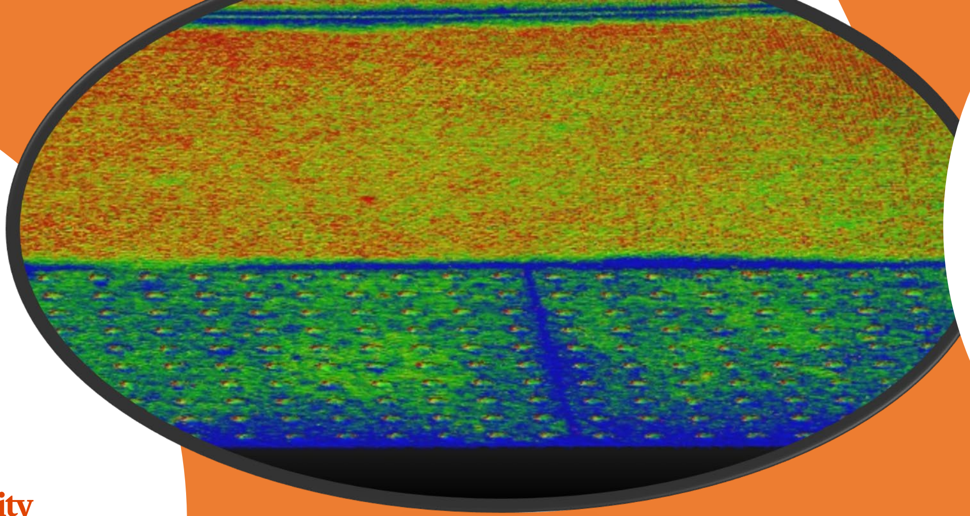

Oregon State University
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Evaluation of different lidar systems for curb ramp slope measurements

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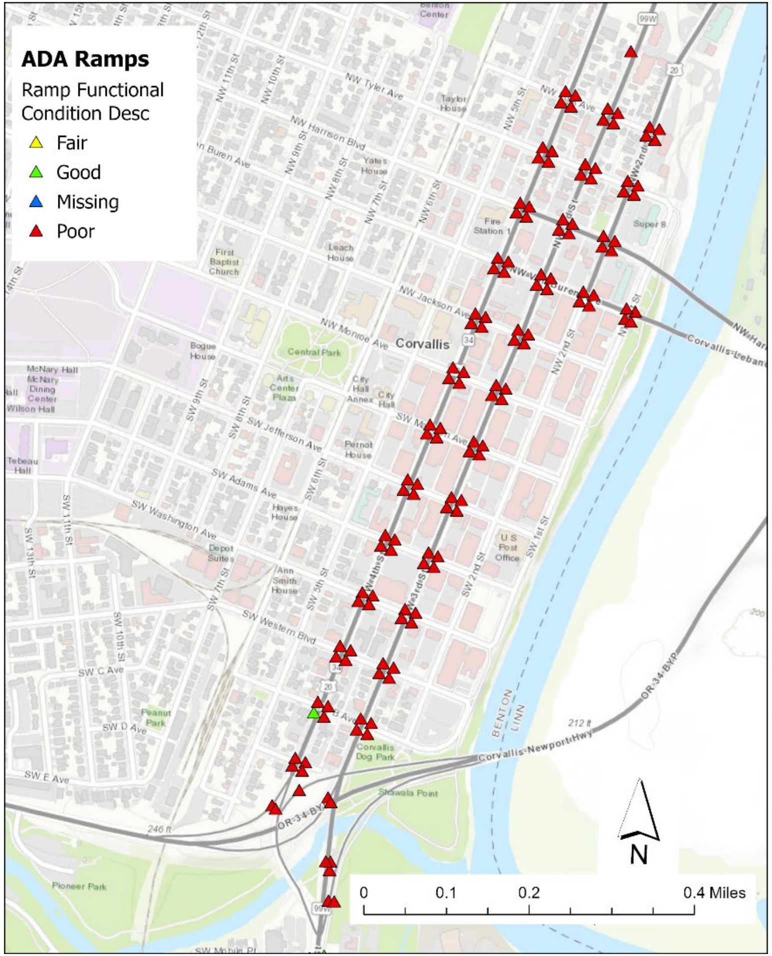
Background

- The Americans with Disabilities Act (ADA) establishes accessibility standards for public spaces, including curb ramps and sidewalks, ensuring accessibility for individuals with disabilities.
- Ensuring ADA compliance for curb ramps is challenging due to variations in measurement processes, tools used, inspector methods, and safety considerations.
- Substantial numbers of in-service curb ramps are deemed non-compliant, necessitating reconstruction efforts.
- Reliance on a maximum slope metric is error-prone.



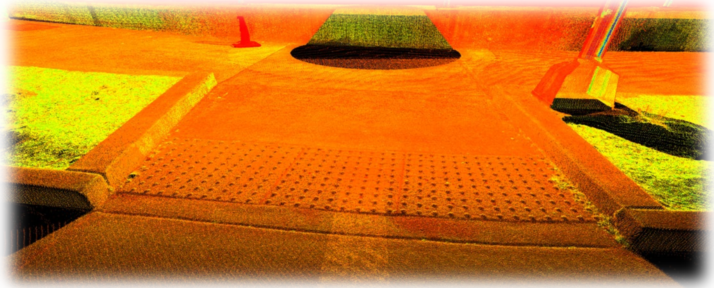
Map showing the functional condition of curb ramps in the ODOT TranGIS platform in Downtown Corvallis, Oregon where only one curb ramp is in good functional condition in a 1.3 km-long section.

Motivation/Objectives

- Lidar technology offers a promising solution for virtual ADA compliance assessment, although its application in this context is relatively untested.

- With accurate georeferenced three-dimensional point cloud data and a high-scanning frequency, lidar technology could allow safer and more effective curb ramp slope measurements at highway speed.

- This presentation assesses the suitability, effectiveness, and consistency of various terrestrial and pocket lidar systems in acquiring slope measurements to facilitate the virtual assessment of ADA compliance for curb ramps.



Equipment used

Pocket Lidar (Apple iPhone 13 pro with lidar sensor).

When we refer to "Pocket Lidar," (PL) it means having the capability of a lidar scanner within the convenience of your pocket.

SmartTool digital inclinometer (Smart Level – 60 cm length)

Terrestrial lidar systems (TLS)

Leica ScanStation P50

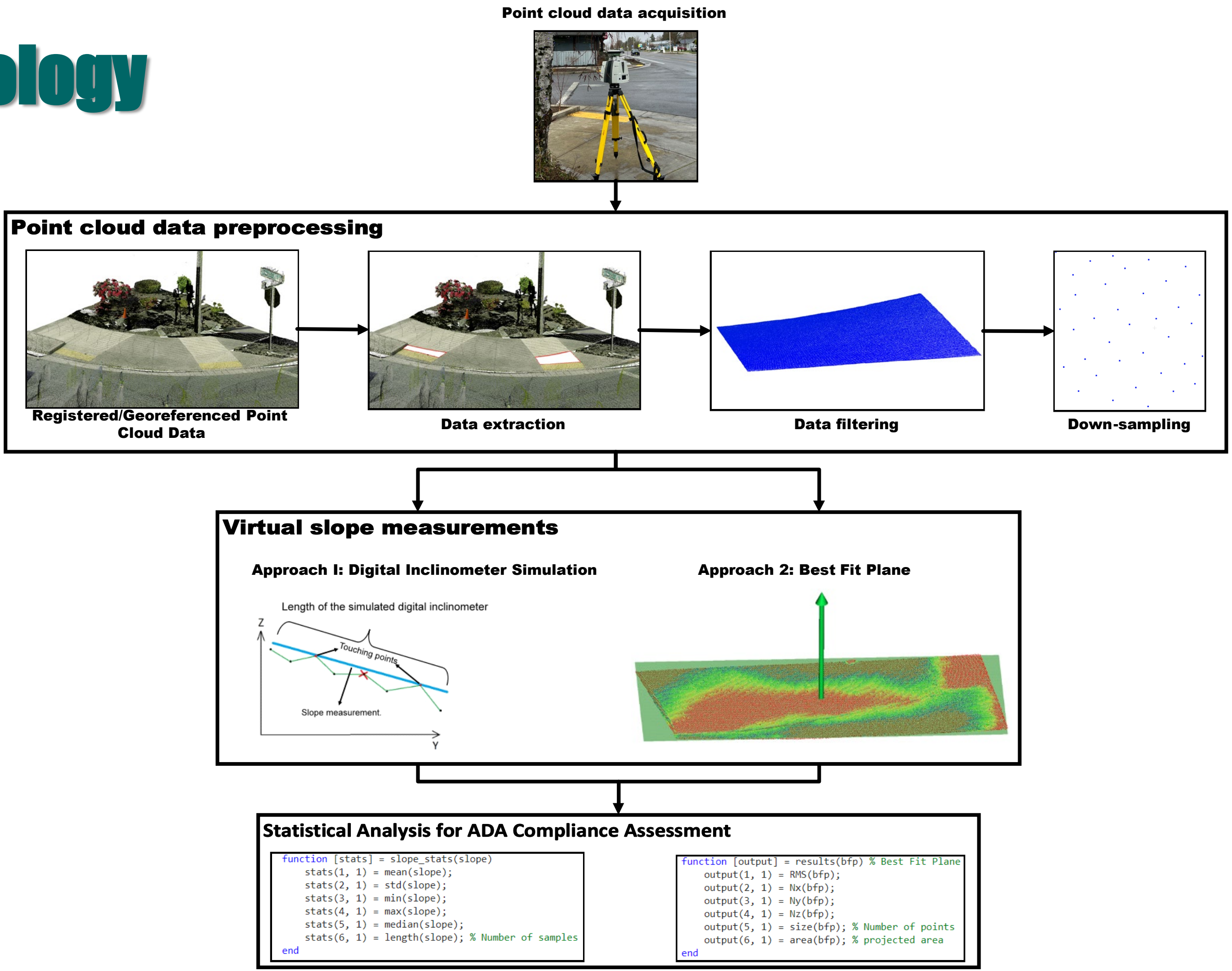
Leica RTC360 scanner

A small, lightweight Leica BLK 360 Generation 2 scanner

ODOT Mobile lidar system (Leica Pegasus:Two)

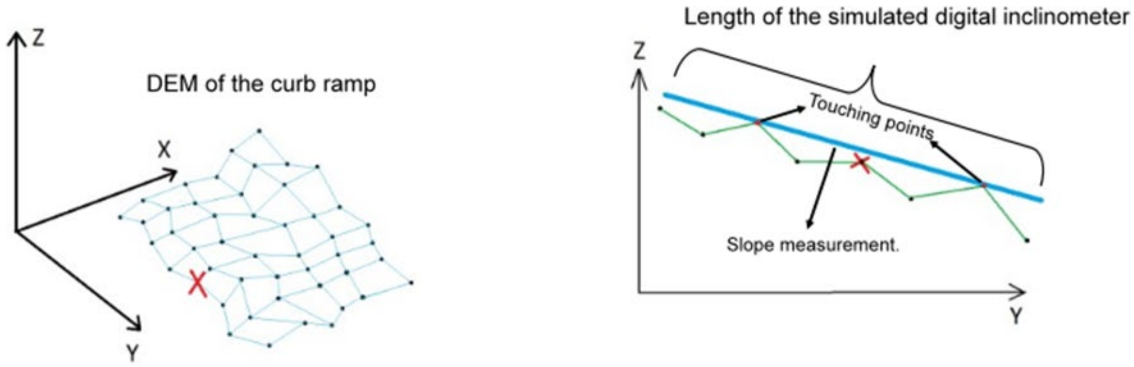
point cloud data of 46 curb ramps were collected with each lidar sensor

Methodology



Smart level simulation – Touching point (TP)

- The TP method identifies two specific contact points on the DEM that can support the smart level based on two criteria:
    1. Each touching point is located on opposite sides of the smart level's center of gravity, and
    2. All parts of the virtual smart level must remain above the ground (DEM).



Schematic illustration of the TP approach (Zhou et al., 2022)

Slope metric considering roughness

- From the smart level simulation, several important metrics were gathered, including the mean, standard deviation, and maximum slope.

- An additional metric (slope metric considering roughness) developed by Olsen et al. (2023) for ODOT was utilized in the virtual analysis.

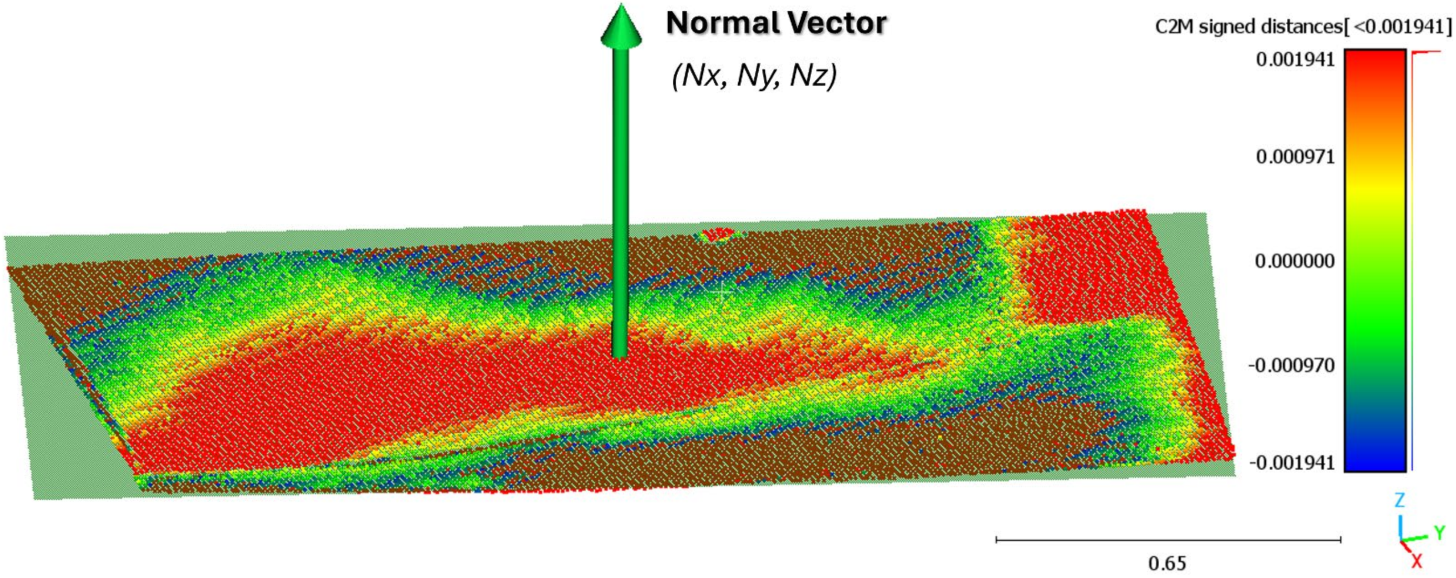
- This metric can be computed using the following equation:

$$\text{Estimated Max Slope} = \text{Slope AVG} + \text{CISF} \times \text{Slope STD}$$

- CISF is a scale factor to the appropriate confidence interval (e.g., 1.65 for 90% confidence).

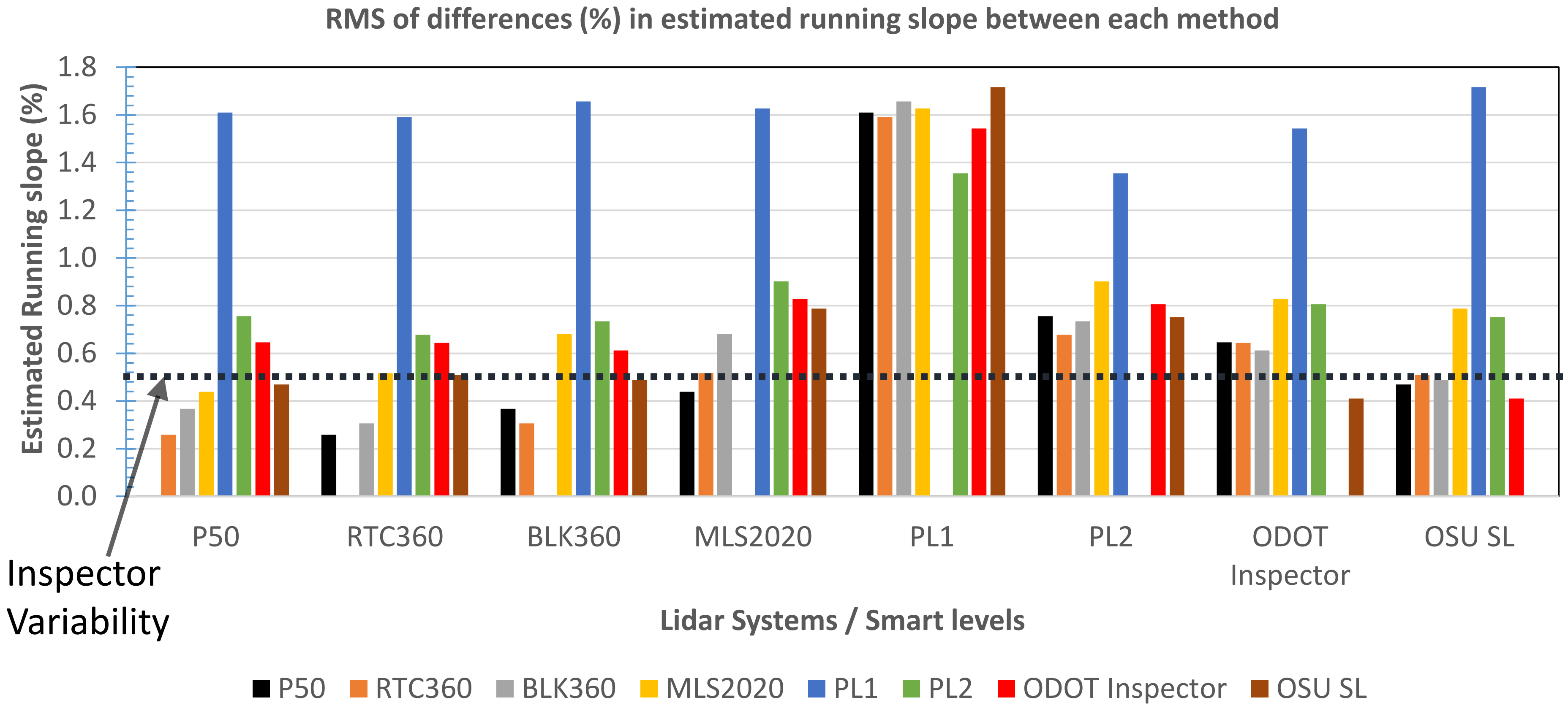
Best fit plane (BFP) approach

- In this approach, a plane is fitted to the point cloud and the plane normal vector is computed.

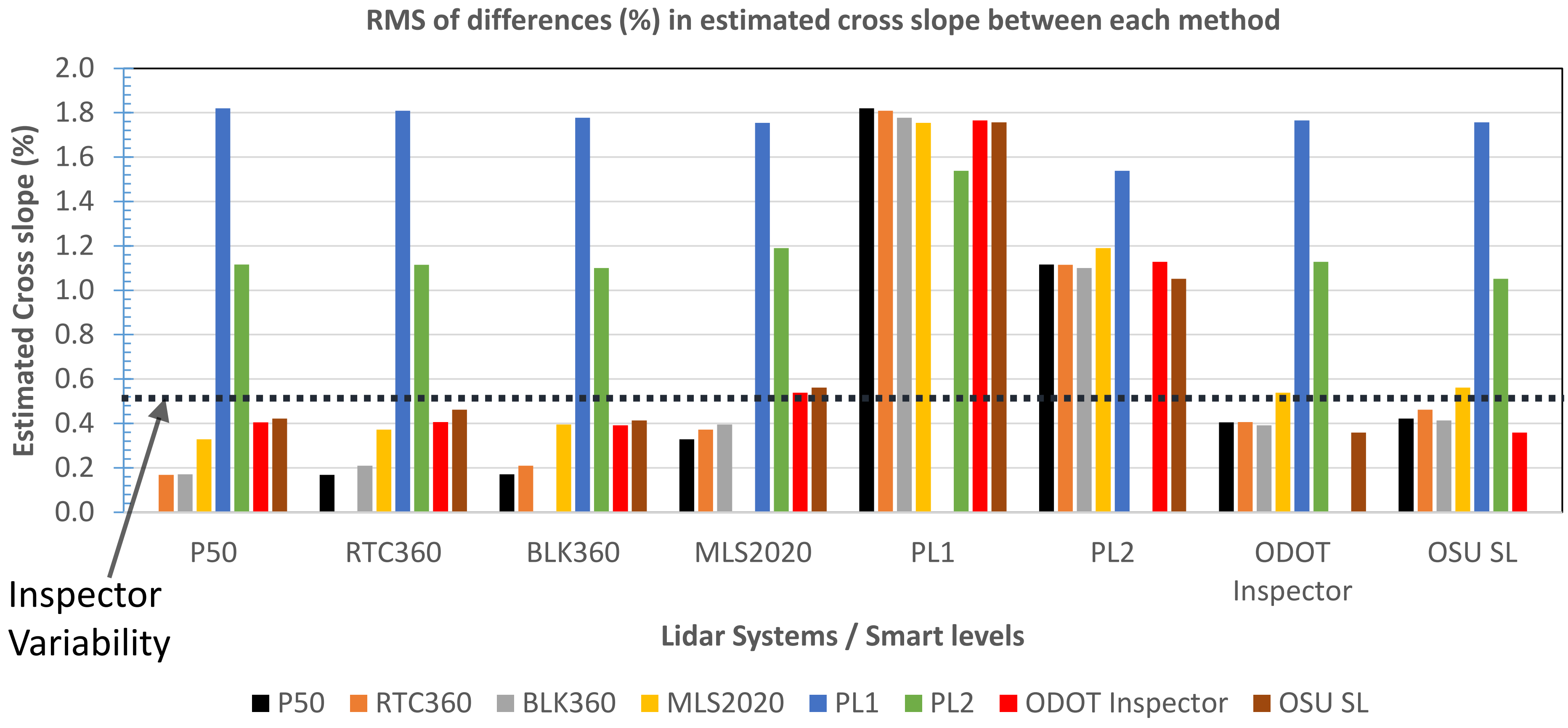


- The slope of the plane is computed from *Nz*.
- RMS of the fit is an indication of the planarity or roughness of the surface.

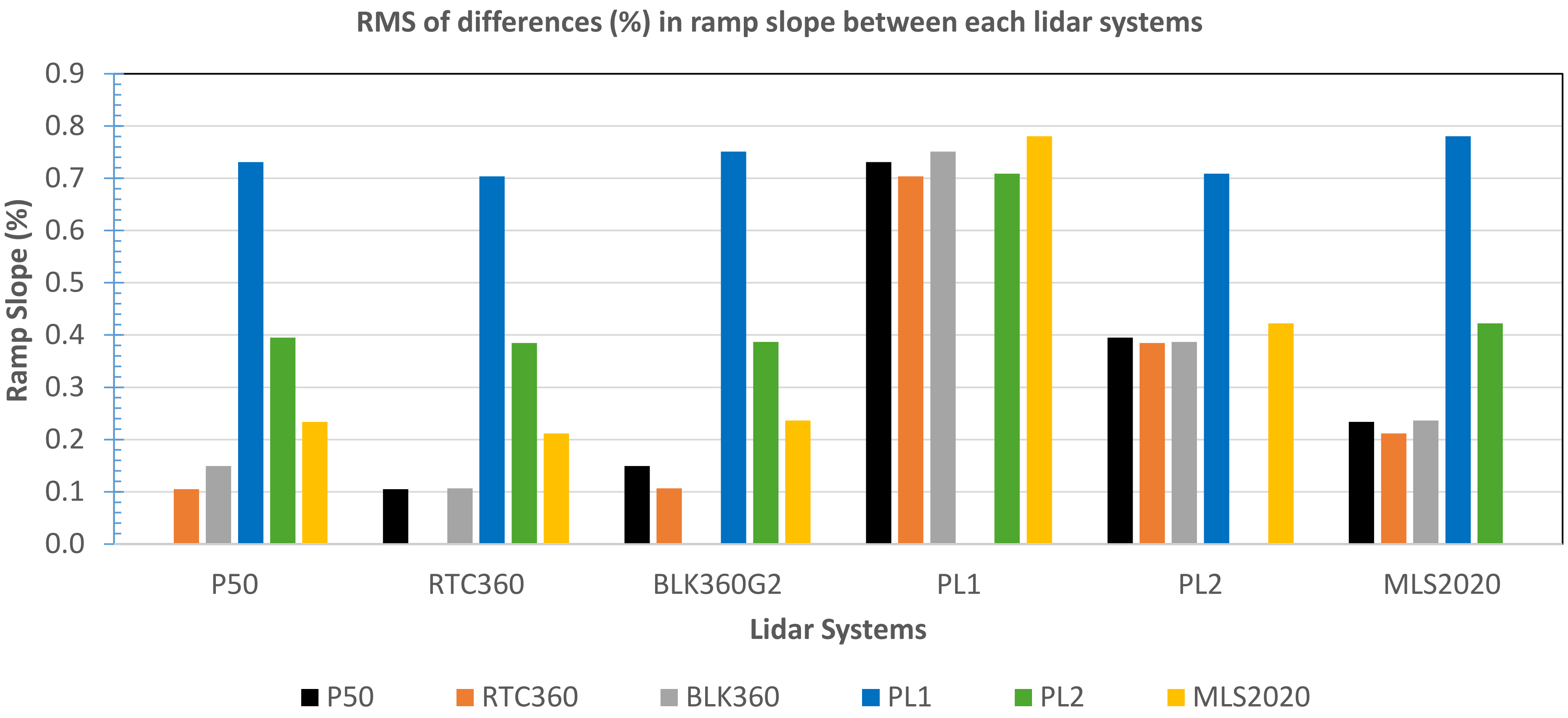
Simulation results (Running Slope)



Simulation results (Cross Slope)



Experimental results (Plane fitting analysis)



Conclusion

- Laser scanning can reduce blunders by inspectors mixing ramps, erroneous readings, or improperly calibrated smart levels.
- Lower-cost systems such as pocket lidar and BLK360 G2, despite higher error rates, remain plausible for ADA compliance assessments.
- Near-compliance ramps can benefit from lidar systems providing detailed analysis for compliance decisions.
- Study impacts lidar system selection for curb ramp slope measurements.
  - Several forms of lidar are effective curb ramp evaluation.
  - Lidar measurements are much more systematic than smart level measurements.
  - Pocket lidar results vary depending on the app.

Future research

- Insights critical for ADA compliance with lidar system selection and pairing.

- Future research could delve deeper into the causes of variability observed in certain system combinations.

- Future studies could explore the impact of environmental factors, operational techniques, and technological advancements and provide further clarity on optimizing system performance.

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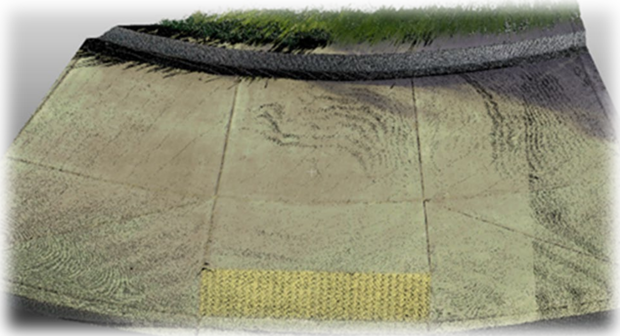
- Leica Geosystems supported the study by providing surveying equipment and processing software.
- This research study used CloudCompare and EzVox (EZDataMD, LLC) for data preprocessing, and RAMBO for plane fitting.



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Thank you for Listening

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