Research Journal of Agricultural Science, 58 (3), 2026; ISSN: 2668-926X;

http://doi.org/10.59463/RJAS.2026.3.28

OPERATIONAL EFFICIENCY OF SINGLE-SESSION HANDHELD SLAM FOR RAPID 3D DOCUMENTATION OF A UNIVERSITY BUILDING

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Abstract. *The demand for three-dimensional models of buildings has grown together with the needs for documentation, management and renovation of the built stock, and the acquisition method directly influences the cost and duration of the work. Static terrestrial laser scanning offers high accuracy but requires numerous setups and long field time. Handheld mobile scanning based on SLAM offers a different, speed-oriented trade-off. This paper quantifies the operational efficiency of a single-session handheld workflow, applied to a university building in Cluj-Napoca. The ground floor, the first floor and the outer perimeter were documented by a single operator, along a closed-loop trajectory, with a SLAM scanner and processing in CoPre; accuracy was independently checked with a laser distance meter. The 33-minute session produced a cloud of 242.7 million points, with a throughput of about 122,560 points per second and 8.13 GB of data (about 252 MB per minute), at a mean density of 14,500 points per cubic metre. The documentation rate, relative to the covered area, was around 45–60 m² per minute. The spot check indicated differences below one centimetre against the field measurements. The results confirm that a single-pass handheld workflow rapidly documents an entire building with a single operator, at an accepted trade-off in density and accuracy compared with static scanning.*

Keywords: *SLAM; mobile laser scanning; 3D documentation; point cloud; operational efficiency*

INTRODUCTION

The demand for three-dimensional models of buildings has grown steadily in recent years, driven by the needs for documentation, management and renovation of the built stock. A faithful 3D model supports architectural surveys, intervention planning and monitoring of the building over time, and the way these data are obtained directly influences the cost and duration of a documentation project (REMONDINO, 2011; VOLK et al., 2014).

Static terrestrial laser scanning (TLS) has become the standard for such work, providing high density and accuracy. However, the method has an important operational cost: complete documentation requires numerous setups, with overlap between scans and significant field and post-processing time (CONTI et al., 2024). For large buildings with many rooms and corridors, the number of setups and the total time grow quickly.

Handheld mobile scanning, based on SLAM (Simultaneous Localization and Mapping), proposes a different trade-off. A single operator moves through the space with the equipment carried on the body, and the position is estimated in real time by combining LiDAR data with inertial data, without fixed setups and without mandatory targets. The main advantage is speed and continuity: interiors and exteriors can be linked in a single pass, through a closed-loop trajectory that corrects accumulated errors (CADENA et al., 2016; THOMSON et al., 2013).

Recent comparisons between the two approaches confirm this trade-off. On a public building, a portable SLAM system documented the target in 20 minutes, in a single pass, versus about two days with a static terrestrial scanner, while retaining only a fraction of the points (CONTI et al., 2024). Performance assessments of portable systems report lower accuracy than TLS but a consistent gain in speed, accessibility and flexibility (BONORA & COLAPIETRO, 2026; NOCERINO et al., 2017; LEHTOLA et al., 2017; DI STEFANO et al., 2021). The focus of these studies is generally on accuracy and completeness.

Less documented is the operational productivity profile of a single handheld session — time, data throughput, density and covered area — on a real institutional building, with both interior and exterior routes. This paper addresses precisely this aspect: quantifying the efficiency of a single-session handheld SLAM workflow, applied to a university building, together with a usability check of the obtained data.

MATERIAL AND METHODS

Study area

The subject of the study is a university building with an educational function, located in Cluj-Napoca. It was built in the late 1960s, in reinforced concrete, in the functional modernist style of the period — simple volumes, long corridors serving lecture rooms, laboratories and offices. The educational function has been kept to this day. The documentation covered the ground floor and the first floor, together with the outer perimeter; the remaining levels were not included, for access reasons.

Equipment and software

Acquisition was carried out with a handheld mobile scanning system based on SLAM (CHCNAV RS10), carried on a harness by a single operator. For cloud colourisation, a panoramic Insta360 X4 camera was mounted, and field control was done from a tablet, via the SmartGo application, with real-time visualization. Cloud processing was performed in CoPre, and the independent accuracy check used a Leica DISTO D110 laser distance meter. The system characteristics and acquisition settings are summarized in Table 1.

Table 1

Equipment specifications and acquisition settings

Parameter	**Value**
Scanning system	CHCNAV RS10 (handheld SLAM)
LiDAR channels	32
Field of view	360° × 270°
Measurement rate (sensor)	640,000 pts/s (single return); up to 1,920,000 (triple return)
Detection range (sensor)	0.5–300 m
Set scanning range	60 m
Relative accuracy (sensor)	< 1 cm
Absolute accuracy (sensor)	H/V < 5 cm RMS
IMU	0.005° RMS pitch/roll; 0.010° RMS heading
Colourisation camera	Insta360 X4 (externally mounted)
Scanning mode	Integration of indoor & outdoor

Trajectory type	closed loop
Movement	single operator, constant normal speed
Acquisition duration	33 min
Field / processing software	SmartGo / CoPre
Export format	LAS 1.4; XYZ (m); RGB 0–255
Independent check	Leica DISTO D110

Data acquisition

Scanning took place in a single session, around midday, for uniform natural light. The route started indoors, from the main entrance, ran through the ground floor (offices, rooms O2, O14, O15, the corridors) up to the stairs, climbed to the first floor (central hall, lecture theatres OA5, OA4, OA1) and descended by the second staircase, returning to the starting point. From the main hall, the route continued outside, around the whole perimeter, connecting at the end with the interior part into a single job. Loop closure allowed the SLAM algorithm to correct the errors accumulated along the way. The dataset analysed here was acquired as part of the first author's master's dissertation (MANOLE, 2026).

Evaluated indicators

The evaluation of operational efficiency was based on indicators derived directly from the session: total acquisition time, the number of retained points and the corresponding throughput (points/s), the data volume and generation rate (MB/min), the mean cloud density, and the documentation rate relative to the covered area (m²/min). Accuracy was treated as a usability check, not as the main objective: a control distance measured independently in the field was compared with the same distance from the point cloud.

RESULTS AND DISCUSSION

Acquisition efficiency

The whole target area — ground floor, first floor and outer perimeter — was documented by a single operator, in a single 33-minute session, without stops or repeats. The session produced a cloud of 242,670,484 points, with a mean throughput of about 122,560 points per second and a data volume of 8.13 GB, i.e. a rate of about 252 MB per minute. The mean density, of about 14,500 points/m³, proved sufficient for architectural documentation and for generating the virtual tour (SCHÜTZ, 2016). Relative to the covered interior area (estimated at 1,500–2,000 m²), the documentation rate is around 45–60 m²/minute. The indicators are summarized in Table 2.

Table 2

Productivity indicators of the scanning session

Indicator	**Value**
Acquisition duration	33 min (1,980 s)
Operators	1
Documented zones	ground floor + first floor + outer perimeter
Retained points	242,670,484
Point throughput	~122,560 pts/s
Data volume (LAS)	8.13 GB
Data rate	~252 MB/min (4.2 MB/s)

Mean density	~14,500 pts/m³
Documented interior area	~1,500–2,000 m² (estimated)
Documentation rate	~45–60 m²/min (estimated)
Web dissemination conversion	~39 s (PotreeConverter)

Data usability check

Accuracy was treated as a usability check, not as the study objective. In a representative room (O15), two distances measured independently in the field with the laser distance meter were compared with the same distances extracted from the point cloud (Table 3). The differences — 6 mm in length and 2 mm in width — fall below one centimetre, in agreement with the sensor's stated relative accuracy of under 1 cm. The check confirms that the cloud generated in a single fast pass remains usable for architectural documentation, although the control was limited to a single room.

Table 3

Accuracy check: field vs. point cloud (room O15)

Dimension	**Field (DISTO D110)**	**Point cloud (CoPre)**	**Difference**
Length	12.332 m	12.338 m	6 mm
Width	5.454 m	5.456 m	2 mm

Comparison with the literature

The obtained profile — a building wing plus the outer perimeter, documented in a single 33-minute pass by a single operator — falls within the performance reported for handheld mobile scanning systems. CONTi et al. (2024) document a public building with a portable SLAM system in only 20 minutes, in a single pass, versus about two days and 70 setups required with a static terrestrial scanner. The portable system retained about 15% of the static scanner's points but covered a larger area in that time. The time gain on the order of days, in favour of mobile scanning, is also found in the present results.

The price of speed is lower density and accuracy than static terrestrial scanning. Studies on portable systems report georeferencing residuals on the order of a few centimetres (BONORA & COLAPIETRO, 2026; NOCERINO et al., 2017), and direct TLS–SLAM comparisons, usually carried out through M3C2-type algorithms (LAGUE et al., 2013), indicate local differences of up to ±10 cm where the scanning route is sparse (CONTI et al., 2024). Nevertheless, the sub-centimetre relative accuracy obtained in the spot check remains in agreement with the sensor specifications and, according to literature validations (SAMMARTANO & SPANÒ, 2018), sufficient for architectural documentation.

Table 4

Handheld mobile scanning versus static terrestrial scanning (data from the literature and from this study)

System / source	Acquisition time	Points	Working mode
Handheld SLAM (this study)	33 min	242.7 M	single operator, single pass, ground + first floor + exterior
Handheld SLAM (Conti et al., 2024)	20 min	385.7 M	single operator, single pass
Static TLS (Conti et al., 2024)	~2 days / 70 setups	2,641 M	multi-setup, tripod

Limitations

The study has some acknowledged limitations. Coverage was partial — only the ground floor and the first floor, imposed by access — although the scanned areas form a continuous whole. Glazed surfaces generated doubled points, removed manually, and exterior vegetation required subsequent cleaning. The colourisation quality varied with the trajectory, a limitation that opens a separate research direction. In addition, the documented area was estimated, not measured from a dimensioned plan, which affects the precision of the documentation rate; a real area would strengthen this indicator.

CONCLUSIONS

A single handheld scanning session, of 33 minutes and with a single operator, was sufficient to document the ground floor, the first floor and the outer perimeter of a university building, with a cloud of 242.7 million points and a density adequate for architectural documentation. The productivity indicators — point throughput, data volume per minute and documentation rate — show a time gain on the order of days compared with static terrestrial scanning, confirmed by the literature comparisons. The usability check indicated differences below one centimetre, sufficient for the intended purpose, although density and accuracy remain below those of static scanning. The method suits rapid, low-cost documentation of the built stock, useful in management and renovation planning. The limitations — partial coverage and the estimated, not measured, area — indicate the immediate directions for continuation, along with the link between the scanning trajectory and the colourisation quality and the extension of the workflow to more complex spaces, including underground enclosures (ZLOT & BOSSE, 2014).

BIBLIOGRAPHY

BONORA, V., COLAPIETRO, M., 2026 - Performance Assessment of Portable SLAM-Based Systems for 3D Documentation of Historic Built Heritage. Sensors, 26(2), 657.

CADENA, C., CARLONE, L., CARRILLO, H., LATIF, Y., SCARAMUZZA, D., NEIRA, J., REID, I., LEONARD, J.J., 2016 - Past, Present, and Future of Simultaneous Localization and Mapping: Toward the Robust-Perception Age. IEEE Transactions on Robotics, 32(6), 1309–1332.

CONTI, A., PAGLIARICCI, G., BONORA, V., TUCCI, G., 2024 - A comparison between terrestrial laser scanning and hand-held mobile mapping for the documentation of built heritage. ISPRS Archives, XLVIII-2/W4-2024, 141–148.

DI STEFANO, F., CHIAPPINI, S., GORREJA, A., BALESTRA, M., PIERDICCA, R., 2021 - Mobile 3D scan LiDAR: a literature review. Geomatics, Natural Hazards and Risk, 12(1), 2387–2429.

LAGUE, D., BRODU, N., LEROUX, J., 2013 - Accurate 3D comparison of complex topography with terrestrial laser scanner: application to the Rangitikei canyon (N-Z). ISPRS Journal of Photogrammetry and Remote Sensing, 82, 10–26.

LEHTOLA, V.V., KAARTINEN, H., NÜCHTER, A., et al., 2017 - Comparison of the Selected State-of-the-Art 3D Indoor Scanning and Point Cloud Generation Methods. Remote Sensing, 9(8), 796.

MANOLE, A., 2026 - Three-dimensional scanning and modelling of a university building for teaching and research use. Master's dissertation, Technical University of Cluj-Napoca, Cluj-Napoca.

NOCERINO, E., MENNA, F., REMONDINO, F., TOSCHI, I., RODRÍGUEZ-GONZÁLVEZ, P., 2017 - Investigation of indoor and outdoor performance of two portable mobile mapping systems. Proc. SPIE, 10332, 103320I.

REMONDINO, F., 2011 - Heritage Recording and 3D Modeling with Photogrammetry and 3D Scanning. Remote Sensing, 3(6), 1104–1138.

SAMMARTANO, G., SPANÒ, A., 2018 - Point clouds by SLAM-based mobile mapping systems: accuracy and geometric content validation in multisensor survey and stand-alone acquisition. Applied Geomatics, 10, 317–339.

SCHÜTZ, M., 2016 - Potree: Rendering Large Point Clouds in Web Browsers. Diploma thesis, Technische Universität Wien.

THOMSON, C., APOSTOLOPOULOS, G., BACKES, D., BOEHM, J., 2013 - Mobile Laser Scanning for Indoor Modelling. ISPRS Annals, II-5/W2, 289–293.

VOLK, R., STENGEL, J., SCHULTMANN, F., 2014 - Building Information Modeling (BIM) for existing buildings — Literature review and future needs. Automation in Construction, 38, 109–127.

ZLOT, R., BOSSE, M., 2014 - Efficient Large-Scale 3D Mobile Mapping and Surface Reconstruction of an Underground Mine. In: Field and Service Robotics, Springer Tracts in Advanced Robotics, 92, 479–493.

*** CHCNAV, 2024 - RS10 Handheld SLAM Scanner — Technical Specifications. CHC Navigation.