Evaluating the Viability of Smartphone-Based Gaussian Splatting for 3D Sidewalk Modeling Against a LiDAR Benchmark

How viable is smartphone-based Gaussian Splatting for 3D sidewalk modeling compared to LiDAR-based methods?

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INTRODUCTION

This project focuses specifically on helping residents within Harlem, with the help of the 125th Street Business Improvement District (BID), with easing the identification and reporting of sidewalk issues they encounter in their daily lives. Effective advocacy of these issues depends on having clean, easy to understand, and accurate evidence. The city government is more likely to be adequately prepared to solve problems when there is a clear representation of the issue being addressed.

To address this challenge of not having clarity in the reporting of sidewalk issues, we are investigating whether everyday smartphone-based scans can reproduce visuals of similar quality as those produced by expensive LIDAR technology. This work was conducted by researchers at Columbia University's Center for Smart Streetscapes (CS3), in collaboration with civil engineering professor Zhengbo Zou and the ICON Lab. Through this partnership, we explored how engineering and emerging technologies can be applied to give Harlem residents and community organizations more effective tools for documenting streetscape conditions and accessibility issues, and to improve quality of life.

Faults with Current LiDAR Use:

3D scans generated with a LiDAR scanner can be used for multiple purposes, one of which being a mobile application to flag sidewalks in need of immediate maintenance with accurate examples of destruction and erosion.

There are many flaws in the current usage of LiDAR machinery. First, LiDAR technology will pick up on any object so long as it is stationary for the amount of time it takes to create one frame. Many dynamic objects such as people, trash, and vehicles are picked up in the scan, preventing a clear, unobstructed assessment of underlying pavement quality.[1] LIDAR technology is also extremely expensive and hard to come across: the technology we used cost more than $4,000, creating a significant cost barrier for community groups and non-research groups. High-quality LiDAR machinery can range in prices, from a $4,000 model, which has minimal functionality, to a $40,000 scanner of higher accuracy.[2]

Additionally, reflective, transparent and light-absorbent surfaces are not recorded as well. LiDAR technology works by sending out lasers that bounce off objects and recording the time the lasers take to return to their point of origin. The scanner then assesses the location based on the recorded distance traveled by the lasers, assigning coordinates to each point (x, y, z). Dark or light-absorbent surfaces absorb laser energy rather than reflecting it back, causing less of the laser to return to the machine, therefore causing the recording to be less accurate.[3] Likewise, for

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[1] Zhenyu Liu, Peter van Oosterom, Jesús Balado, Arjen Swart, and Bart Beers, "Data Frame Aware Optimized Octomap-Based Dynamic Object Detection and Removal in Mobile Laser Scanning Data," *Alexandria Engineering Journal* 74 (2023): 327–344, https://doi.org/10.1016/j.aej.2023.05.014

[2] Calebe Pereira Mendes and Norman T-Lon Lim, "EcoLiDAR: An Economical LiDAR Scanner for Ecological Research," *PLOS ONE* 19, no. 6 (2024): e029871, https://doi.org/10.1371/journal.pone.0298712

[3] Bala Muralikrishnan, "Performance Evaluation of Terrestrial Laser Scanners—A Review," *Measurement Science and Technology* 32, no. 7 (2021), https://doi.org/10.1088/1361-6501/abdae3

reflective surfaces, the laser bounces off, some of which does not return to the LiDAR machine, resulting in missing points and blank spaces in the scan. There is a similar conclusion made with translucent or transparent surfaces as well, as the lasers move through the material, leading to refraction, causing there to be blotches in the data, therefore making it inaccurate.[4]

Moreover, LiDAR technology is frequently used in airborne laser scans, such as videos taken from drones. Airborne and drive-by LiDAR methods frequently suffer from line-of-sight blockage caused by tree canopies, building overhangs, and parked vehicles, all of which make it nearly impossible to create an accurate scan of the sidewalks underneath. For example, tree branches may block the view of sidewalk destruction or erosion for airborne LiDAR machines.

Finally, drive-by recordings on the street made by vehicles with LiDar machines are also faulty. Similar to airborne scanning, there are a lot of obstacles from the roadside view, such as parked cars, lamp posts, garbage, and many other objects. As a result, scanning done by vehicles is another inefficient method of obtaining accurate readings in order to report streetscape maintenance.[5]

METHODS & DATA

Field Site & Research Design

As for some baseline data points to highlight the critical need of this research, about 80% of individuals live within urban environments, 13% of which also live with a disability.[6] Seniors, young children, and people with disabilities are the most susceptible to these issues. "Approximately 10,000 older adults (65+) are treated in emergency departments every day due to fall injuries."[7] Potholes, cracks, overgrown roots and trash are the lead causes. Therefore our research is paramount to keeping our community safe.

We used a mixed-methods design that combined pedestrian surveys, interviews, and 3D computer vision processing. Field research took place along the 125th Street commercial corridor in Harlem (between Malcolm X Blvd. and St. Nicholas Ave.), a central retail and transit thoroughfare located within the 125th Street Business Improvement District (BID). The 125th BID requested a 3D model of this area, and it was an effective location because of its high foot traffic, public transportation access points, heavy street vendor presence, and visible sidewalk damage.

Each method was selected to gather a specific layer of data needed for the project. The quantitative surveys gathered hard data on how often pedestrians deal with sidewalk hazards,

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[4] R. Koch, S. May, and A. Nüchter, "Detection and Purging of Specular Reflective and Transparent Object Influences in 3D Range Measurements," *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-2/W3 (2017): 377–84, https://doi.org/10.5194/isprs-archives-XLII-2-W3-377-2017

[5] "Gap Completion in Point Cloud Scene Occluded by Vehicles Using S..." *ISPRS Journal of Photogrammetry and Remote Sensing* (2024), https://doi.org/10.1016/j.isprsjprs.2024.09.014

[6] Raju Vaishya and Abhishek Vaish, "Falls in Older Adults are Serious," *Indian Journal of Orthopaedics* 54, no. 1 (2020): 69–74, https://doi.org/10.1007/s43465-019-00037-x

[7] Vaishya and Vaish, "Falls in Older Adults are Serious."

their mobility limitations, and public support for city repair funding. The semi-structured intercept interviews offered qualitative context, allowing residents to describe their daily travel challenges, helping us separate permanent concrete defects from temporary street clutter. Finally, 3D computer vision processing gave us precise spatial measurements (such as vertical lip offsets, where one concrete slab sits higher than an adjoining slab to create a trip hazard: ≥0.5 in) to test whether low-cost smartphone scans could deliver the sub-centimeter accuracy required for municipal engineering audits.

Community Field Data Collection

Our data collection relied on two methods: a 13-question survey and brief pedestrian interviews.

1. Survey: We ran 44 13-question surveys on 125th Street asking passersby about sidewalk conditions, transit habits, mobility limitations, demographics, and whether they support spending more local funds on street repairs.[8] We planned to use this data to get a clear starting picture of how pavement damage affects daily travel across different demographic groups, particularly vulnerable pedestrians like residents living with mobility disabilities and parents with strollers.

2. Interviews: We conducted 28 short, semi-structured interviews to record pedestrians' use of sidewalks, their concerns on sidewalk maintenance, and the specific obstacles that get in their way.[9] Audio was recorded, transcribed and coded into six themes: ROLE (reason for travel), IMPORTANCE (priority level), OBSTACLE (fixed pavement damage), ATTITUDE (movable obstacles like vendors or trash), IMPROVEMENTS (suggested fixes), and TREND (changes in quality over time).[10]

Computer Vision Processing and Camera Capture

Traditional municipal surveying relies on industrial Mobile LiDAR vehicles (≥$100k). LiDAR vehicles drive along public streets using roof-mounted laser scanners and high-precision sensors to map surrounding physical infrastructure into detailed 3D models. This technique, however, creates a high financial barrier for frequent sidewalk audits. Enabling everyday residents to collect spatial data using accessible, personal devices could eliminate this cost obstacle, opening the door for continuous, community-driven monitoring of local streets. To test whether accessible consumer hardware could replace these systems, our team personally conducted field-scanning passes using an iPhone. This scanning used MiSensorKit to record 60 fps RGB video, camera intrinsics, and spatial IMU motion data.

We processed the video frames and camera trajectories in Google Colab using 3D Gaussian Splatting (3DGS) to reconstruct the sidewalk in 3D. Because street garbage, parked e-bikes, and scaffolding corrupt 3D geometry, we added dynamic loss masking during model training. This mask (M) zeroes out reconstruction loss over transient street objects, forcing the optimizer to ignore temporary clutter and focus exclusively on the concrete underneath to expose physical cracks (≥0.5 in).

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[8] **Appendix B:** Quantitative Survey Questionnaire

[9] **Appendix A:** Interview Questions

[10] **Appendix D:** Qualitative Codebook for Harlem Sidewalk and Pedestrian Assessment

To test how accurate our smartphone-generated 3D models were, we needed a high-precision "gold standard" to compare them against. We scanned the exact same section of 125th Street using both a $4,000 commercial LiDAR scanner, which fires laser pulses to build an extremely precise 3D map of the physical streetscape, as well as smartphone devices. We then imported the 3D point clouds from both the $4,000 LiDAR scanner and the smartphone scan into CloudCompare, an open-source software used for analyzing 3D spatial data. Inside CloudCompare, we aligned both models onto the exact same coordinate system and performed a "cloud-to-cloud" distance check—a process that calculates the physical gap between every matching point of the two scans. This allowed us to measure the smartphone model's margin of error and verify whether a standard phone camera could achieve sub-centimeter accuracy (≤1 cm), which is the precision standard traditionally needed to detect real sidewalk trip hazards for city repairs.

GIS Data Schema & Field Adjustments

We organized our spatial outputs in ArcGIS Pro using a File Geodatabase with two main feature groups: static elements (Sidewalk_Segment, Streetlight, Trash_Bin, Bus_Stop) and temporary blockages (Illegal_Dumping, Street_Vendor). To track changes between initial scans (T1) and follow-up scans (T2), we added temporal tracking fields: Survey_Date, Persistence_Flag (0 for temporary clutter removed by T2; 1 for persistent concrete damage), and Defect_Delta_in ($\Delta h = hT2 - hT1$) to log crack growth over time.

Constructing our database in this way directly addresses our core research question by separating temporary street clutter from concrete failure. Being able to properly distinguish transient blockages such as trash piles or vendor setups from permanent pavement features needing repair, issues can be more appropriately addressed. Furthermore, tracking Persistence_Flag and Defect_Delta_in across multiple scans turns static 3D models into an active monitoring system, allowing municipal teams to identify which sidewalk cracks are actively expanding and require urgent repair.

During field research on 125th Street, shifting sunlight and dense pedestrian crowds created noise in our initial video passes. We resolved this by locking camera exposure settings prior to scanning and relying on our dynamic loss mask to filter out moving pedestrians in post-processing.

Community and Social Science Data

To characterize pedestrian experiences and perceptions of sidewalk conditions in the Harlem area, both quantitative survey data and qualitative interview data were analyzed. The survey captured respondents' demographic characteristics, frequency of exposure to the study area, perceptions of sidewalk quality and government responsibility, and specific hazards affecting mobility. Interviews provided additional context on these experiences. They were coded to identify recurring themes and distinguish between fixed structural defects that can be captured through 3D reconstruction and dynamic obstacles that may require masking during analysis. Together, these datasets provide both a broad measure of perceived sidewalk conditions and a more detailed account of the specific infrastructure and accessibility challenges experienced by pedestrians.

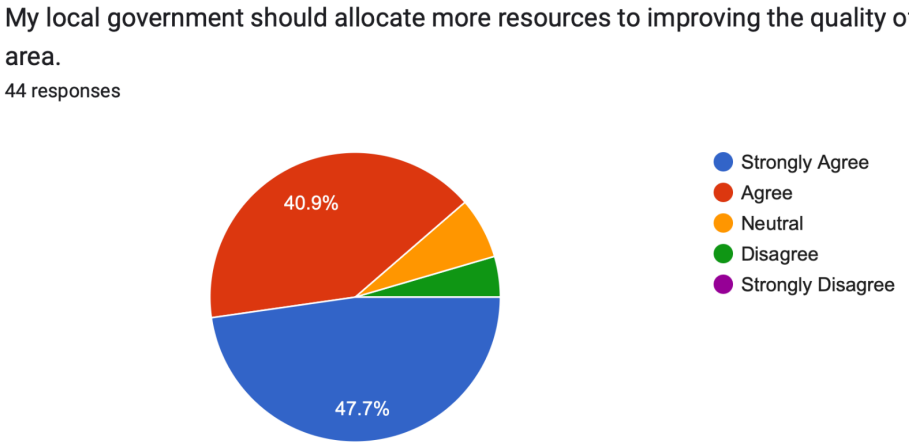


Figure C.g.[11]

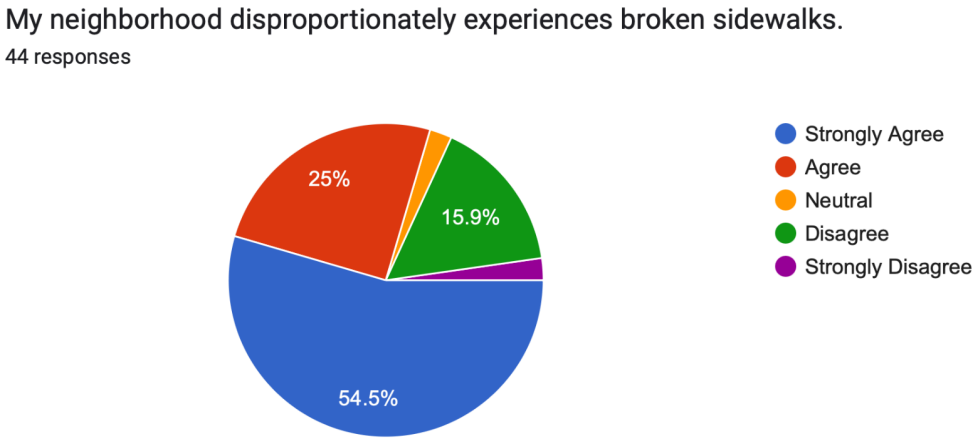


Figure C.h.[12]

Survey data were collected from N = 44 respondents in the Harlem study area via a structured questionnaire covering demographics, sidewalk-quality perceptions, and specific hazard experiences.

The sample was 59% female and 41% male, with a majority (68%) of respondents residing in Harlem; the remaining 32% reported walking in the area regularly, with 47% doing so daily. Age skewed younger, with 42% between 18-35, 23% between 36-50, and 16% each in the 51-64 and 65+ brackets. Notably, 65% of respondents reported having children, and 18% reported living with a disability that affects mobility—showing that the sample includes a large percentage of residents with heightened sensitivity to pedestrian infrastructure quality.

Technical Engineering Results

Sidewalk segments in the study area were scanned using a high-precision LiDAR sensor to generate a raw point cloud (x, y, z coordinates) for each surveyed corridor. Raw scans were imported into CloudCompare, where a denoising pass was applied to strip isolated and noisy

[11]**Appendix C,** Figure C.g.
[12]**Appendix C,** Figure C.h.

points that did not correspond to real surface geometry (e.g., transient reflections, sensor artifacts). The resulting cleaned point clouds—including detailed captures of Harlem storefronts and building facades (Figure 1) — served as the ground-truth benchmark against which the smartphone-derived models were evaluated.

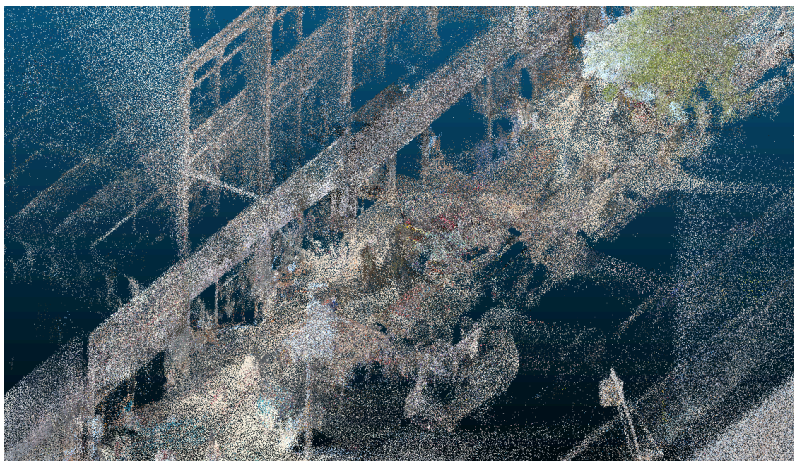


Figure 2. 125th street, Harlem. Storefronts and buildings rendered by a LiDAR scan.

In parallel with the LiDAR scan, walkthrough video of the same areas was recorded using an iPhone running MiSensorKit. Each video was split into individual frames paired with a camera pose JSON file, then processed in Google Colab. The pipeline generated a point cloud from the frame sequence and assigned each point a Gaussian "blob" (defined by shape, color, and transparency), which was then splatted to 2D for rendering.

A key objective of the Colab pipeline was to identify and mask dynamic, non-permanent objects—pedestrians in particular—from individual frames, so that temporary street activity would not be integrated into the final scan. Masking performance was inconsistent, however: Colab did not always correctly identify and remove dynamic clutter, in some cases failing to mask pedestrians and in other cases erroneously removing static elements (e.g., a statue) it misclassified as transient.



Figure 3. Dynamic object (pedestrian) identified, masked and removed from a frame of a sidewalk scan.

To evaluate the viability of the smartphone pipeline, both point clouds were aligned into a shared coordinate frame. Georeferencing was performed by matching points from the LiDAR scan to corresponding coordinate points identified on Google Maps, allowing both datasets to be spatially registered against real-world geography. Once aligned, the smartphone-derived (3DGS)

model was compared against the LiDAR benchmark for geometric accuracy, using metrics such as crack width, to assess how closely the low-cost method could approximate professional-grade scanning. Validated results were then fed into ArcGIS Pro for spatial mapping and integration with the project's broader taxonomy.

As a preliminary field validation, we manually measured several curb dimensions along 125th Street and compared these measurements with corresponding measurements generated using MiSensorKit and LiDAR. Although this was a brief test with a limited number of measurements, the results showed an approximate overall mean error of 12% for MiSensorKit and 10% for LiDAR relative to our manual measurements. The relatively small difference between the technology-assisted measurements and our manual measurements suggests that both methods were reasonably accurate for this initial test. While these results are not sufficient to establish definitive accuracy, they provide preliminary evidence that smartphone-based scanning may be a viable, lower-cost approach for documenting sidewalk conditions and identifying potential infrastructure defects.

FINDINGS

Data collected along Harlem's 125th Street (from Malcolm X Boulevard to St. Nicholas Avenue) points to a clear consensus: residents feel local sidewalk conditions are subpar and could be better maintained. In our survey (N=44), 59.0% of respondents agreed or strongly agreed that sidewalk quality regularly poses a problem during their daily trips. When asked which physical issues caused the most trouble, large cracks and uneven concrete stood out above everything else, selected by 70.5% (n=31) of survey takers. Other frequent hazards included damaged or missing curb ramps (45.5%, n=20), standing water and blocked pathways (43.2%, n=19), steep drop-offs (38.6%, n=17), and accumulated trash (15.9%, n=7). These physical barriers can create daily headaches especially for vulnerable community members such as those living with a disability limiting their mobility (18.6%, n=8) and those with children (65.1%, n=28)

In our qualitative intercept interviews (N=28), participants broke down these issues into two main categories: fixed concrete damage and moving street clutter. Pedestrians repeatedly brought up deep pavements cracks, steep drop-offs, and missing curb cuts as serious fall hazards for older adults, people using mobility aids (like crutches or walkers), and parents pushing strollers. Beyond broken pavement, people voiced frustration over temporary blockages, such as police cars parked up on the sidewalk, commercial delivery e-bikes weaving through footpaths, overflowing trash cans, dog waste, and crowded vendor setups. Across both the surveys and the interviews, participants focused on the same core issues: safety, accessibility, and basic respect for public space.

A strong pattern of perceived neighborhood neglect runs through the entire dataset. An overwhelming 79.5% of respondents (n=35) agreed or strongly agreed that Harlem experiences broken sidewalks disproportionately compared to other New York City neighborhoods, with over half (54.5%, n=15) holding a strongly affirmative view. This perceived disparity directly informs public expectations for government accountability, as 88.6% (n=36) of surveyed pedestrians reported that broken concrete regularly impairs their ability to navigate the neighborhood.

Reinforcing the survey findings on widespread travel disruption and municipal neglect, our qualitative interviews revealed a distinct spatial trend along 125th Street between Malcolm X Boulevard and St. Nicholas Avenue. People noted that sidewalk maintenance varies wildly depending on who owns the adjacent property. Sidewalks right in front of major corporate stores, new luxury apartment buildings, or wealthier residential blocks are kept clean and smooth. Meanwhile, other nearby residential blocks and city-owned property are accompanied by streets that remain cracked, littered, and neglected. In addition, after adding a supplemental question late in our fieldwork to gauge interest in crowdsourced reporting, 77.8% (n=7) said they would be willing to use an iPhone app to scan and report damaged pavement to city agencies, showing strong interest in community-driven auditing.

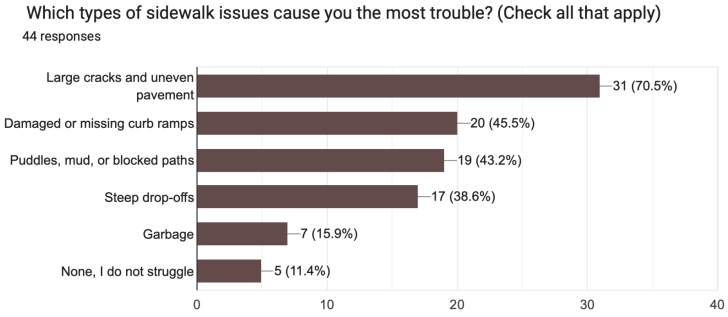


Figure C.i. Bar chart showing results of survey identifying common sidewalk issues.

Comparing the survey results with the interview transcripts revealed a few surprising disconnects that challenged our initial research expectations. The biggest surprise was the difference between what people emphasized in interviews versus what they ranked highest on surveys. In interviews, participants spent a lot of time addressing trash, dog waste, street vendors, and crowded walkways, which resulted in an 85.7% dynamic obstacle flag in our qualitative coding. However, when survey takers had to pick their biggest navigation difficulty, they overwhelmingly chose physical structural damage (70.5% for cracks and uneven concrete) over trash alone (15.9%). This shows that while daily street clutter causes constant annoyance, physical pavement failure is viewed as a much more direct hazard to safety.

Interviewees often cited unsanitary conditions such as loose trash on sidewalks and roads as major concerns. Additionally, several interviewees mentioned rats, public drug use, and loitering as non-structural issues that posed a detriment to their experience walking the streets of Harlem. As one interviewees stated: “Sanitation is definitely a big [issue], and also, like, just people [not] being mindful of their surroundings and being more socially aware when they're walking.” This quote from an interviewee shows that sidewalk issues go beyond static structural problems, with some of the most critical issues often being temporary, such as out-of-place trash and distracted pedestrians.

When asked how often sidewalk damage (cracks, missing ramps, uneven pavement) impedes their ability to get where they need to go, 36% of respondents said “Always,” 13% “Often,” and 31% “Sometimes”—meaning 81% experience at least intermittent mobility disruption from sidewalk conditions, versus only 9% who reported “Rarely” and 9% who reported “Never”.

In a multi-select question (respondents could choose more than one), large cracks and uneven pavement was the dominant complaint, cited by 70% (31/44) of respondents. This was followed by damaged or missing curb ramps (45%, 20/44), puddles/mud/blocked paths (43%, 19/44), and steep drop-offs (38%, 17/44). Garbage was cited less frequently (15%, 7/44), and only 11% (5/44) reported no difficulty at all.

In addition to the six coding themes described earlier, each transcript was tagged with two binary flags used to bridge the qualitative and engineering datasets: a Static Defect Flag, indicating whether the participant described a fixed structural hazard mappable through LiDAR/3DGS, and a Dynamic Obstacle Flag, indicating whether the participant described a moveable, non-permanent obstruction requiring masking or removal during 3D reconstruction.

The majority of coded interviewees were Harlem residents (64%, 18/28), followed by workers (17%, 5/28), commuters (10%, 3/28), and visitors (7%, 2/28). Self-reported priority level split roughly evenly between ‘High’ (50%, 14/28) and ‘Medium’ (46%, 13/28), with only one respondent (3%) rating sidewalk quality a ‘Low’ priority relative to other civic issues.

Field interviews showed that 85.7% of pedestrians face dynamic blockages (like parked scooters or vendor setups) while 60.7% encounter static concrete defects (such as cracks and vertical lip offsets ≥ 0.5 in). Crucially, 46.2% experience both simultaneously at the same location.

Structural complaints centered overwhelmingly on cracking and uneven pavement, with several respondents specifically raising the needs of wheelchair users, stroller-pushing parents, and elderly pedestrians using walkers. Non-structural complaints centered on sanitation (trash, dog waste) and, less frequently, on public safety concerns such as loitering or drug activity.

Key Overlaps

Among respondents who reported having a disability, nearly all reported very frequent difficulty with mobility especially with regards to damaged curb ramps and steep drop-offs, as opposed to able-bodied people, who were less likely to list the damaged corners as daily obstacles. Harlem residents were more likely to perceive disproportionate lack of maintenance than non-residents. Parents of children were also more likely to support increased sidewalk investments, which may be due to frequent use of strollers and increased concern for child safety.

CONCLUSION

The purpose of this project is to make it easier to present problems of streetscape erosion and destruction to the city government with clearly defined examples. The easier it is to record common issues, the easier it is to report them with evidence.

Our field research demonstrates that sidewalk accessibility in Harlem is threatened by two overlapping challenges: temporary street clutter and permanent concrete decay. Across both our survey and interviews, these two problem types surfaced consistently—residents distinguished between fixed structural damage (cracks, uneven pavement, damaged curb ramps) and moveable

obstructions (trash, vendor setups, parked scooters), and many described encountering both on the same stretch of sidewalk in the course of a single trip.

These findings are significant not only because of the issues they cause pedestrians, but also because they disproportionately occur in Harlem.[13] Our interviews found that residents overwhelmingly view sidewalk neglect as an opportunity for municipal services. Together, with our engineering results, our social science data reveals a structural problem—where the communities most affected by sidewalk decay are often those without access to the $4,000+ LiDAR equipment municipalities rely on to document it. Our work showed that smartphone-based 3D Gaussian Splatting can approximate LiDAR-grade accuracy on real-world sidewalk defects at a fraction of the cost, using hardware nearly everyone already owns. The shift from specialized equipment to a consumer iPhone can change who gets to produce documentation of infrastructure failure. Rather than waiting for a city agency to undergo a LiDAR survey of a block, residents and community organizations could generate their own data and send it to city officials. Our project not only proves a technical benchmark but also provides more access to advocacy of street maintenance through credible data.

One possible next step to be considered from this project is the creation of a mobile application that would allow iPhone users to quickly take scans of sidewalks that require immediate maintenance and mark its location on a map of New York City. City government officials could then easily check the areas with reported problems, spot patterns in where these problems occur, and determine whether they require immediate attention. There are already a few applications where individuals can submit images of broken sidewalks, however these apps are very inefficient to use and have meager ratings. A mobile application with simple, game-like features could make scanning more engaging and encourage more residents to participate.

Our goal, as researchers in the CS3 My Streetscape Summer Research Institute, is to make daily life for those living in Harlem as efficient and comfortable as possible, and the emergence of an application such as this would bring us one step closer to achieving safer, more accessible urban spaces. This project is the stepping stone to a more clean and well maintained city for everyone to enjoy.

[13] Citizens' Committee for Children of New York. *2021 Street and Sidewalk Cleanliness Survey*. CCC New York, 2021, https://data.cccnewyork.org/data/map/1501/street-and-sidewalk-cleanliness#1501/a/3/1836/127/a/a

APPENDIX

Appendix A: Interview Questions

Interview Questions:

1. Do you live in Harlem, work here, go to school here, or are you visiting?

2. In your opinion, how important is sidewalk quality compared to other issues?

3. What is the biggest obstacle or challenge you encounter when navigating the sidewalks in the Harlem area?

4. What improvements do you think are necessary for sidewalks in Harlem?

5. How has sidewalk maintenance and quality changed as you've traveled through Harlem over the years?

Appendix B: Survey Questionnaire

Survey Questions:

1. Do you live in Harlem? (Yes/No)

2. If you do not live in Harlem, how often do you walk in the area? (Daily/A few times a week/ A few times a month/A few times a year/Once a year or less/ N/A)

3. Sidewalk quality often poses a problem to me? (Strongly Agree/Agree/Neutral/Disagree/Strongly Disagree)

4. Do you have any children? (Yes/No)

5. My local government should allocate more resources to improving the quality of sidewalks in my area. (Strongly Agree/Agree/Neutral/Disagree/Strongly Disagree)

6. My neighborhood disproportionately experiences broken sidewalks. (Strongly Agree/Agree/Nuetral/Disagree/Strongly Disagree)

7. How often does sidewalk damage (cracks, missing ramps, uneven pavement) make it hard for you to get where you need to go? (Always/Often/Sometimes/Rarely/Never)

8. Which types of sidewalk issues cause you the most trouble? [Check all that apply] (Large Cracks and uneven pavement/Damaged or missing curbs/Puddles, mud or blocked paths, steep drop-offs/Garbage/None, I do not struggle)

9. Would you be willing to take the time to use your phone to submit scans of broken sidewalks for maintenance? (Yes/No)
10. Age Range (18-35/36-50/51-64/65+)

11. Do you live with a disability that affects your mobility? (Not restricted to physical) (Yes/No)

12. What is your gender? (Male/Female/Non-binary/Prefer not to say/Other)

Appendix C: Survey Pie Chart Data Reports

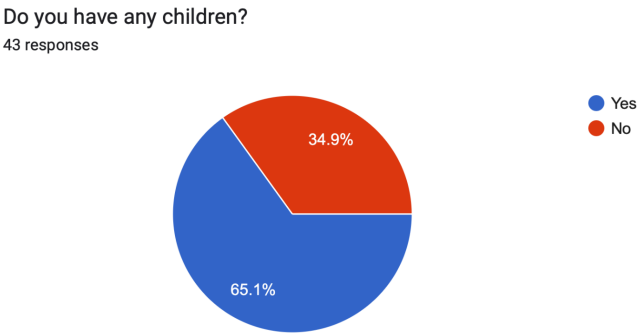


Figure C.a. *Respondent Parental Status*

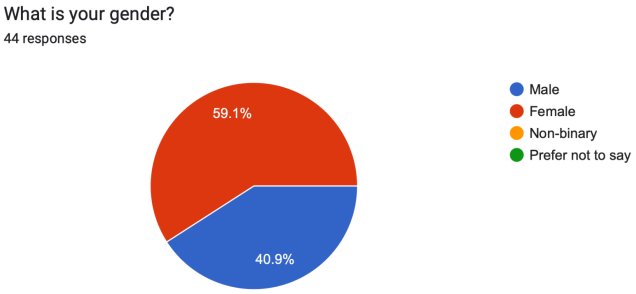


Figure C.b. *Respondent Gender Identification*

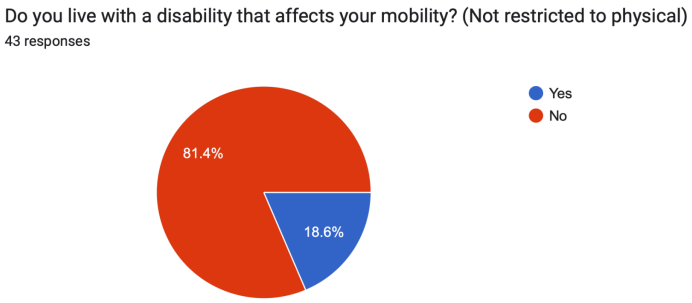


Figure C.c. *Respondent Mobility Disability Status*

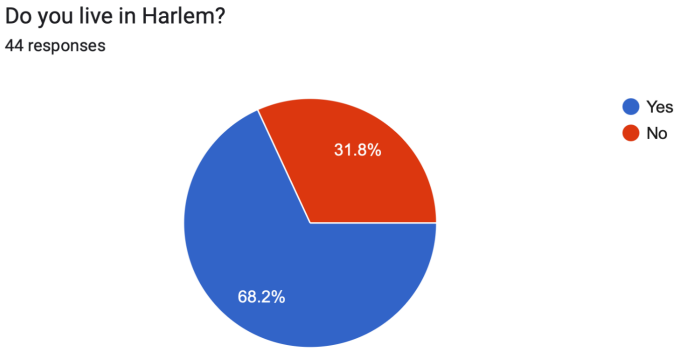


Figure C.d. *Respondent Residency Status in Harlem*

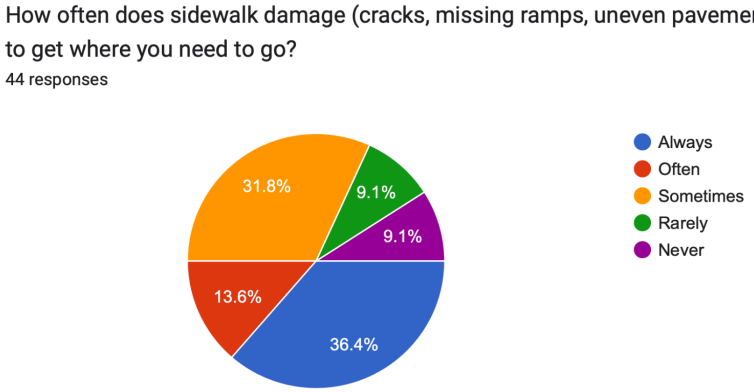


Figure C.e. *Frequency of Pedestrian Disruption Caused by Sidewalk Damage*

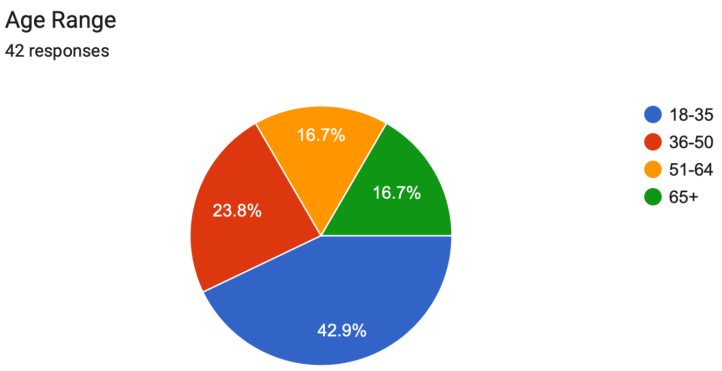


Figure C.f. *Frequency of Pedestrian Disruption Caused by Sidewalk Damage*

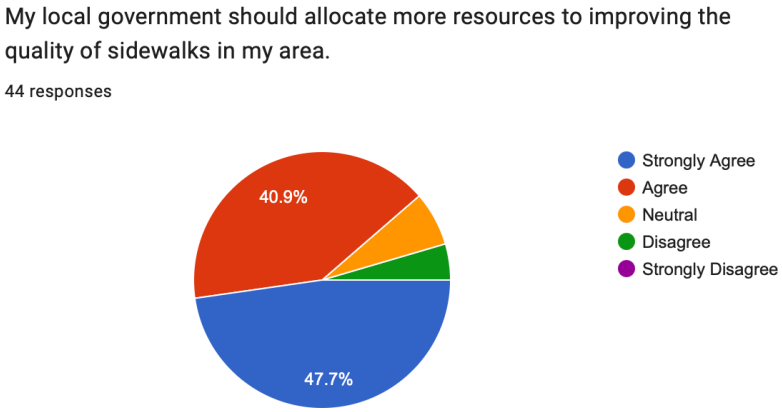


Figure C.g. *Pedestrian Support for Local Government Sidewalk Investment*

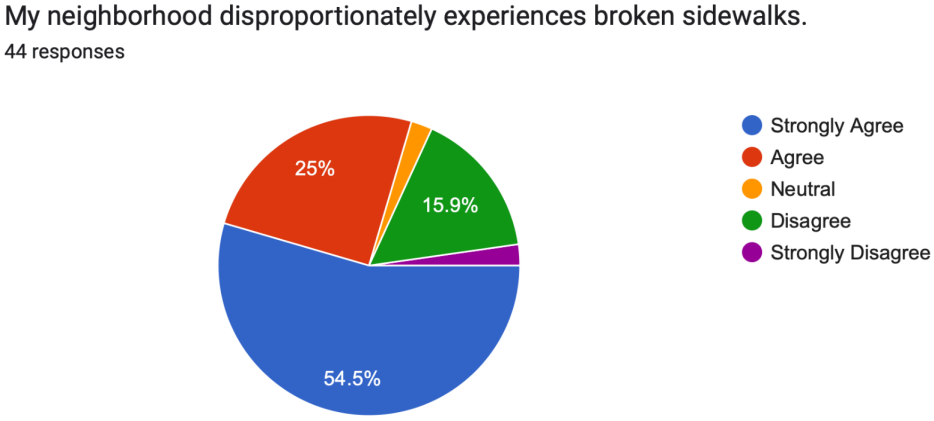


Figure C.h. *Resident Perceptions of Disproportionate Neighborhood Sidewalk Damage*

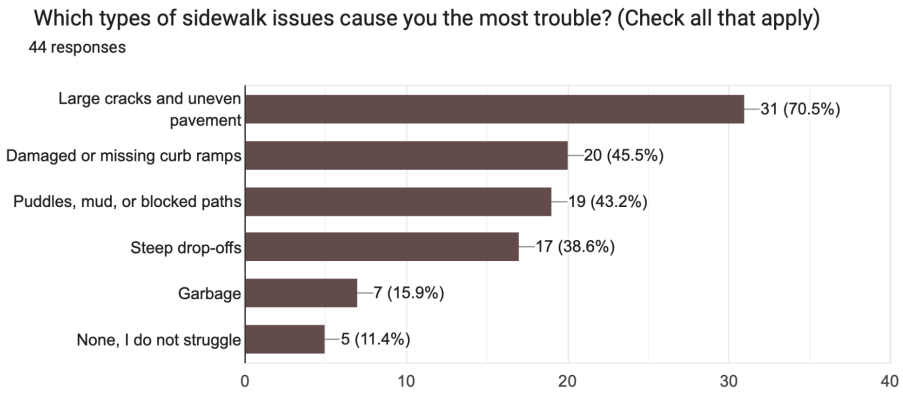


Figure C.i. *Most Frequent Sidewalk Hazards Reported by Pedestrians*

Appendix D: Qualitative Codebook for Harlem Sidewalk and Pedestrian Assessment

CODE	DESCRIPTION
ROLE	The reason why these people are traveling through the Harlem area and how long they've been doing so.
IMPORTANCE	How important is sidewalk maintenance to that person and why it is important .
OBSTACLE	What the issue with the sidewalks may be - immobile obstacles.
ATTITUDE	Idea of people and vendors - mobile obstacles.
IMPROVEMENTS	What would need to get done in order to fix our sidewalks: suggested by pedestrians.
TREND	Differences: has the quality improved, worsened?

Bibliography

Citizens' Committee for Children of New York. *2021 Street and Sidewalk Cleanliness Survey*. CCC New York, 2021, https://data.cccnewyork.org/data/map/1501/street-and-sidewalk-cleanliness#1501/a/3/1836/127/a/a

"Gap Completion in Point Cloud Scene Occluded by Vehicles Using S..." *ISPRS Journal of Photogrammetry and Remote Sensing* (2024). https://doi.org/10.1016/j.isprsjprs.2024.09.014.

Koch, R., S. May, and A. Nüchter. "Detection and Purging of Specular Reflective and Transparent Object Influences in 3D Range Measurements." *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-2/W3 (2017): 377–84. https://doi.org/10.5194/isprs-archives-XLII-2-W3-377-2017.

Liu, Zhenyu, Peter van Oosterom, Jesús Balado, Arjen Swart, and Bart Beers. "Data Frame Aware Optimized Octomap-Based Dynamic Object Detection and Removal in Mobile Laser Scanning Data." *Alexandria Engineering Journal* 74 (2023): 327–344. https://doi.org/10.1016/j.aej.2023.05.014

Mendes, Calebe Pereira, and Norman T-Lon Lim. "EcoLiDAR: An Economical LiDAR Scanner for Ecological Research." *PLOS ONE* 19, no. 6 (2024): e0298712. https://doi.org/10.1371/journal.pone.0298712

Muralikrishnan, Bala. "Performance Evaluation of Terrestrial Laser Scanners—A Review." *Measurement Science and Technology* 32, no. 7 (2021). https://doi.org/10.1088/1361-6501/abdae3.

Vaishya, Raju, and Abhishek Vaish. “Falls in Older Adults Are Serious.” *Indian Journal of Orthopaedics* 54, no. 1 (2020): 69–74. https://doi.org/10.1007/s43465-019-00037-x