TECHNOTE

Pocket Lidar Curb Ramp Assessments

FHWA Publication No.: FHWA-HRT-25-014

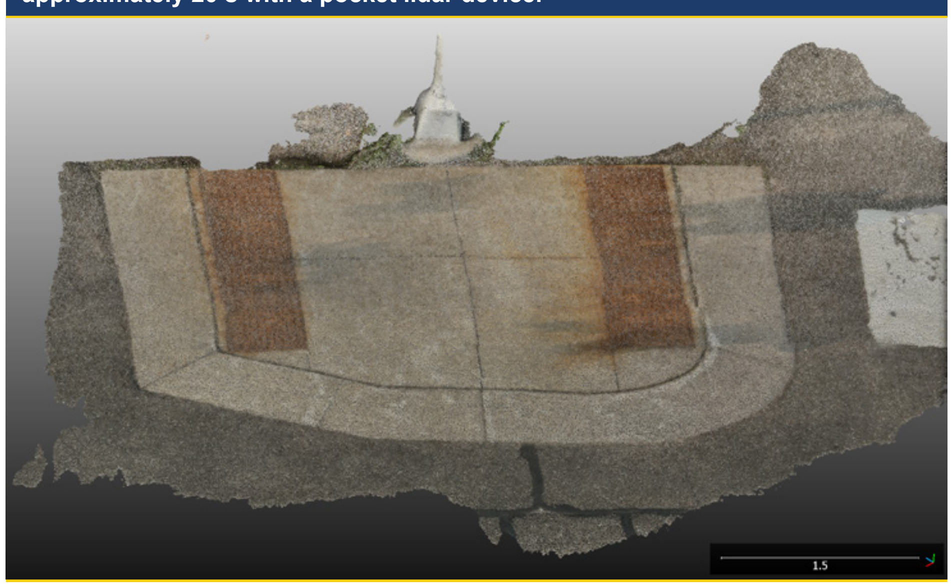
FHWA Contact: Matthew Corrigan (ORCID: 0000-0002-1230-8462), HRDI-20, FHWA Infrastructure Analysis and Construction Team, 202-493-3365, matthew.corrigan@dot.gov

This document is a technical summary of a case study for the Federal Highway Administration report *Leveraging Pocket Lidar for Construction Inspection and Digital As-Builts—Phase 1* (Forthcoming).

OVERVIEW

Curb ramps are a critical interface that enables pedestrians to safely transition between the street and sidewalk, particularly pedestrians with disabilities. The Americans with Disabilities Act requires that curb ramp running slopes (direction of travel) remain less than 8.3 percent to ensure safe access.[1,2,3] Unfortunately, the assessment of curb ramp conditions is a challenging process. Current techniques for measuring ramp slopes and dimensions are manual and error prone. Slope measurements are often obtained with digital inclinometers, commonly referred to as a smart level.[4,5] These devices are similar to carpenter levels but have a digital inclinometer built in to measure the slope. Readings can vary substantially due to the precision of the instrument, number of measurements, calibration, inspection technique, and the location of the measurement. One potential use case of the pocket lidar system is to quickly obtain dimensions and slope measurements of curb ramps for rapid assessment (figure 1).

Figure 1. Screenshot. Example point cloud of a worn curb ramp captured in approximately 20 s with a pocket lidar device.



Federal Highway Administration (FHWA). Created using data from the 3D Scanner App visualized in CloudCompare version 2.13.[6,7]

U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank
Highway Research Center

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

https://highways.dot.gov/research

Using pocket lidar provides many benefits over conventional techniques, including the following:

- Capturing a three-dimensional (3D) model that can be interrogated and evaluated for other information later as well as provide context for the measurements obtained for more thorough validation.
- Obtaining Global Navigation Satellite System (GNSS) positioning information through the pocket lidar in conjunction with the scan to help ensure the same ramp is investigated if different inspectors are performing measurements. This benefit also helps ensure that the ramp is tagged properly in an asset management framework as inspectors can confuse the locations of multiple ramps at an intersection, which can lead to erroneous assessments.
- Creating more systematic and repeatable processes that can be followed to extract the slope measurements from the data compared with measurements on arbitrary locations on the ramps.
- Making the work less strenuous on the inspector as they do not need to crouch or be on their hands and knees to obtain the data.
- Using a small device allows it to be operated efficiently and safely on the curb ramp and sidewalk in proximity to traffic, pedestrians, or bikes without obstructing their paths, which can be challenging or unsafe to capture with other methods.

This case study explores the capabilities and limitations of pocket lidar for curb ramp inspections. Specifically, the study focuses on the ability of the pocket lidar to extract slope measurements, which often poses difficulties in reliably obtaining this information.

WHAT IS POCKET LIDAR?

Pocket lidar systems are lidar systems integrated into a consumer-grade pocket device such as a smartphone or tablet. Currently, the lidar sensor integrated into the Apple® iPhone™ and iPad™ devices is a flash lidar sensor, which essentially captures a “video stream” of low-resolution depth maps (each pixel represents a distance to an object). These data are then blended with the video streams from the cameras through an artificial intelligence, deep-learning process to produce a depth map in a higher resolution. Using time-stamp information, these depth maps are related to the inertial measurement unit providing positional and orientation information necessary to construct the full 3D point cloud. Some applications (apps) also utilize the GNSS sensor within the device to reference the data into a world coordinate system (typically the Universal Transverse Mercator).[8] In some cases, this fusion of measurements from multiple sensors can result in higher quality data. Each depth map can be accompanied by a confidence map to screen out unreliable measurements.

> ***Key Takeaway:***
>
> Lidar technology has become very important for many construction applications. PL is a potential game changer for curb ramp assessments given that it has made powerful lidar technology accessible at an inspector’s fingertips.

While not a full replacement for technologies such as terrestrial laser scanning for the highest accuracy, the pocket lidar technology can be suitable for many purposes. Pocket lidar fills a niche for capturing good geometric information on objects and localized areas that are too time-consuming for terrestrial laser scans (TLS) but cannot be adequately captured with photographs. The simplicity of the apps and the intuitive operation of the device enables a diverse workforce to use pocket lidar with minimal training and support. A variety of editing procedures such as cropping, as well as some analyses, can be completed directly in the app. For many purposes, users do not need to learn complex desktop software. Given the prolific nature of consumer-grade pocket devices and the fact that apps on these devices use gestures similar to other apps for tasks, the apps are generally intuitive and straightforward to operate. However, for effective operation, testing is necessary to develop clear workflows that field personnel can follow for consistent results.

DATA ACQUISITION

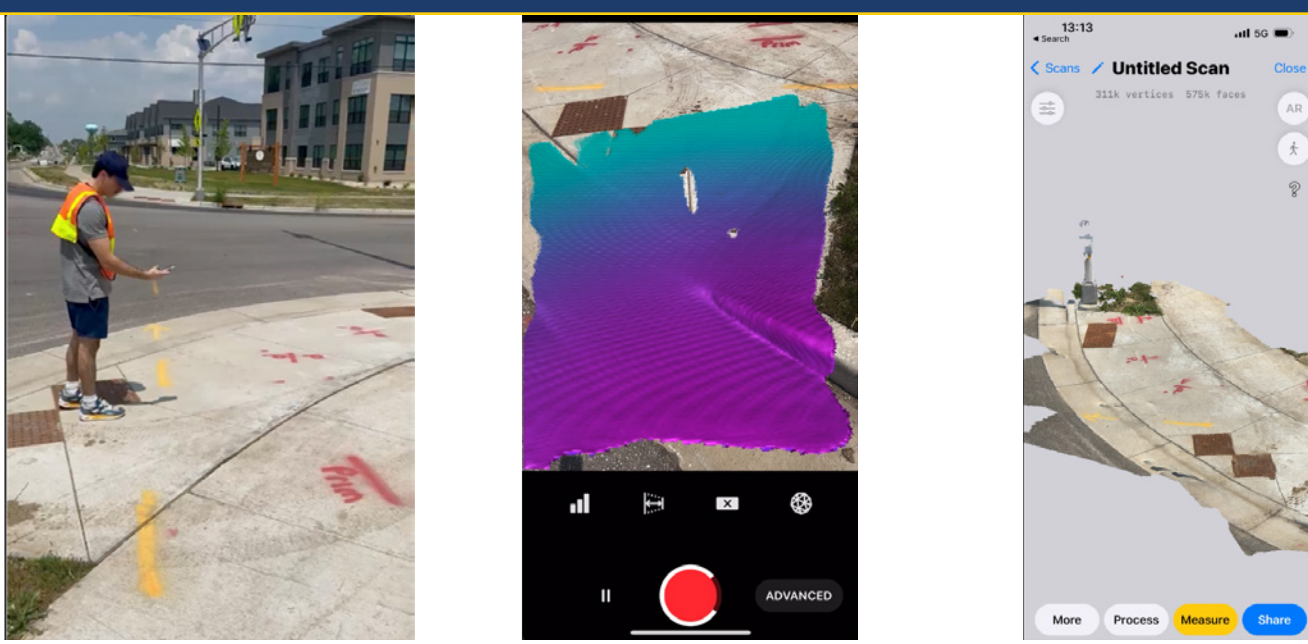
The BLK360 terrestrial laser scans were registered in During the first phase of the research project, the team reached out to a variety of transportation agencies to identify candidate case studies. The Minnesota Department of Transportation (MnDOT) expressed strong interest in collaborating on a case study to investigate capabilities of the sensor for curb ramp assessments. MnDOT had collected TLS for 13 sites in an urban area of Anoka County, which MnDOT provided as a reference to evaluate the pocket lidar results. The TLS data were collected with a Trimble® SX10 laser scanner and were subsampled to an approximately 3-cm spacing. The TLS data were not collected for the sole purpose of curb ramp evaluation. Different collection and processing strategies may have been implemented had this been the prior motivation. Nevertheless, the data coverage on the curb ramps was generally at a sufficient resolution to clearly identify the ramp and see basic geometric details. At a few locations, the scanner was set up directly over the ramp, which resulted in a significant portion of the ramp missing from the scan.

The team then identified potential ramps within these sites using a combination of the TLS data visualized in CloudCompare and imagery in Google® Earth™ as a reference (figure 2).[7,9] A naming convention was designed that tagged each scan to the site name, a unique ramp number ID, and the software app used for the collection. While most scans were of a single ramp, multiple ramps on the same island or corner were sometimes captured in a single scan. The team used three iOS™-based apps to capture data on the ramps—Abound Labs Inc Metascan, Niantic Scaniverse, and Laan Labs® 3D Scanner App—and to evaluate the consistency between the apps.[6,10,11] Figure 3 shows an example of the data collection procedure and app interface. Table 1 provides the settings used in each app for the data collection.

Figure 2. Map. Example aerial map of ramps identified at an intersection.[9]

Original photo: © 2023 Google® Maps™.[12] Modified by FHWA (see Acknowledgements section).

Figure 3. Photo and screenshots. Example acquisition process in the field.



A. Operation of pocket lidar for data collection in 3D Scanner App.[6]

B. 3D Scanner App interface during collection.[6]

C. Data visualization in the 3D Scanner App following collection.[6]

All images source: FHWA.

Table 1. App settings used in data acquisition.

Setting	Metascan[10]	Scaniverse[11]	3D Scanner App[6]
Version	2.9.3	2.1.4	1.1.4
Scan mode	Lidar	Area	Lidar
Orientation and	Heading Alignment: On	Range: 5.0 m	Z-Up, GPS: Off*
geometry	N/A	Mesh simplification: Off 8k	High definition, high density
Detail and texture	LAS, OBJ	LAS, OBJ	Zipped E57, OBJ

*The GNSS setting is off by default and was not enabled as an oversight in the field. The researchers recommend using this option, so that the acquired data are georeferenced.
GPS = global positioning system; N/A = not applicable; LAS = LASer exchange format by ASPRS (American Society for Photogrammetry and Remote Sensing).

DATA PROCESSING

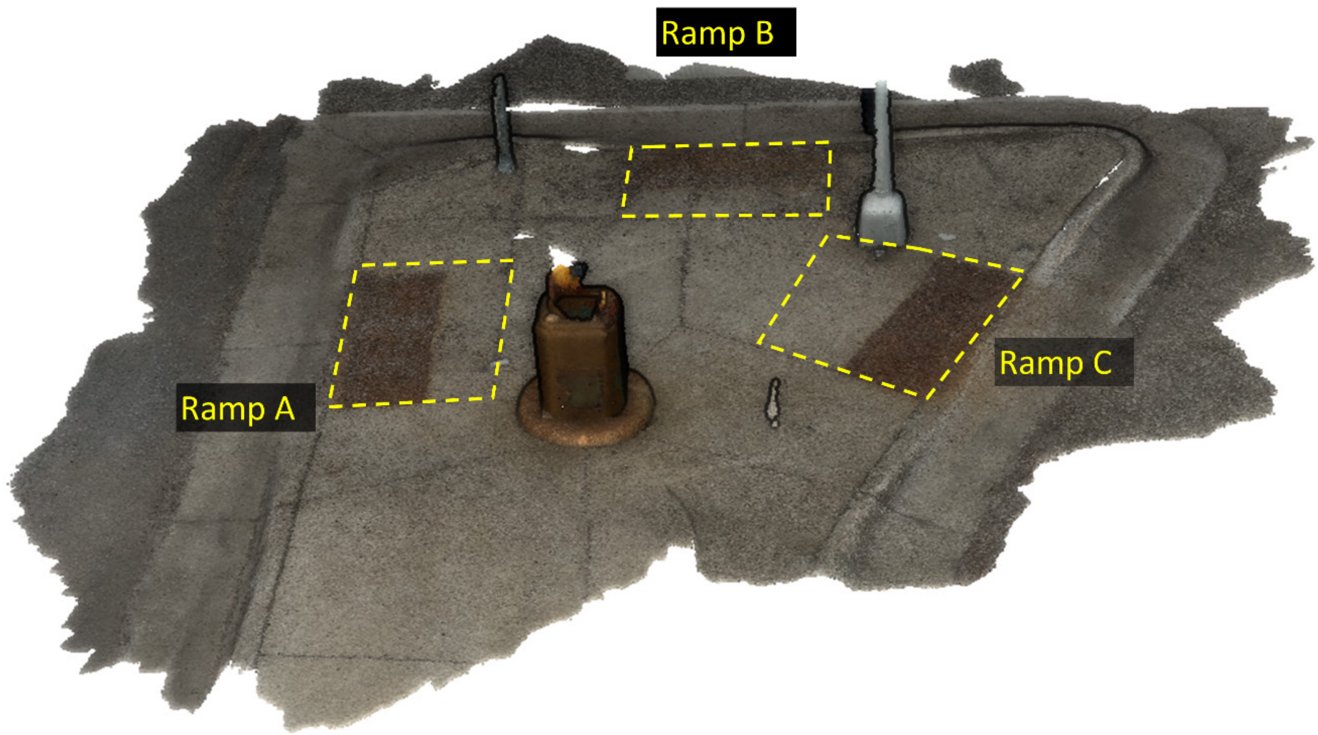
After completing the preprocessing in the apps, the data were processed on a desktop computer using the following procedure:

1. Each ramp was extracted from the point cloud using the interactive extraction tool in the CloudCompare software and exported as a new point cloud (figure 4).[7] For scans containing multiple ramps, each was given an alphabetical identifier as a secondary ID. For the extraction, care was taken by the research team to avoid obstructions, remove artifacts from people present on the ramp during time of scan (not common in pocket lidar scans but occasionally in TLS data), and select a section of the ramp with a singular slope (i.e., avoid side flares or multiple concrete blocks). Detectable warnings (raised bumps on the ramp to alert visually impaired pedestrians) were included in the area extracted. Notably, the extraction process was often simpler with the pocket lidar data given the higher level of detail, especially in terms of the texture and color information, compared with the TLS data due to the downsampling performed on the TLS data.
2. The exported scans were then batch processed in the EZDataMD Rambo software to obtain the best fit plane and the root mean square (RMS) values of the offset distances for the points used in the fit to evaluate the quality of the fit (figure 5).[13] The software provides the normal vector of the best fit plane. The slope can be computed as the arccosine of the Z-component of that normal vector when expressed as a unit vector. This value is then converted into a percent slope from the value in degrees, which is the convention for curb ramps in design, construction, and inspection. Note in typical curb ramp assessment procedures performed by transport agencies, the slope measurement is typically divided into a running (parallel to direction of user travel) and cross slope (perpendicular to direction of user travel).[5] In this study, these components of the slope were not evaluated separately. Rather, the study focuses on how accurately slopes can be estimated from the pocket lidar rather than performing the full assessment.
3. Additional metrics, such as slope, roughness, curvature, and point density, were also computed in the Rambo software.[13]

APP COMPARISON

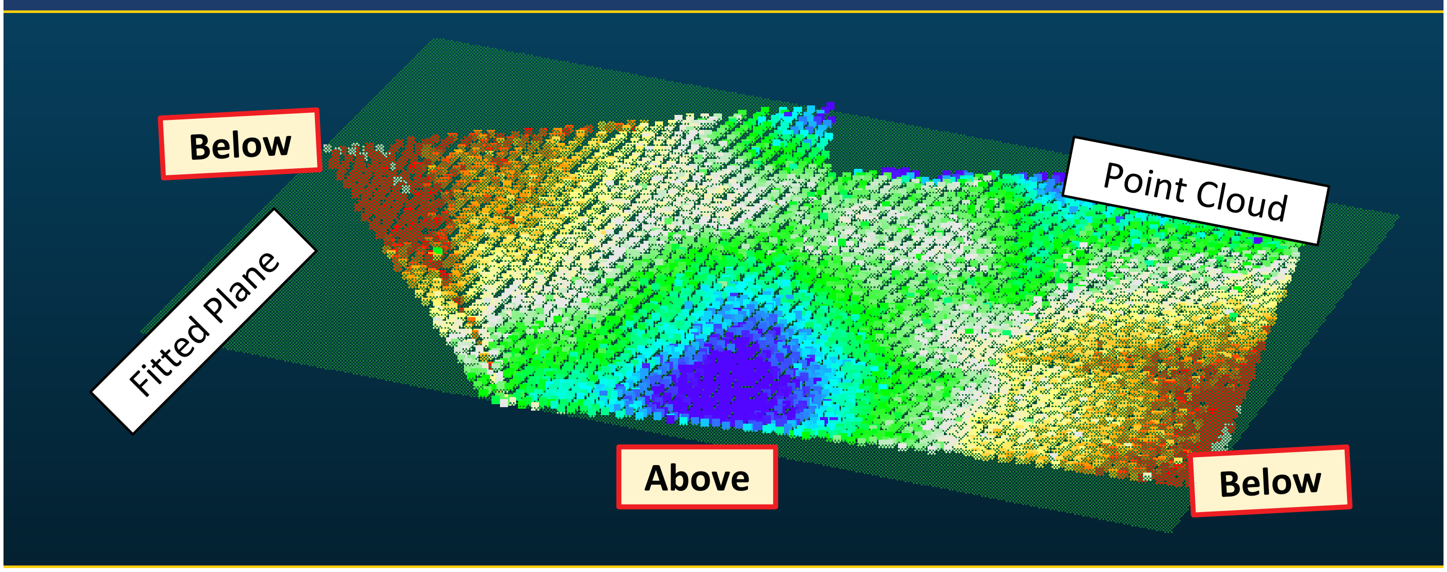
Although the apps tend to function similarly for the data collection, the team noted some differences between the three apps (table 2). All apps were simple to use and intuitive and most had options to adapt the settings based on whether one was scanning an object or an area. Data processing rarely required more than 1 min per ramp. The most significant differences were noted in terms of the accuracy, detail, and stability of the apps. Metascan also had highly erroneous GNSS coordinates.[10] Figure 6 shows some examples of point clouds collected with the different apps.

Figure 4. Screenshot. Example point cloud of a curb ramp captured in approximately 30 s with a pocket lidar device.



Source: FHWA. Data captured with 3D Scanner App and visualized in CloudCompare version 2.13 software.(6,7)

Figure 5. Screenshot. Example fit of a plane to the point cloud of a curb ramp.



Source: FHWA. Data from 3D Scanner App analyzed and visualized in CloudCompare version 2.13 software.(6,7)

ANALYSIS RESULTS

Several data quality metrics were evaluated quantitatively, including the following:

- RMS of the deviations of the points to the best fit plane (table 3)—This factor can indicate the level of noise present in the data or how rough the surface is. The TLS has high precision with an RMS of 0.005 m. Two of the pocket lidar apps were very close to the TLS (RMS = 0.006 m and 0.008 m). However, one app was nearly double (RMS = 0.011 m) because of several surface reconstruction errors that created duplicate surfaces at the same location.
- Comparison of slope values between each app and the TLS reference data (table 4)—Overall, the apps

Table 2. Comparisons between apps used in the data collection.

Feature	Metascan[10]	Scaniverse[11]	3D Scanner App[6]
Ease of use	Easy user interface and straightforward process.	Easy to use interface.	Easy to use interface.
Collection time	—	Fastest in collecting. Could move quickly while initializing the scan without redoing the scan.	—
Processing speed	Longest to process after the scan. Typically approximately 45 s after the scan was complete.	Scans typically processed in less than 30 s.	Quick processing after the scan was completed.
Accuracy and detail	Issues with accurate reconstruction of some ramps. Appears to preserve a lot of detail.	Performs substantial filtering, reducing detail. However, still provides an accurate representation.	Scans were accurate and preserved detail.
Georeferencing	GNSS coordinates typically off by 10s of meters.	GNSS coordinates typically within a few meters of the ramp location.	The GNSS setting was not initialized as planned and could not be directly evaluated. In previous testing, the GNSS coordinates were similar to those in Scaniverse.[11]
App stability	Only crashed once.	No crashes encountered.	Most crashes encountered, requiring scans to be repeated.

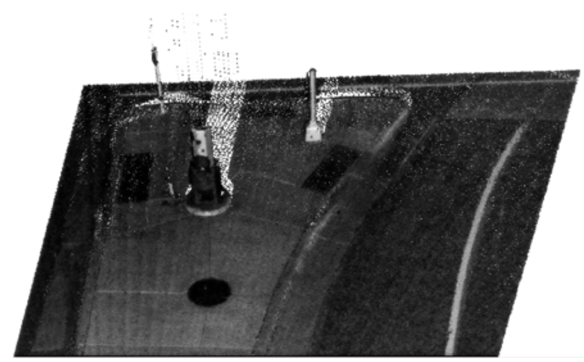
—No input.

Figure 6. Screenshots. Example pocket lidar scans from the apps tested compared with the TLS data.

A. 3D Scanner App.[6]

B. Metascan.[10]

C. Scaniverse.[11]



D. TLS

Source: FHWA. Data from 3D Scanner App, Metascan, Scaniverse, and the Trimble SX10 visualized in CloudCompare version 2.13 software.[6,7,10,11]
Note: Color information is often available with TLS data but was not available with this dataset.

Table 3. Comparison of RMS values (meters) for plane fitting between TLS and the apps tested.

Statistic	TLS	Metascan[10]	Scaniverse[11]	3D Scanner App[6]
Average (m)	0.0046	0.0087	0.0071	0.0053
Std. dev. (m)	0.0027	0.0063	0.0040	0.0032
Minimum (m)	0.0021	0.0026	0.0015	0.0014
Maximum (m)	0.0145	0.0352	0.0192	0.0170
Count (number)	56	38	54	51
RMS (m)	0.0054	0.0107	0.0081	0.0062
95-percent conf (m)	0.0105	0.0209	0.0159	0.0121

Note: Lower values indicate higher accuracy.
Std. dev. = standard deviation; conf = confidence interval.

Table 4. Comparison of slope measurements for curb ramps relative to the TLS data.

Statistics	Metascan[10]	Scaniverse[11]	3D Scanner App[6]
Average (percent)	−0.04	−0.05	0.01
Std. dev. (percent)	1.12	0.73	0.84
Minimum (percent)	−2.26	−1.95	−1.97
Maximum (percent)	2.53	1.70	1.90
Count (number)	38	52	49
RMS (percent)	1.10	0.72	0.84
95-percent conf (percent)	2.16	1.41	1.64

performed reasonably well with RMS values between 0.72 and 1.10 percent. Measurements obtained by multiple inspectors using current digital inclinometer devices tend to show a substantial amount of variability (RMS = 0.5 percent).[5] This variability between inspectors using digital inclinometers occurs as a result of sensor limitations, calibration errors, differences in the number of measurements obtained, location of the measurements, and variability of the surface. Pocket lidar has the advantage of being a more consistent, systematic approach. However, Metascan had a scan with a highly erroneous slope measurement because Metascan constructed two different surfaces across the ramp in processing due to biases.[10]

- Comparison of point density between apps (table 5)—3D Scanner App showed the highest point density, while Scaniverse showed the lowest point density given that Scaniverse does a substantial amount of noise filtering and retains a smaller portion of the points.[6,10] The TLS data had a lower point density overall, partially due to the filtering processes applied to the data during the initial processing.

Figure 7 provides some example results of evaluating surface roughness, local slope, and point density between the different apps. Notably in the roughness, the TLS data adequately preserve joints in the concrete, which are less pronounced in the app scans given the smoothing that occurs. Metascan produced a duplicate surface in that ramp, causing erroneous values in the middle.[10] The slope maps tend to be similar between each ramp. Substantial differences are observed in the point density between the apps given the different levels and methods of filtering and smoothing between each app.

ADDITIONAL OPPORTUNITIES

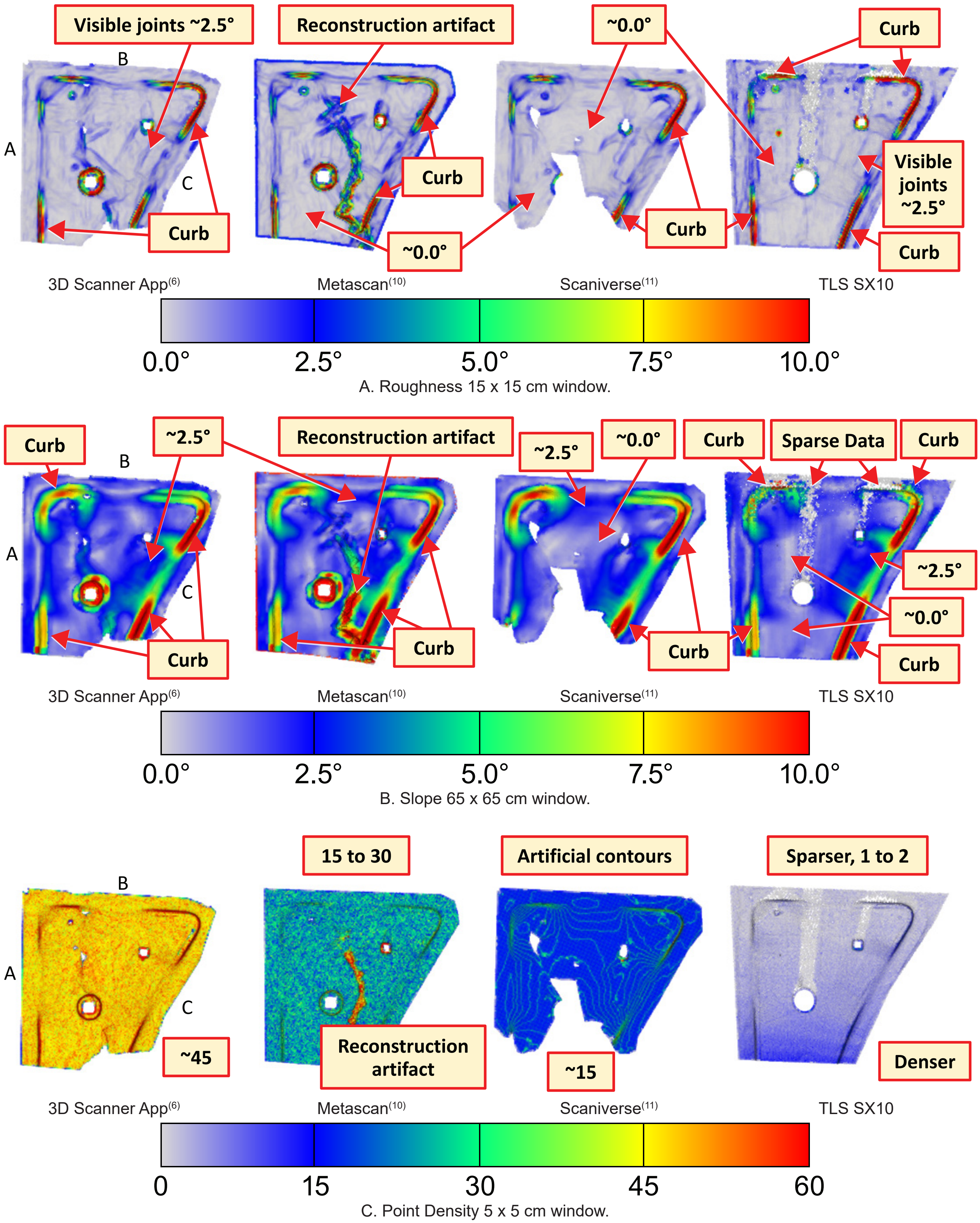
Pocket lidar can also support extraction of dimensions of curb ramps, landing pads, and sidewalks (figure 8). Related capabilities were studied in detail in prior field testing in the research project. Further, pocket lidar can be used for other related assessments, including the following:

- Evaluate the overall condition of the ramp or sidewalk by identifying rough surfaces due to spalled concrete.
- Detect the presence of debris.
- Identify obstructions to ensure adequate passage and turning space.
- Capture other assets such as the presence of walk buttons. Additionally, the augmented reality capabilities (e.g., figure 3) can help promote collaborative discussions to resolve issues directly in the field.

Table 5. Comparison of point density (points per square meter) between TLS and the apps tested.

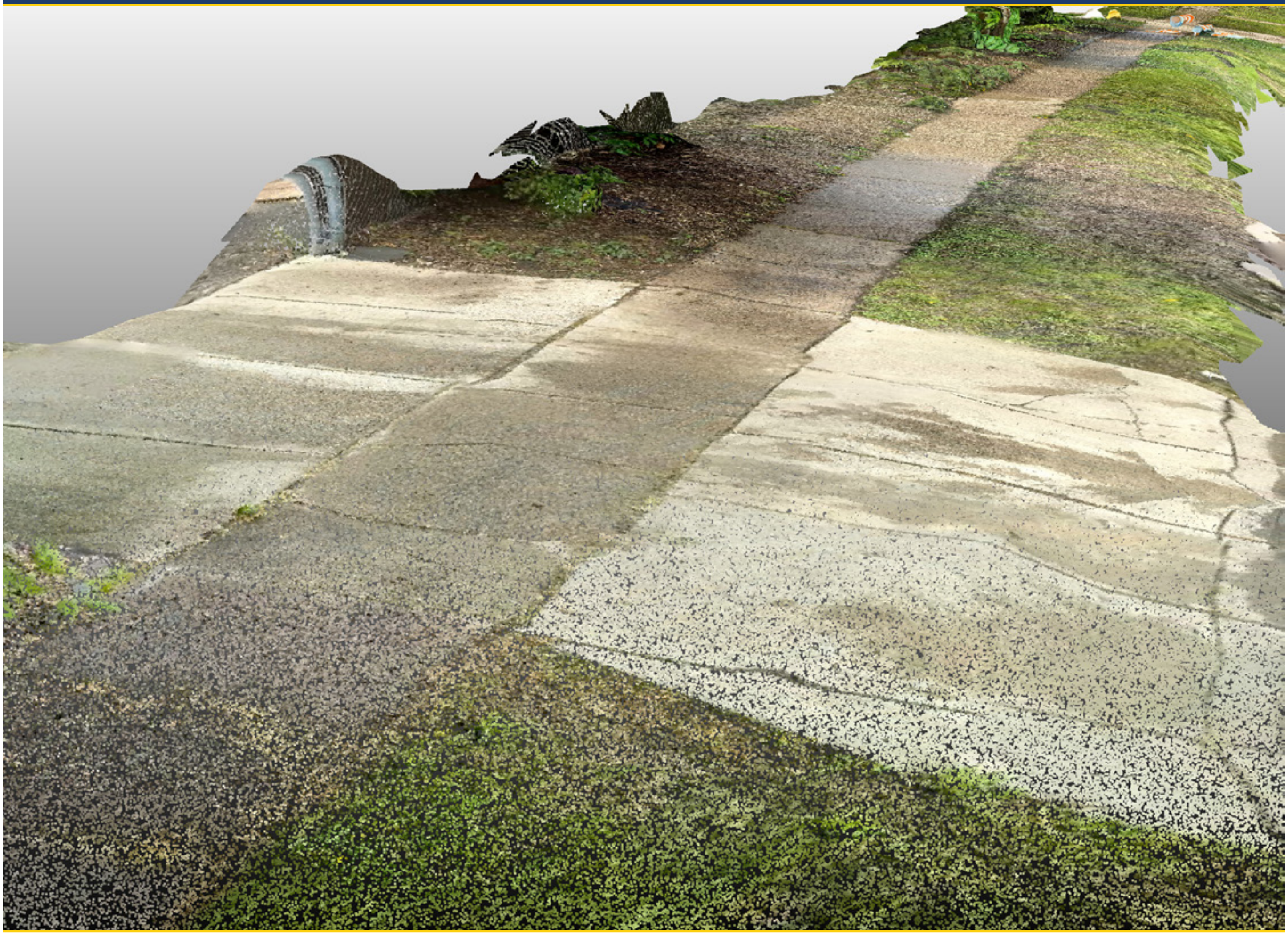
Statistic	TLS	Metascan[10]	Scaniverse[11]	3D Scanner App[6]
Average	18,223	9,454	12,098	18,262
Std. dev.	18,895	365	7,526	1,674
Minimum	568	8,890	1,634	16,886
Maximum	96,909	11,227	36,384	25,747
Count (number)	56	38	54	51
RMS	26,129	9,461	14,211	18,338
95-percent conf	51,213	18,543	27,853	35,942

Figure 7. Illustrations. Example morphological analysis of pocket lidar scans from the apps tested compared with the TLS data.



Source: FHWA. Created using data from 3D Scanner App, Metascan, Scaniverse, and the Trimble SX10 analyzed in the Rambo software and visualized in CloudCompare version 2.13 software.[6,7,10,11,13]

Figure 8. Screenshot. Example pocket lidar scan of a sidewalk and drive approach.



Source: FHWA. Data from 3D Scanner App analyzed and visualized in CloudCompare version 2.13 software.[6,7]

SUMMARY

Overall, pocket lidar provided data that were nearly as accurate (0.75-percent standard deviation) as the current state of practice of using digital inclinometers (1.25 percent (blunders) 0.50 percent (no blunders) standard deviation.[5] With this level of performance, pocket lidar can be suitable for compliance assessment when the derived slope values are clearly passing or clearly failing. However, for ramps that are close to the passing threshold (e.g., within 1.0 percent), higher accuracy methods and techniques should be used. While obtaining dimensions was not directly evaluated in this case study, obtaining dimensions was studied in prior work on this research project by extracting measurements on a variety of objects. Those results are described in the final report. Ultimately, pocket lidar was found to provide sufficiently accurate measurements of lengths and widths to within a few centimeters.

Key Takeaway:

Pocket lidar devices showed good performance for evaluating slopes of curb ramps and are almost on the same level with digital inclinometer technology. However, for ramps close to the passing threshold, higher accuracy methods and techniques should be used. Nevertheless, pocket lidar provides many additional benefits by providing a detailed, georeferenced, 3D model.

This case study identified many benefits of pocket lidar over digital inclinometers, including the following benefits:

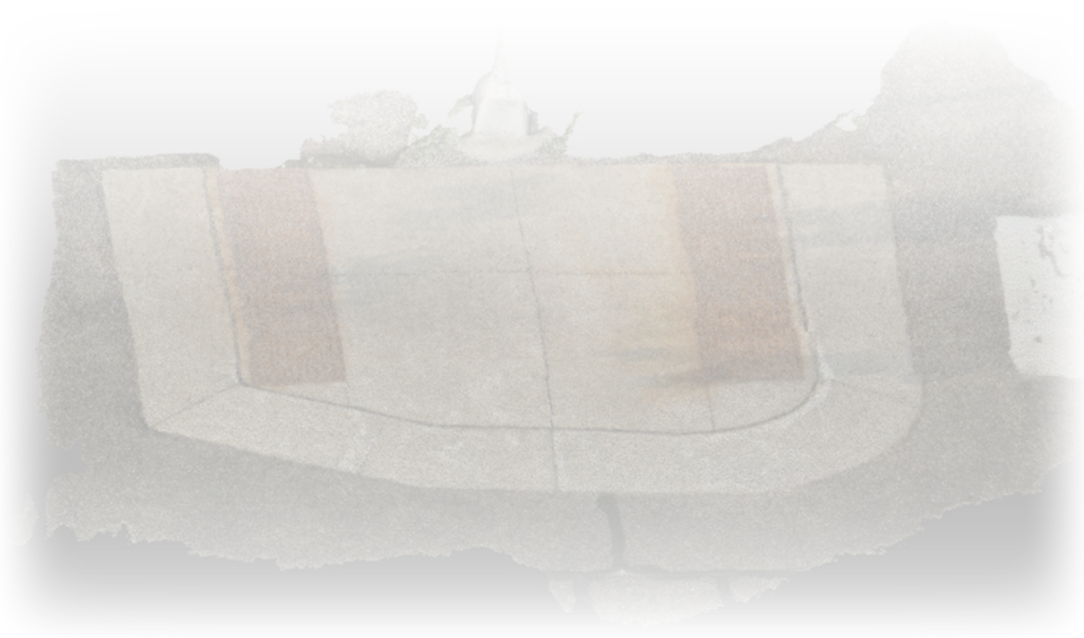
- Maintains the 3D model of the ramp in case future discrepancies arise, providing a more systematic, consistent evaluation process.
- Uses GNSS to verify which ramp was captured.
- Places less physical stress on the inspectors, who simply need to walk the ramp rather than obtain measurements on their hands and knees.

ACKNOWLEDGEMENTS

The authors modified the map in figure 2 to mark locations of the curb ramps on Pederson Drive in Saint Francis, MN. The original map is the copyright property of Google® Maps™ and can be accessed at https://www.google.com/maps/place/45%C2%B023’19.0%22N+93%C2%B022’12.2%22W/@45.3880212,-93.3690136,17z/data.(12)

REFERENCES

1. Americans With Disabilities Act of 1990. 1990. Public Law 101-336. 108th Congress, 2nd session. https://www.govinfo.gov/app/details/CREC-2002-01-29/CREC-2002-01-29-pt1-PgS222, last accessed December 18, 2023.
2. U.S. Access Board 2023. “Public Right-of-Way Accessibility Guidelines” (web page). https://www.access-board.gov/prowag/, last accessed December 18, 2023.
3. U.S. Access Board 2023. “Advancing Full Access and Inclusion for All” (web page). https://www.access-board.gov/ada/guides/chapter-4-ramps-and-curb-ramps/, last accessed December 18, 2023.
4. Ai, C., and Y. Tsai. 2016. “Automated Sidewalk Assessment Method for Americans with Disabilities Act Compliance Using Three-Dimensional Mobile Lidar.” *Transportation Research Record* 2542 no. 1: 25–32.
5. Olsen, M. J., E. Che, and D. Trejo. 2024. *Evaluation of Curb Ramp Compliance: Review of Tools, Methods, and Time to Develop Error Tolerances*. Report No. FHWA-OR-RD-24-05. Salem, OR: Oregon Department of Transportation.
6. Laan Labs. 2024. *3D Scanner App* (software). https://3dscannerapp.com/, last accessed October 25, 2024.
7. CloudCompare. 2023. GPL (software). Version 2.13. http://www.cloudcompare.org/, last accessed November 27, 2024.
8. U.S. Geological Survey. n.d. “What does the term UTM mean? Is UTM better or more accurate than latitude/longitude?” (web page). https://www.usgs.gov/faqs/what-does-term-utm-mean-utm-better-or-more-accurate-latitudelongitude, last accessed November 27, 2024.
9. Google. 2023. *Google Earth* (software). https://earth.google.com/web, last accessed November 22, 2024.
10. Abound Labs Inc. 2024. *Metascan* (software). https://metascan.ai/, last accessed October 25, 2024.
11. Niantic, Inc. 2024. *Scaniverse* (software). https://scaniverse.com/, last accessed October 25, 2024.
12. Google. 2024. *Google Maps* (software). https://maps.google.com/, last accessed November 22, 2024.
13. EZDataMD, LLC. 2024. *Rambo* (software). https://ezdatamd.com/products/#rambo, last accessed November 27, 2024.
14. @applelidarfortransportatio1925. n.d. Apple Lidar for Transportation. YouTube channel. https://www.youtube.com/channel/UC9WAoH6_qsH1yobqCviqDbg, last accessed November 22, 2024.
15. @RamiTamimi. n.d. Rami Tamimi. YouTube channel. https://www.youtube.com/@RamiTamimi/featured, last accessed November 22, 2024.



Federal Highway Administration (FHWA). Created using data from the 3D Scanner App visualized in CloudCompare version 2.13.[6,7]

Researchers—This study was conducted by EZDataMD LLC, 5C Strategy, and MPN Components in collaboration with MnDOT. Michael Olsen (EZDataMD), Ezra Che (EZDataMD), John Caya (5C Strategy), Michael Caya (5C Strategy), Gene Roe (MPN Components), James Schnieder (MnDOT), and Rebecca Embacher (MnDOT) contributed to this case study. The work was completed under order number 693JJ321P000047.

Distribution—This TechNote is being distributed according to a standard distribution. Direct distribution is being made to the FHWA divisions and Resource Center.

Availability—This TechNote may be obtained at https://highways.dot.gov/research.

Key Words—Pocket lidar, curb ramps, measurements, slope, ADA.

December 2024

Recommended citation: Federal Highway Administration, *TechNote: Pocket Lidar Curb Ramp Assessments* (Washington, DC: 2024) https://doi.org/10.21949/1521530

FHWA-HRT-25-014
HRDI-20/12-24(WEB)E