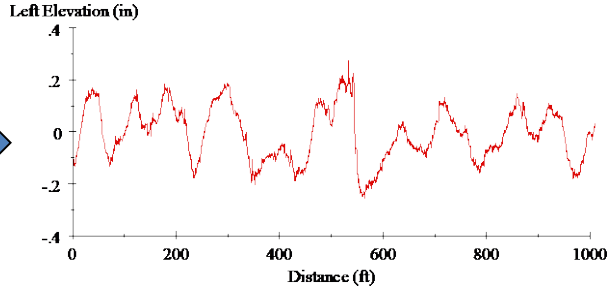
62nd Illinois Bituminous Paving Conference

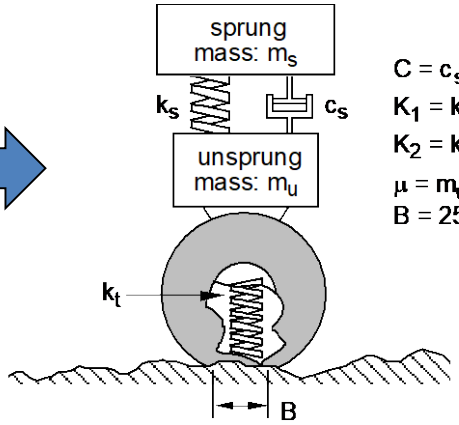
Profile Measurement and Interpretation

Steven M. Karamihas

December 7, 2021

Road Profile Measurement and Interpretation





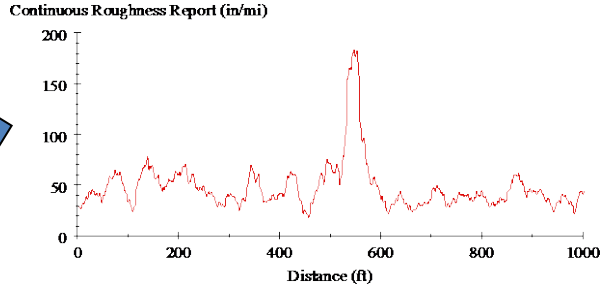
$C = c_s/m_s = 6.0\ sec^{-1}$

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

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

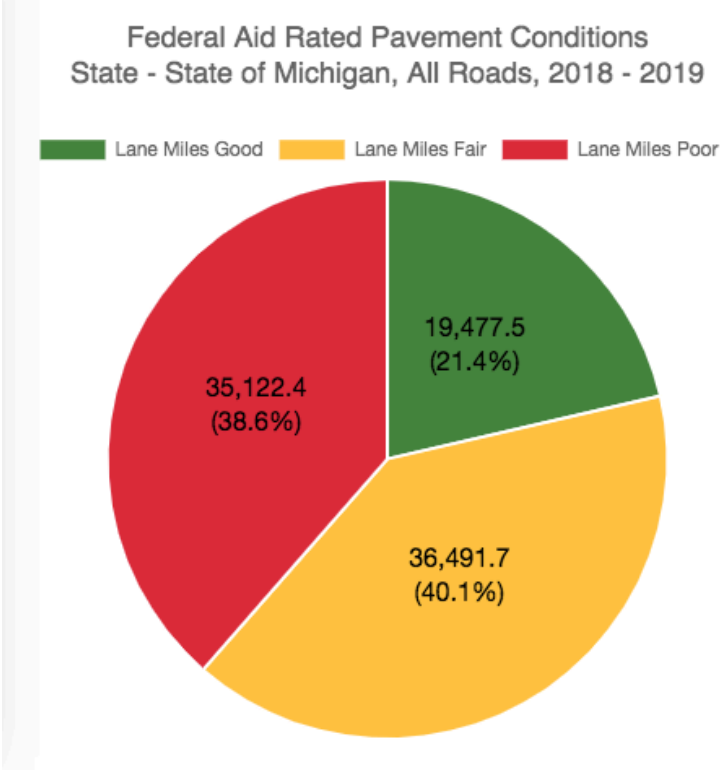
$\mu = m_u/m_s = 0.15$

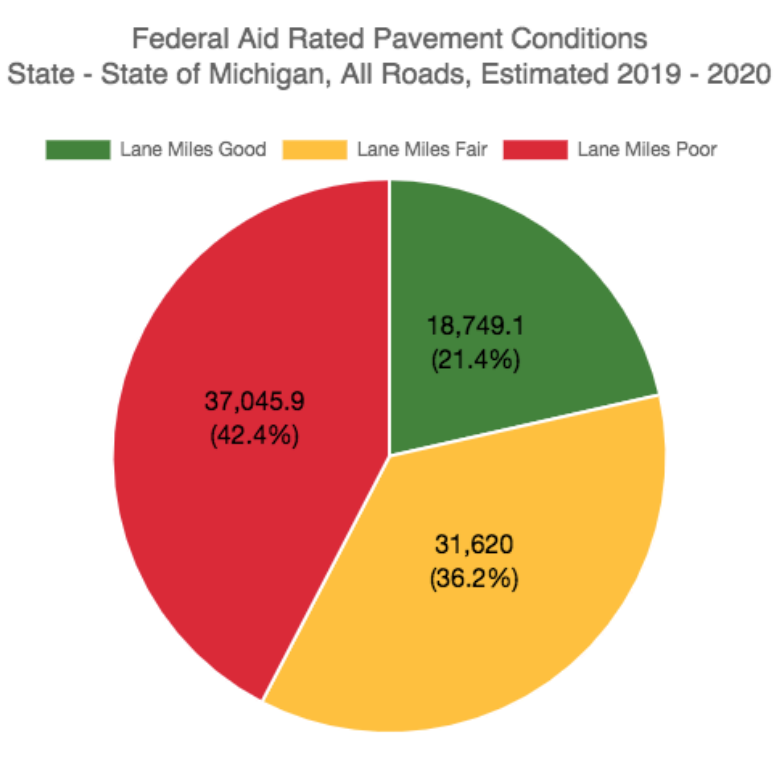
$B = 250\ mm$



IRI

Motivation



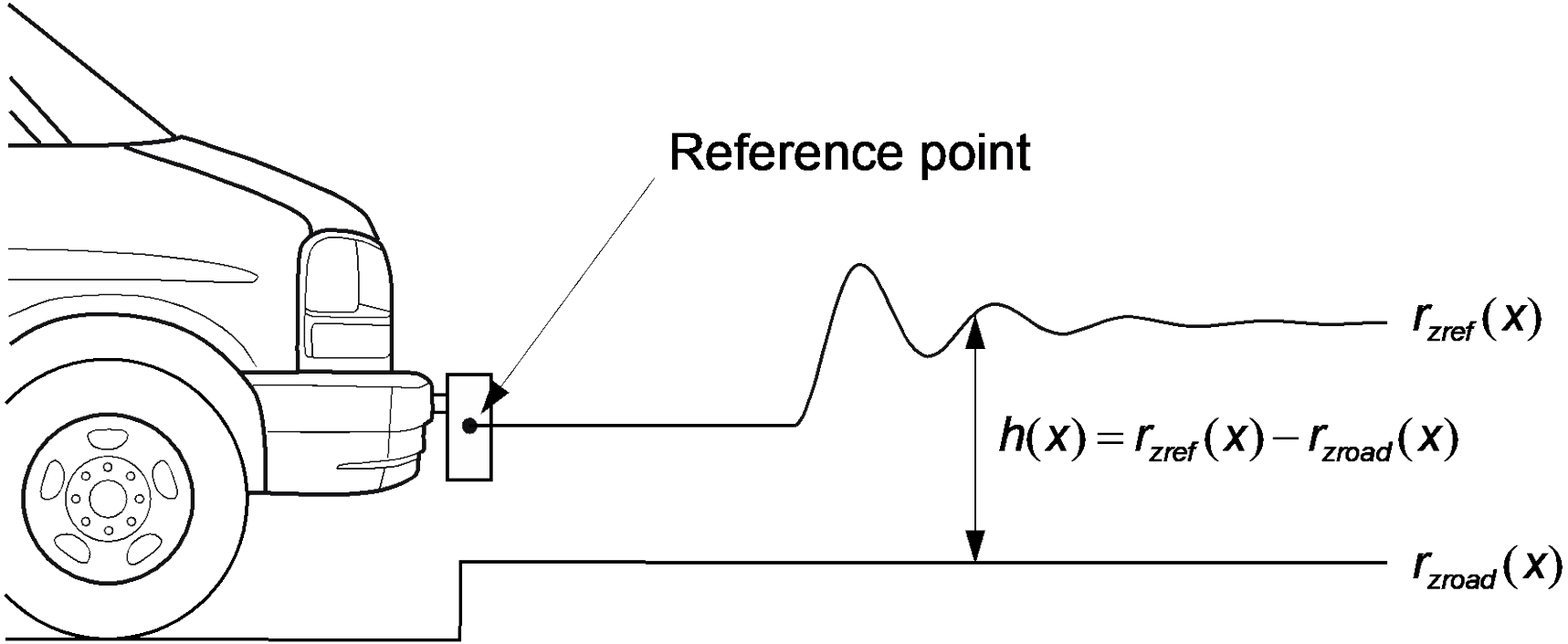


http://www.mcgi.state.mi.us/mitrp/tamcDashboards

Outline

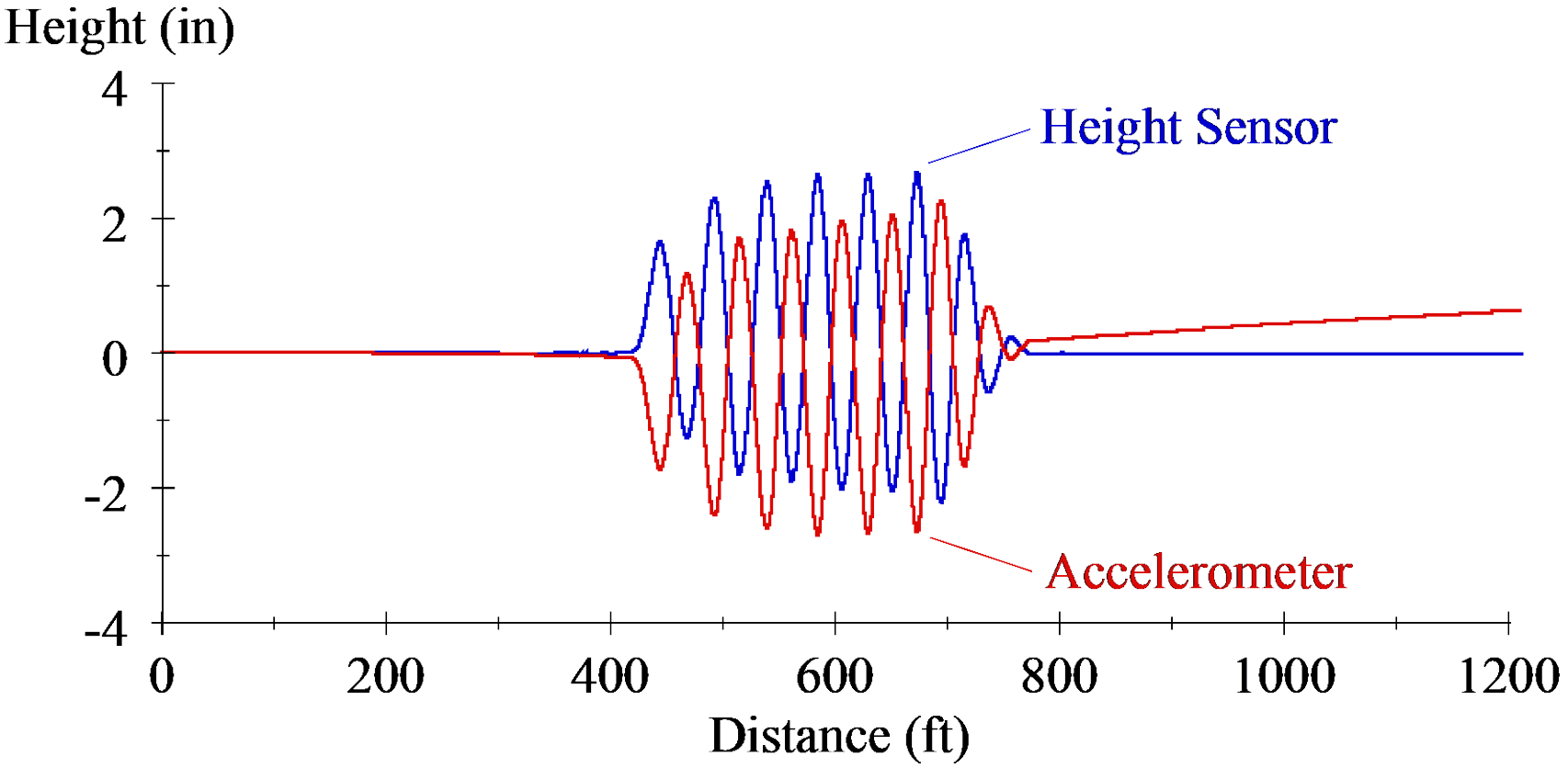
- Profiler Measurement Principal
- International Roughness Index (IRI)
- Roughness Profiles
- Certification/Cross Correlation
- Technical Challenges
  - Braking/Stops
  - Low-Speed/Urban Roughness Index
  - 3-D Systems

Inertial Profiler, Principle of Operation

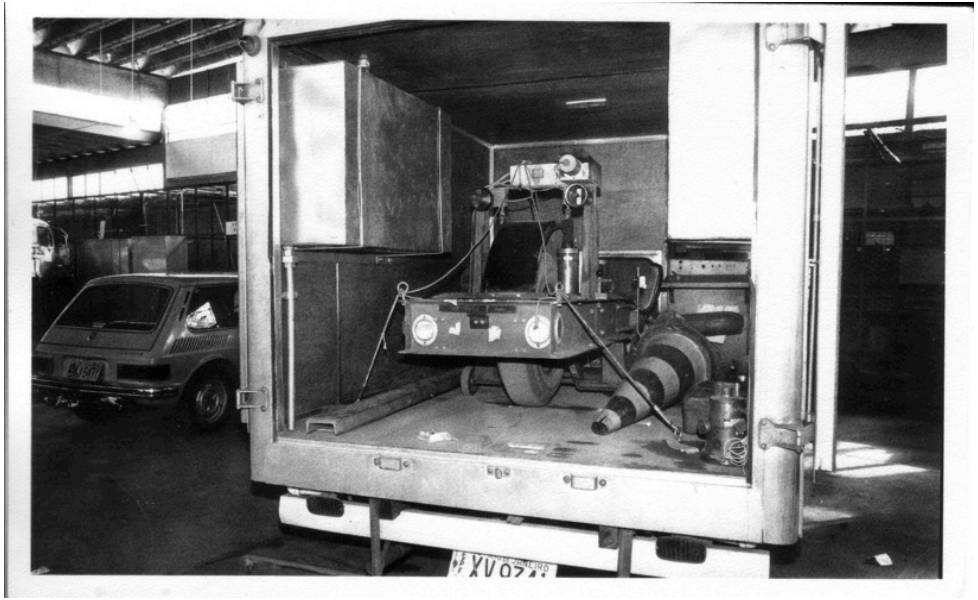


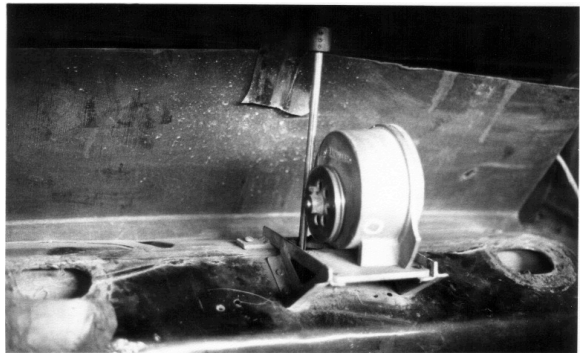
Schematic resembles: Huft, D. L., “South Dakota Profilometer.” *Transportation Research Record 1000* (1984) p. 1-8.

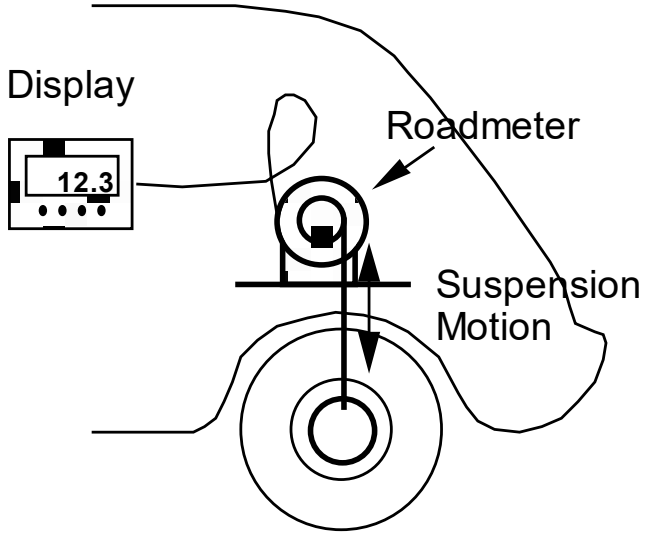
Bounce Test



IRI Origins: Response-Type Systems

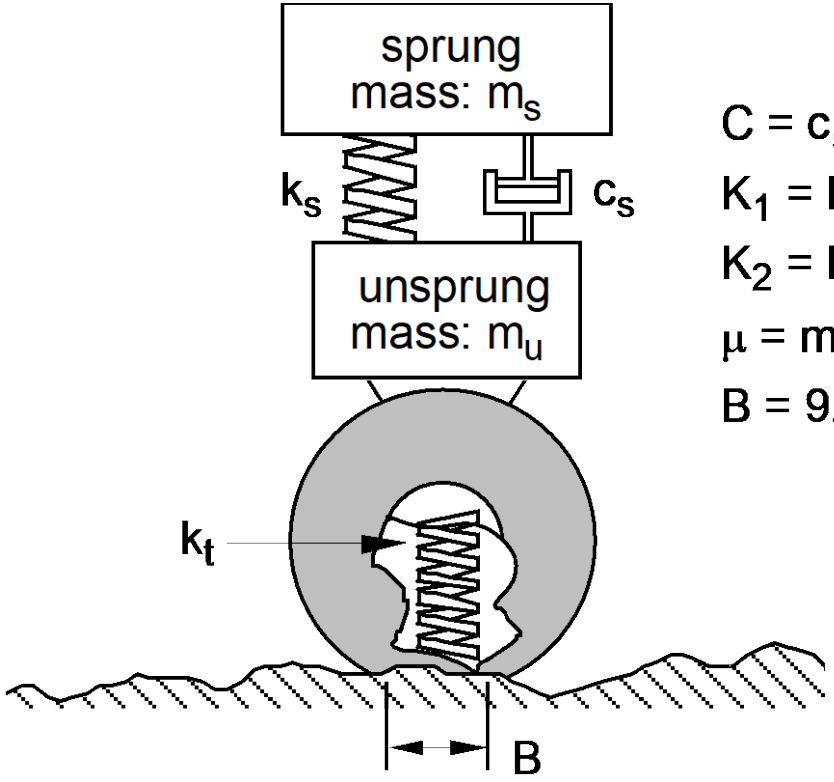






Source: Mike Sayers

International Roughness Index



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

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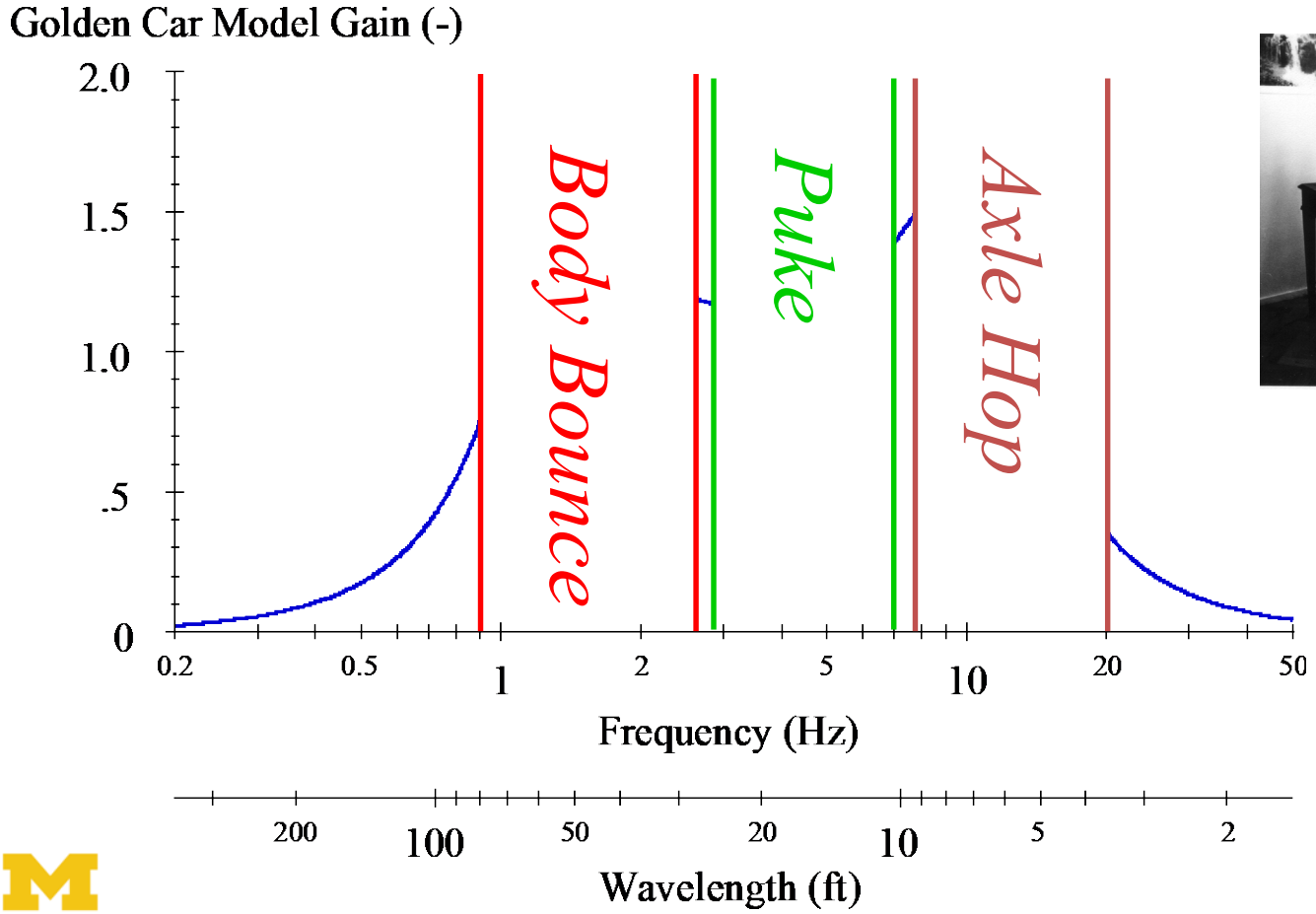
$K_2 = k_s/m_s = 63.3\ \text{sec}^{-2}$

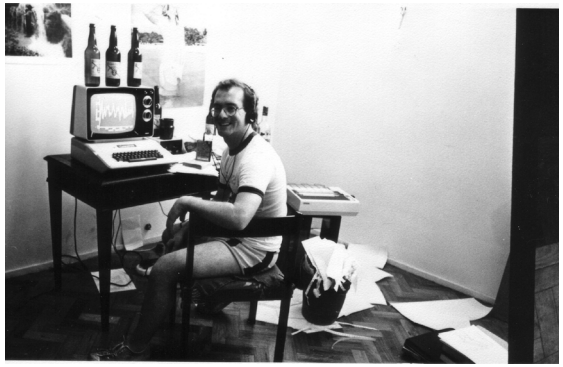
$\mu = m_u/m_s = 0.15$

$B = 9.84$ in

Sayers, M.W., "On the Calculation of International Roughness Index from Longitudinal Road Profile." *Transportation Research Record 1501* (1995) pp. 1-12.

Golden Car Model Gain



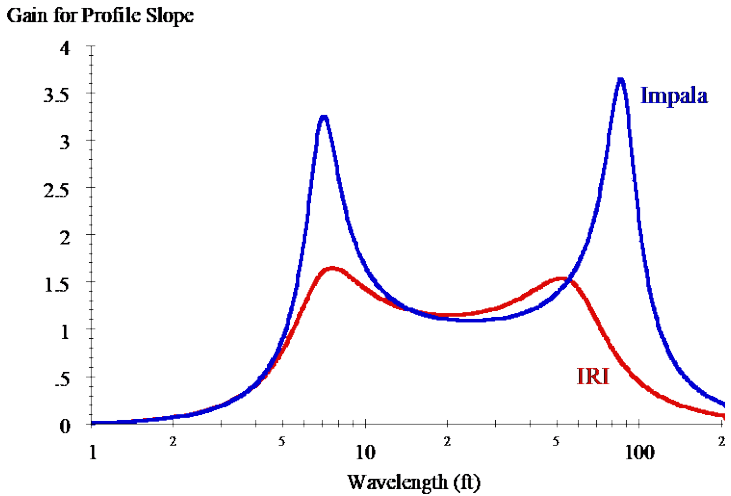


Source: National Cooperative Highway Research Program Report 914.

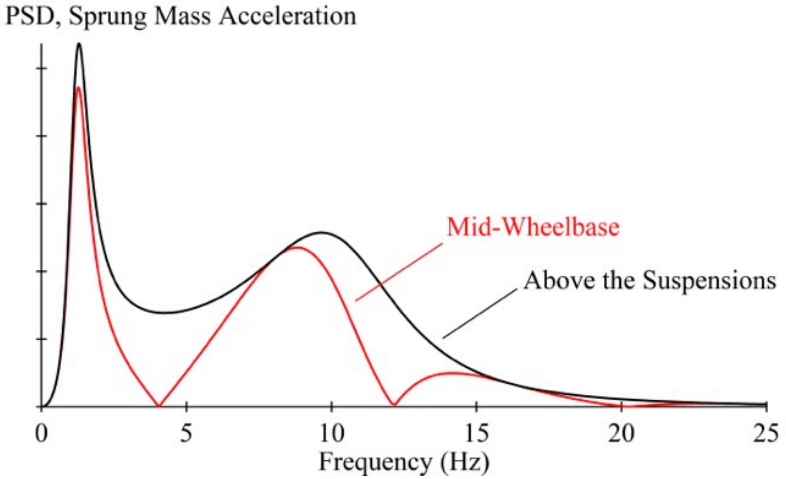
IRI Generality

Frequency response depends on:

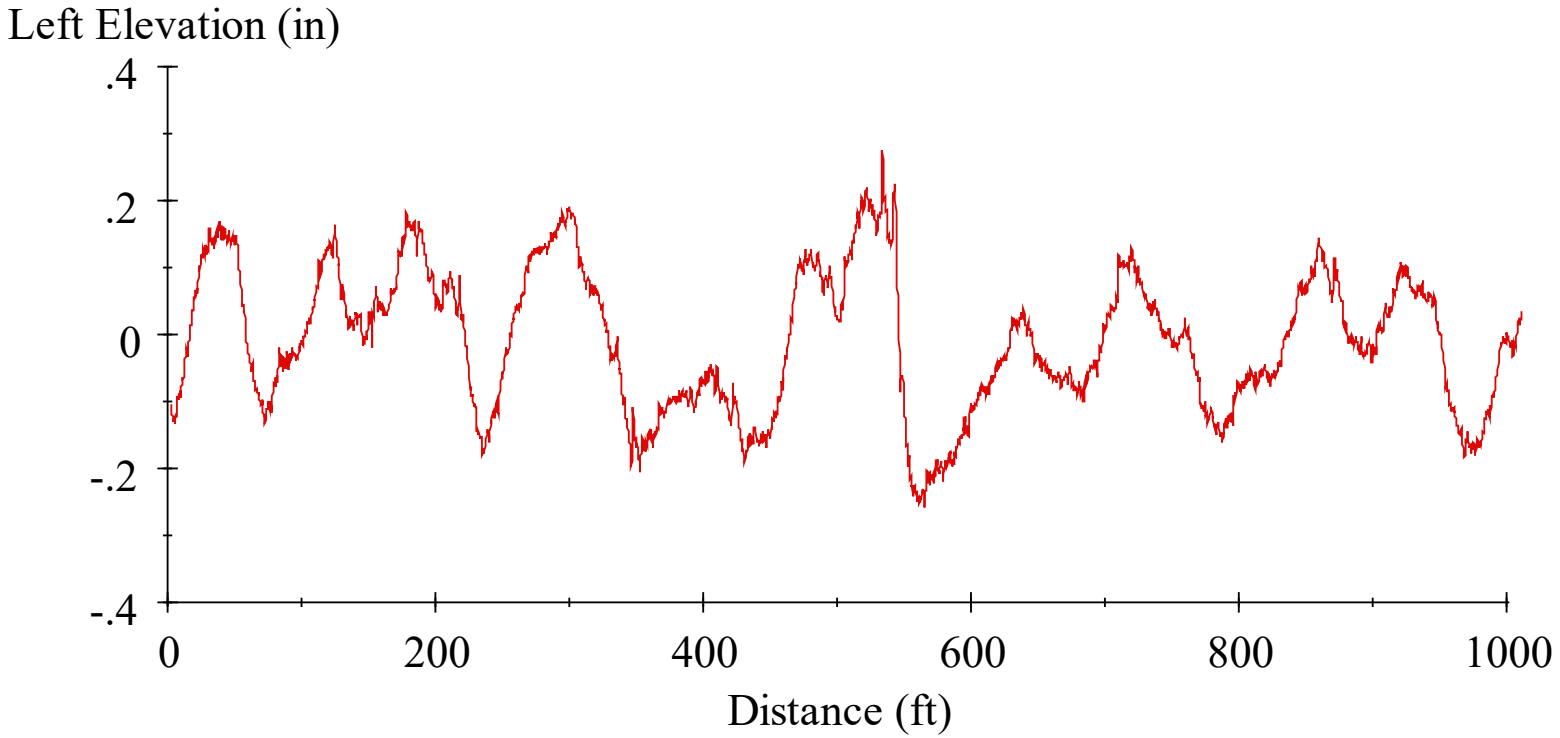
- Response type
- Vehicle type



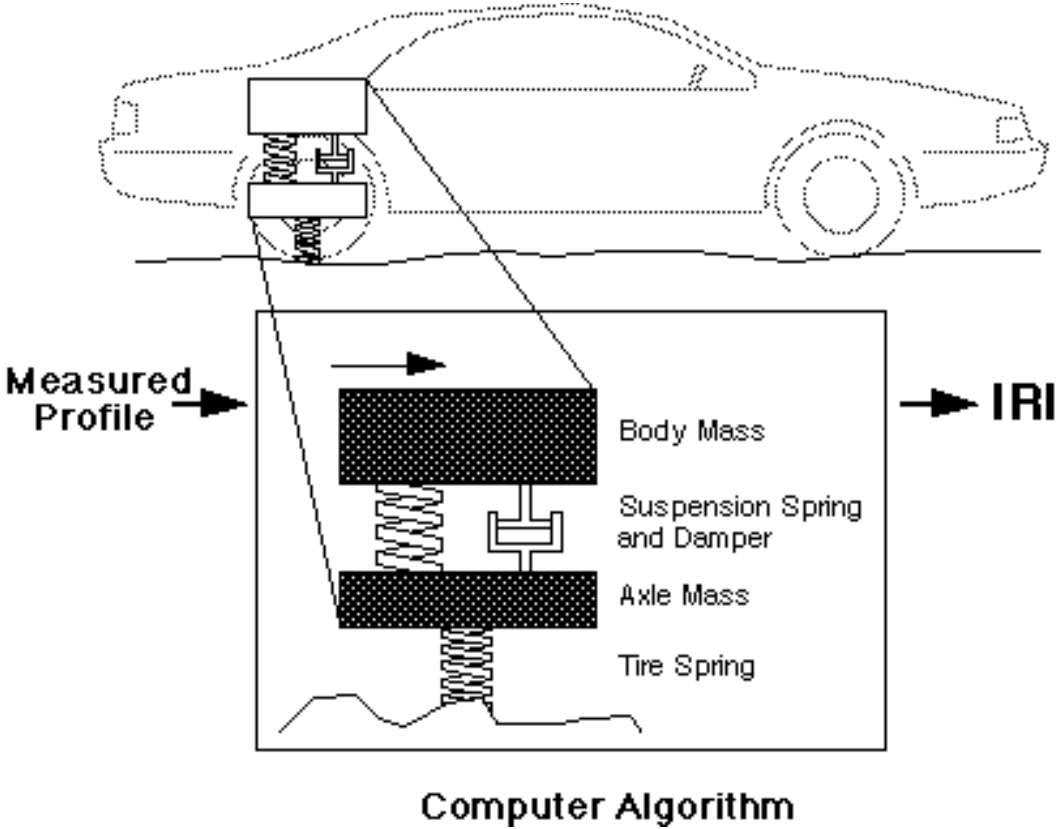
- Position within the vehicle



Sample Profile: New AC Surface

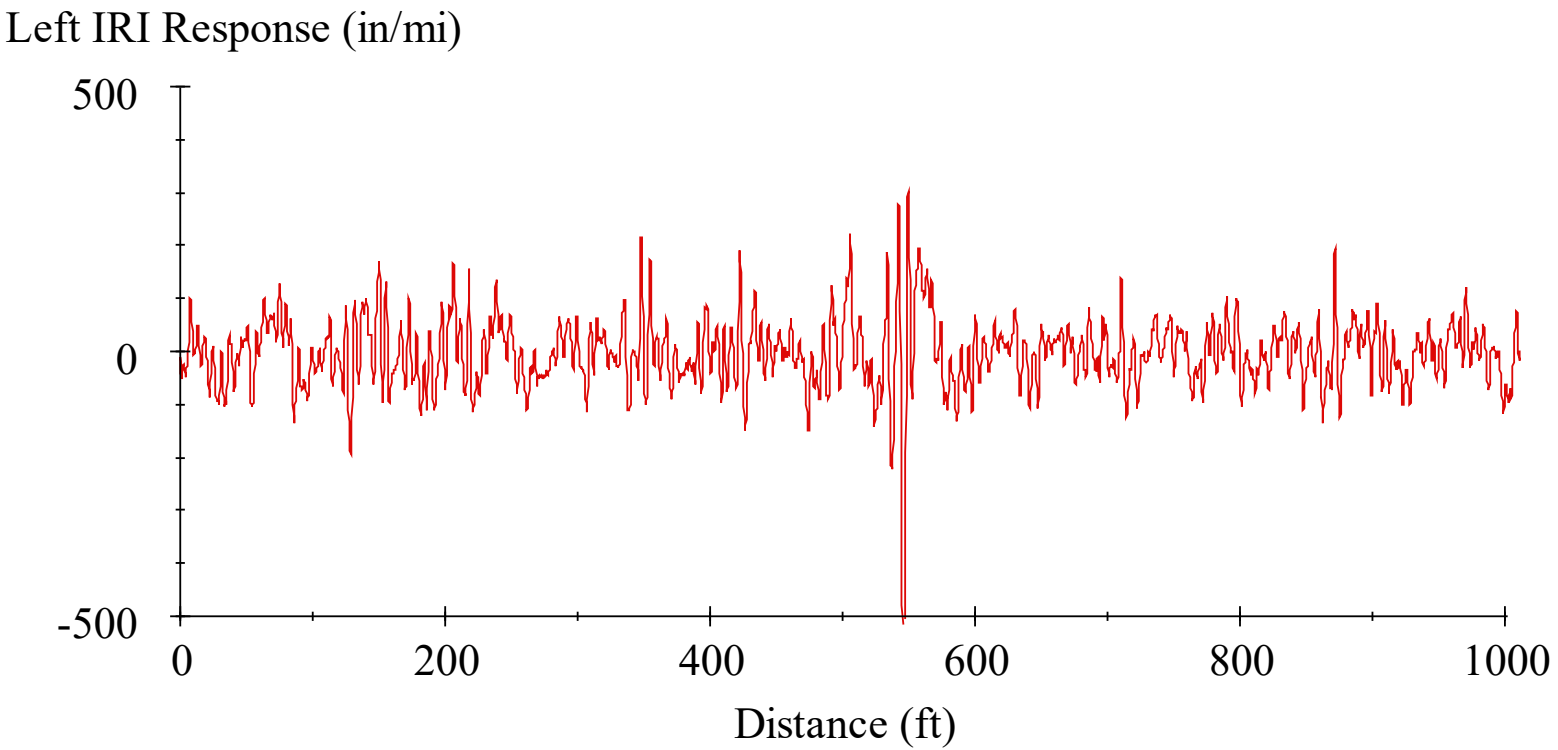


International Roughness Index



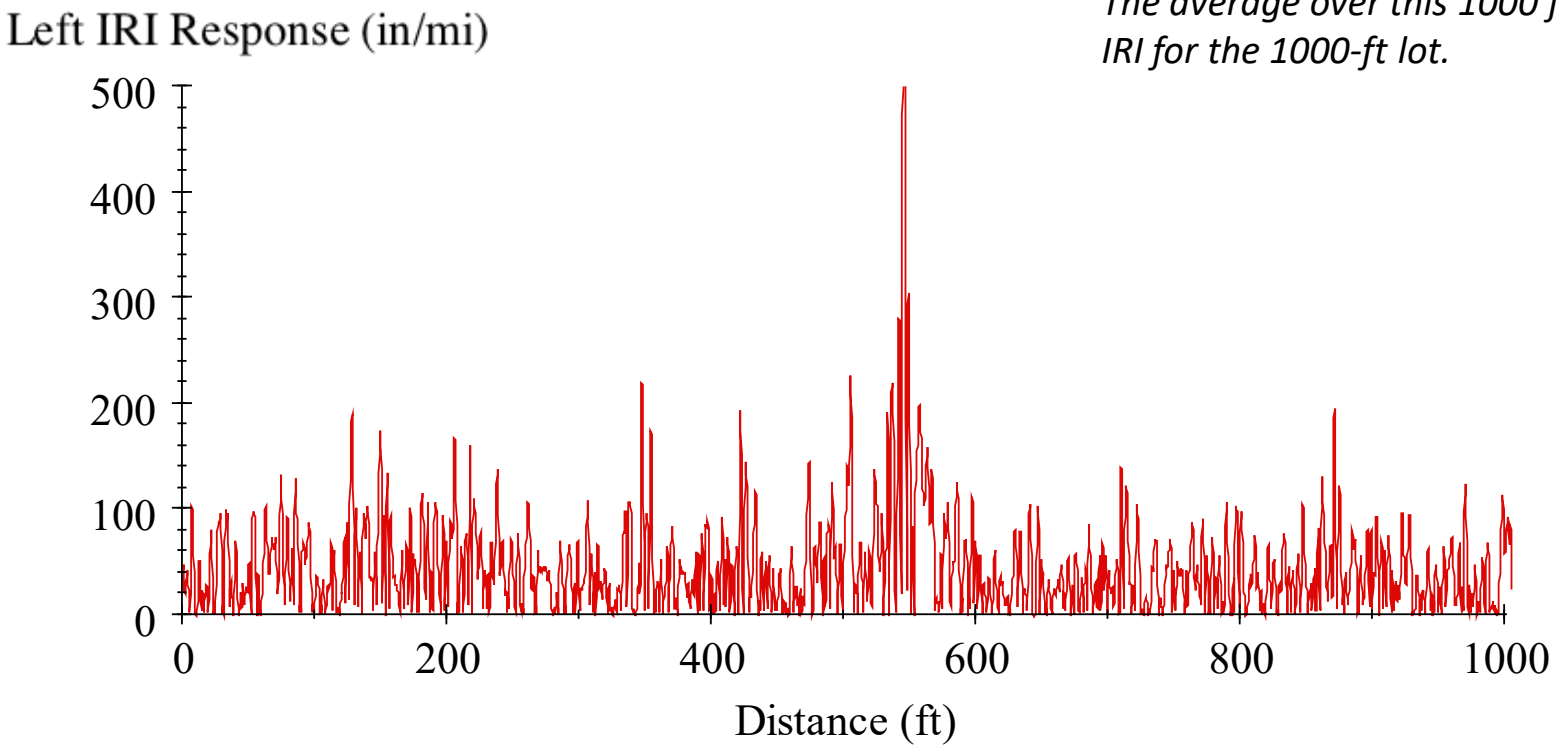
Gillespie, T. D., "Everything You Ever Wanted to Know About the IRI but Were Afraid to Ask!" RPUG Proceedings (1992).

Raw IRI Filter Output

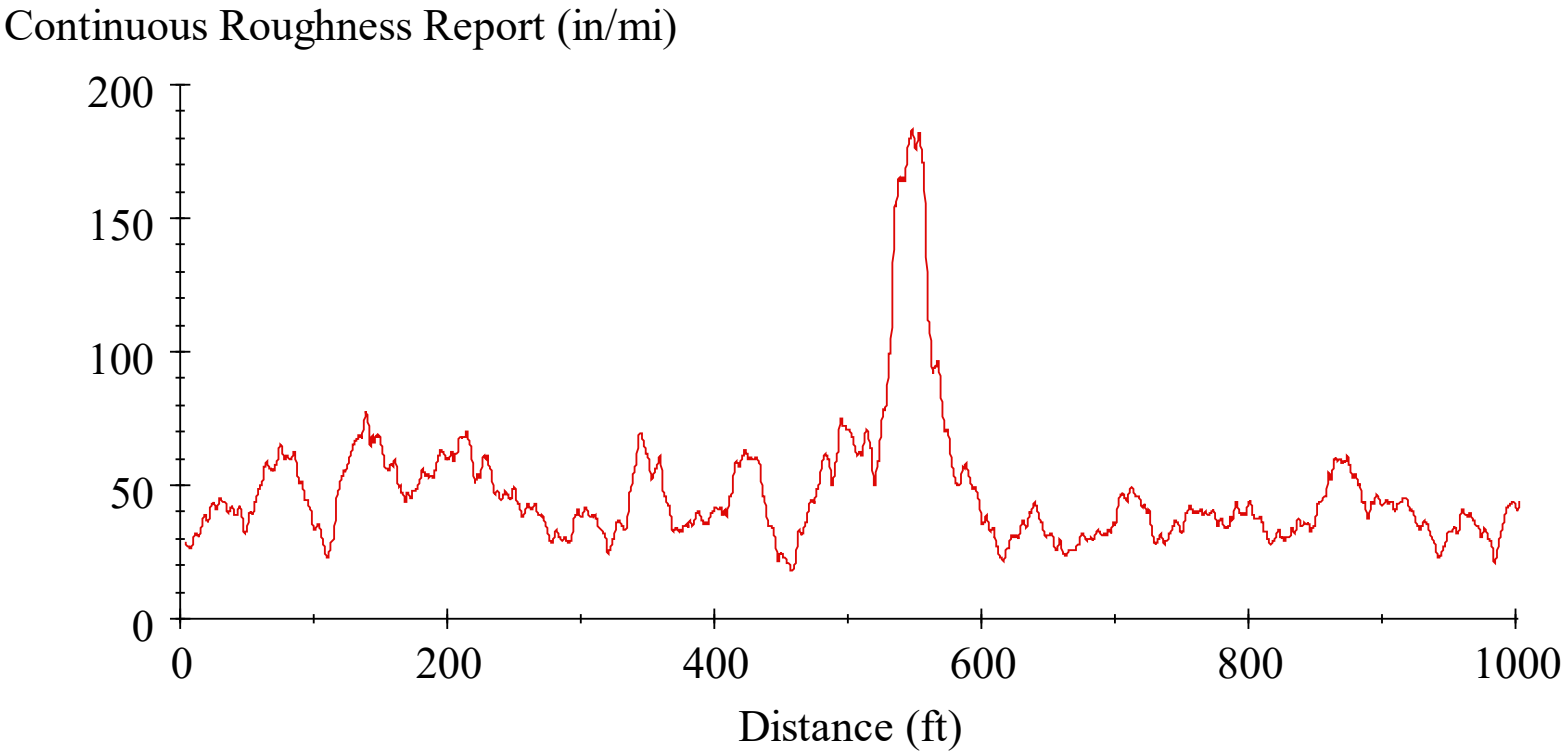


Rectified IRI Filter Output

The average over this 1000 feet is the IRI for the 1000-ft lot.



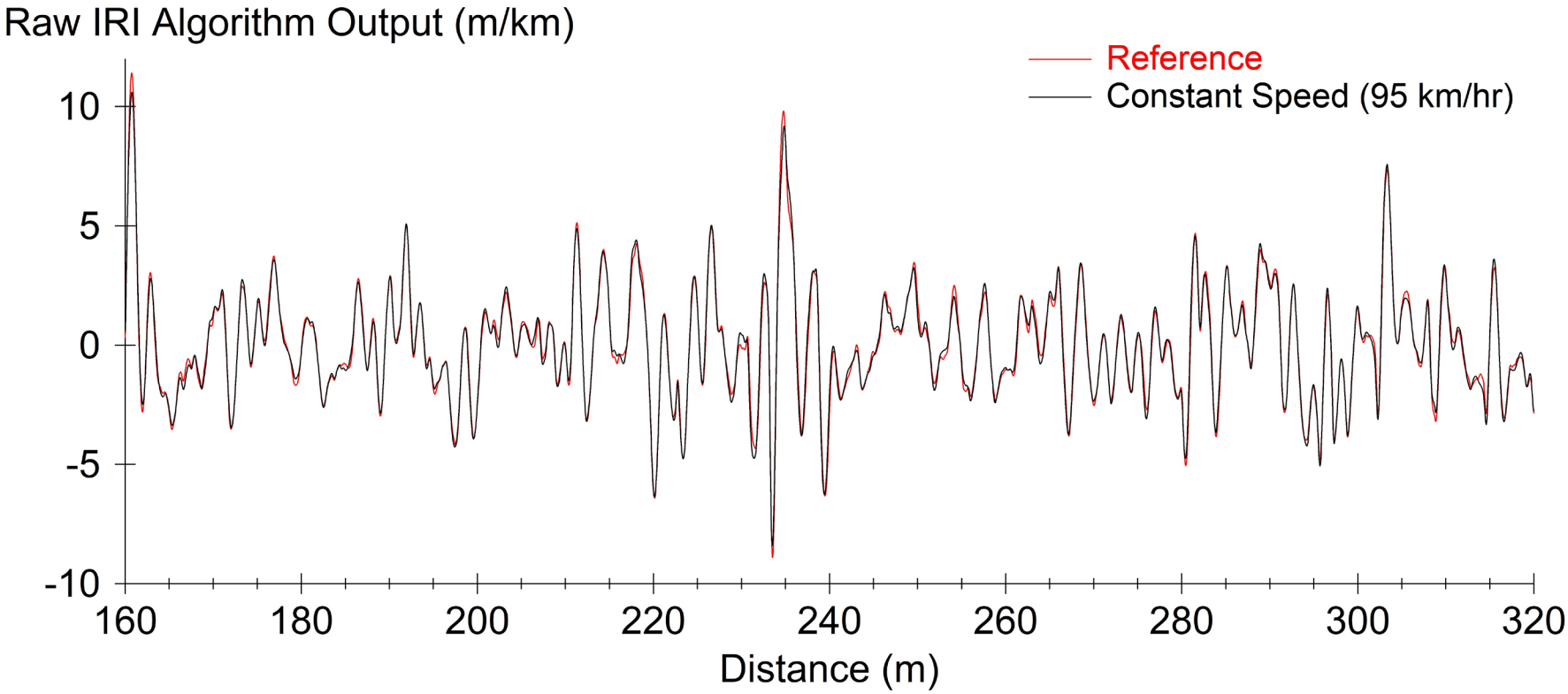
Roughness Profile



Profiler Certification

Source: 2013 Benchmark Profiler Experiment

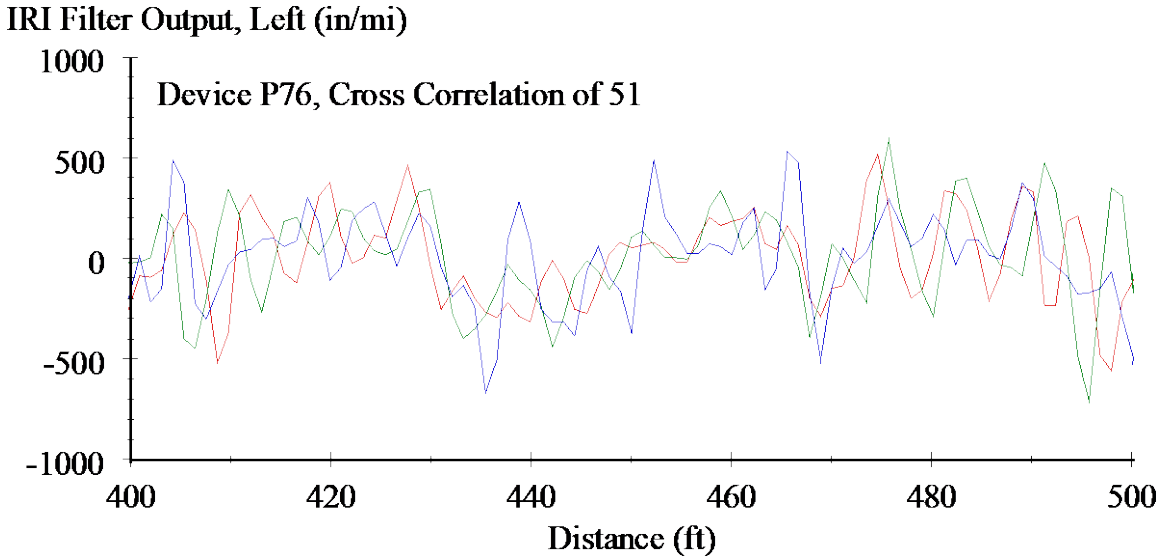
Certification/Cross Correlation (= 0.98)



See: AASHTO R56-14, *Standard Practice for Certification of Inertial Profiling Systems*.

Certification

- Agreement in both IRI and profile are required to ensure accurate production measurements.
- Many profilers that performed well on smooth texture performed poorly on coarse textures.



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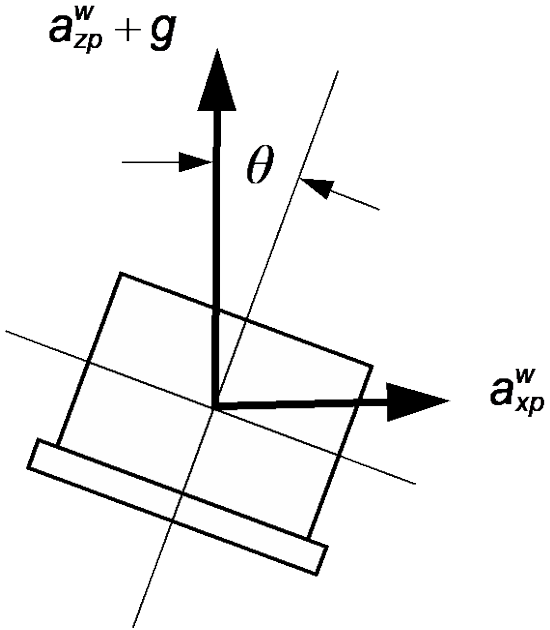
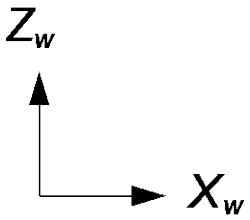
Stop and Go: Accelerometer Alignment





2013 Philadelphia County Road Survey, Courtesy of Pennsylvania DOT

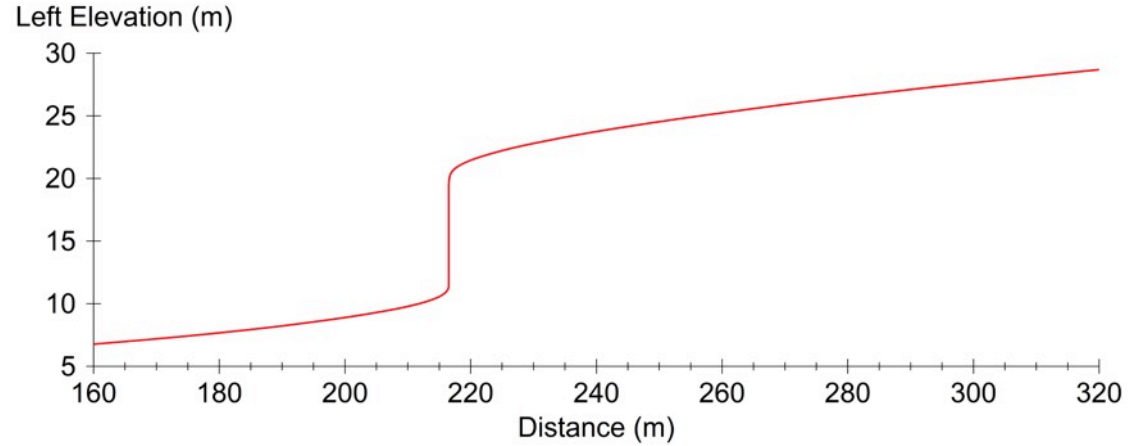
Tilted due to longitudinal deceleration

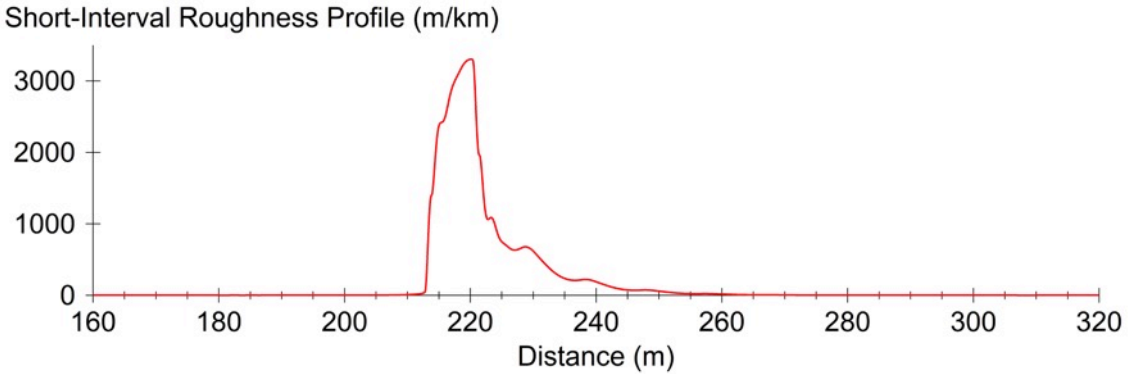
$$a^b_{zp} = a^w_{xp}\sin(\theta) + \left(a^w_{zp} + g\right)\cos(\theta) - g$$

$$a^b_{zp} - a^w_{zp} = a^w_{xp}\sin(\theta) + \left(a^w_{zp} + g\right)\left(\cos(\theta) - 1\right)$$

Sayers, M. W. and S. M. Karamihas, *The Little Book of Profiling.* University of Michigan Transportation Research Institute (1998) 100 p.

11-Second Long Stop





Reference Run:

Segment IRI = 100 in/mi

Long Stop:

Segment IRI = 13,134 in/mi

Peak IRI = 209,075 in/mi

Braking, Stop-and-Go

- Mitigate errors with better processing algorithms.
- Mitigate or eliminate errors using additional sensors.

See: Karamihas, S. M., “Improvement of Inertial Measurements of Urban and Low-Speed Roadways.” Ph.D. Dissertation, University of Michigan (2021).

Urban/Low-Speed Roughness

- Measured profile and passenger accelerations simultaneously.
- Tested on urban and low-speed roadways
- Applied ISO 2631 vibration assessment.
  (That is, we rated ride the way auto companies do it.)

Urban/Low-Speed Roughness

- Below 35 mph, a change in “Golden Car” simulation speed was needed to maximize correlation between roughness and ride.
- A temporal index (in/sec) was more successful than a spatial index (in/mi).
- Transient events (that is, localized roughness) was very important.

Source: Pennsylvania DOT

See: National Cooperative Highway Research Program Report 914.

3-D Systems

Thanks!

The Little Book of Profiling

http://www.umtri.umich.edu/content/LittleBook98R.pdf

stevemk@umich.edu