Evaluating Point Cloud Measurement Accuracy for Residential Property Valuation: A Case Study Using LiDAR Scanning

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Abstract—The most important part of property valuation is accurate property measurement. The more accurate measurement of all types of property, including residential buildings, could lead to an equal and fair value for the property. By comparing linear wall-to-wall measurements taken from point clouds with those taken from certified floor plans, this study evaluates the potential of three-dimensional (3D) point cloud data for use in property measurement. Dimensional measurements were obtained by processing 3D data of a residence in Kajang, Malaysia, using LiDAR-based scanning via PolyCam Pro on an iPhone 14 Pro Max. To assess the workflow's generalizability, a sample dataset provided by PolyCam representing a landed residential unit was also tested using the same measurement procedure. The results indicate that consumer-grade point cloud data can achieve accuracy sufficient for expert valuation support, with deviations of approximately ±10 mm in the primary dataset and ±3.5 mm in the validation dataset. This shows how point cloud technology can improve transparency, reduce measurement errors caused by individuals, and help in the digital transformation of valuation workflows

Keywords: Point cloud, Measurement accuracy, Residential property valuation, LiDAR scanning, Floor plan comparison

I. Introduction

Residential property valuation depends on precise measurements of property features such as usable floor areas and wall dimensions [1]. However, traditional methods like manual tape-based inspection or reliance on architectural floor plans often introduce human error and inconsistencies [2]. These measurement differences can accumulate throughout the valuation process, potentially affecting the final assessed value and reducing professional credibility [3].

Recent developments in 3D sensing technologies particularly LiDAR and photogrammetry, enable the capture of highly detailed geometric data in the form of point clouds [4], [5]. Point cloud data allow for objective, repeatable measurements by digitally representing the real-world geometry of built environments. This capability improves measurement reliability and optimizes workflows in property valuation, though its integration into valuation practice remains at an exploratory stage [6].

The objective of this study is to determine whether wall measurements based on 3D point clouds meet professional accuracy tolerances for use in residential property valuation. The implications of using such data to enhance the accuracy and transparency of valuation measurement procedures are also examined.

Background on Point Cloud Applications

Point cloud data are widely used in geoinformatics, engineering, and architecture for 3D reconstruction, infrastructure mapping, and building documentation. With millions of spatial points captured, it offers a comprehensive geometric representation of built environments [4], [5]. [7] confirmed the spatial accuracy potential of 3D city models using point clouds, while [8] demonstrated that handheld LiDAR scanners can achieve centimeter-level accuracy suitable for indoor mapping and modeling.

Accessibility has improved through the introduction of mobile LiDAR, particularly in smartphones [9]. Professionals can now collect geometric data efficiently using consumer devices instead of costly terrestrial laser scanners. Although sensor resolution is lower than that of professional systems, studies have shown that consumer-grade devices can still provide reliable and consistent results when processed appropriately [10].

Measurement Accuracy Studies

Measurement accuracy remains critical in both construction and valuation practices. Previous studies ([7], [8], [10]) have shown that under controlled indoor conditions, low-cost LiDAR scanning technologies can maintain acceptable error margins, often within ±2%. Under Malaysian property and valuation standards, a ±2% difference in floor area measurements is permitted [12]. Therefore, testing the precision of wall-to-wall measurements derived from point clouds is essential to determine whether this technology can replace manual tape-based methods in valuation workflows.

Applications in Property Valuation

Over the past decade, the integration between valuation practice and geospatial technology has expanded considerably. [13] and [14] explored how combining GIS and Building Information Modelling (BIM) enhances property data management and valuation accuracy. [15] emphasized that 3D property information introduces volumetric data beyond traditional 2D boundaries, improving the understanding of built form and value relationships.

However, the application of such advanced models in practice remains limited due to their reliance on automated extraction workflows and complex data preparation. [17] proposed combining BIM and machine learning for automated valuation, yet this requires significant computational expertise and data preprocessing. Direct measurement from point cloud data, by contrast, offers a more accessible and cost-effective approach to improving measurement accuracy in property valuation.

II. Methodology

Study Area and Data Source

A residential apartment unit in Kajang, Selangor, Malaysia, was selected for this study because of its standardized internal layout, accessibility for scanning, and availability of verified architectural floor plans. The PolyCam Pro mobile application was used on an iPhone 14 Pro Max equipped with a built-in LiDAR sensor to generate dense three-dimensional point clouds in .ply format. This consumer-grade device was chosen for its affordability, portability, and demonstrated ability to capture high-resolution spatial data [9]. To maintain even coverage and minimize occlusion, the scanning was performed at approximately eye level with smooth horizontal motion around the interior of the unit. Adequate indoor lighting was ensured during the capture process, although variations in lighting and scanning angles were not quantitatively assessed in this study. Fig. 1 shows the overall scanning coverage and geometric completeness of the captured unit.
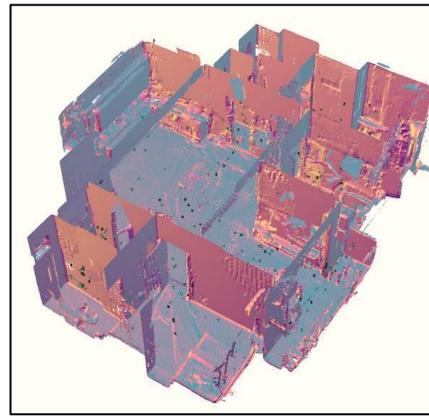

Fig. 1 3D point cloud model of the residential unit captured using PolyCam Pro on an iPhone 14 Pro Max

Point Cloud Processing and Measurement

PolyCam Pro automatically merged multiple scans to produce a metrically referenced point cloud model of the entire internal geometry. Wall intersection points were visually identified for use in subsequent linear distance measurements.

For measurement and visualization, the point cloud was exported from PolyCam in .ply format and imported into CloudCompare. Because PolyCam automatically generates scaled data, no additional scaling, denoising, or filtering was required under the controlled indoor conditions.

After import, the point cloud was visually inspected to confirm completeness and alignment. Minor edge noise was observed but found negligible, and therefore no filtering or subsampling was applied. The coordinate scale generated by PolyCam was validated against a known wall-to-wall distance measured on-site, confirming metric accuracy and minimizing potential systematic errors during measurement.

Using CloudCompare's distance tool, wall-to-wall linear distances were extracted directly between defined wall intersection points. The same process was repeated across multiple wall segments to ensure consistency and allow direct comparison with the architectural floor plan.
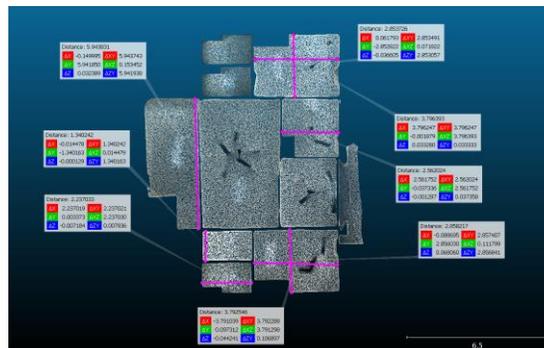

Fig. 2. Wall-to-wall measurement extraction in CloudCompare using the distance tool

Fig. 2 illustrates the extraction of wall-to-wall measurements in CloudCompare using the distance tool and the complete point-cloud processing and measurement workflow is summarized in Fig. 3.
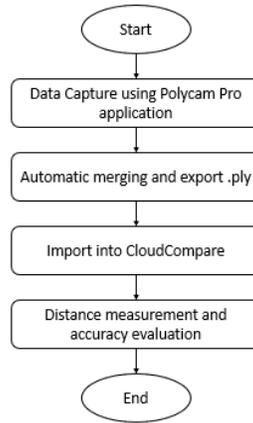

Fig. 3. Point-cloud processing and measurement workflow

Accuracy Assessment

Measurements from the architectural floor plan served as the reference benchmark. The percentage difference (PD) between floor-plan and point-cloud-derived measurements was calculated as:

$$PD = \frac{|M_{PC} - M_{FP}|}{M_{FP}} X\ 100$$

where M_{FP} is the reference floor-plan measurement and M_{FPC} is the corresponding point-cloud measurement. PD was chosen instead of Root Mean Square Error (RMSE) because the objective was to assess dimensional agreement rather than model-fit accuracy.

Average deviations were approximately ±10 mm, corresponding to the reference wall lengths. These values fall within the tolerance range (±2 %–5 %) recognized by Malaysian valuation and architectural measurement standards [12].

To determine whether mobile LiDAR scanning meets these professional thresholds, the deviations were evaluated against the accepted measurement accuracy criteria. The analysis confirmed that consumer-grade LiDAR can provide measurement precision adequate for professional property valuation tasks under controlled conditions.

III. Results

Primary Measurement Comparison

The dimensional differences between the architectural floor plan and the LiDAR-derived point cloud remained well within the limits of professional tolerance. The average of roughly ±10 mm, is minimal and generally not significant in valuation practice, approximately 5 cm over a 3.5 m wall.

These findings agree with the results of [8] and [11], who demonstrated that portable LiDAR systems can achieve sub-centimetre precision in indoor settings.

Table I summarizes the comparison between floor-plan and LiDAR-derived measurements across the selected wall segments while Fig. 4 illustrates the overall floor plan dimensions and measurement locations used in the comparison.

TABLE I. Comparison of wall-to-wall measurements between floor plan and point cloud

Wall ID	Floor Plan (Centerline) (m)	Floor Plan (Offset Adjusted) (m)	Point Cloud Measurement (m)	Difference vs. Centerline (m)	Difference vs. Offset (m)
W1 (Master Bedroom)	3.950	3.800	3.793	0.157	0.007
W2 (Master Bedroom)	3.000	2.850	2.858	0.142	0.008

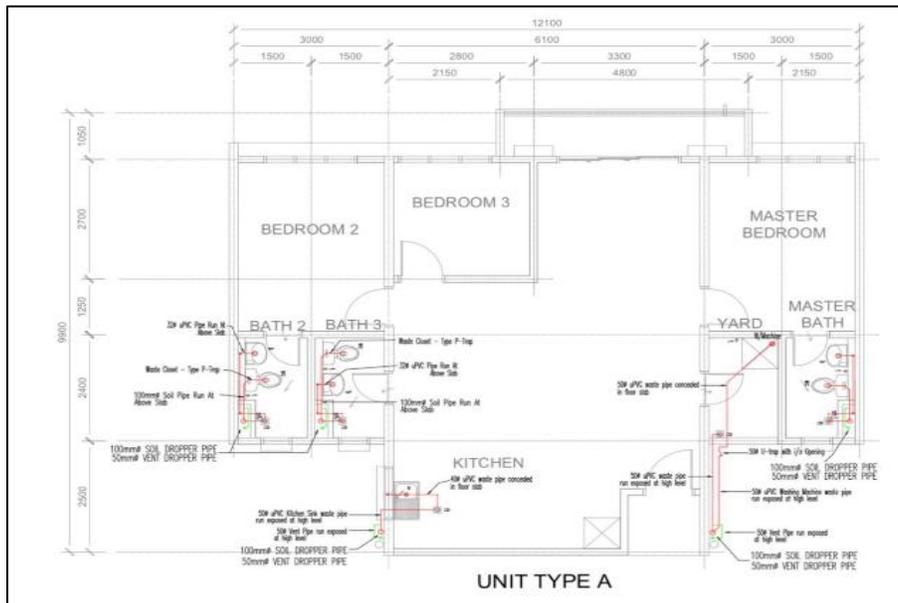|					
W3 (Bedroom 2)	3.000	2.850	2.854	0.146	0.004
W4 (Bedroom 2)	3.950	3.800	3.796	0.154	0.004
W5 (Bedroom 3)	2.700	2.550	2.562	0.138	0.012
W6 (Master Bath)	2.400	2.250	2.237	0.163	0.013
W7 (Yard)	1.500	1.350	1.340	0.160	0.010
W8 (Kitchen)	6.100	5.950	5.944	0.156	0.006

Fig. 4 Floor plan dimensions

Model Validation Using Secondary Dataset

To evaluate the generalizability of the proposed workflow, a sample scan dataset provided by PolyCam was used for validation. The dataset represents a landed residential unit, which differs from the primary apartment case in overall layout and scale. The same point cloud processing and measurement workflow described in Section II was applied without modification.
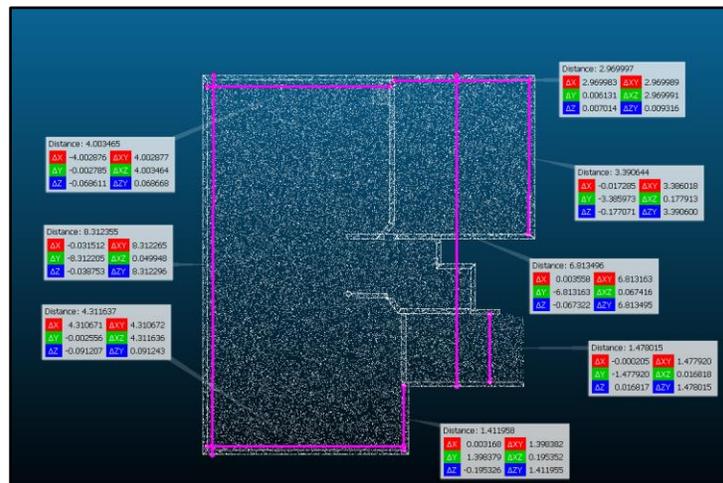

Fig. 5 Measurement extraction in CloudCompare using the distance tool

Measurements were extracted in CloudCompare from the sample scan's point cloud and compared with the automatically generated floor plan dimensions supplied by PolyCam's built-in floor plan generator.
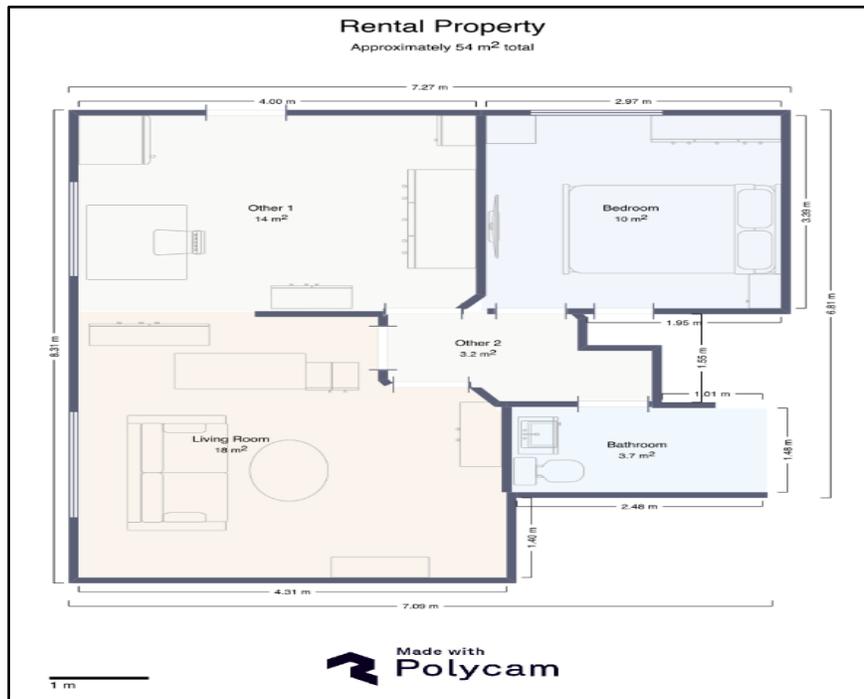

Fig. 6 Floor plan dimensions generated by PolyCam

The validation results showed an average deviation of approximately ±3.5 mm, with the highest recorded difference being 11 mm. These deviations are smaller than those observed in the primary dataset (±10 mm) and remain well within the ±2% tolerance defined by professional valuation standards [12]. The minimal variation confirms that the workflow maintains consistent geometric precision even when applied to a different residential property type. This finding demonstrates that the approach is robust, repeatable, and generalizable across varied datasets, including those not directly captured by the researcher.

TABLE II. Validation results comparing PolyCam-generated floor plan and CloudCompare measurements from the sample dataset

Wall ID	Floor Plan (m)	Point Cloud Measurement (m)	Difference (m)
W1 (Bedroom)	2.970	2.970	0.000
W2 (Bedroom)	3.390	3.391	0.001
W3 (Bedroom + Bathroom)	6.810	6.813	0.003
W4 (Bathroom)	1.480	1.478	0.002
W5 (Living room)	1.400	1.411	0.011
W6 (Living room)	4.310	4.312	0.002
W7 (Living room + Other 1)	8.310	8.312	0.002
W8 (Other 1)	4.000	4.003	0.003

IV. Discussion

The findings show that consumer-grade LiDAR sensors can produce 3D point cloud data with dimensional precision appropriate for measurements related to valuation. Based on the Malaysian Valuation Standards (MVS) and the Royal Institution of Chartered Surveyors (RICS), the observed average deviation of approximately 10 millimetres lies comfortably within the tolerance limits generally accepted in professional valuation measurement [12].

A comparison between the primary dataset (apartment unit) and the validation dataset (landed residential unit) revealed consistent measurement accuracy across both cases, with average deviations of ±10 mm and ±3.5 mm, respectively. The slightly smaller deviation in the validation dataset indicates that the workflow remains stable and can even achieve improved precision when applied to other residential property types. Both results remain well within the ±2% professional tolerance, confirming that the workflow

performs reliably and demonstrates strong generalizability across different datasets.

Implications for Valuation Practice

The application of point cloud data introduces measurable improvements in valuation accuracy and transparency. Unlike manual tape-based methods, point cloud measurement offers objective, repeatable, and verifiable results independent of individual skill or bias. This improves reliability and aligns with the emphasis on accountability and transparency in modern valuation governance frameworks [2].

Furthermore, 3D spatial data provide context often absent from 2D floor plans, enabling valuers to verify as-built conditions, assess spatial relationships, and detect irregularities remotely. This capability supports emerging practices such as digital valuation models and remote inspections, which have become increasingly common during and after the COVID-19 pandemic [14].

In practical terms, an average dimensional deviation of approximately 10 millimetres could translate to about 1.5% variance in reported floor area, which in typical Malaysian residential markets corresponds to a value difference of roughly RM 3,000–5,000 for an RM 300,000 property [12]. Although this falls within acceptable valuation error margins, it highlights the importance of adopting standardized digital measurement procedures in professional practice.

Limitations and Considerations

The study acknowledges several limitations The analysis was primarily based on one apartment unit, complemented by a validation test on a landed residential dataset, which still limits the statistical generalizability of the findings to a broader range of housing types and environments. Environmental factors such as lighting, surface reflectivity, and scanning angles were not quantified, although care was taken to maintain stable conditions during scanning. Minor geometric distortions may arise from these influences or from device movement during capture.

Additionally, the manual extraction of wall measurements from point clouds requires technical proficiency in software such as CloudCompare, which may limit immediate adoption by valuers without geospatial training. Nonetheless, with standardized procedures, point cloud data can provide a reliable and efficient alternative to manual measurement in residential valuation workflows.

Critical Reflection

This study contributes to the growing body of research on digital transformation in valuation, offering an empirical validation of consumer-grade LiDAR accuracy for professional measurement. While prior studies have emphasized automated 3D reconstruction and BIM integration [13], [17], the present work demonstrates that manual point cloud interpretation can still achieve measurement accuracy suitable for professional standards under controlled conditions.

For future research, expanding the analysis to multiple case studies across different housing types and environmental conditions would strengthen statistical validity. A sensitivity analysis examining how geometric deviations affect valuation outcomes (in percentage or currency terms) would further enhance practical relevance. Future work may also explore semi-automated workflows integrating point cloud processing with valuation software to reduce processing time while maintaining verifiable accuracy.

V. Conclusion

This study evaluated the measurement accuracy of consumer-grade LiDAR point cloud data for residential property valuation and confirmed that dimensional deviations of approximately ±10 mm fall comfortably within professional tolerance limits. Validation using a sample dataset of a landed residential unit provided by PolyCam demonstrated comparable, and in fact slightly improved, precision with an average deviation of ±3.5 mm. These results confirm that the proposed workflow is both reliable and generalizable, maintaining consistent measurement accuracy across different residential property types.

The findings suggest that point cloud measurement derived from mobile LiDAR can serve as a dependable and transparent alternative to manual measurement for valuation purposes. While certain limitations remain particularly regarding environmental control and practitioner familiarity with point cloud tools, the overall workflow demonstrates strong potential for adoption in digital valuation practice. Future studies involving larger datasets and semi-automated approaches could further validate and refine this method for broader application in property valuation and geospatial analytics.

VI. Acknowledgment

References

1. N. French and L. Gabrielli, Property Valuation: The Five Methods, Routledge, 2018.
2. N. Kaluthanthri and A. Hippola, "Uncertainty in valuation practice: Causes and implications," Property Management, vol. 41, no. 1, pp. 89–104, 2023.
3. M. Mallinson and N. French, "Uncertainty in property valuation," Journal of Property Investment & Finance, vol. 18, no. 1, pp. 13–32, 2000.
4. Y. Yi, L. Chen, and X. Zhao, "LiDAR applications in urban mapping," Remote Sensing, vol. 9, no. 9, p. 942, 2017.

5. H. Zhao, Q. Zhang, and X. Huang, "Advances in LiDAR-based building modeling," ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. V-2-2020, pp. 351–360, 2020. [6] H. Yamani, M. Azizan, and S. Noor, "Challenges in integrating 3D data in valuation workflows," Journal of Valuation Science, vol. 10, no. 2, pp. 15–28, 2021.

6. R. Boeters, H. Li, and S. Zlatanova, "3D models and valuation accuracy: An LOD2 approach," ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. II-3/W4, pp. 31–38, 2015.

7. A. Ganz, N. Haala, and G. Mandlburger, "Accuracy analysis of handheld LiDAR devices for indoor mapping," ISPRS Archives, vol. XLII-2/W13, pp. 633–640, 2019.

8. M. Arif, S. Rahman, and H. Zulkifli, "Application of consumer-grade LiDAR for built environment measurement," Journal of Spatial Technologies, vol. 12, no. 3, pp. 44–52, 2024.

9. L. Cai, Y. Wang, and X. Zhou, "Satellite-based LiDAR for urban building measurement: Accuracy and limitations," ISPRS Journal of Photogrammetry and Remote Sensing, vol. 212, pp. 112–124, 2024.

10. M. Borz, D. Rusu, and R. Muresan, "Evaluation of mobile LiDAR accuracy in built environment applications," Remote Sensing Applications, vol. 18, no. 1, p. 101112, 2024.

11. Board of Valuers, Appraisers, Estate Agents and Property Managers (BOVAEP), Malaysian Valuation Standards (8th Edition), Putrajaya: Ministry of Finance Malaysia, 2022.

12. B. Mete and T. Yomralioglu, "Integration of BIM and GIS for 3D property valuation," Land Use Policy, vol. 82, pp. 524–532, 2019.

13. B. Mete, I. Turan, and T. Yomralioglu, "GIS-BIM integration for automated valuation models," Computers, Environment and Urban Systems, vol. 96, p. 101222, 2022.

14. B. Atazadeh, A. Rajabifard, M. Kalantari, and K. Champion, "Extending a BIM-based data model to support 3D digital management of complex ownership spaces," International Journal of Geographical Information Science, vol. 31, no. 7, pp. 1440–1463, 2017.

15. M. Renigier-Biłozor, S. Źróbek, and R. Źróbek, "Integration of uncertainty in automated property valuation," Land Use Policy, vol. 82, pp. 723–735, 2019.

16. Y. Su, J. Zhang, and Y. Zhao, "Automated real estate valuation using BIM and machine learning," Automation in Construction, vol. 126, p. 103116, 202