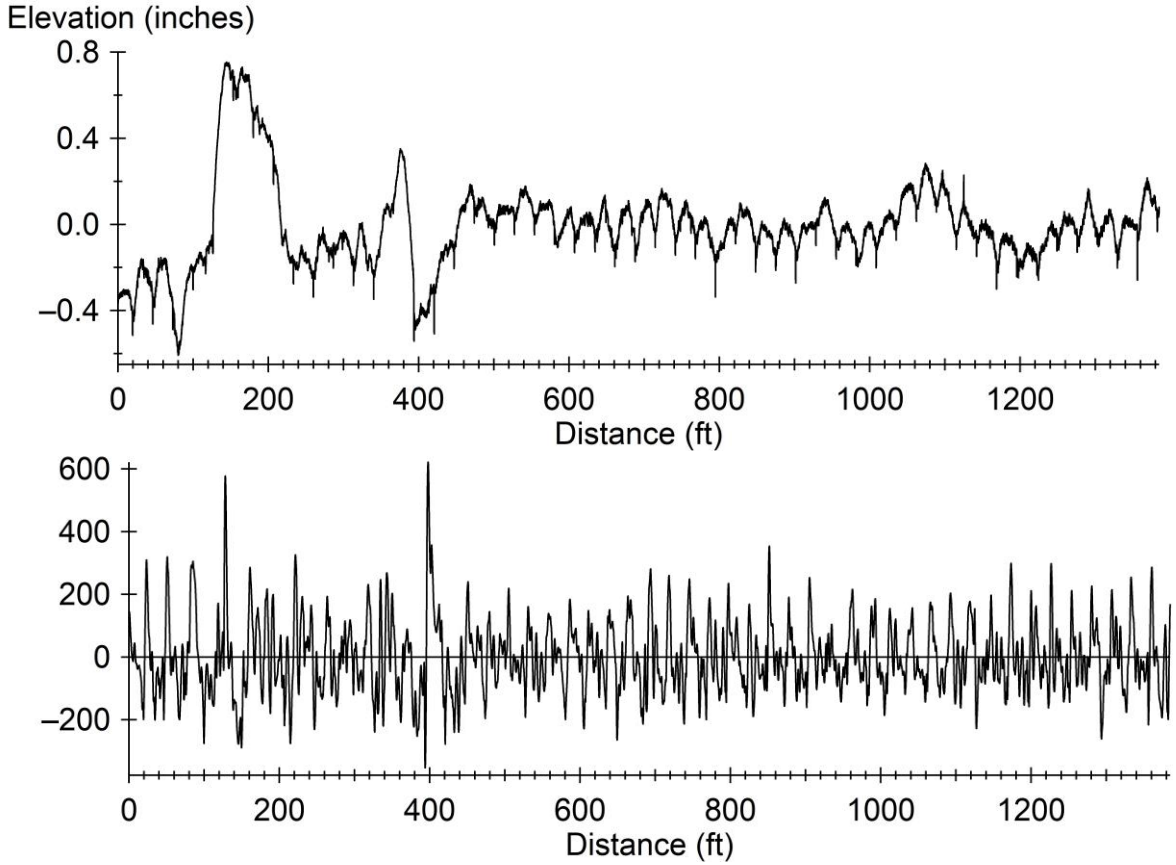
  - Texture sensitivity.

IRI, Segment Length, Roughness Profiles

Filtered Profile

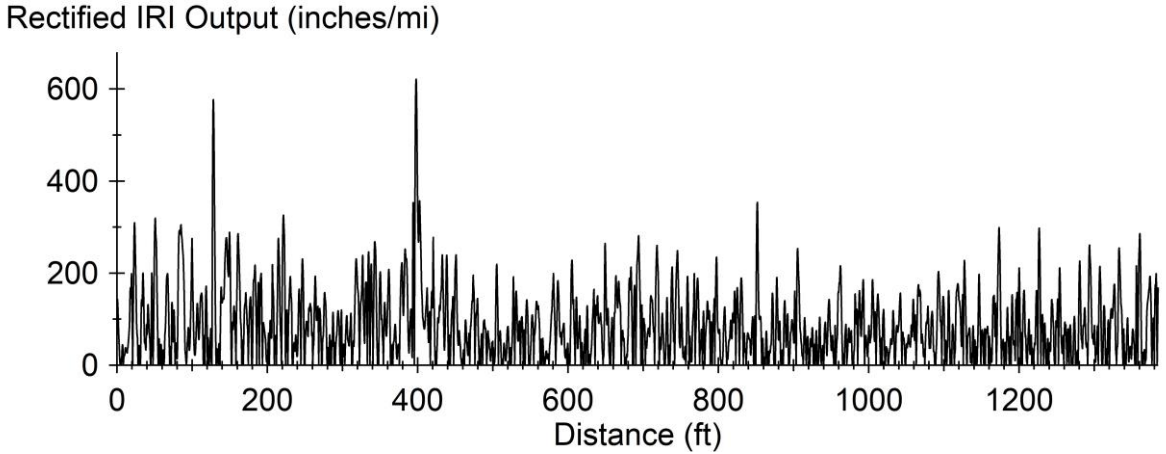
IRI Algorithm Output



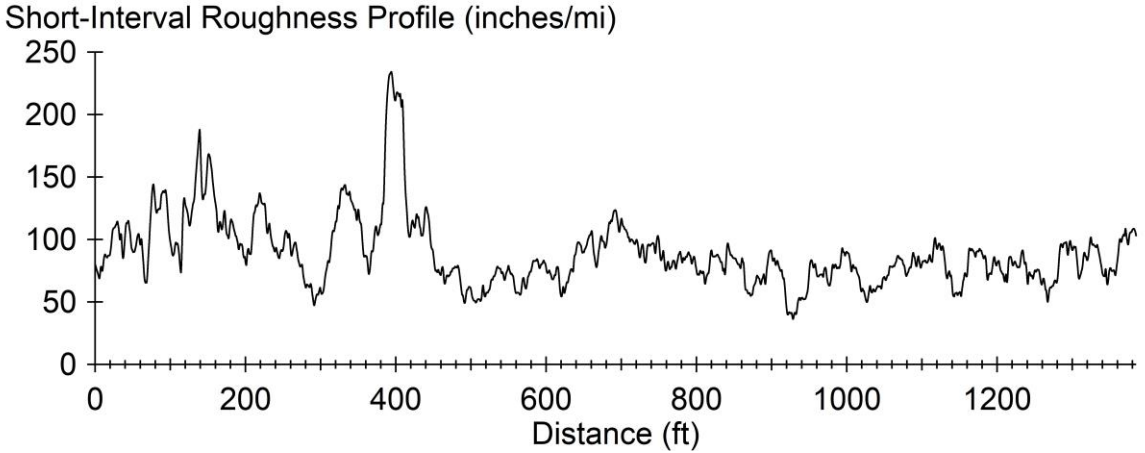
IRI, Segment Length, Roughness Profiles

Rectified IRI Algorithm Output

IRI = 90 inches/mi



Roughness Profile



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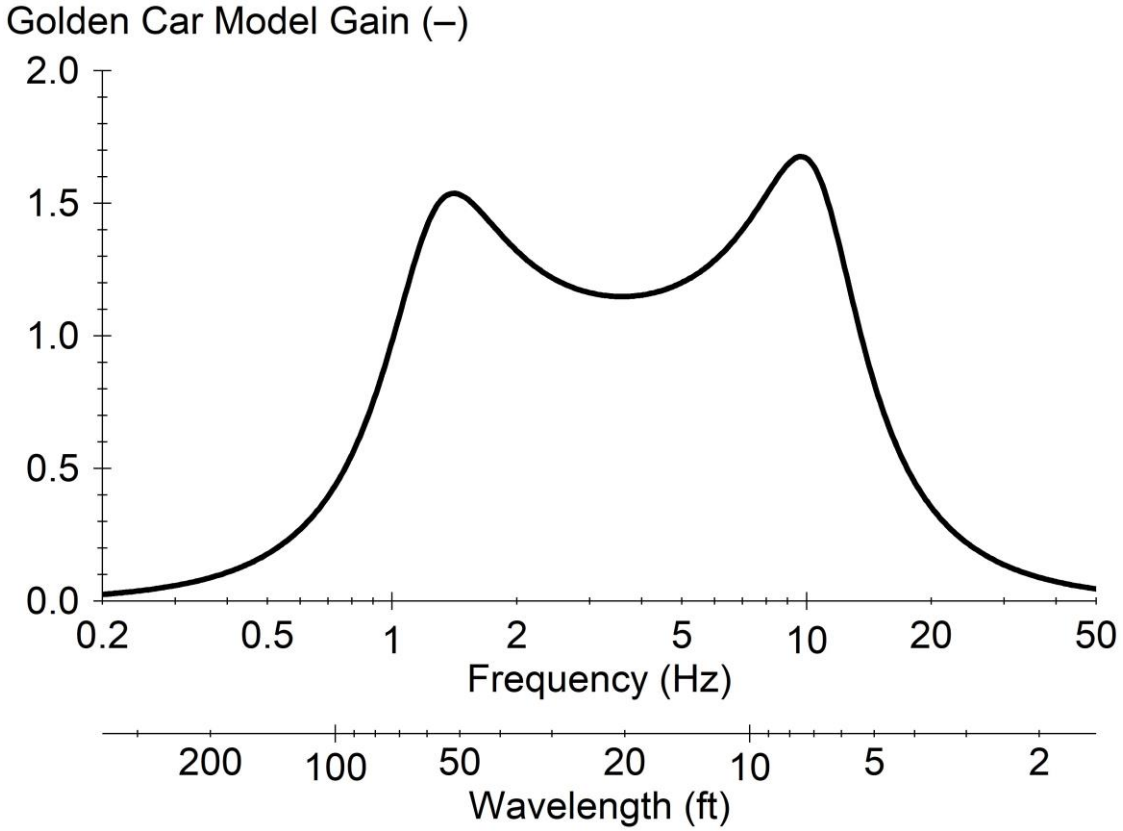
International Roughness Index (IRI) Response



Wavelength
= Speed/Frequency

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International Roughness Index (IRI) Response

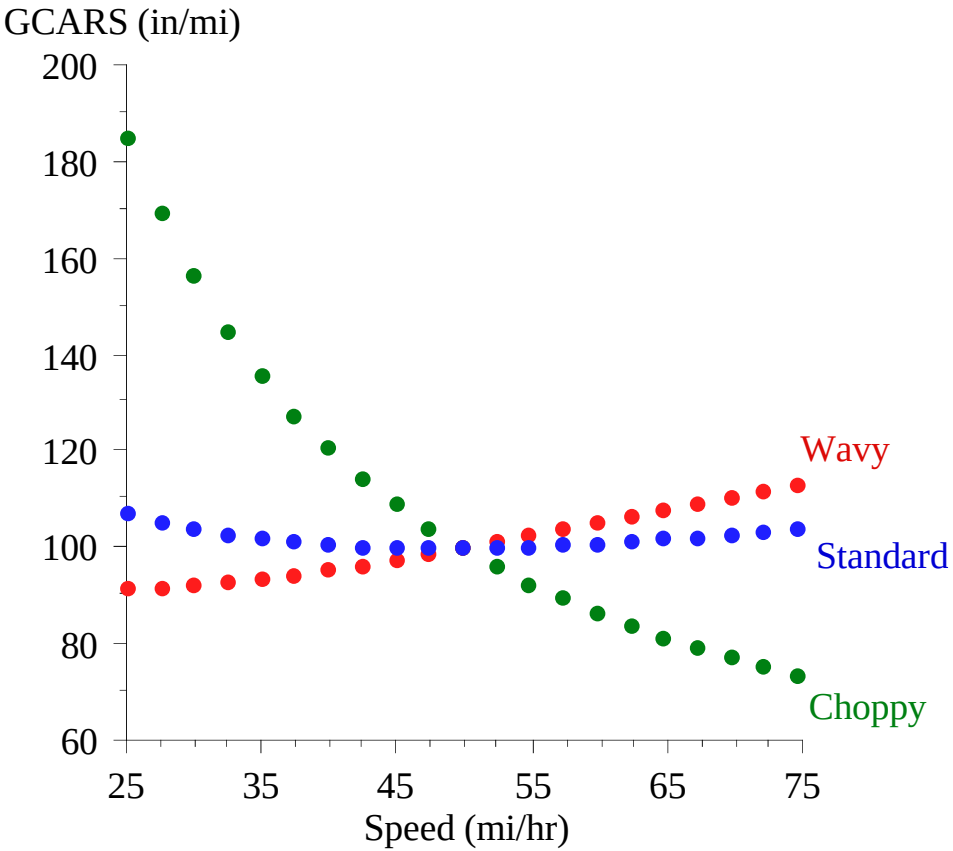
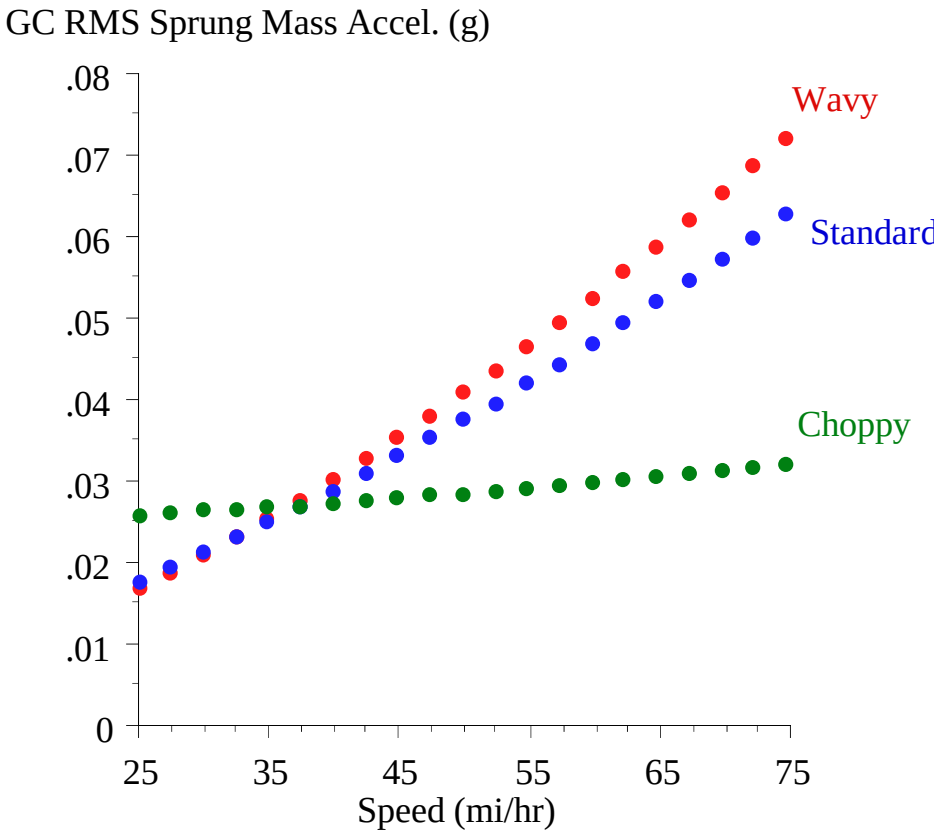


Photo Courtesy of Pennsylvania DOT

Karamihas, S. M., "Golden-Car Simulation Speed and Its Implications to the Relevance of the IRI." *ASTM STP 1555* (2011).

International Roughness Index (IRI) Response



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Golden Car Simulation Speed

Changing speed…

- changes which aspects of the road surface are important.
- alters the “in/mi” value for a given segment.
- alters the rank order of pavements.
- changes the relationship between “in/mi” and vibration intensity.

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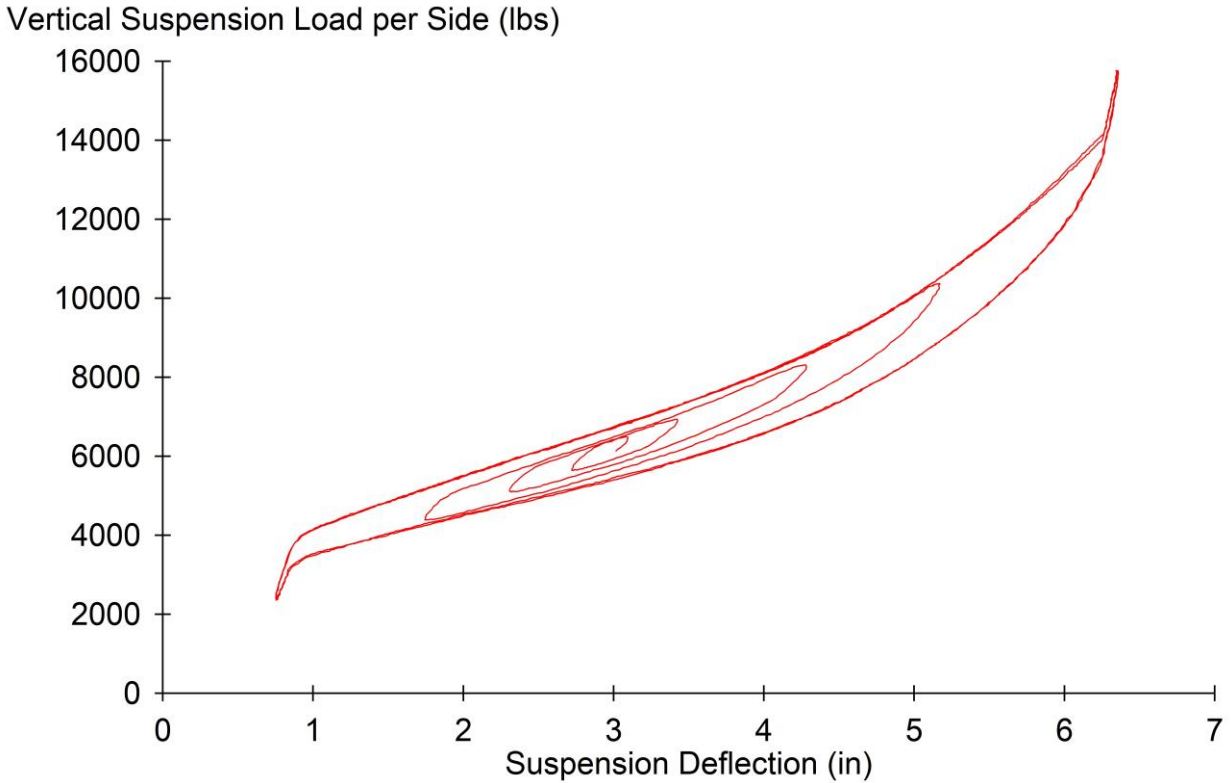
Roughness Thresholds: Suspension Friction



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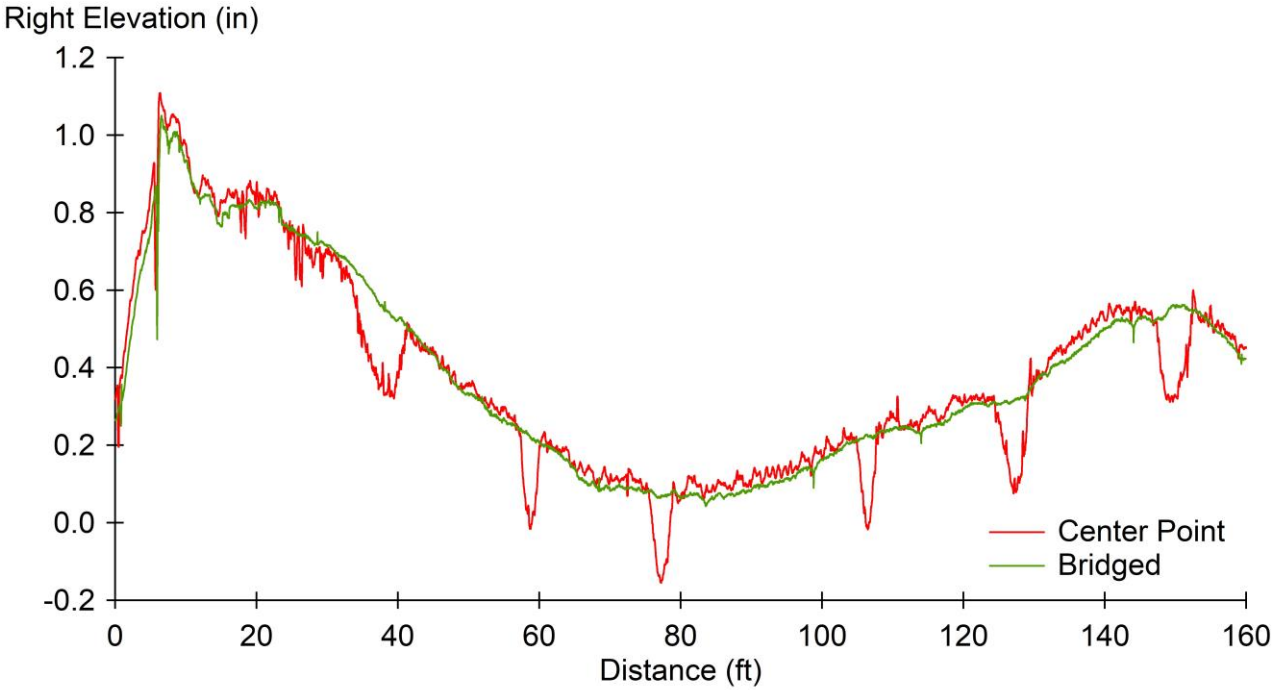
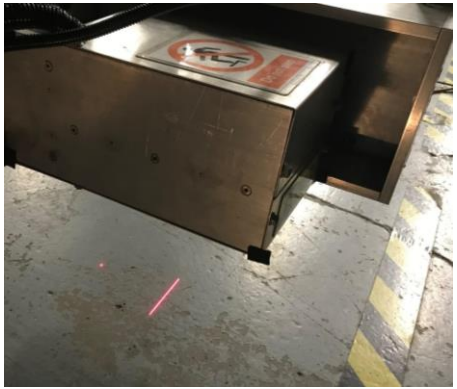
Surface Texture and Height Sensor Footprint





Thanks!