XGRIDS

Accuracy Validation White Paper

Lixel L3 Point Cloud Accuracy Validation

Assessing the geometric accuracy of Lixel L3 handheld mobile laser scanning point clouds through relative accuracy validation

5 mm	**20** sets	**≈507** m^2
Specified accuracy @1σ (typical)	Independent scan sets across 7 units	Composite indoor test site

1. Introduction

> **Handheld mobile laser scanning systems, with their efficient data-capture workflow, automated processing, and rich point cloud deliverables, have become an essential tool in surveying and spatial documentation.**

As their use extends into professional scenarios such as building digitization, BIM modeling, indoor space measurement, and industrial facility digitization, users are placing higher demands on the geometric accuracy of point cloud deliverables.

Yet the industry has still not established a unified accuracy validation standard for mobile laser scanning, and transparent, credible, reproducible evaluation methods remain scarce.

This white paper applies a systematic method grounded in surveying principles to validate the accuracy of point clouds produced by the Lixel L3 handheld mobile laser scanning system, and documents the full test procedure and results.

This validation used 7 Lixel L3 units (covering both the 16-line and 32-line models), performing 20 independent scan sets in total.

The analysis addresses the relative accuracy dimension of the point cloud, comprehensively assessing the geometric accuracy of Lixel L3 scan deliverables.

2. Challenges in validating mobile scanning accuracy

2.1 Why accuracy validation is more complex for mobile scanning systems

Different types of measurement systems call for different validation paradigms. Total stations are typically validated through direct measurement against known targets and coordinate comparison; terrestrial laser scanners (TLS) can be evaluated by extracting point cloud coordinates at targets or known points. These validation methods are relatively mature.

The accuracy of a mobile laser scanning system is influenced by multiple factors — sensor measurement, SLAM localization and mapping, trajectory optimization, and environmental conditions — so its final accuracy cannot be judged from any single hardware specification. At the same time, SLAM estimates the sensor trajectory from continuous observations and adjusts that trajectory globally through loop closure detection and global optimization. The final point coordinates are determined jointly by the optimized trajectory, so no individual point can be mapped directly back to an original measurement pose.

Accuracy validation for a mobile laser scanning system should therefore take the final output point cloud as the object of evaluation, and systematically assess its relative accuracy and overall geometric consistency across varying spatial conditions and measurement distances.

2.2 Our approach

We use a **relative accuracy validation method**, evaluating the geometric accuracy of the scan by comparing the distances between known targets in the point cloud against reference values.

The core advantages of this method:

- Requires no GCPs; it validates the scanning performance of the device and algorithm on their own
- Is unaffected by coordinate-system registration error; it evaluates point cloud geometric distances directly
- Is consistent with comparable industry evaluation methods, making it easy to compare across systems

3. Validation method

3.1 Method overview

This accuracy validation uses the relative accuracy method. The main steps are:

1. **Establish reference values**: place circular high-reflectivity targets throughout the test area and measure their center coordinates with a high-accuracy total station to build the reference dataset.
2. **Capture point clouds**: 5 operators using 7 Lixel L3 units performed repeated independent scans, producing 20 point cloud datasets.
3. **Extract target centers**: automatically identify each target in each dataset and compute its center coordinate.
4. **Compare distances**: compute the point cloud distances between targets and compare them one by one against the true distances measured by the total station, obtaining a distance error for each.
5. **Statistical analysis**: pool the measurement results from all 20 scan sets and analyze the overall accuracy.

3.2 Accuracy metric definitions

Metric	Definition
P68 (≈1σ)	**68% of point-pair distance deviations are at or below this value**
P85	85% of point-pair distance deviations are at or below this value
P97	97% of point-pair distance deviations are at or below this value
Mean	Arithmetic mean of all point-pair distance deviations
RMSE	Root mean square error

This white paper uses **P68 (the 68th percentile, approximately 1σ)** as the primary accuracy metric, consistent with common industry practice.[1]

3.3 Statistical basis

The way results from multiple devices and multiple scans are aggregated directly affects the final figures, so it needs to be stated explicitly. This white paper uses a **pooled percentile basis**:

> All point-pair deviations from all devices and all scans are combined into a single dataset, and percentiles are taken directly from that dataset. That is: 1,524 point-pair distance comparison records from 20 scan sets → pooled and sorted → the value at the 68th percentile position.

This basis is consistent with comparable industry accuracy reports and is straightforward to interpret.

4. Test conditions

4.1 Test site

Testing was carried out on one complete floor of an office building. The figure below is a top-down projection of that floor's point cloud, with all target positions marked.

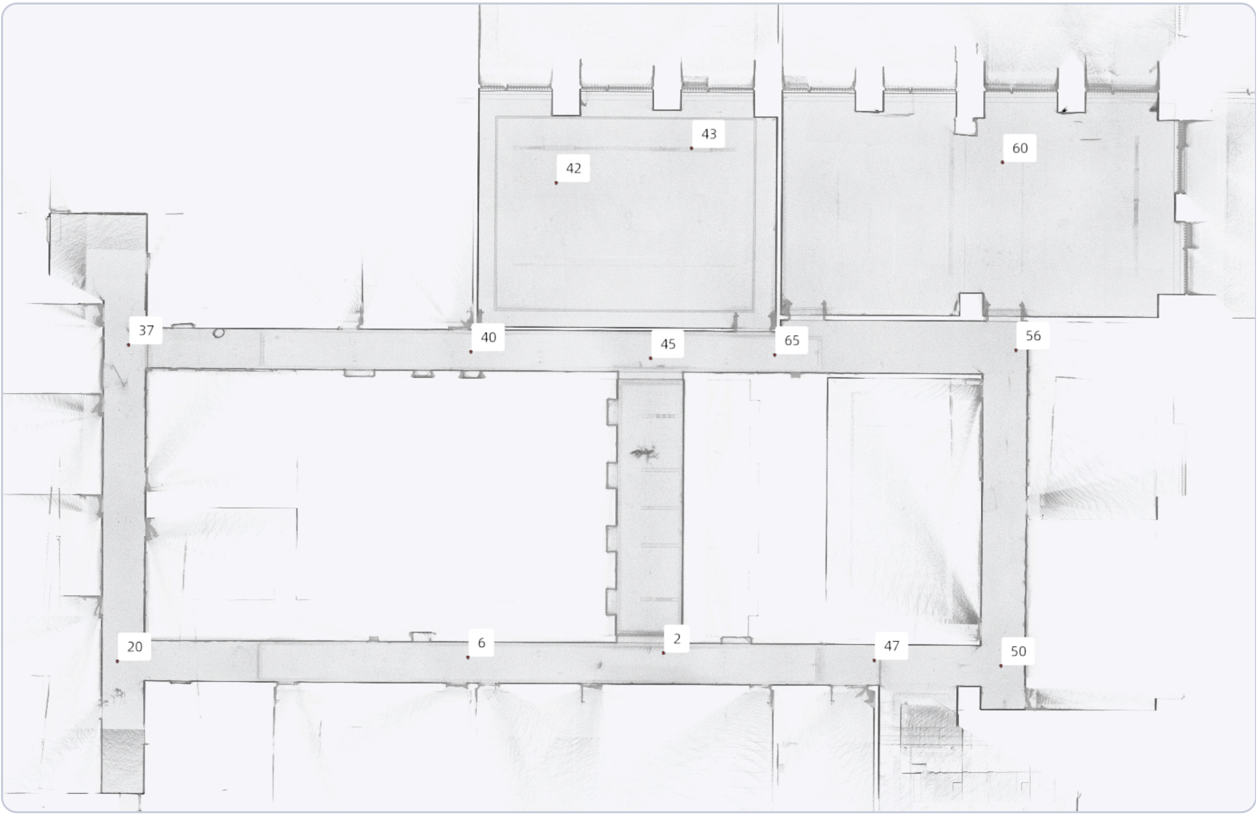

Figure 1: Top view of the test site point cloud and target distribution (the 13 targets included in the evaluation)

Site characteristics:

Item	Parameter
Floor area	Approx. 507 m^2
Target network extent	24.5 m × 38.9 m
Spatial structure	Long corridors on both sides + multiple separate rooms + central stairwell
Floors	Single floor (target height difference < 5 cm)

As the floor plan shows, the site is not a simple open space or a single corridor, but a composite structure of two parallel long corridors, a short connecting corridor, and multiple separate rooms. The corridors are close to 39 m long; the rooms must be entered and exited one at a time, producing frequent turns and loops.

This structure poses two challenges for SLAM: long corridors provide insufficient lateral geometric constraint and are prone to accumulated longitudinal drift; frequent movement in and out of rooms generates a large number of loop closure decisions. In combination, these conditions are closer to the working reality of building survey and interior renovation projects than an open site or a short corridor would be.

4.2 Target layout

- **Target type**: circular high-reflectivity targets, 4 cm diameter
- **Target count**: 13 placed, 13 included in the evaluation
- **Distribution**: along both sides of the corridors and on the walls of each room, covering the full test area (see Figure 1)
- **Point-pair distance coverage**: 5.4 m — 44.2 m (median 20.2 m)
- **Point pairs formed**: 78 per set

Targets were fixed to walls and remained in position for the entire test.

Figure 1 shows the distribution pattern of the targets: spaced evenly along both sides of the two long corridors and extending into each separate room. This layout produces point-pair distances spanning the full 5.4—44.2 m range, with more than half above 20 m — including both short-range pairs within a single space and long-range pairs that cross the entire floor and can only be connected through multiple turns. The latter are the most sensitive to accumulated SLAM error.

4.3 Reference system

Reference coordinates were measured with a high-accuracy total station:

- **Instrument**: Leica TS60
- **Post-adjustment accuracy**: 1.5 mm
- **Method**: multiple sets of observations + network adjustment

The accuracy of the reference system is significantly better than the specified accuracy of the system under test, satisfying the basic requirement for a reference standard in measurement validation.[2]

4.4 Scan configuration

Item	Parameter
System under test	Lixel L3 (16–120 × 4 units + 32–120 × 3 units)
Total devices	7 units
Total scan sets	20 sets
Post–processing	Standard workflow, no GCP optimization
Alignment	Automatic alignment on high–reflectivity targets

All accuracy data was obtained from relative point clouds processed without GCP post–processing, reflecting the raw performance of the device and algorithm.

5. Data processing

5.1 Target extraction

Target center coordinates were extracted from the point cloud using an automated algorithm:

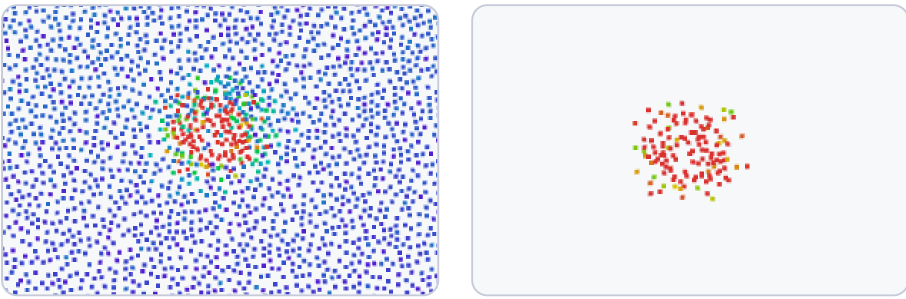

Figure 2: Points extracted from a circular high–reflectivity target in the point cloud

1. Automatically locate circular high–reflectivity target areas from intensity information
2. Fit target center coordinates using a standard industry algorithm
3. Manually review the extraction results to confirm the center position is reasonable

Extraction success rate:

Target identification outcome	Scan sets	Targets	Notes
All targets extracted	17 sets	13	78 valid point pairs per set in the evaluation.
Partial extraction failure	3 sets	12	Each of the 3 affected scans was missing 1 target, giving 66 valid point pairs per set in the evaluation.

Thirteen targets were included in the evaluation, with 257 successful extractions against a theoretical maximum of 260 — a success rate of 98.8%.

Causes of extraction failure: individual targets with insufficient intensity contrast, low point density, or too brief a line of sight.

5.2 Point-pair distance calculation

Targets included in the evaluation were paired with one another. For each pair, the distance between the coordinates extracted from the point cloud was computed alongside the corresponding true distance. The absolute value of the difference is the distance deviation for that pair.

5.3 Point-pair distance distribution

The distance composition for a single scan set (13 targets, 78 pairs) is:

Distance band	Point pairs	Share
5—10 m	11	14.1%
10—20 m	27	34.6%
⩾20 m	40	51.3%
Total	78	100%

Pooled across 20 scan sets, the dataset contains 1,524 point pairs with distances from 5.40 to 44.22 m and a median of 20.23 m. More than 50% of point pairs are above 20 m, fully covering the typical working distance range of a handheld scanner.

6. Results

6.1 Deviation distribution

The chart below shows the distribution of all 1,524 point–pair distance deviations from 7 Lixel L3 units across 20 independent scan sets. Errors are binned at 0.5 mm intervals; the yellow curve shows the cumulative percentage of point–pair errors.

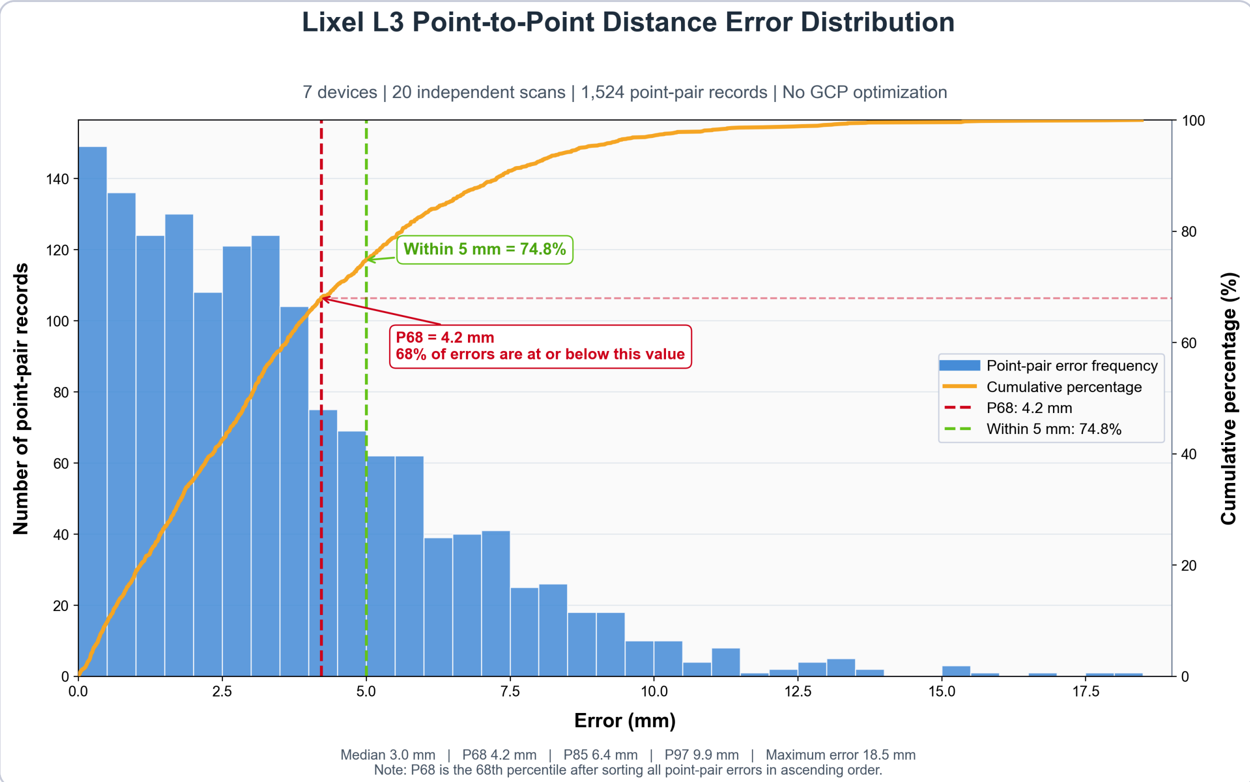

Figure 3: Lixel L3 point–pair distance deviation distribution in an approximately 507 m^2 site (7 devices, 20 scan sets, no GCP)

The red dashed line marks the position of P68 = 4.2 mm, meaning 68% of point–pair distance deviations are at or below that value. The green dashed line marks the 5 mm specified accuracy.

6.2 Summary accuracy metrics

Using the pooled percentile basis described in section 3.3, the statistics for all 1,524 point–pair deviations are:

Percentile	Deviation
P50 (median)	3.0 mm
P68 (≈1σ, primary metric)	**4.2 mm**
P85	6.4 mm
P97	9.9 mm
Mean	3.5 mm

7. Conclusion

- **Key conclusion**

This test used 7 Lixel L3 units in a site of approximately 507 m^2, covering typical composite indoor scenarios such as long corridors, multiple separate rooms, and frequent loop closures. The results show that, for the pooled sample, the absolute point-pair distance deviation at **P68 is 4.2 mm**, better than the specified 5 mm @ 1σ (typical).[3]

Appendix

A. Terminology

Term	Definition
SLAM	Simultaneous Localization and Mapping
GCP	Ground Control Point
P68 / 1σ	Where signed errors are approximately normally distributed with zero mean, P68 is approximately equal to 1σ (one standard deviation)
RMSE	Root Mean Square Error
TLS	Terrestrial Laser Scanner

B. Test equipment list

Item	Specification
System under test	Lixel L3 16–120 × 4 units + Lixel L3 32–120 × 3 units
Reference instrument	High-accuracy total station (post-adjustment accuracy 1.5 mm)
Targets	Circular high-reflectivity targets × 13
Processing software	Lixel Studio version 4.1

NOTES

[1] P68 is the 68th percentile, meaning 68% of measured deviations are at or below that value. Where signed errors are approximately normally distributed with zero mean, P68 is approximately equal to 1σ (one standard deviation). This white paper uses P68 throughout as the measured statistic; the comparison to 1σ applies only where that condition holds. All percentiles in this white paper are computed on the pooled percentile basis defined in section 3.3 (point-pair deviations from all scans combined into a single dataset before percentiles are taken), using a single consistent basis so that different test results can be compared.

[2] The ratio between the reference system accuracy (approximately 1.5 mm) and the specified accuracy of the system under test (5 mm) is about 1:3.3, satisfying the criterion adopted for this project that the reference-to-test capability ratio be no less than 3:1. The reference system still carries its own finite error, so observed deviations include that contribution, making the measured results comparatively conservative. Assuming the reference and test system errors are independent and both characterized at 1σ, separating them by root sum of squares gives a device error contribution of approximately $\sqrt{(4.2^2 - 1.5^2)} \approx 3.9$ mm (a conditional estimate valid only under those assumptions). The directly observed combined absolute point-pair distance deviation at P68, covering reference and test system together, is 4.2 mm.

[3] The specified accuracy of ≤5 mm @ 1σ is the expected performance under typical working conditions. Actual accuracy is affected by site geometry, scan path planning, and environmental conditions, and deviations may vary somewhat in individually demanding scenarios. The data in this white paper was obtained under the specific test conditions described in section 4.