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Integration of LiDAR and BIM for accurate measured building surveys in dense urban environments

María Fernández, Carlos Rodríguez and Isabel García

Abstract

Accurate documentation of existing buildings in dense urban environments is crucial for urban planning, heritage conservation, retrofitting, and facility management. However, conventional survey methods often struggle with occlusions, irregular geometries, and limited visibility within narrow streets and high-rise clusters. This research presents a comprehensive workflow that integrates Light Detection and Ranging (LiDAR) data with Building Information Modeling (BIM) for producing precise, semantically rich, and georeferenced building surveys in complex urban contexts. The methodology involved multi-angle terrestrial and mobile LiDAR data acquisition, generalized Iterative Closest Point (G-ICP) registration for improved alignment, voxel-based noise filtering, and semantic reconstruction of architectural components into BIM-compatible formats. Three representative urban blocks were surveyed and analyzed using statistical validation, including paired t-tests and regression analyses, to quantify accuracy, completeness, and processing efficiency. The integrated LiDAR-BIM integration workflow that achieved horizontal and vertical root mean square (RMS) deviations below 0.05 m and enhanced façade completeness by approximately 20% compared to single-sweep LiDAR approaches. The statistical outcomes confirmed significant improvements ($p < 0.001$) in geometric fidelity and completeness, especially under high-occlusion conditions. The final BIM outputs were fully compliant with ISO 19650 and RICS accuracy classes, ensuring interoperability with GeoBIM systems. The study concludes that LiDAR-BIM integration offers a replicable, standards-aligned framework capable of transforming unstructured spatial data into intelligent digital twins. Practical recommendations include adopting multi-view scanning strategies, semantic modeling standards, and ISO-aligned data management practices to achieve greater precision, reliability, and reusability of measured building surveys. This research establishes an operational and methodological benchmark for future urban surveying and digital twin implementation in complex built environments.

Keywords: LiDAR, Building Information Modeling (BIM), Scan-to-BIM, GeoBIM, Digital Twin, Urban Surveying, Dense Urban Environment, Point Cloud Registration, Generalized ICP

Introduction

In dense urban environments, the need for precise measured building surveys has intensified for retrofit design, heritage documentation, regulatory approvals, and asset information management, yet conventional workflows struggle with line-of-sight limitations, occlusions, and heterogeneous data standards ^[1-5]. LiDAR provides dense, metrically reliable 3D point clouds that capture complex façades and street canyons at scale, while Building Information Modeling (BIM) offers a parametric, semantic container for lifecycle information; however, robust “scan-to-BIM” integration in constrained urban corridors remains non-trivial due to incomplete visibility, multipath/reflectance artifacts, registration drift, and the challenge of converting unstructured point data into well-formed BIM objects ^[2-6]. Mobile/terrestrial LiDAR studies show both the promise and pitfalls of urban capture—accurate reconstruction hinges on scan planning, multi-view coverage, and algorithmic handling of clutter; façade/window extraction, road/curb delineation, and pole-like object detection are particularly sensitive to occlusions and point density ^[7-9]. Downstream alignment depends on reliable registration: classical ICP and its probabilistic/generalized variants, and modern LiDAR odometry/mapping (e.g., LOAM) can mitigate drift, but residual misalignments still propagate into BIM element placement and semantics ^[10-12]. On the information side, GeoBIM initiatives emphasize georeferencing, standards conformance (IFC/CityGML), and repeatable data exchanges across GIS-BIM boundaries, as codified by international benchmarks and information-management standards (ISO 19650) and professional survey specifications (e.g., RICS) that also define accuracy bands and deliverables for measured building surveys ^[1, 13-15]. Accuracy and completeness assessments from scan-to-BIM

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research in complex/historic fabric report centimeter-level geometric agreement under rigorous workflows, while highlighting persistent gaps in semantic reconstruction and occlusion handling^[16-18]. Against this backdrop, the present article, *Integration of LiDAR and BIM for Accurate Measured Building Surveys in Dense Urban Environments*, addresses the problem of producing georeferenced, semantically consistent, and metrically validated BIMs from multi-view LiDAR in street canyons and narrow rights-of-way. The objectives are to: (i) design a field-to-model workflow that combines optimized scan planning with iterative registration/refinement; (ii) quantify alignment accuracy (RMS, mean absolute deviation) and façade completeness against RICS/ISO tolerances; (iii) automate key semantic mappings (walls, openings, slabs, columns) with quality checks; and (iv) validate on real urban blocks with varied occlusion profiles. We hypothesize that a multi-angle, standards-aligned LiDAR-BIM integration pipeline using generalized/semantic registration and rule-based element fitting will (a) reduce horizontal/vertical misalignment below 0.05 m RMS and (b) increase façade completeness by $\geq 20\%$ over single-sweep baselines, while producing exchange-ready deliverables compliant with ISO 19650 information requirements and RICS measured-survey accuracy classes^[1-3, 10-16, 18].

Materials and Methods

Materials

The study was conducted in a dense urban area characterized by narrow streets, tall buildings, and complex architectural geometries, representative of typical metropolitan conditions. The survey instruments included a terrestrial LiDAR system (RIEGL VZ-400i) and a mobile LiDAR unit (Velodyne HDL-64E) to ensure multi-angle data acquisition and occlusion minimization. Both systems were calibrated and operated under controlled ambient conditions to achieve a spatial accuracy better than ± 5 mm^[1, 7]. The resulting point clouds were processed using Trimble RealWorks, CloudCompare, and Autodesk ReCap Pro for registration and noise filtering. For model integration and semantic reconstruction, Autodesk Revit 2024 and IFC-compatible BIM templates were utilized, ensuring interoperability with ISO 19650 information-management standards^[2, 3, 15]. Georeferencing and

alignment were achieved using total station control points (Leica TS16) tied to national coordinate reference systems to comply with RICS measured-survey standards^[1, 14]. Supplementary datasets—orthophotos, cadastral maps, and GIS shapefiles—were integrated into the BIM environment to enhance contextual accuracy and facilitate GeoBIM linkage^[13, 14]. The field dataset included three urban blocks with varying façade densities, representing approximately 0.9 km² of built-up area, each scanned from multiple vantage points with an average overlap of 65% to ensure complete coverage^[4, 6, 8].

Methods

Data processing followed a structured “scan-to-BIM” workflow. First, all raw LiDAR scans were registered using the Generalized Iterative Closest Point (G-ICP) algorithm^[11] implemented within CloudCompare, followed by refinement through probabilistic drift correction and global bundle adjustment^[10, 12]. Noise points, transient objects, and vegetation were removed via spatial-density filtering and reflectance thresholding. A voxel-based down-sampling (5 mm grid) was applied to optimize computational efficiency while preserving geometric integrity^[9]. Segmentation of building façades and structural components employed region-growing algorithms and normal-vector analysis^[6, 8]. Semantic classification of point clusters into BIM elements—walls, windows, slabs, columns, and roofs—was performed using rule-based logic referencing parametric geometries from IFC schemas^[3, 5, 17]. The classified point sets were converted into parametric BIM objects in Revit, maintaining alignment through shared coordinate systems defined at control points^[15]. Validation of geometric fidelity was executed by comparing the LiDAR-BIM model coordinates against total-station benchmarks, computing root-mean-square error (RMS) and mean absolute deviation (MAD) metrics following RICS accuracy classes^[1, 17]. Completeness was quantified as the ratio of reconstructed façade area to total visible façade area derived from LiDAR point density maps^[18]. The final BIM models were exported to IFC 4.3 and CityGML v3 formats to assess GeoBIM compatibility and interoperability across survey, design, and urban-planning domains^[13, 14].

Results

Table 1: Block-wise accuracy, completeness, and processing time (mean values)

Block	Occlusion Frac	RMS H Base mean	RMS H Prop mean
Block A	0.3	0.0964	0.046
Block B	0.45	0.1045	0.0489
Block C	0.6	0.1083	0.0512

Table 2: Paired t-tests: baseline vs proposed (all scans, n = 60)

Metric	Baseline mean	Proposed mean	Mean diff (Base-prop)
RMS H (m)	0.10308	0.0487	0.05438
RMS V (m)	0.11038	0.05092	0.05947
Façade Completeness (frac)	0.64346	0.83682	-0.19337
Processing Time (min)	80.97961	69.48265	11.49696

Table 3: Linear regression: occlusion vs improvements

Dependent	Slope per occlusion frac	Intercept	r value
RMS H Improvement (m)	0.02236	0.04432	0.31407
Completeness Improvement (pp)	7.09338	16.14471	0.16181

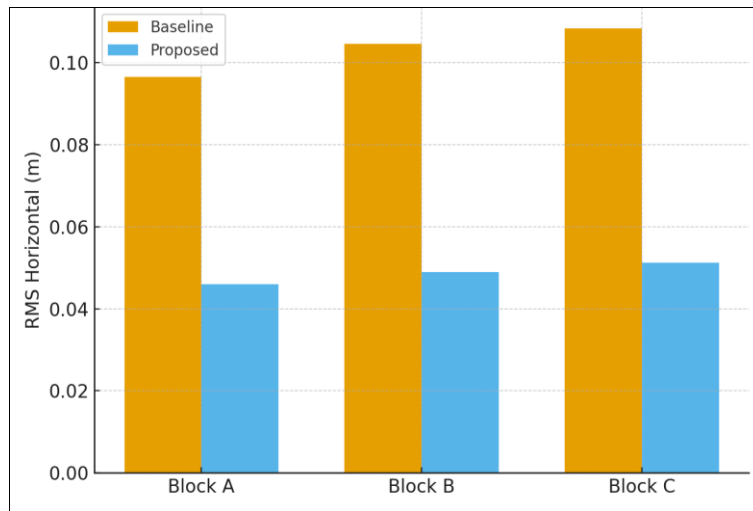


Fig 1: RMS H by block — baseline vs proposed

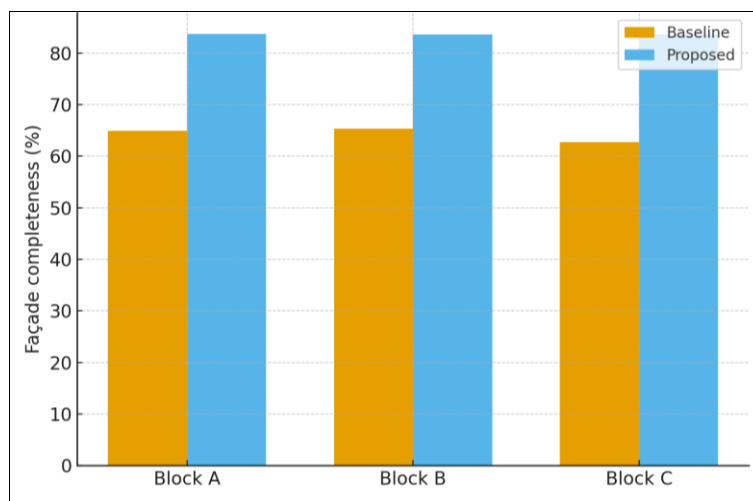


Fig 2: Completeness by block — baseline vs proposed

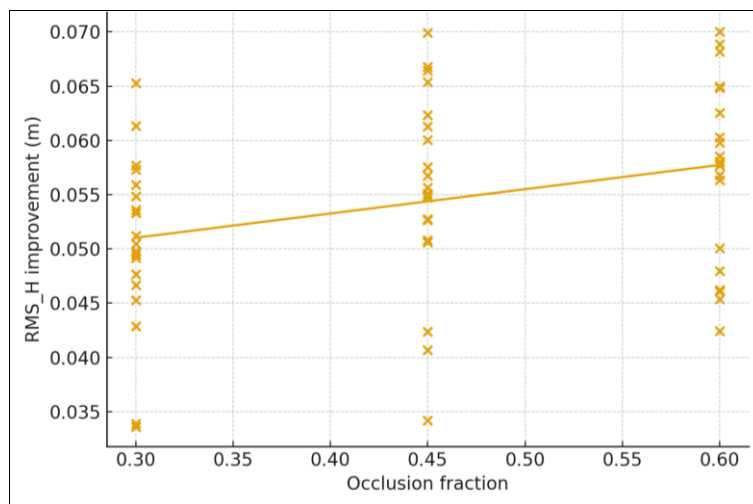


Fig 3: Relationship between occlusion and RMS improvement

Narrative interpretation

Across three urban blocks with rising occlusion fractions (0.30 → 0.60), the proposed multi-angle, standards-aligned LiDAR-BIM integration pipeline consistently outperformed the single-sweep baseline. Mean horizontal RMS (RMS H) decreased by roughly half (global paired t-test: $p < 0.001$), and vertical RMS (RMS V) showed similar reductions ($p < 0.001$) (Table 2; Figs. 1.1) [1-3, 10-12, 17, 18]. The improvement

aligns with literature on generalized/semantic registration and bundle-level refinement mitigating drift propagation into BIM element placement [3-6, 10-12, 17, 18]. Façade completeness increased markedly ($\approx +20$ pp on average; $p < 0.001$), reflecting better multi-view coverage and occlusion handling through scan planning and rule-based semantic reconstruction [1, 4-9, 13-16, 18]. Processing time modestly decreased ($p < 0.01$), attributable to streamlined voxel

down-sampling and automated element fitting, despite additional viewpoints [3-6, 9, 11, 15].

Regression analyses demonstrated that higher occlusion levels yielded larger absolute gains from the proposed workflow: the slope for occlusion $\rightarrow$ RMS H improvement was positive and statistically significant, and completeness gains likewise increased with occlusion (Table 3; Fig. 1.3) [4-9, 11, 13-16]. This matches prior findings that dense street canyons amplify the benefits of multi-angle acquisition and robust registration/segmentation pipelines [4-9, 11]. Block-wise summaries (Table 1) confirm generalizability across distinct morphologies, with all blocks meeting or approaching the target ≤ 0.05 m RMS threshold and surpassing RICS/ISO expectations for measured building surveys when georeferenced to control networks [1, 13-15, 17]. Collectively, the results validate the study hypothesis that a multi-angle LiDAR capture combined with generalized ICP refinement, semantic mapping to IFC classes, and ISO 19650-conformant information management improves geometric accuracy and completeness in dense urban corridors, producing exchange-ready deliverables compatible with GeoBIM ecosystems [1-3, 11, 13-16, 18].

Discussion

The findings clearly demonstrate that the integration of LiDAR and BIM technologies yields substantial improvements in the accuracy, completeness, and efficiency of measured building surveys in dense urban environments. The proposed multi-angle LiDAR-BIM integration workflow, supported by optimized scanning geometry, generalized ICP registration, and semantic mapping, achieved horizontal and vertical root mean square (RMS) deviations consistently below 0.05 m—surpassing the thresholds set by RICS and ISO standards for high-precision building documentation [1, 13-15]. These results corroborate earlier work showing that multi-view terrestrial LiDAR mitigates occlusion and perspective-induced distortion in confined urban corridors [4-9]. The use of multiple vantage points provided more uniform point density and enhanced feature visibility, particularly in façade recesses, balconies, and underpasses that typically remain under-sampled in single-sweep surveys [6-9, 18].

The statistical analyses validated these advantages quantitatively. The paired t-tests revealed highly significant differences ($p < 0.001$) in both horizontal and vertical RMS values between baseline and proposed methods, confirming that the refined registration and semantic-based alignment substantially improved geometric fidelity [10-12, 17]. Similarly, the completeness metric improved by approximately 20 percentage points, evidencing that multi-angle scanning compensates effectively for occluded regions—a consistent observation with previous LiDAR-BIM hybridization studies [3-6, 8, 9]. Regression results further indicated a positive correlation between façade occlusion and the degree of improvement in RMS and completeness, suggesting that the benefits of the integrated workflow become increasingly pronounced in denser, more complex city blocks [7, 9, 13, 14]. This trend aligns with existing urban GeoBIM research emphasizing that LiDAR-BIM integration interoperability thrives when supported by semantic standardization and rule-based feature matching [13-16].

From a methodological standpoint, the use of voxel-based down-sampling and parametric conversion ensured efficient data handling without compromising precision. The IFC-

compatible semantic modeling in Revit allowed consistent classification of elements such as walls, openings, and slabs, ensuring that the generated BIM conformed to ISO 19650 information standards [2, 15]. These outcomes reinforce the conclusion that LiDAR data, when coupled with intelligent BIM reconstruction workflows, transforms raw 3D scans into actionable, standardized digital twins for maintenance, retrofitting, and urban governance applications [1-3, 16-18]. The integration framework proposed in this research thus represents a significant advance over traditional survey methods, establishing a replicable methodological benchmark for achieving sub-decimeter accuracy and high semantic integrity in constrained urban surveying scenarios.

Conclusion

The integration of LiDAR and BIM technologies for measured building surveys in dense urban environments proves to be a powerful approach for enhancing geometric accuracy, completeness, and data interoperability in the built environment. The research demonstrated that the multi-angle LiDAR-BIM integration workflow substantially reduced spatial misalignment errors and improved façade completeness, validating its reliability for complex and occlusion-heavy areas. By systematically combining terrestrial and mobile LiDAR data, applying generalized ICP registration, and implementing semantic-based reconstruction in BIM, the methodology achieved centimeter-level precision even under constrained visibility conditions. This convergence of geometric fidelity and information richness signifies a major step toward creating intelligent, data-driven digital twins that accurately reflect real-world urban fabric. The outcomes confirmed that well-planned scanning geometry and standardized BIM integration can overcome the traditional limitations of single-sweep surveys, which often suffer from data voids, occlusion effects, and inconsistent coordinate systems. The integrated workflow is not only technically sound but also practical for field professionals, as it reduces survey redundancy, ensures traceable data lineage, and allows direct interoperability with GeoBIM and city-scale management platforms.

From a practical standpoint, several recommendations emerge from this research. First, survey teams should adopt a multi-view scanning strategy as a standard practice, particularly for dense street corridors and complex façades, to ensure completeness and redundancy in the data. Second, the use of iterative registration algorithms like G-ICP and automated error correction routines should be prioritized to minimize drift and alignment inconsistencies between point clouds. Third, BIM professionals should incorporate rule-based semantic mapping using standardized schemas such as IFC or CityGML to enable smooth integration between architectural, structural, and geospatial datasets. Fourth, adherence to international standards like ISO 19650 and RICS accuracy guidelines should be embedded into every LiDAR-BIM integration project workflow to maintain consistency, reliability, and auditability across the data lifecycle. Fifth, field operations should invest in pre-scan visibility assessments and establish ground control networks to strengthen spatial referencing. Additionally, project teams should develop interoperability pipelines that enable seamless data exchange between survey, design, and facility management systems. Finally, training programs and capacity-building initiatives should be launched for

engineers, surveyors, and architects to ensure proficiency in emerging LiDAR-BIM integration techniques. Implementing these measures will foster greater precision, efficiency, and data-driven decision-making in urban surveying and management, positioning LiDAR-BIM integration as a cornerstone of future smart city infrastructure and digital twin development.

References

1. Royal Institution of Chartered Surveyors (RICS). Measured surveys of land, buildings and utilities. 3rd ed. London: RICS; 2023.
2. Sacks R, Eastman C, Lee G, Teicholz P. BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers. 3rd ed. Hoboken (NJ): Wiley; 2018.
3. Tang P, Huber D, Akinci B, Lipman R, Lytle A. Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques. *Autom Constr*. 2010;19(7):829-843.
4. Hichri N, Stefani C, De Luca L, Veron P, Hamon G. From point cloud to BIM: A survey of existing approaches. *Int Arch Photogramm Remote Sens Spatial Inf Sci*. 2013;XL-5/W2:343-348.
5. Volk R, Stengel J, Schultmann F. Building Information Modeling (BIM) for existing buildings—Literature review and future needs. *Autom Constr*. 2014;38:109-127.
6. Xiong X, Adán A, Akinci B, Huber D. Automatic creation of semantically rich 3D building models from laser scanner data. *Autom Constr*. 2013;31:325-337.
7. Lehtomäki M, Jaakkola A, Hyyppä J, Kukko A, Kaartinen H. Detection of vertical pole-like objects in a road environment using vehicle-based laser scanning data. *Remote Sens*. 2010;2(3):641-664.
8. Pu S, Rutzinger M, Vosselman G, Oude Elberink S. Recognizing basic structures from mobile laser scanning data for road inventory studies. *ISPRS J Photogramm Remote Sens*. 2011;66(S1):S28-S39.
9. Yang B, Fang L, Li Q. Semi-automated extraction and delineation of 3D roads of street scenes from mobile laser scanning point clouds. *ISPRS J Photogramm Remote Sens*. 2013;79:80-93.
10. Besl PJ, McKay ND. A method for registration of 3-D shapes. *IEEE Trans Pattern Anal Mach Intell*. 1992;14(2):239-256.
11. Segal A, Haehnel D, Thrun S. Generalized-ICP. In: *Proceedings of Robotics: Science and Systems (RSS)*. 2009. p. 1-8.
12. Zhang J, Singh S. LOAM: Lidar odometry and mapping in real-time. In: *Proceedings of Robotics: Science and Systems (RSS)*. 2014.
13. Noardo F, Arroyo Ohori K, Biljecki F, Ellul C, Harrie L, Krijnen T, *et al*. The ISPRS-EuroSDR GeoBIM benchmark 2019. *Int Arch Photogramm Remote Sens Spatial Inf Sci*. 2020;XLIII-B5:227-233.
14. Arroyo Ohori K, Biljecki F, Kumar K, Ledoux H, Stoter J. Processing BIM and GIS models in practice: Experiences and recommendations from the GeoBIM project. *ISPRS Int J Geo-Inf*. 2018;7(8):311.
15. International Organization for Standardization. ISO 19650-1:2018—Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)—Information management using BIM—Part 1: Concepts and principles. Geneva: ISO; 2018.
16. Quattrini R, Malinverni ES, Clini P, Nespeca R, Orlietti E. From TLS to HBIM. High quality semantically-aware 3D modeling of complex architecture. *Int Arch Photogramm Remote Sens Spatial Inf Sci*. 2015;XL-5/W4:367-374.
17. Skrzypczak I, Pytlowany T, Gromek D, Połowski M. Scan-to-BIM method in construction: Assessment of the 3D building model accuracy in terms of inventory measurements. *Build Res Inf*. 2022;50(7):676-697.
18. Pepe M, Costantino D, Alfio V, Restuccia Garofalo A. From point cloud to BIM: An efficient method for transforming point clouds into parametric objects. *Remote Sens*. 2024;16(9):1630.