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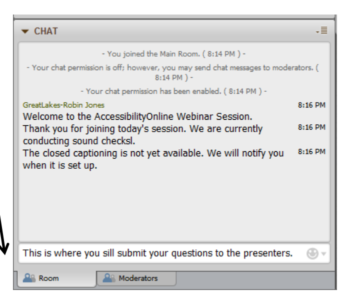

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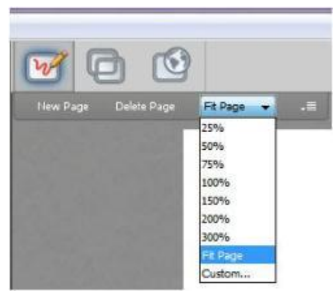

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  2. Email webinars@accessibilityonline.org ; or
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Surface Roughness and Rollability

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Presenters

Scott Windley **Jon Pearlman**

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Agenda

- Access Board Involvement
- Roughness and Rollability Research Efforts
- What's Next
- Questions and Answers

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Access Board's Involvement

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PROW Access Advisory Committee

- The Public Right of Way Access Advisory Committee recommended a "reduced vibration zone":
  - X02.1.2.2 Reduced Vibration Zone. Within the pedestrian access route, there shall be an unobstructed reduced vibration zone meeting the requirements of this section. The reduced vibration zone shall be a contiguous part of the pedestrian access route that connects to elements required to be accessible in Section X02.3, and shall meet the requirements set forth in Section X02.1.1 through Section X02.1.7.
- How do we measure the vibration?
- What is too much vibration?

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Pedestrian Pathway Research

Jon Pearlman, PhD

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Affiliations

- Positions & Affiliations
  - Assistant Professor, Dept. of Rehab Science & Tech.
  - Associate Director of Product Innovation & Translation, Human Engineering Research Labs
  - Biomedical Research Engineer, VA Pittsburgh
  - Co-founder and advisor, pathVu
    - Equity stake

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Funding Sources

- Veterans Affairs (~$2Million; $200k to JP)
- Access Board ($300,000)
- ICPI & BIA ($200,000; $70k to JP)
- Innovation-related funding for pathVu ($90,000)
  - Innovation Works, BNY Mellon, VentureWell

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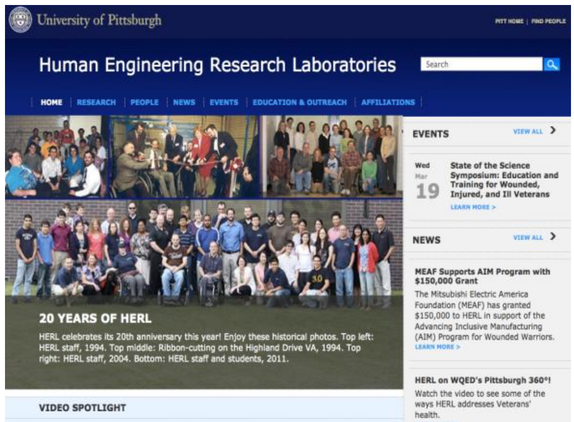
Mission

To continuously improve the mobility and function of people with disabilities through advanced engineering in clinical research and medical rehabilitation.



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Pedestrian-related statistics

- 1:3 older Americans trip annually
- TBI most frequently a result of trips/falls (35.2%)
- $30B of direct medical costs are related to falls annually
- Among WC users
  - Trips/falls are most common source of injury
  - 2x more likely to have back or neck pain

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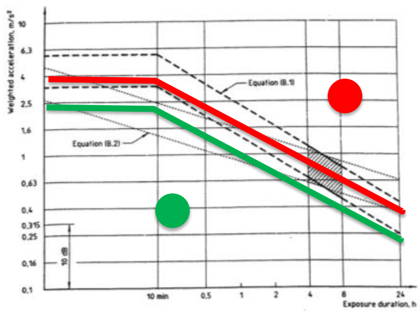
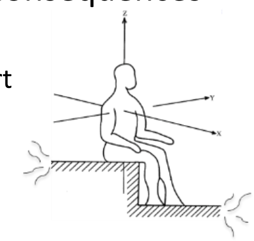
Health Motivation

- WC users experience may have health consequences related to vibration
  - 60% of WC users report neck pain & discomfort
  - Postural issues are common among WC users





- Vibration Exposure Standards (ISO 10326 & 2631)
  - Provide measurement and analysis techniques
  - Provide exposure thresholds

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Research Questions

Primary: Are wheelchair users exposed to unsafe levels of vibration?

If **YES**

1) What are the factors that impact risk?
2) What interventions mitigate the risk?

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Related Research

- Roadloads (Van sickle ‘94,’96, ‘97, ’00,’04)
  - Developed instrumentation to measure reaction force at caster and propulsion wheels of MWC & recorded data in-lab and in-home & during wheelchair testing.
- Seating System Influence (DiGiovine 2000 & 2003)
  - Influence of seating system on comfort and vibration exposure in-lab human trials.
- ICPI/BIA (Wolf, Cooper, Pearlman 2004 & 2007)
  - Influence of surface features on vibration exposure
- Suspension (MWC: Kwarciak; PWC: Wolf, 2008)
  - Influence of suspension system on vibration exposure
- **Influence of Cushion (Pearlman, Garcia & Cooper, 2011)**
  - Characterization of the WC cushion transmissibility
- **Community Vibrations (Pearlman, Garcia & Cooper, 2012)**
  - Evaluation of MWC vibration exposure in the community
- **Pathway Roughness of Sidewalks (Pearlman, Duvall, Sinagra, 2013 & 2014)**
- **Pathway Measurement Tool (Sinagra, Duvall, Pearlman, 2014)**
- **Pathway Roughness Thresholds (Duvall, Pearlman, Cooper, 2016)**
- **ASTM Pathway Roughness Standard (2016)**

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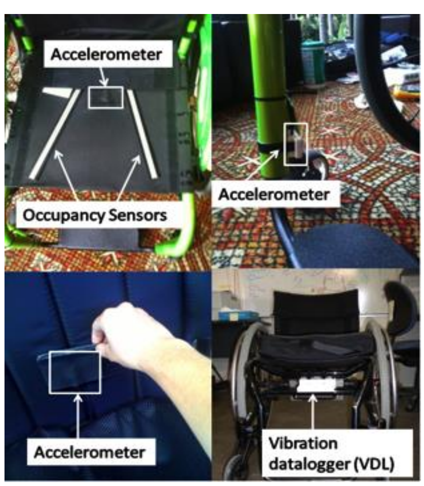
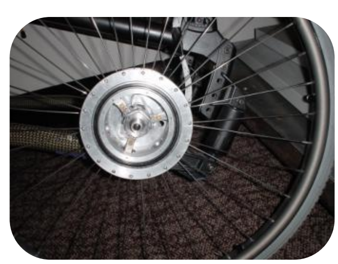
Primary Research Question: Tools





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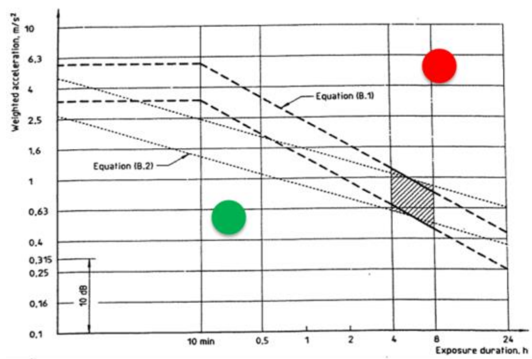
Research Question 1: Answer

– Exposure is mostly within or above caution zone
– Results insensitive to WC type

	Health Caution Zone		
Site	% Below	% Within	% Above
Seat	0	30	70
Back	3	80	17



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Research Question 2: Risk Factors

- Intrinsic Factors
  – Wheelchair, cushion, wheelchair user
- Extrinsic Factors
  – Sidewalks

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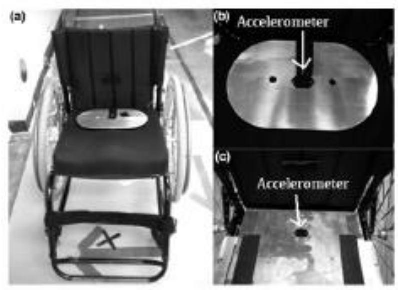
Intrinsic Factors

- Cushions
  - Often amplify vibrations into body (Garcia ‘12)
  - Are not selected such that they minimize vibration (DiGiovine ‘00**)**



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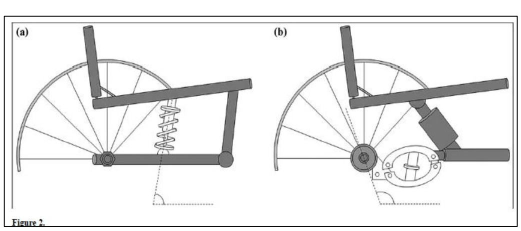
Intrinsic Factors

- Suspension
  - Not optimized in manual (Kwarciak) or Power Wheelchairs (Wolf)



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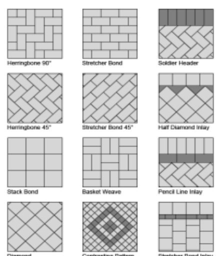
Extrinsic Factors

- Pedestrian Pathways
  - Vibration on newly installed segmental pavers depends on paver bevel and pattern
  - Some paver surfaces are smoother than poured concrete



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Extrinsic Factors

Table II. Comparison to ISO 2631-1 lower boundary of the Health Guidance Caution Zone.

Surface	Material, chamfer Width, herringbone pattern angle	Manual wheelchair Exposure limit (h) at 1 m/s	Electric-powered wheelchair Exposure limit (h) at 1 m/s	Electric-powered wheelchair Exposure limit (h) at 2 m/s
1	Poured concrete	6.77	11.62	1.26
2	Concrete, 0 mm, 90°	13.38	24.31	4.72
3	Concrete, 2 mm, 90°	8.53	16.40	3.14
4	Concrete, 8 mm, 90°	2.34	2.43	2.31
5	Brick, 4 mm, 45°	6.38	15.98	2.52
6	Brick, 0 mm, 45°	6.00	12.82	2.03
7	Concrete, 6 mm, 90°	4.32	4.81	3.49
8	Concrete, 6 mm, 45°	2.46	12.57	2.66
9	Concrete, 4 mm, 90°	6.52	11.16	4.44

Disability and Rehabilitation, December 2005; 27(23): 1443–1449

Taylor & Francis

ASSISTIVE TECHNOLOGY

Vibration exposure of individuals using wheelchairs over sidewalk surfaces

ERIK WOLF[3,4], JONATHAN PEARLMAN[3,4], RORY A. COOPER[1–4], SHIRLEY G. FITZGERALD[1,2,4], ANNMARIE KELLEHER[1,4], DIANE M. COLLINS[1,4], MICHAEL L. BONINGER[1–4], & ROSEMARIE COOPER[1,2,4]

[1]Department of Rehabilitation Science & Technology, [2]Department of Physical Medicine & Rehabilitation, [3]Department of Bioengineering, University of Pittsburgh, Pittsburgh, PA 15261, USA, and [4]Human Engineering Research Laboratories, VA Rehabilitation Research and Development Centre, VA Pittsburgh Healthcare System, Pittsburgh, PA 15206, USA

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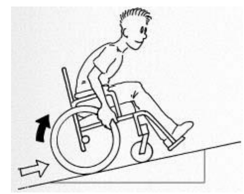
Outputs & Outcomes

- Extrinsic Factors are determined by US Access Board based on ADA & ABA
- Current Guidelines
  - Running slope (1:20)
  - Cross-slope (1:50)
  - Level Changes (1/4")
  - Stable, firm, & Slip Resistant
  - **Roughness?**



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Project Goals

1. Characterize the relationship between surface roughness, vibrations and user-response
2. Develop 'threshold' roughness which is both comfortable and safe for users
3. Design a surface roughness measurement device for industry use
4. Promote threshold and relevant measurement techniques through publications and standards

Funded by the US Access Board

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Simulated Surfaces

Surface	Roughness Index (in/ft)	Crack Frequency (in)	Crack Width (in)
1	0.20	No cracks	0
2	0.29	12	0.80
3	0.36	8	0.80
4	0.53	12	1.25
5	0.53	4	0.80
6	0.66	8	1.25
7	0.84	8	1.55
8	1.10	4	1.25
9	1.36	8	2.00

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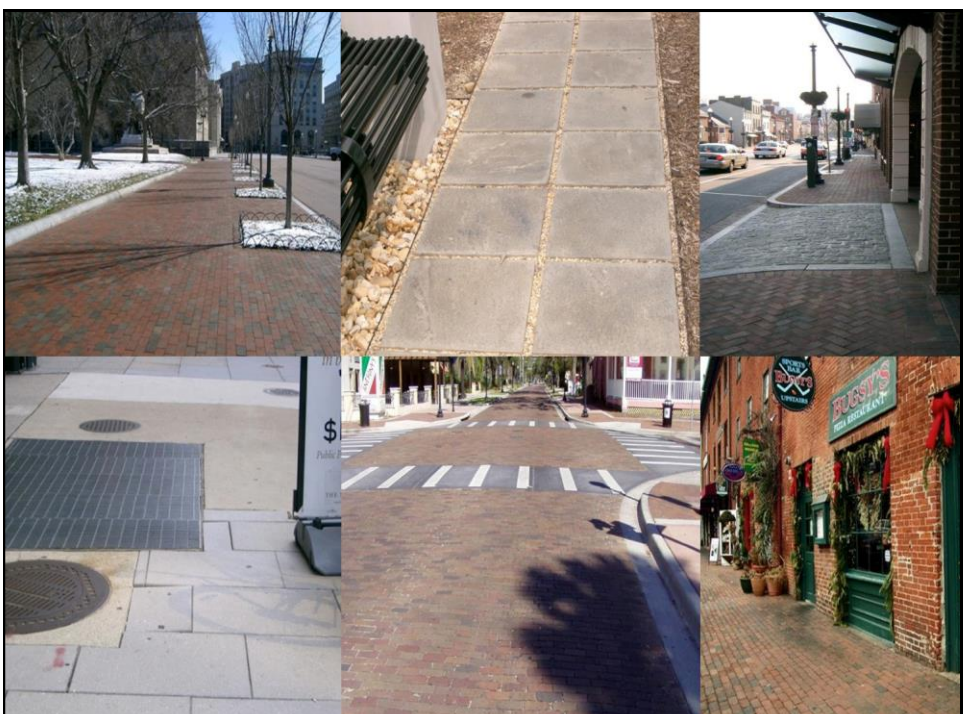
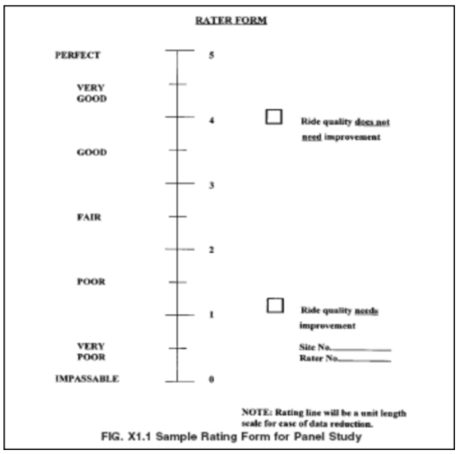


Outcome Tools

Subjective Ratings


RATER FORM

PERFECT — 5
VERY GOOD
4 — ☐ Ride quality does not need improvement
GOOD
3
FAIR
2
POOR
1 — ☐ Ride quality needs improvement
VERY POOR
IMPASSABLE — 0

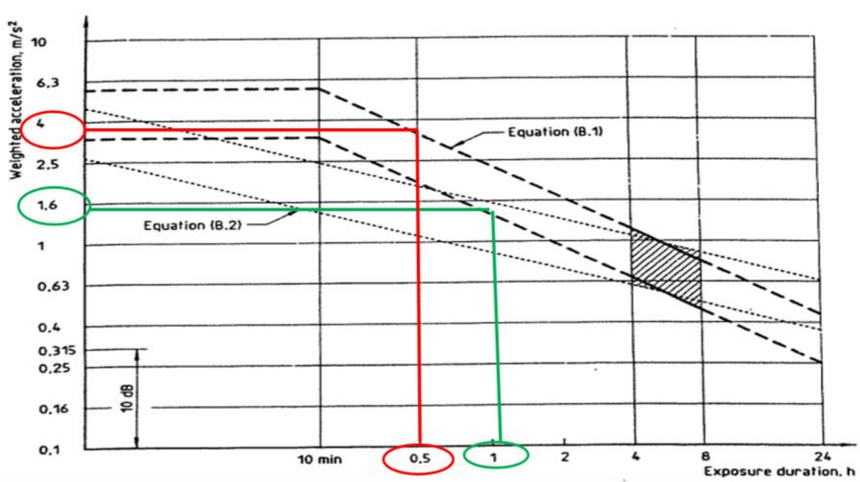
Site No.________
Rater No.________

NOTE: Rating line will be a unit length scale for ease of data reduction.

FIG. X1.1 Sample Rating Form for Panel Study

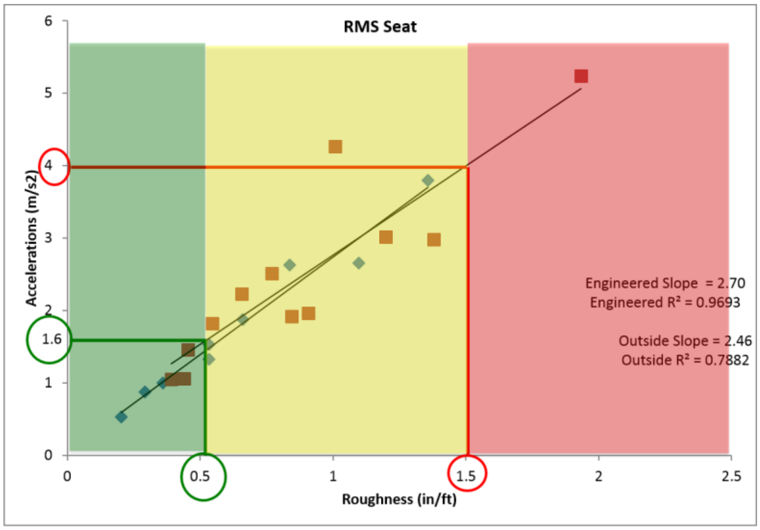
Accelerations

Threshold



ISO 2631-1

Simulated & Community



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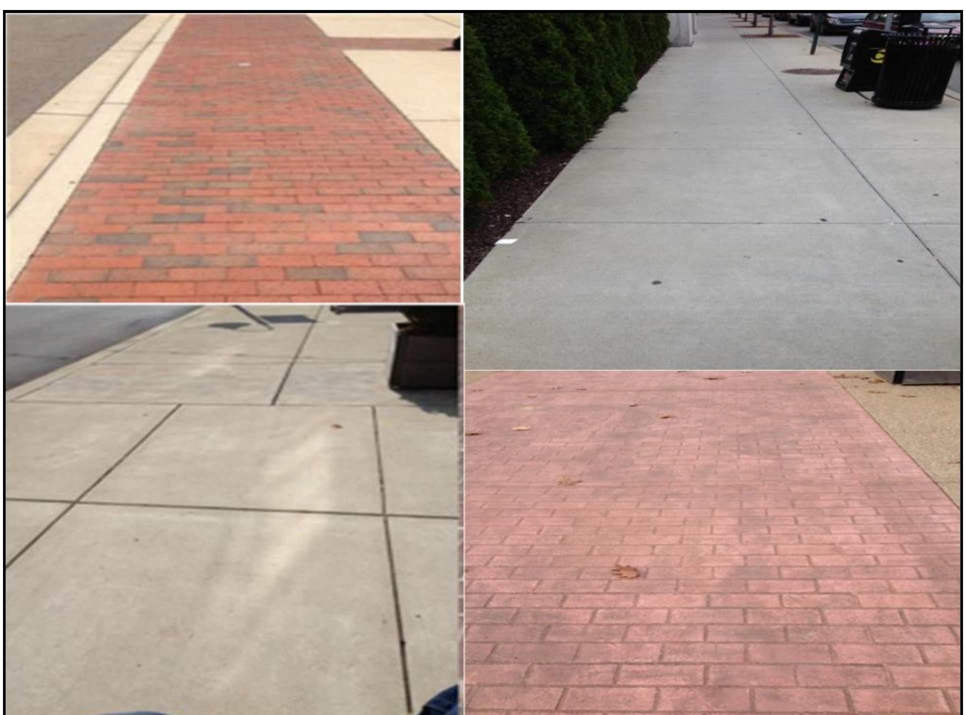

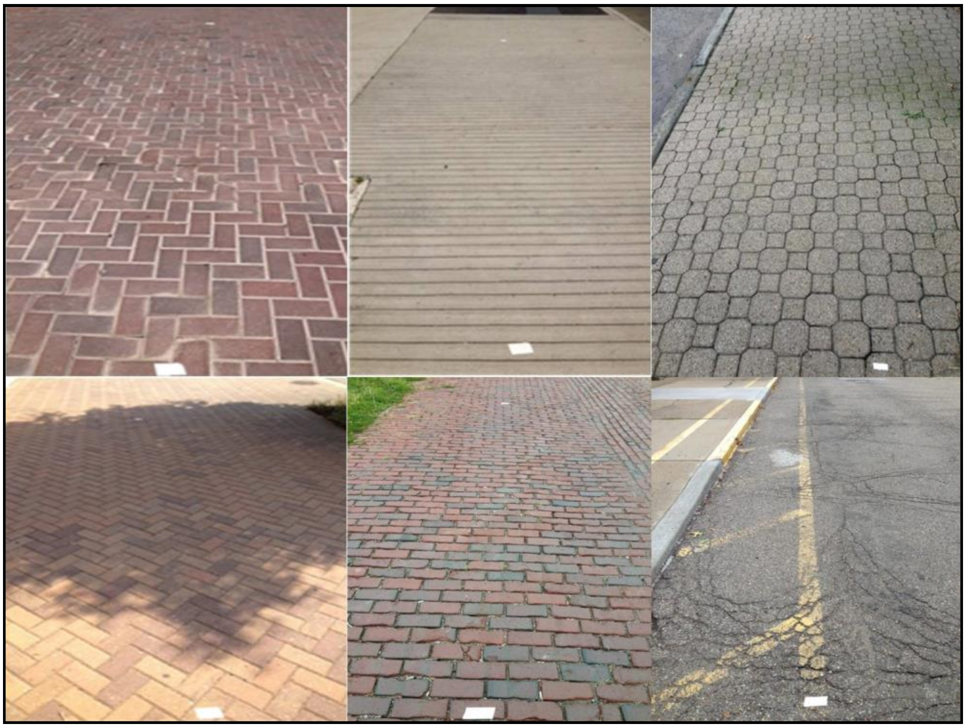

Publications & Standards related to Sidewalk Roughness

- ***Pedestrian Pathway Characteristics and Their Implications on Wheelchair Users.*** Jonathan Pearlman PhD, Rory Cooper PhD, Jonathan Duvall BS & Ryan Livingston (2013), Assistive Technology: The Official Journal of RESNA.
- ***Development of Surface Roughness Standards for Pathways Used by Wheelchairs*** Duvall J., Cooper R. A., Sinagra E., Stuckey D., Brown J., Pearlman J. , (2013), Transportation Research Record , no. 2387, pp. 149156
- ***Proposed Pedestrian Pathway Roughness Thresholds to ensure safety and comfort for Wheelchair Users*.** Duvall, J. Sinagra, E., Cooper, R., J. Pearlman (2016), Assistive Technology: The official Journal of RESNA
- ***Standard Practice for Computing Wheelchair Pathway Roughness Index related to User comfort, acceptance and Whole body vibrations from longitudinal profile measurements.*** Proposed in E17.33 subcommittee.

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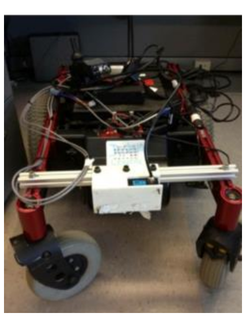
Tools Developed as part of the work: Pathway Measurement Tool (PathMET)

A



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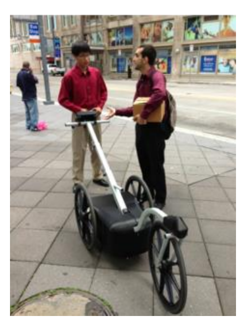

A) funded by US Access Board
B&C) Funded by ICPI/BIA support

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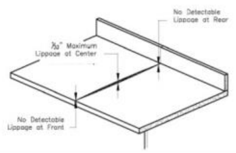
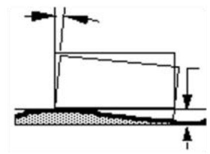
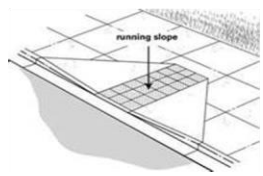
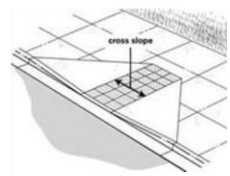
Output Measurements

- Roughness
- Lippage/Step Height
- Flatness
- Running Slope
- Cross Slope
- Location (GPS)
- Photograph
- Roughness









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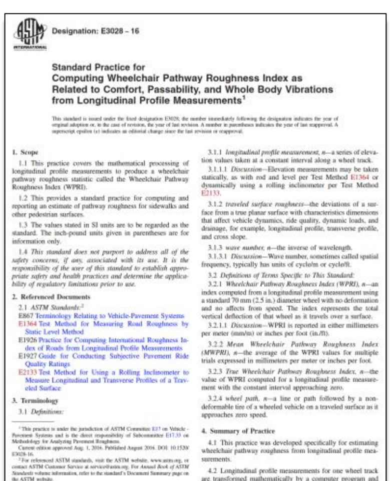
ASTM 3028



Designation: E3028 – 16

Standard Practice for Computing Wheelchair Pathway Roughness Index as Related to Comfort, Passability, and Whole Body Vibrations from Longitudinal Profile Measurements[1]

This standard is issued under the fixed designation E3028; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the mathematical processing of longitudinal profile measurements to produce a wheelchair pathway roughness statistic called the Wheelchair Pathway Roughness Index (WPRI).

1.2 This provides a standard practice for computing and reporting an estimate of pathway roughness for sidewalks and other pedestrian surfaces.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E867 Terminology Relating to Vehicle-Pavement Systems
E1364 Test Method for Measuring Road Roughness by Static Level Method
E1926 Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements
E1927 Guide for Conducting Subjective Pavement Ride Quality Ratings
E2133 Test Method for Using a Rolling Inclinometer to Measure Longitudinal and Transverse Profiles of a Traveled Surface

3. Terminology

3.1 *Definitions:*

3.1.1 *longitudinal profile measurement, n*—a series of elevation values taken at a constant interval along a wheel track.

3.1.1.1 *Discussion*—Elevation measurements may be taken statically, as with rod and level per Test Method E1364 or dynamically using a rolling inclinometer per Test Method E2133.

3.1.2 *traveled surface roughness*—the deviations of a surface from a true planar surface with characteristics dimensions that affect vehicle dynamics, ride quality, dynamic loads, and drainage, for example, longitudinal profile, transverse profile, and cross slope.

3.1.3 *wave number, n*—the inverse of wavelength.

3.1.3.1 *Discussion*—Wave number, sometimes called spatial frequency, typically has units of cycle/m or cycle/ft.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *Wheelchair Pathway Roughness Index (WPRI), n*—an index computed from a longitudinal profile measurement using a standard 70 mm (2.5 in.) diameter wheel with no deformation and no affects from speed. The index represents the total vertical deflection of that wheel as it travels over a surface.

3.2.1.1 *Discussion*—WPRI is reported in either millimeters per meter (mm/m) or inches per foot (in./ft).

3.2.2 *Mean Wheelchair Pathway Roughness Index (MWPRI), n*—the average of the WPRI values for multiple trials expressed in millimeters per meter or inches per foot.

3.2.3 *True Wheelchair Pathway Roughness Index, n*—the value of WPRI computed for a longitudinal profile measurement with the constant interval approaching zero.

3.2.4 *wheel path, n*—a line or path followed by a non-deformable tire of a wheeled vehicle on a traveled surface as it approaches zero speed.

4. Summary of Practice

4.1 This practice was developed specifically for estimating wheelchair pathway roughness from longitudinal profile measurements.

4.2 Longitudinal profile measurements for one wheel track are transformed mathematically by a computer program and

[1] This practice is under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and is the direct responsibility of Subcommittee E17.33 on Methodology for Analyzing Pavement Roughness.
Current edition approved Aug. 1, 2016. Published August 2016. DOI: 10.1520/E3028-16.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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Key Contribution of E3028

- Defines key terminology
  - Wheelchair Pathway Roughness Index (WPRI)
- Defines measurement approach
  - Short & extended distance
  - Accuracy expectations
- Provides example computer code to measure WPRI from high-resolution profile measurements.

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Community Use: WPRI Evaluation

Measurement (ASTM 3028)

+

Roughness Thresholds*

- ≤ 50mm/m for long (100m) segments
- ≤ 100mm/m for short (3 m) segments

***Proposed Pedestrian Pathway Roughness Thresholds to ensure safety and comfort for Wheelchair Users**. Duvall, J. Sinagra, E., Cooper, R., J. Pearlman (2016), Journal of Assistive Technology

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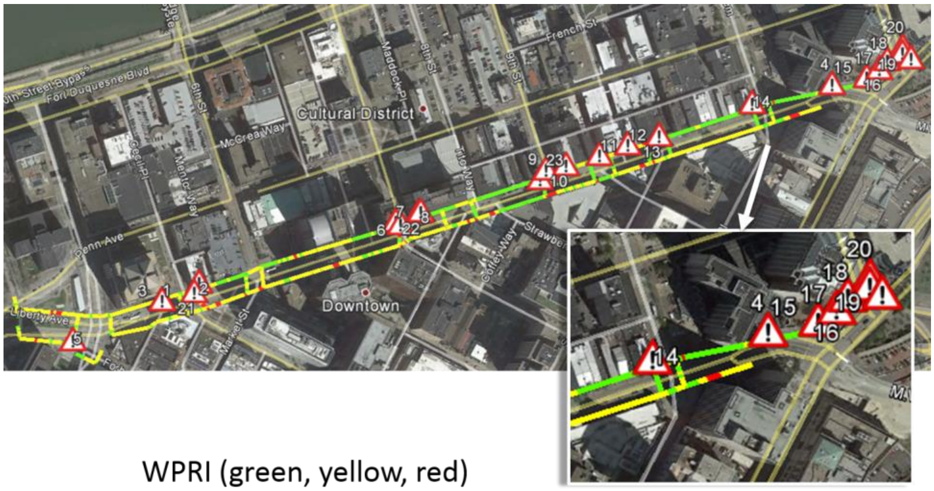
Example Data (from pathVu)



WPRI (green, yellow, red)

Trip hazards

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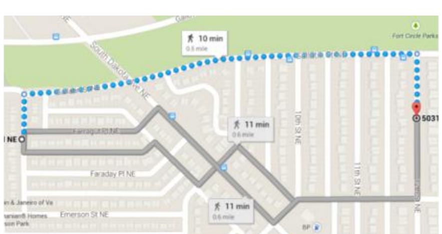
Community use: Navigation

WPRI can be used to developed customized routes for WC users based on Route Accessibility Index (RAI)



Google Maps Routing on Street Centerlines

Sidewalk Routes using RAI

Duvall, Jonathan A., Jonathan L. Pearlman, and Hassan A. Karimi. "Development of Route Accessibility Index to Support Wayfinding for People with Disabilities." Smart City 360°.

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Acknowledgements

Funding

- Funded by Access Board Grant #'s H133E070024 & H133N110011
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- The Roughness Team
  - Eric Sinagra
  - Dianna Stuckey
  - Josh Brown
  - John Duvall
- Shop staff, Clinical staff other staff/students at HERL

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What's Next

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Where We Can Go From Here

- Any jurisdiction or entity can make use of the ASTM Standard.
- The Board could propose to use the findings in a future rulemaking.
- The Final Report of the Research is available on our website https://www.access-board.gov/research/completed-research/surface-roughness-final-report

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Questions?

You may type and submit questions in the Chat Area Text Box or press Control-M and enter text in the Chat Area

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Continuing Education

AIA Provider Number: I017

Course Title: Surface Roughness and Rollability
AIA Course Number: GL20170803
Date: August 3, 2017

Credits earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion are available upon request.

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Thank you for participating in today's webinar

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