Sensitivity of Inertial Profilers to Operational Conditions on Urban and Low-Speed Roadways

By

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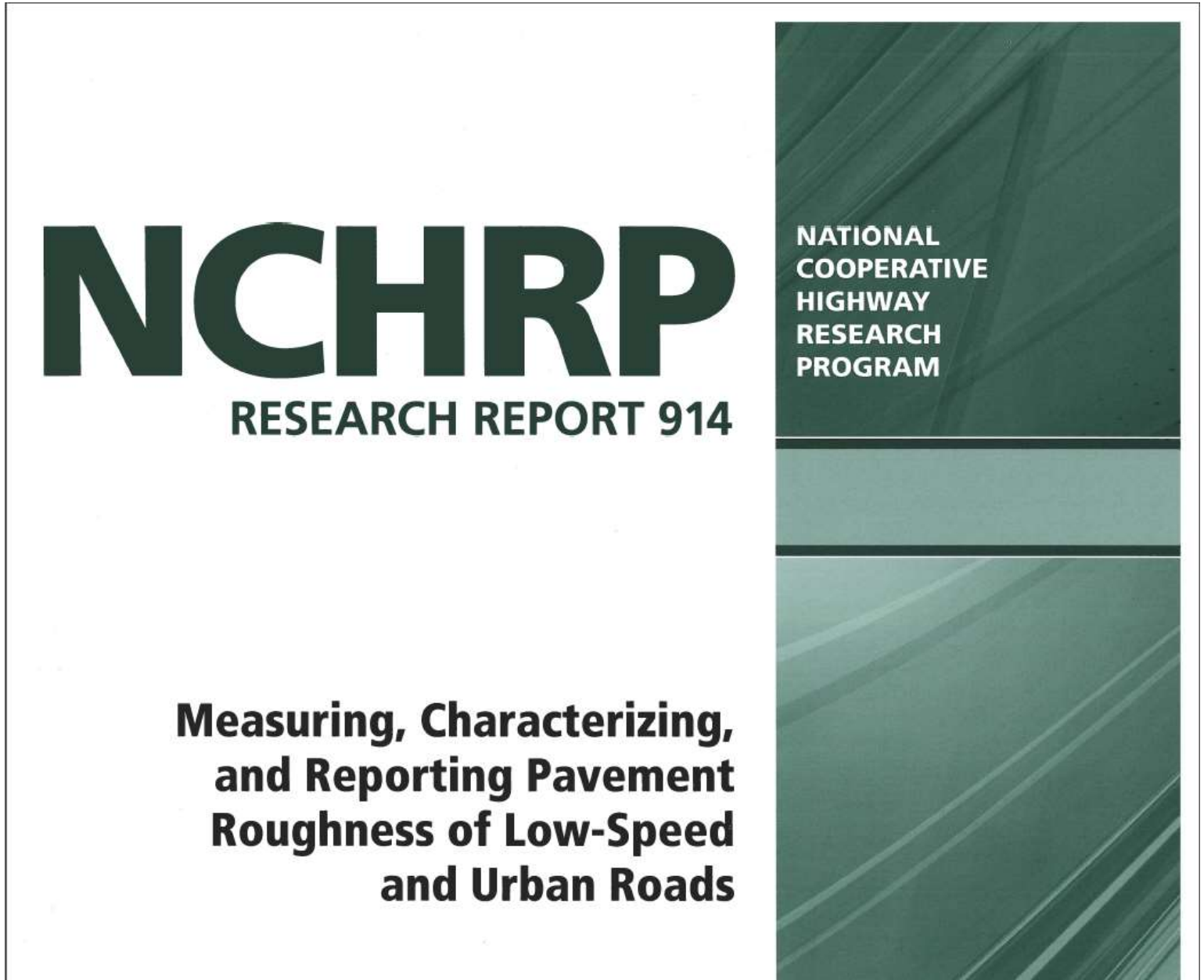
NCHRP 10-93



COTR:
Amir Hanna

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NCHRP 10-93 Approach

Valid measurement of longitudinal profile is at the core of the approach.

- Reproducibility/Time Stability
- Versatility
- Diagnostics

Characterization of the roughness will depend on profile, not the roughness source.

- Vehicle response (e.g., ride) is of primary importance.
- Tools are needed to identify roughness sources.

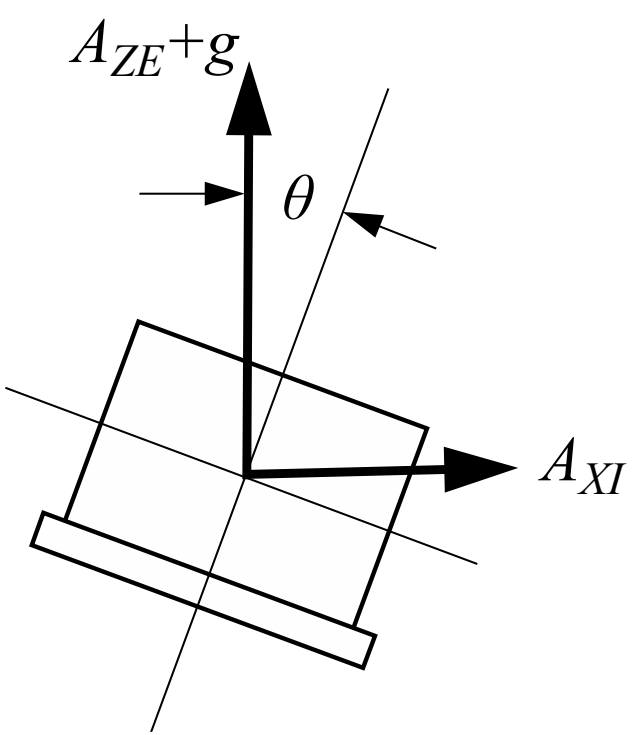
NCHRP 10-93 Study Components

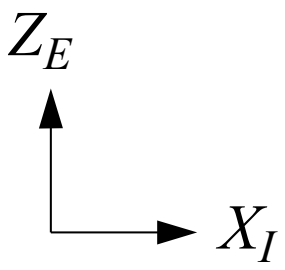
Measurement: testing of existing profilers

Characterization: ride experiment

Reporting: built-in features, specialized content

Background: Accelerometer Tilt





$$A_{ZV} = A_{XI}\sin(q) + (A_{ZE} + g)\cos(q) - g$$

$$A_{ZV} - A_{ZE} = A_{XI}\sin(q) + (A_{ZE} + g)(\cos(q) - 1)$$

Tilted due to longitudinal deceleration

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

Test Program

- Purpose
  - Learn the status of the in-service fleet.
  - Identify limitations.
  - Establish profiler test methods.
- Tested 6 high-speed profilers.
- Used staged versions of typical operational conditions.
- Tests at MnROAD.

Profilers

Source: NCHRP Rpt. 914

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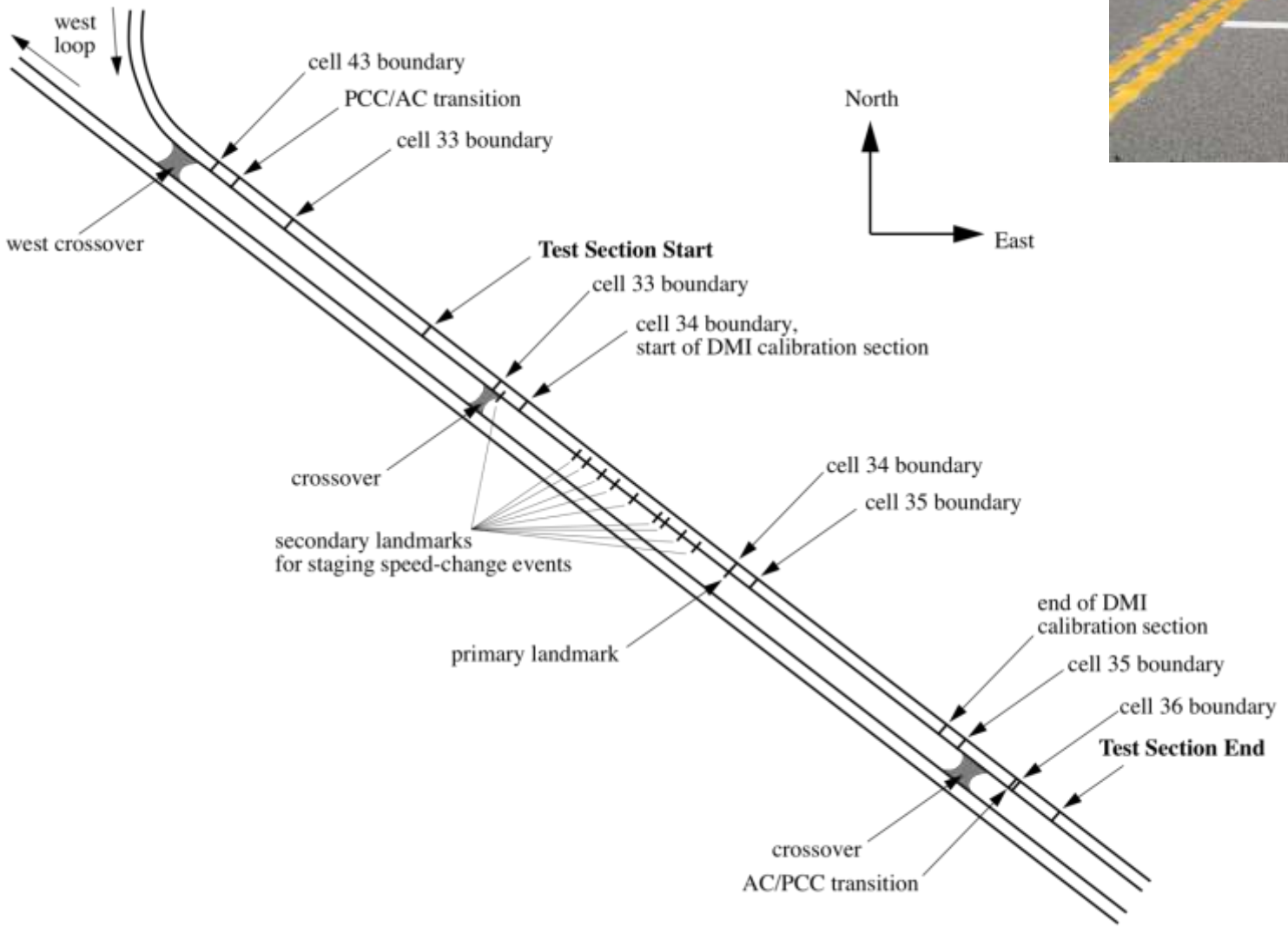
Test Section



Source: NCHRP Rpt. 914

133019 at 22.7 years

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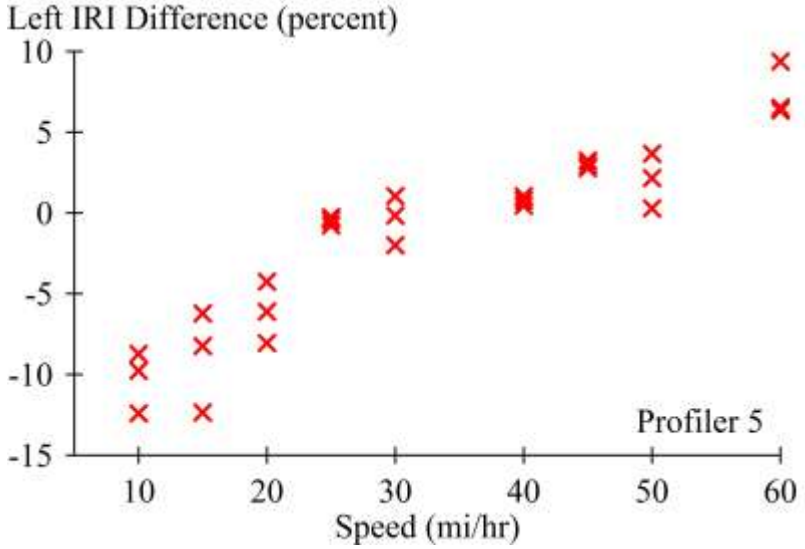
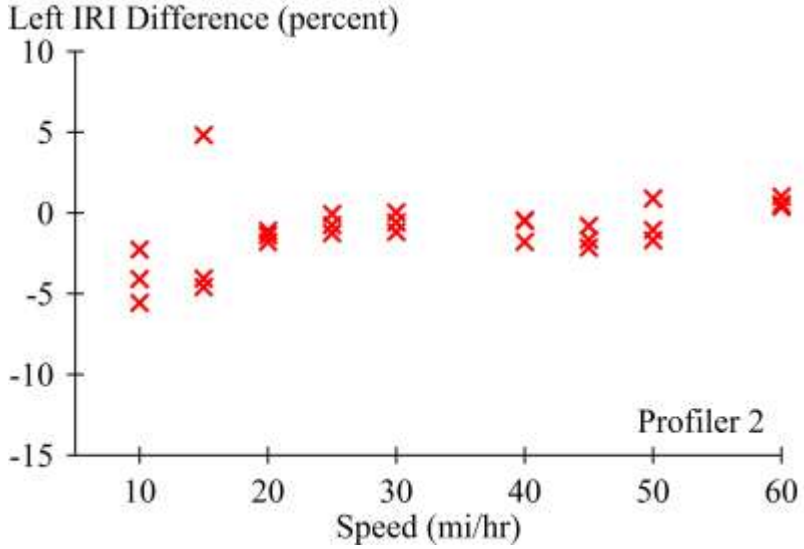
Test Conditions

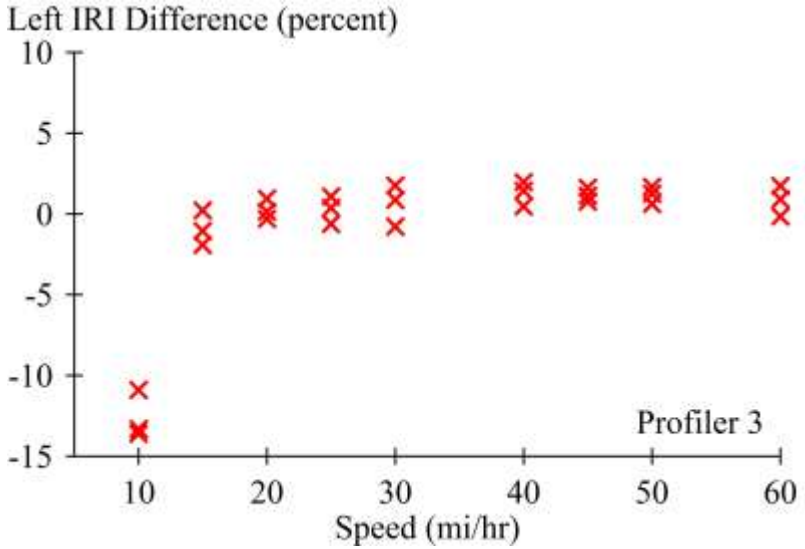
Test Type	Number	Test Conditions
Constant Speed	9	60, 50, 45, 40, 30, 25, 20, 15, and 10 mi/hr
Coast	1	initial speed 45 mi/hr
Braking	6	braking from 45-20 mi/hr at 0.1, 0.2, and 0.3 g braking from 30-15 mi/hr at 0.1, 0.2 and 0.3 g
Throttling	1	normal and heavy acceleration from 20-45 mi/hr
Stop-and-Go	4	braking at 0.1 g to stop from 30 mi/hr; stop for 5 sec; accelerate to 30 mi/hr braking at 0.2 g to stop from 30 mi/hr; stop for 5 sec; accelerate to 30 mi/hr braking at 0.2 g to stop from 45 mi/hr; stop for 5 sec; accelerate to 45 mi/hr braking at 0.2 g to stop from 45 mi/hr; stop for 1 sec; accelerate to 45 mi/hr
Dead Stop	2	normal and heavy acceleration to 45 mi/hr
Operation on a Curve	3	20, 30, and 40 mi/hr

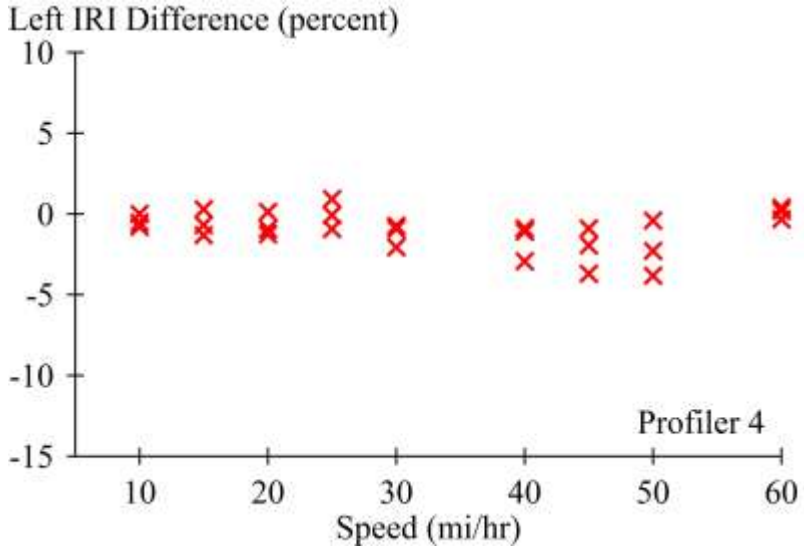
Source: NCHRP Rpt. 914

IRI Agreement Versus Speed









Source: NCHRP Rpt. 914

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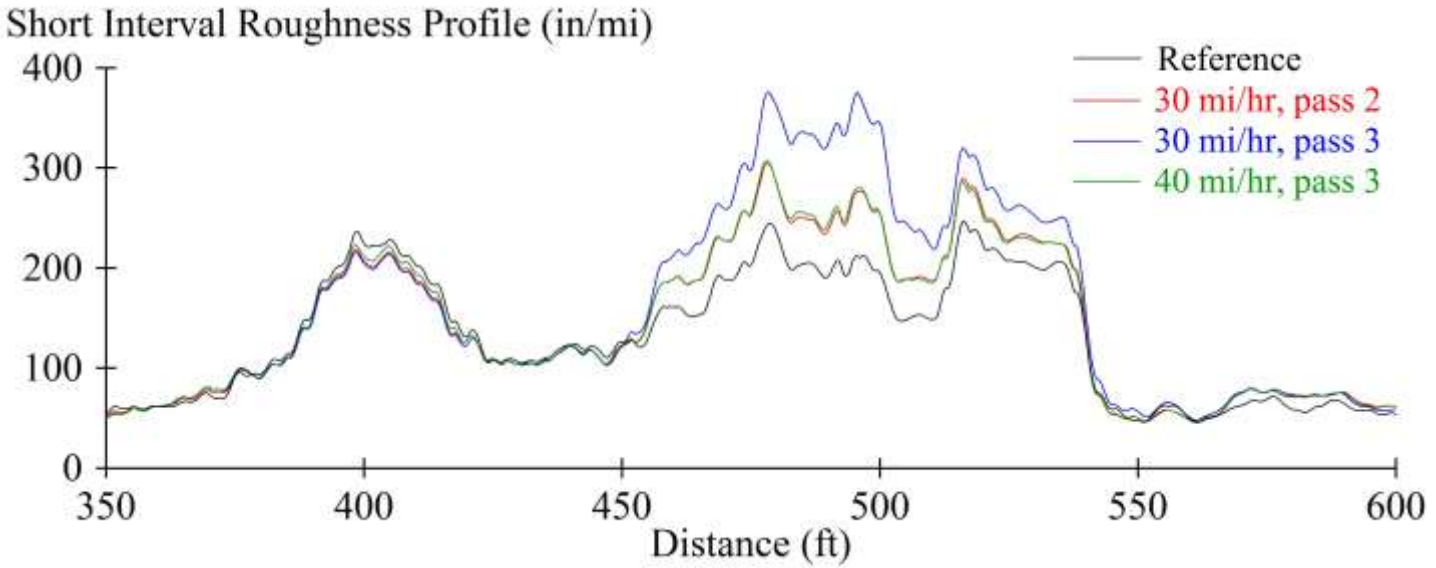
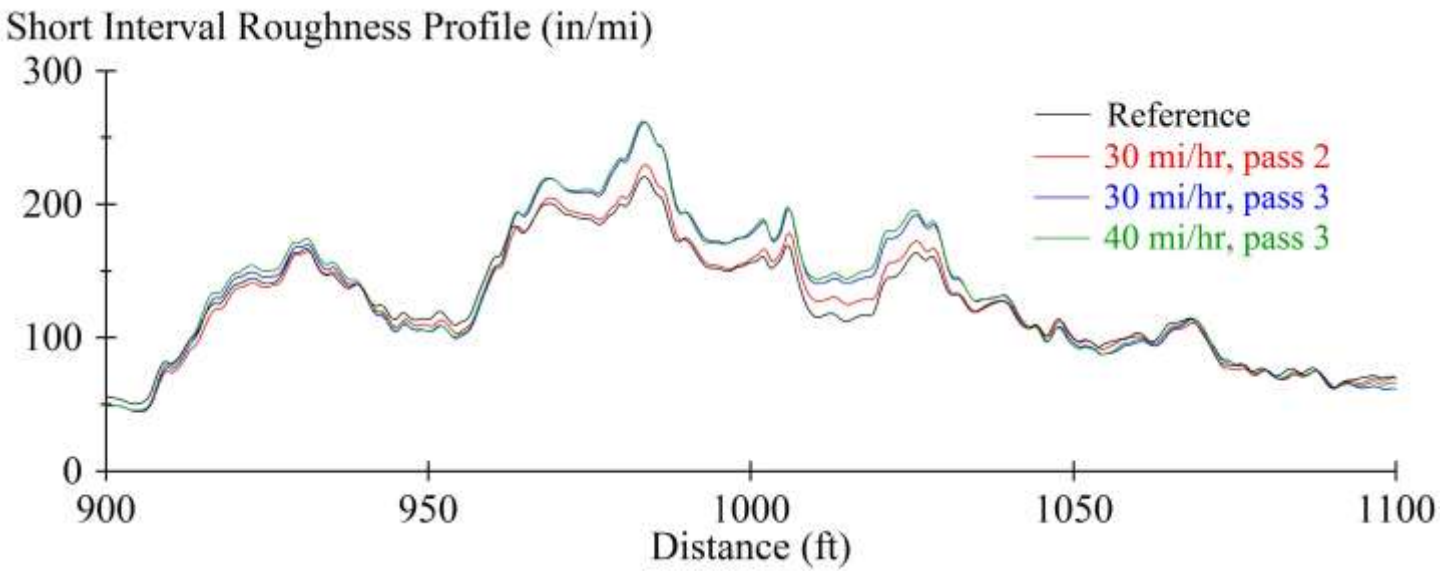
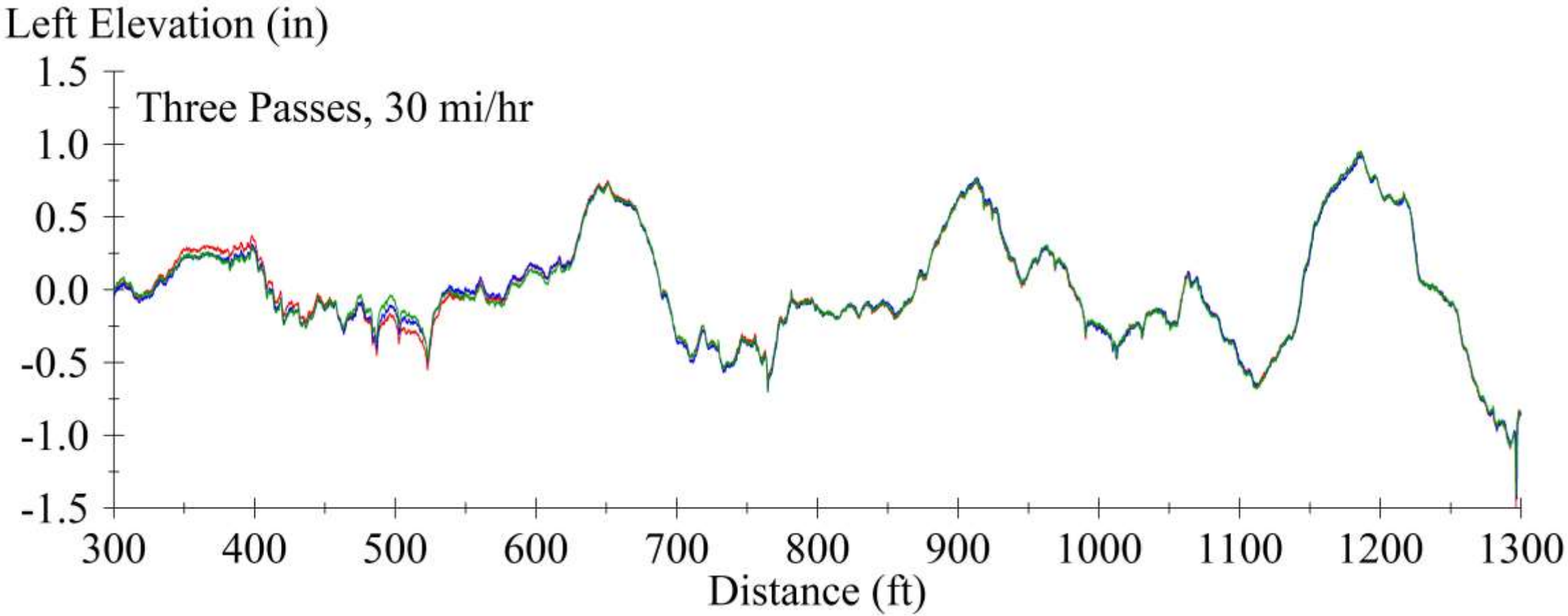
Sensitivity to Lateral Tracking





Source: NCHRP Rpt. 914

Raw Profiles, 30 mph



Source: NCHRP Rpt. 914

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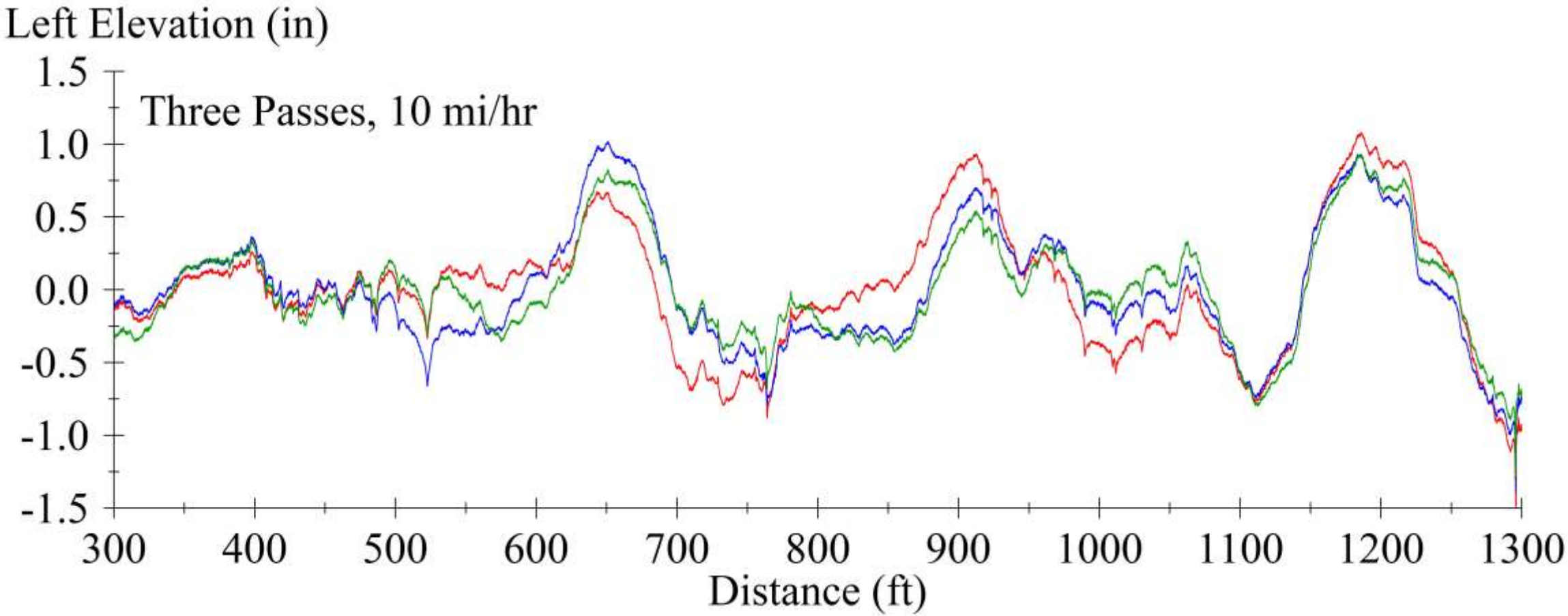
Raw Profiles, 10 mph



Source: NCHRP Rpt. 914

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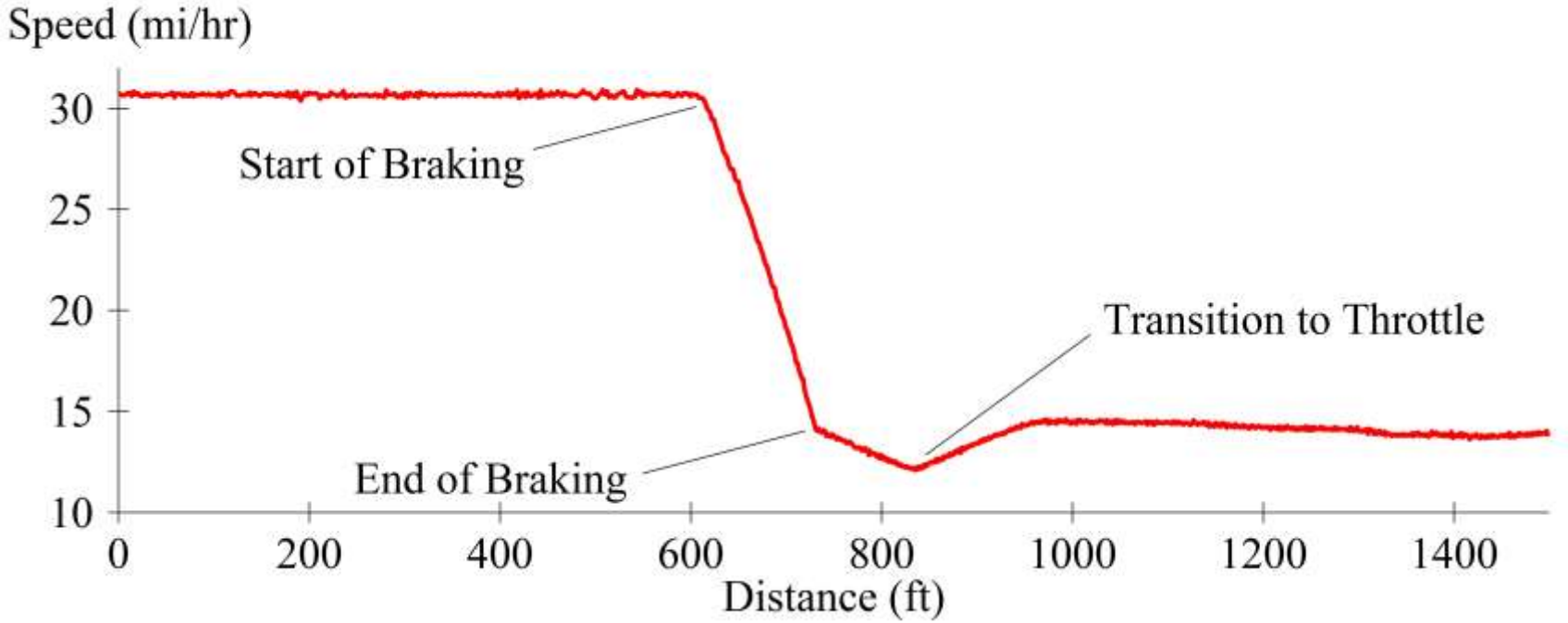
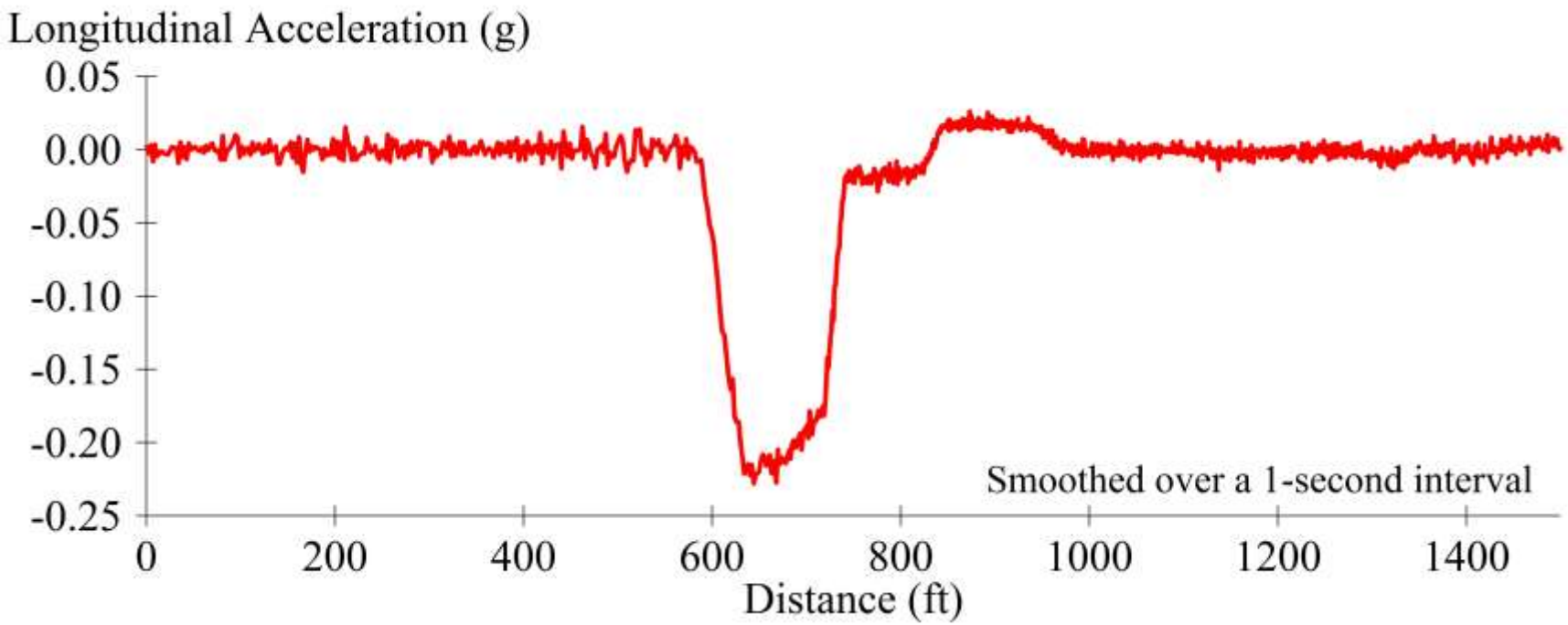
Repeatability Score Versus Speed

	10 mph	15 mph	20 mph	25 mph	30 mph	40 mph	45 mph	50 mph	60 mph
60 mph	0.963	0.971	0.983	0.983	0.976	0.972	0.974	0.974	0.990
50 mph	0.942	0.954	0.976	0.984	0.986	0.987	0.992	0.992	
45 mph	0.942	0.955	0.978	0.986	0.989	0.990	0.992		
40 mph	0.941	0.955	0.980	0.985	0.992	0.991			
30 mph	0.946	0.961	0.984	0.991	0.996				
25 mph	0.953	0.966	0.988	0.991					
20 mph	0.954	0.969	0.986						
15 mph	0.958	0.964							
10 mph	0.948								

Source: NCHRP Rpt. 914

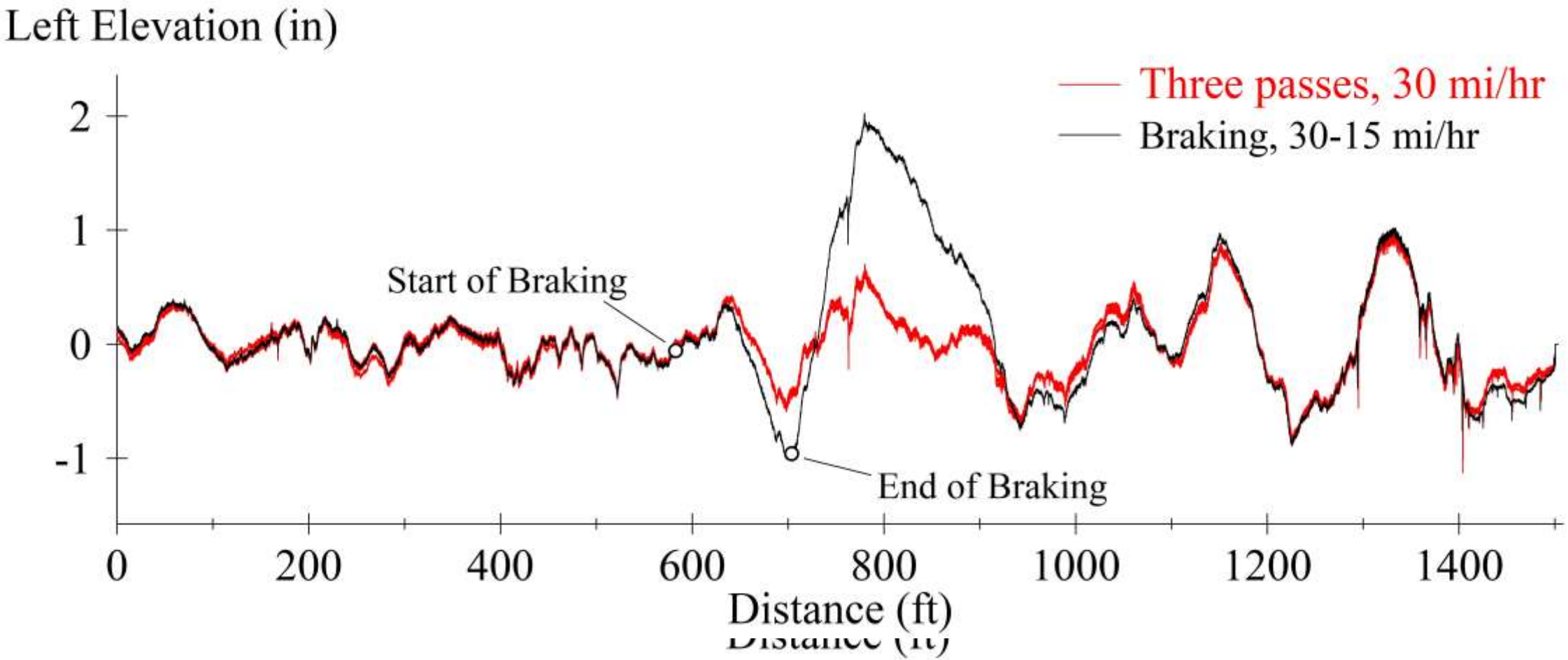
Braking





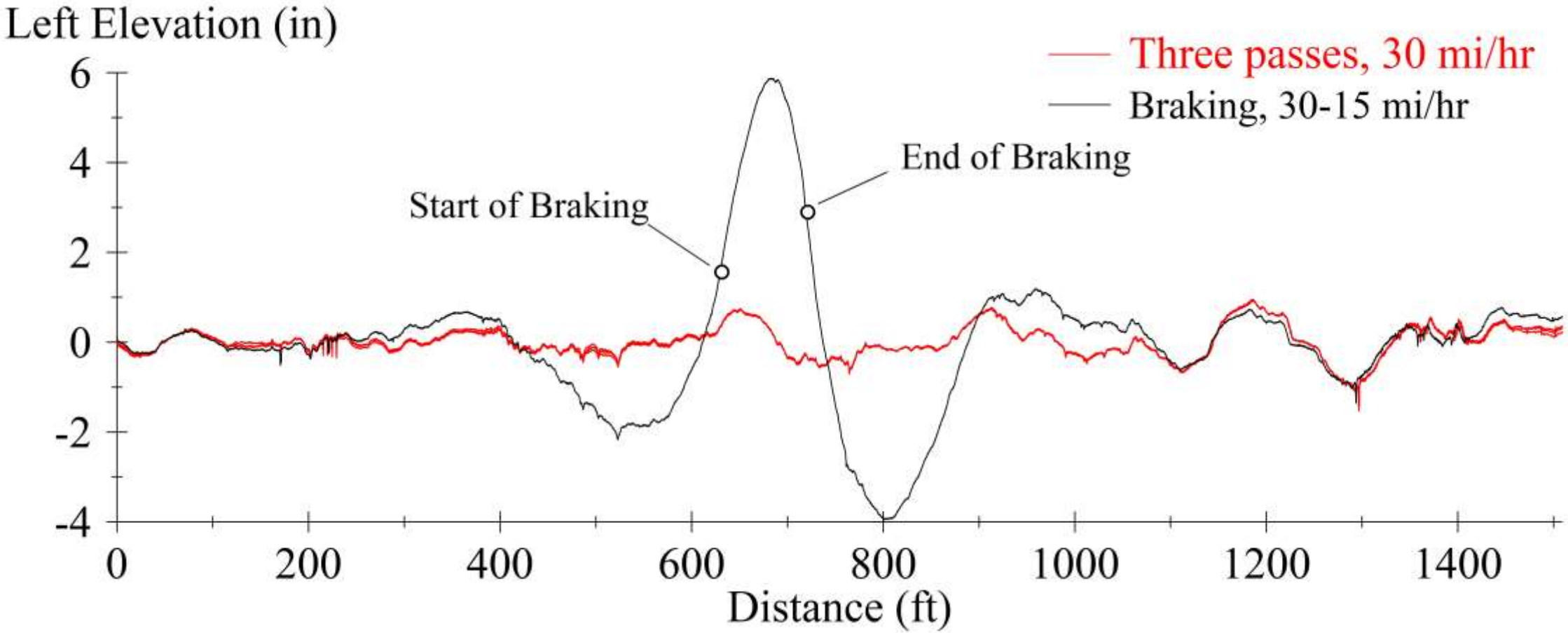
Source: NCHRP Rpt. 914

Braking, Raw Profile



Source: NCHRP Rpt. 914

Braking, Raw Profile



Source: NCHRP Rpt. 914

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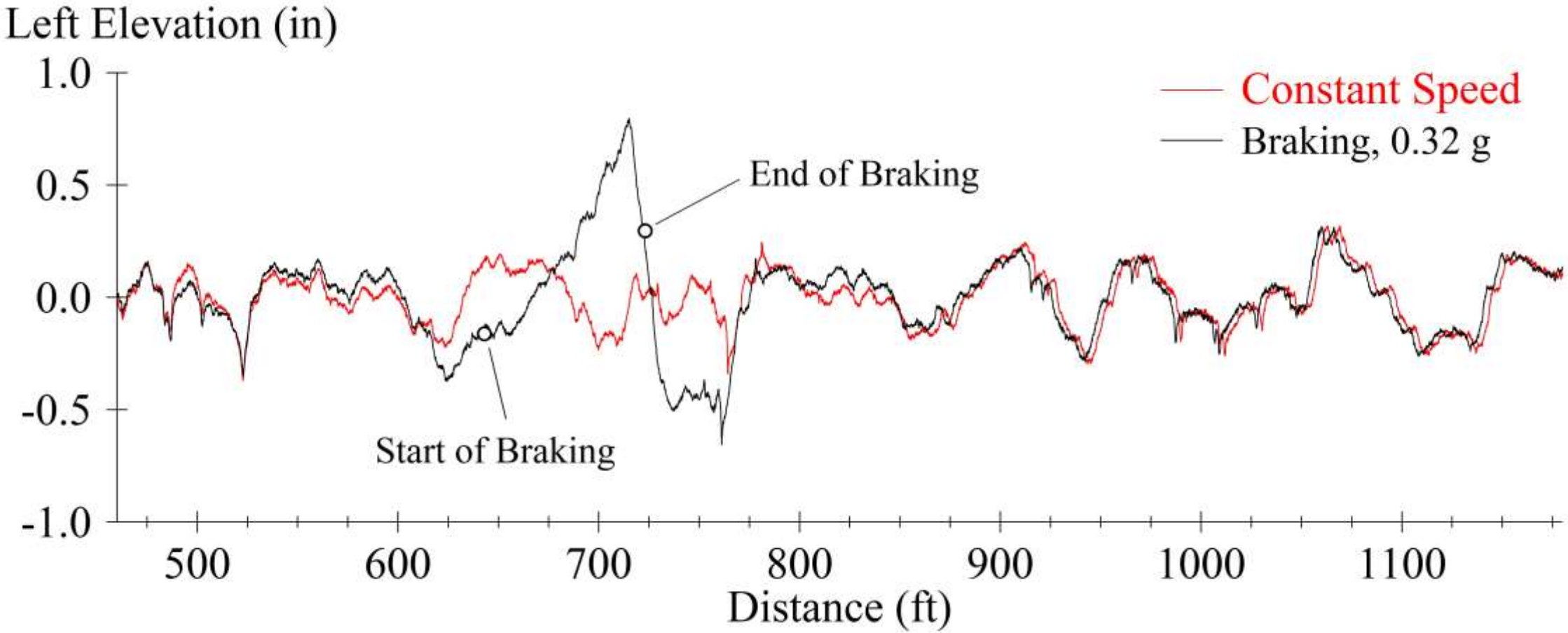
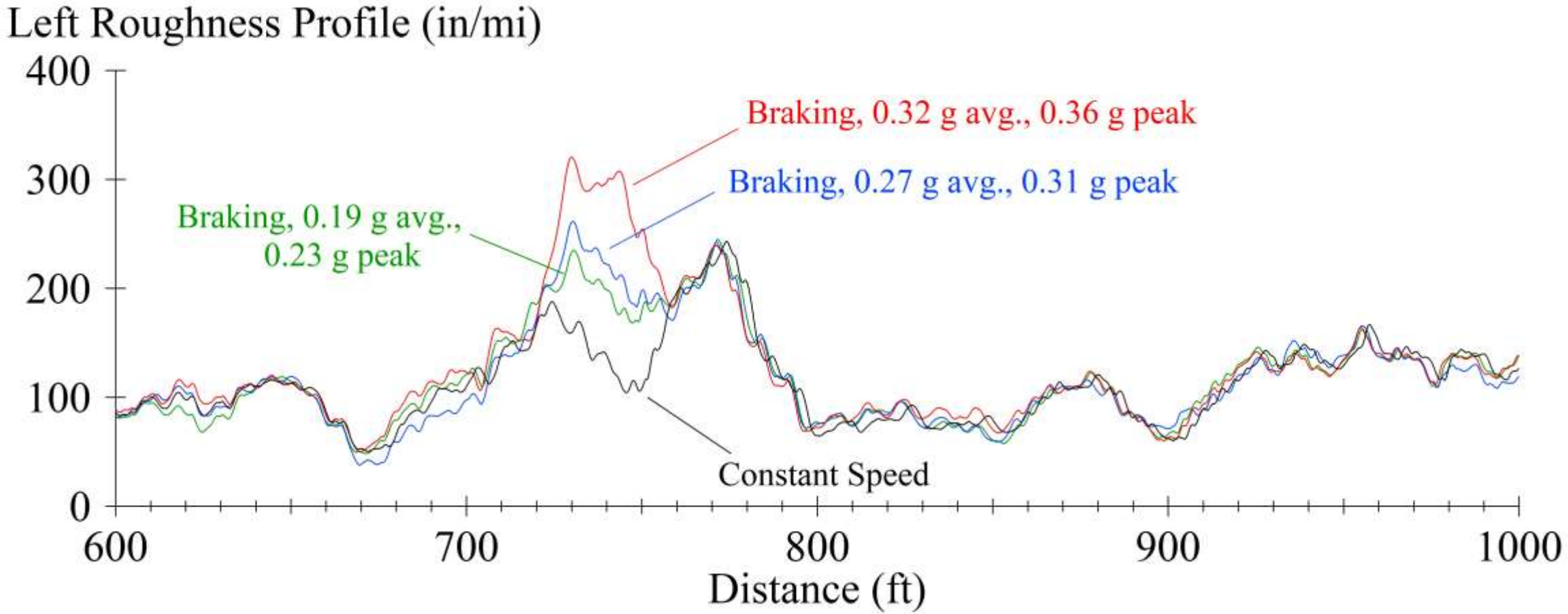
Braking, High-Pass Filtered Profile



Source: NCHRP Rpt. 914

Braking, Roughness Profile



Source: NCHRP Rpt. 914

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Braking, “Contaminated Region”

Braking events, 30-15 mph

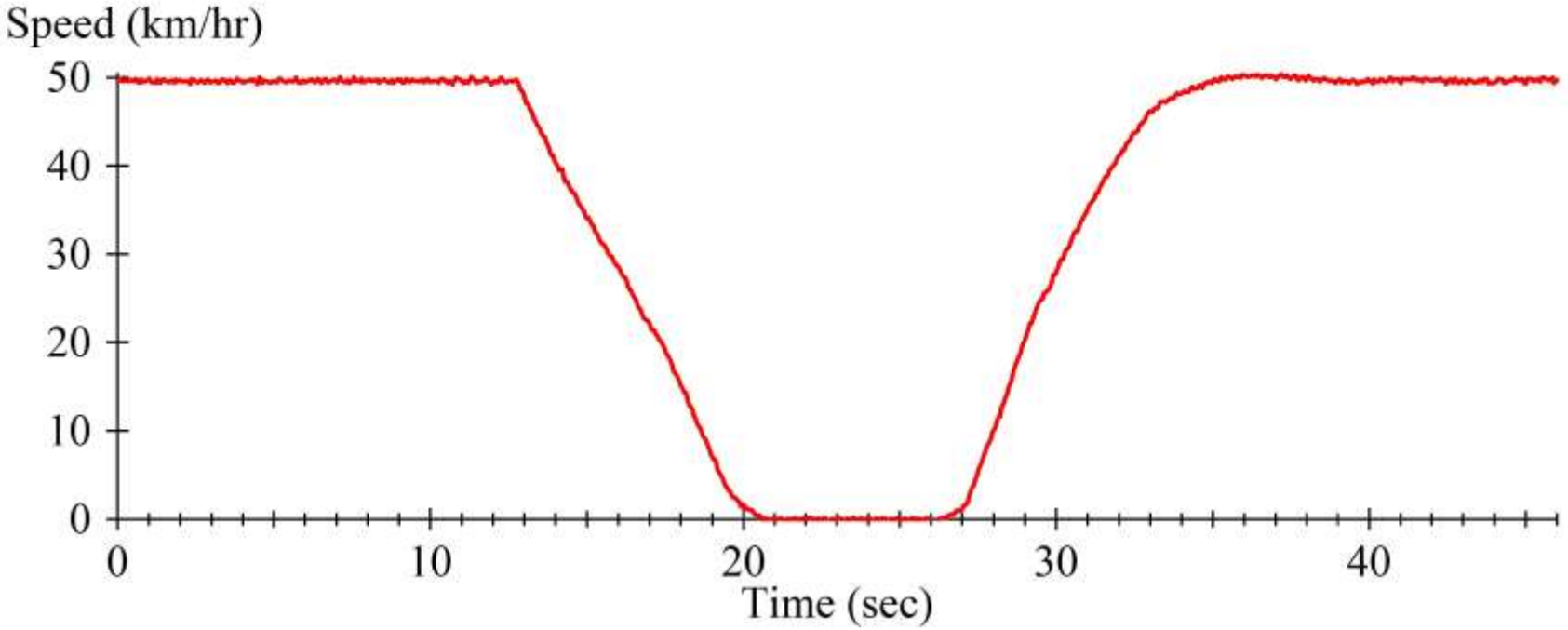
Deceleration Range (g)		Number of Passes		
Peak	Average	Total	Altered Roughness	Localized Roughness Increase
0.09-0.16	0.05-0.13	23	4	1
0.18-0.25	0.16-0.20	16	12	5
0.26-0.43	0.22-0.40	25	23	16

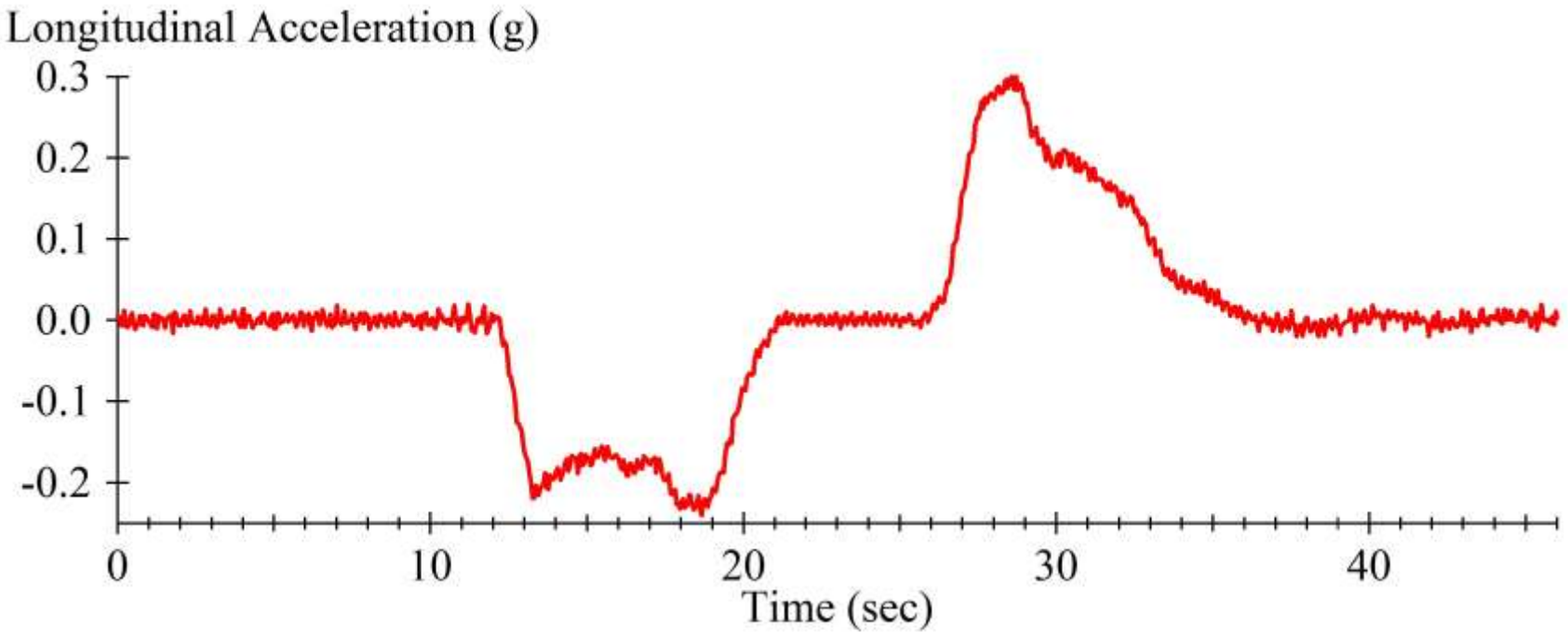
Braking events, 45-20 mph

Average Deceleration (g)	Number of Passes		
	Total	Altered Roughness	Localized Roughness Increase
0.04-0.16	26	5	0
0.17-0.23	26	11	4
0.24-0.35	23	16	12

Source: NCHRP Rpt. 914

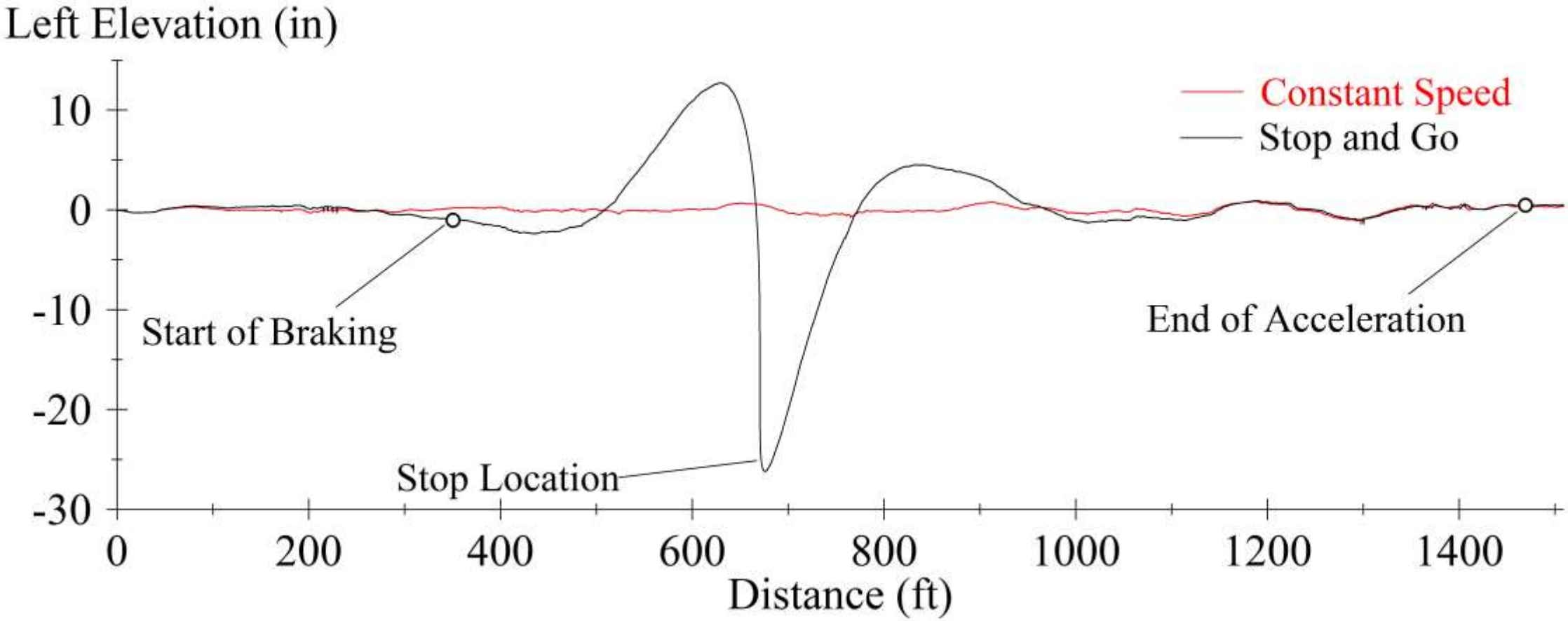
Stop and Go





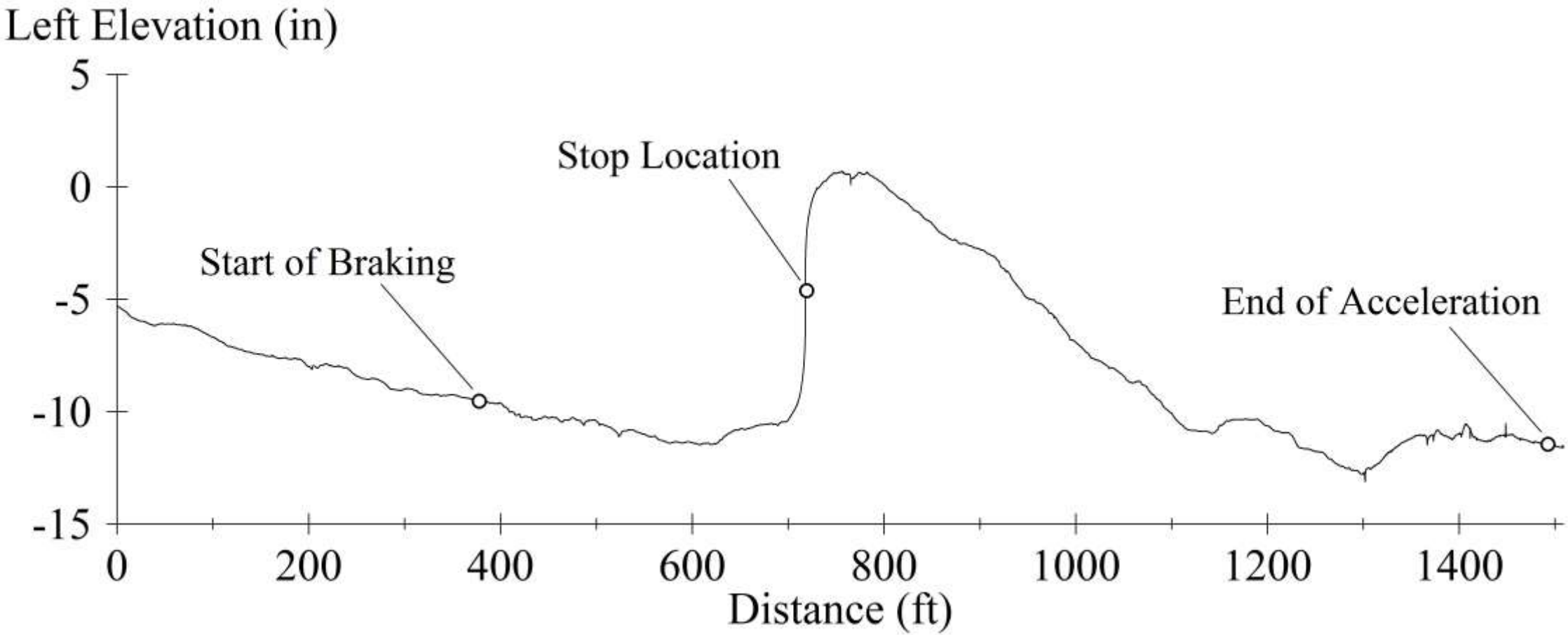
Source: NCHRP Rpt. 914

Stop-and-Go, Raw Profile



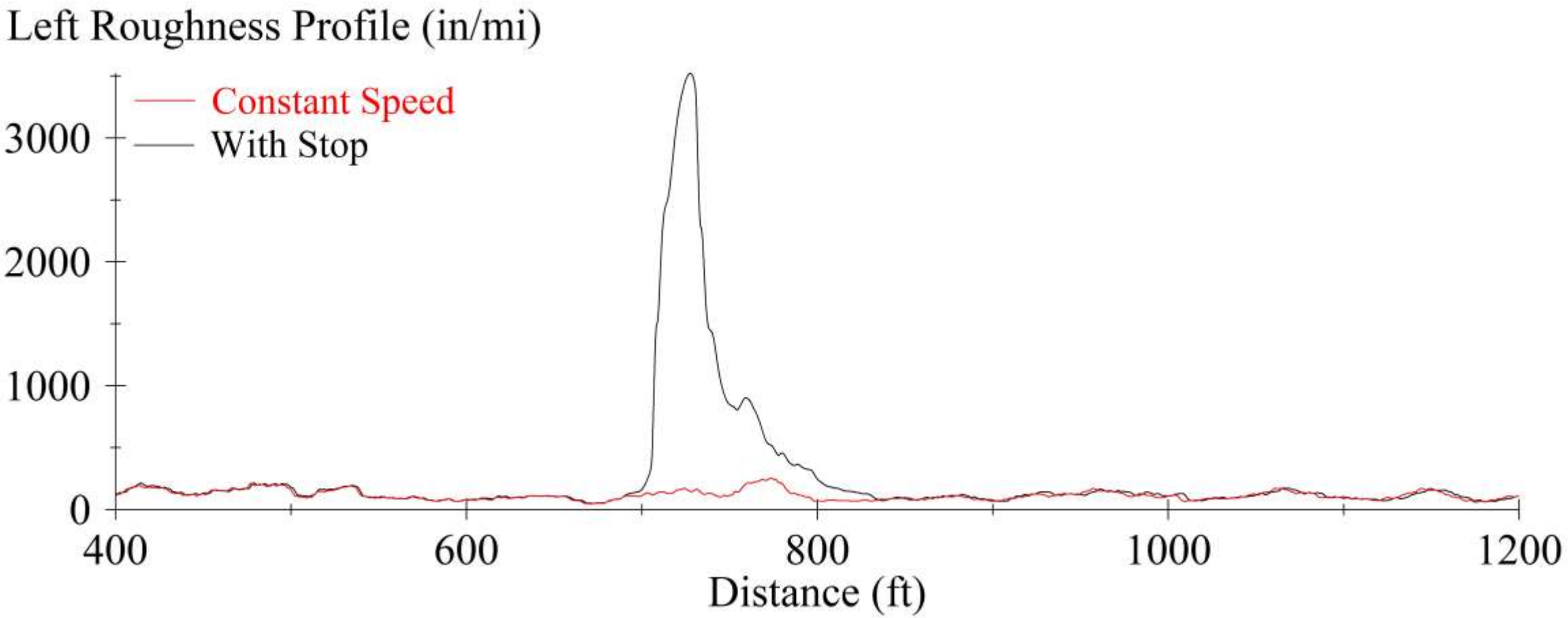
Source: NCHRP Rpt. 914

Stop-and-Go, Raw Profile



Source: NCHRP Rpt. 914

Stop-and-Go, Roughness Profile



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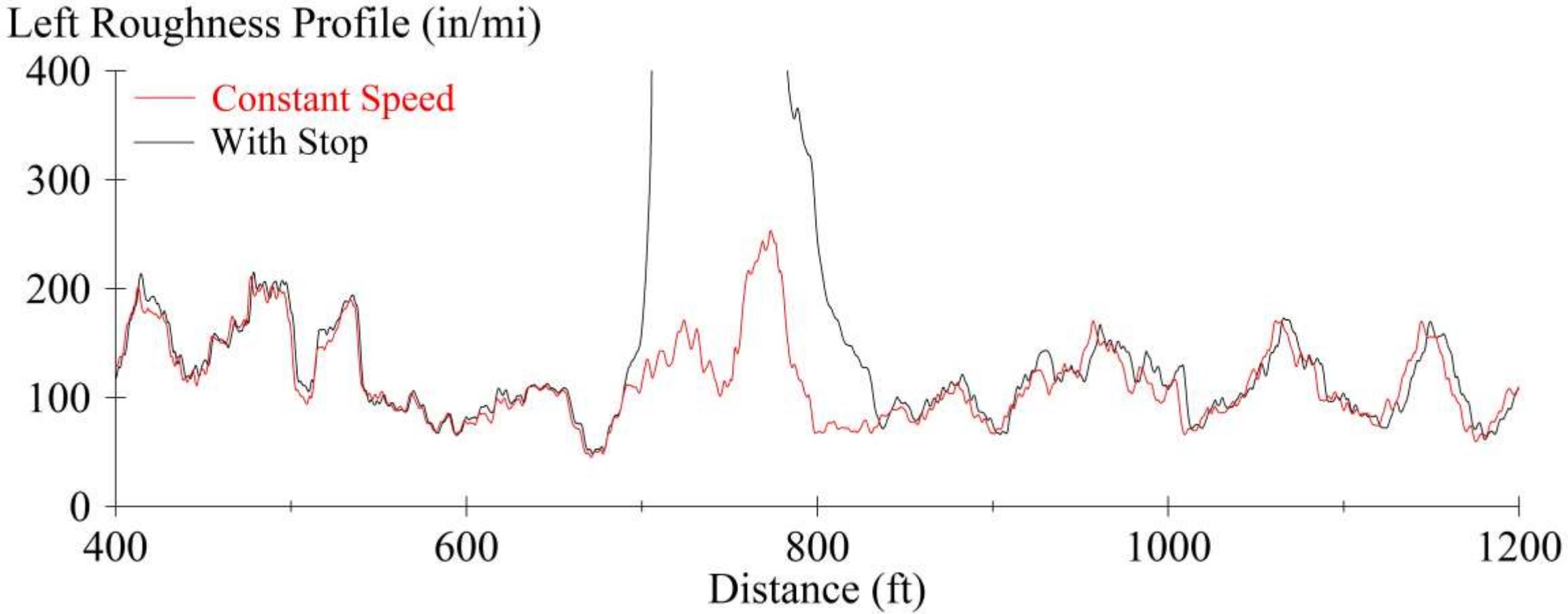
Stop-and-Go, Roughness Profile



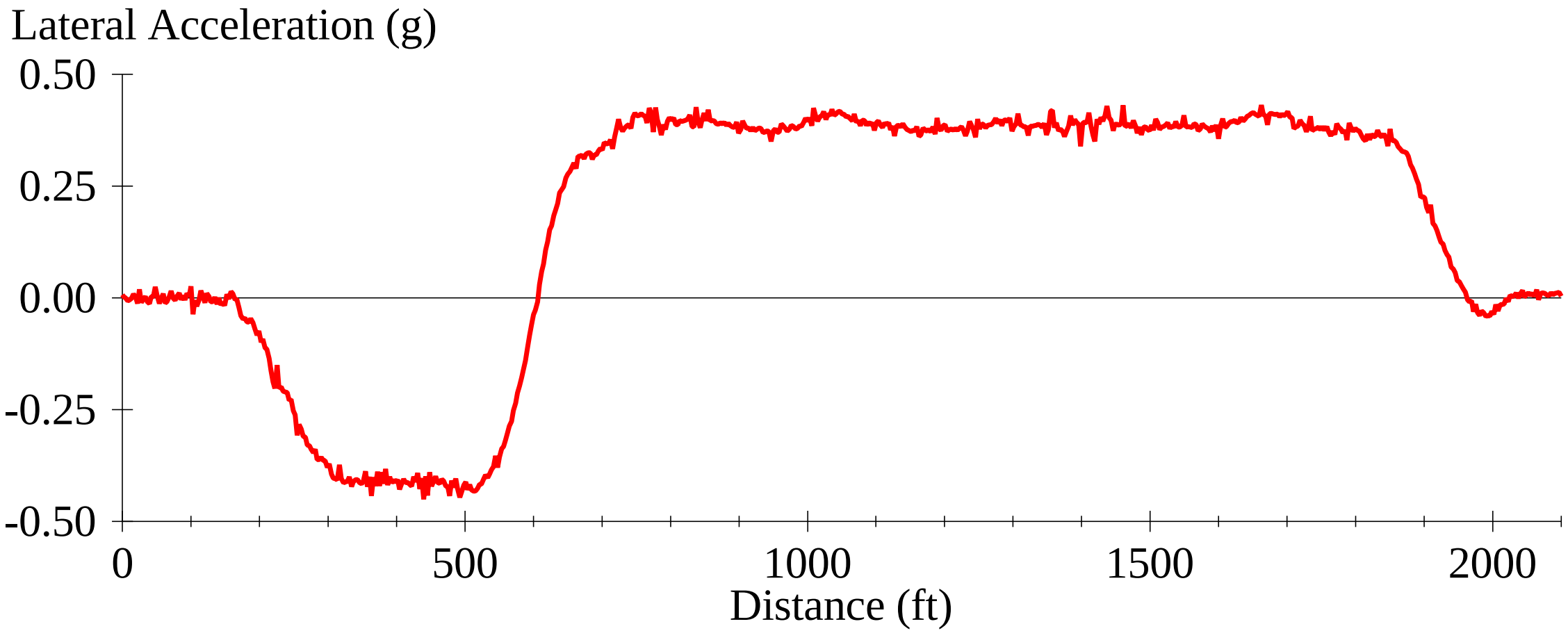
Source: NCHRP Rpt. 914

Stop-and-Go, “Contaminated Region”

Profiler	Side	Passes	Peak Localized Roughness (in/mi)	Contaminated Area (ft)	
				Upstream	Downstream
Profiler 1	Left	14	570-1,265	-44	77
	Right	14	380-635	-44	137
Profiler 2	Left	12	3,040-6,275	-46	160
	Right	12	0-2,220	-34	123
Profiler 3	Left	13	0-190	-33	96
	Right	13	30-190	-59	93
Profiler 4	Left	13	6,526-41,247	-78	171
	Right	13	4,055-37,000	-46	156
Profiler 5	Left	13	26,930-170,945	-152	248
	Right	13	10,330-256,610	-155	245
Profiler 6	Right	12	1,900-10,075	-74	153

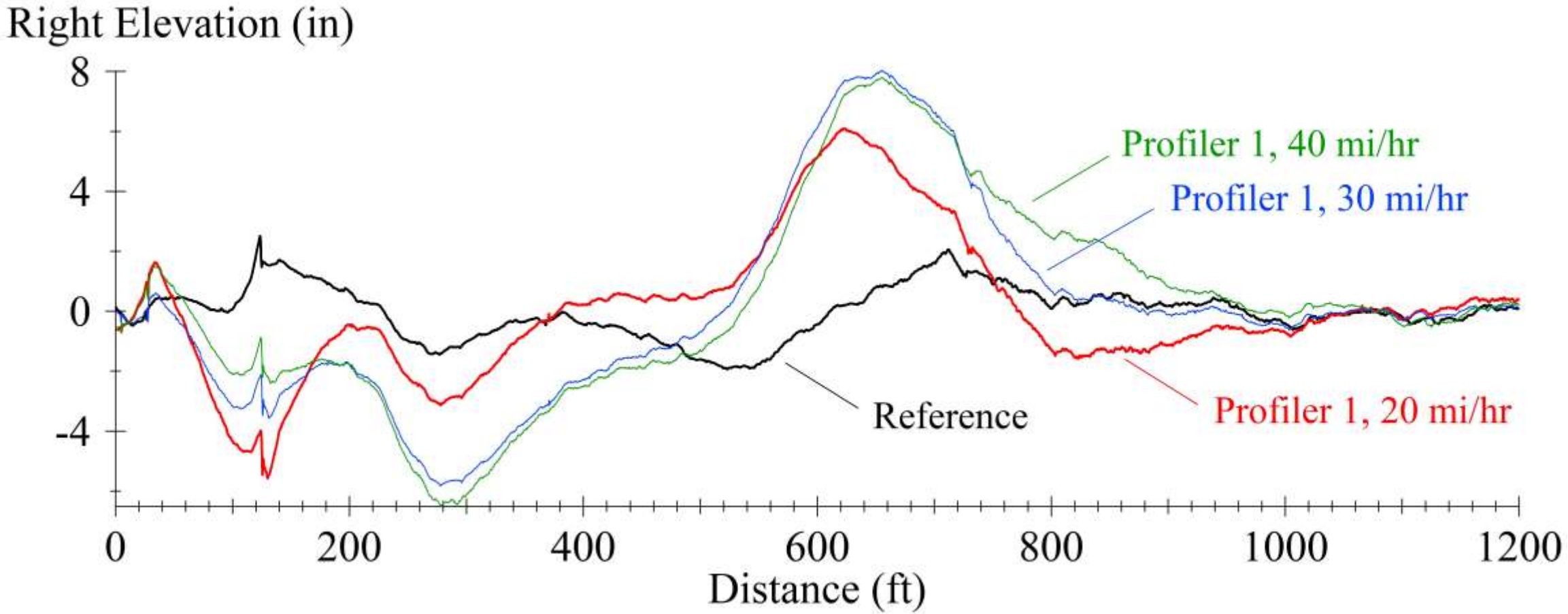
Source: NCHRP Rpt. 914

Curve, Lateral Acceleration



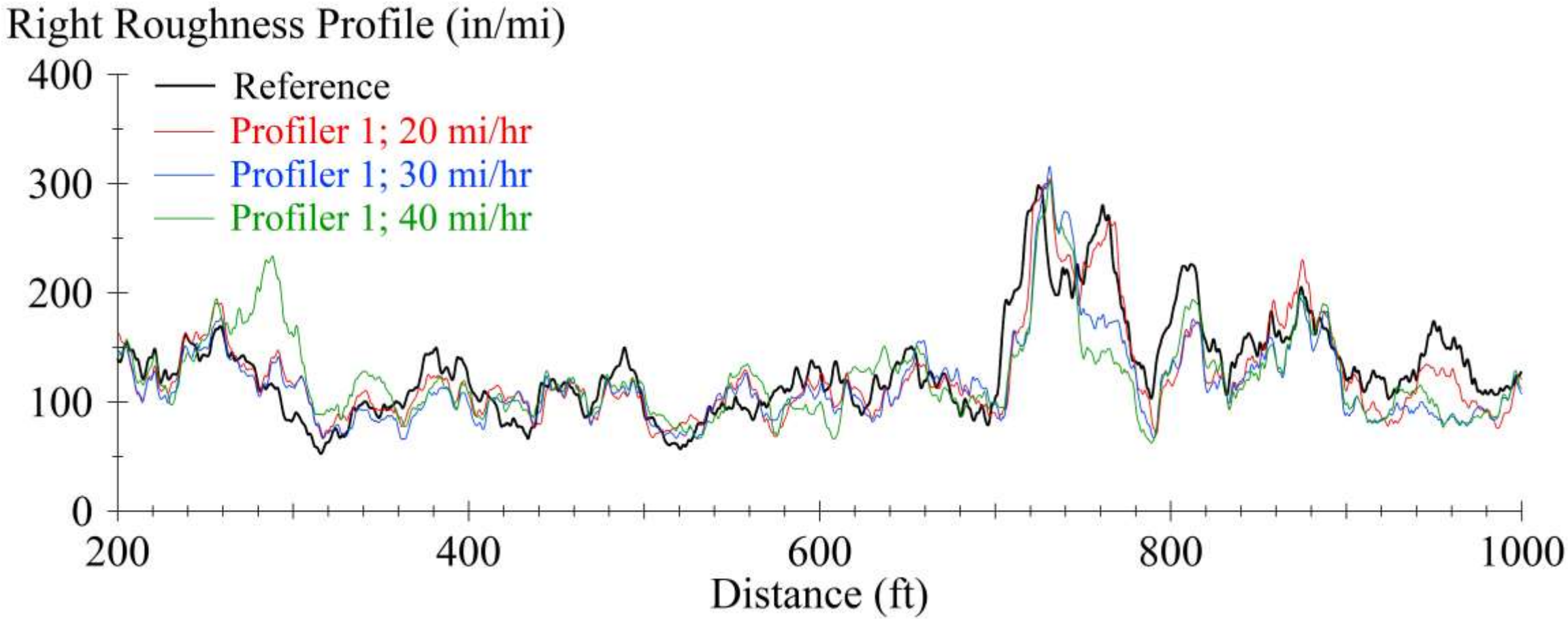
Source: NCHRP Rpt. 914

Curve, Raw Profiles



Source: NCHRP Rpt. 914

Curve, Roughness Profiles



Source: NCHRP Rpt. 914

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Summary

- Travel speed
  - Speed affects the quality of the inertial platform.
  - IRI agreement was confounded by other sources of variation (lateral tracking, signal timing, DMI).
  - Not all profilers have the same low-speed limit.
- Braking
  - Artificial roughness is introduced by accelerometer tilt.
  - Errors in IRI appear where the brakes are released.
  - All profilers exhibited errors with braking above a given threshold.
  - Threshold acceleration levels and errors in IRI varied.

Summary

- Stop-and-Go
  - Events include low speed, deceleration, operation at zero speed, and acceleration.
  - The largest error occurs as localized roughness at the position of the stop.
  - The level of artificial roughness grows with misalignment and stop duration.
  - The area of profile that is contaminated depends on filtering.

AASHTO Specifications

M 328: Standard Equipment Specification for Inertial Profiler

- Valid operating speed below 20 mph is preferred.
- Real-time identification of adverse conditions is required.
- “Adverse” conditions include low speed, stops, sensor readings out of range, excessive acceleration.

R 56: Certification of Inertial Profiling Systems

- Includes testing to determine the low speed limit.
- Includes testing performance during braking to seek the deceleration limit.
- Includes testing of stop-and-go operation to define the contaminated area.

The Report……

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Thank you!!!!