Comparison of mobile laser scanning systems for component-based scan-to-BIM evaluation: NavVis VLX2, XGRIDS L2 Pro, and XGRIDS K1

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Abstract

Mobile SLAM-based laser scanning is an efficient alternative to static capture. Using publicly available point clouds from a practical comparison, this study evaluates three different devices (NavVis VLX2, XGRIDS L2 Pro, and XGRIDS K1) in terms of their scan quality. The aim of the study is to conduct a scientifically sound and component-related evaluation of mobile laser scanning systems. To this end, the NavVis VLX2, XGRIDS L2 Pro, and XGRIDS K1 systems are compared using defined criteria based on established scan-to-BIM evaluation standards. The point clouds used as a basis were captured under identical conditions, enabling a direct comparison of quality. Six parameters were used for the evaluation: total score, geometric completeness and accuracy, object recognizability, intensity, deviations, and noise.
Results: NavVis VLX2 confirms its status as a mature device with consistent quality. Based on the available comparative data, XGRIDS L2 Pro is technically and economically promising—RTK integration, local processing, and higher point density. The compact XGRIDS K1 is suitable for smaller scenarios but is limited in terms of range and homogeneity.
Since peer-reviewed evidence on XGRIDS is still scarce, this work contributes to the systematic evaluation of raw data based on defined criteria. It also provides a solid foundation for rigorous, component-oriented benchmarking of mobile laser scanning systems and supports researchers and practitioners in selecting suitable technologies.

1. Introduction

Mobile 3D scanning of buildings has become a central component of digital planning, documentation, and monitoring processes in recent years. Advances in simultaneous localization and mapping (SLAM) algorithms have made it possible to overcome the traditional limitations of static laser scanning systems and enable mobile devices to be used indoors and outdoors. This allows buildings to be captured in less time, with fewer personnel, and during ongoing operations.

The issue of data quality in mobile systems is becoming increasingly important, particularly in the context of Building Information Modeling (BIM) and the increasing automation of scan-to-BIM workflows. While stationary scanners such as the Leica RTC360 have been proven to achieve high accuracies in the millimeter range, the quality of mobile point clouds depends heavily on sensor parameters, the stability of SLAM algorithms, and the respective environmental conditions. Various studies have shown that mobile systems can deliver accurate results under controlled conditions (Chrbolková et al., 2025; Štroner et al., 2025). However, there is currently a lack of studies that systematically transfer these findings to new systems available on the market.

With the advent of the XGRIDS L2 Pro, a device is now available that promises comparable performance at a significantly lower purchase price than established systems such as NavVis VLX2. However, there is currently little peer-reviewed literature on XGRIDS systems, as they have only recently become available on the market. This is where the present study comes in. By analyzing publicly available point clouds (RealityCapture Training, 2025), we investigate the extent to which these new systems can compete with existing solutions in terms of accuracy, homogeneity, and object recognizability.

The aim of the study is to conduct a scientifically sound and component-related evaluation of mobile laser scanning systems. To this end, the NavVis VLX2, XGRIDS L2 Pro, and XGRIDS K1 systems are compared using defined criteria based on established Scan to BIM evaluation standards (Valero et al., 2022; Salah et al., 2025). The point clouds used as a basis were recorded under identical conditions (RealityCapture Training, 2025), enabling a direct comparison of quality.

The study follows a systematic structure. First, the state of research on mobile laser scanning systems is presented. Next, the methodology and evaluation criteria are explained. This is followed by a detailed analysis of the point clouds in terms of geometric accuracy, intensity, and noise. Finally, the results are critically discussed and reflected upon in terms of the state of the art and the economic benefits of new devices.

2. Background

Mobile laser scanning technology has undergone rapid development in recent years, evolving from a supplementary method to an independent technology for precise building documentation. In contrast to classic terrestrial systems, which operate stationary and rely on a fixed measurement geometry, mobile laser scanners use simultaneous localization and mapping (SLAM) methods. This makes it possible to continuously capture the environment while simultaneously determining their own position in space (Zlot and Bosse, 2014).

The decisive advance lies in the combined use of several sensor types, such as LiDAR, inertial sensors, and RGB cameras. This sensor fusion allows for stable trajectory determination and consistent point cloud registration, even in complex indoor environments (Masiero et al., 2018; Torresani, 2022). However, accuracy remains highly dependent on the environment and

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motion guidance. Studies show that homogeneous or reflective surfaces in particular can lead to errors in trajectory reconstruction (Jarzabek-Rychard and Maas, 2022).

Mobile laser scanning systems can be roughly divided into two classes. Systems such as the NavVis VLX2 take an integrative approach with close software-hardware coupling and a cloud-based workflow. Other systems, such as the XGRIDS L2 Pro, rely on local data processing and open formats. Recent research shows that local real-time processing on edge devices reduces dependence on cloud resources while improving data privacy and cost-effectiveness (Ben Ali et al., 2023; Cao et al., 2024).

A key area of research is the question of the quality of the point clouds generated. In addition to geometric accuracy, qualitative characteristics such as homogeneity, object recognizability, and noise are increasingly being systematically investigated, especially in comparison of mobile SLAM systems to static scanners (Urban et al., 2024; Chrbolková et al., 2025; Štroner et al., 2025). model-related workflows, Malihi & Bosché propose metric-based approaches that quantify coverage, distance, and distribution between point clouds and BIM elements, thereby evaluating the suitability of the data for scan-to-BIM (Malihi et al., 2023). These evaluation approaches are crucial for reliably classifying the suitability of mobile point clouds for modeling and further processing in BIM systems; overview studies on scan-to-BIM also underscore the need for multidimensional, application-oriented quality assessment (Valero et al., 2022).

Scan-to-BIM has established itself as an interface between data acquisition and digital modeling. The process enables the conversion of point clouds into semantically structured building models that serve as a basis for planning, monitoring, and inventory analysis (Valero et al., 2022; Salah et al., 2025). This requires sufficient geometric and radiometric quality of the point clouds. Current research is therefore focusing on the development of standardized quality parameters that allow objective evaluation of different scanning systems.

Although there are now numerous studies on established systems such as NavVis, Leica BLK2GO, and GeoSLAM ZEB, there is a significant research gap when it comes to newly introduced devices. To date, there are no scientific comparative studies for the XGRIDS L2 Pro system. This paper addresses this gap and analyzes publicly available data sets to evaluate the performance of new mobile scanning systems based on defined quality criteria. The aim is to expand the scientific discussion on the accuracy, cost-effectiveness, and practicality of modern mobile scanning technologies with empirical findings.

3. Methodology

3.1 Study framework

This study aims to assess the performance of mobile laser scanning systems based on defined quality criteria. The analysis uses point clouds from a practice-oriented comparison project that are publicly available (RealityCapture Training, 2025). These datasets were captured under identical conditions with NavVis VLX2, XGRIDS L2 Pro, and XGRIDS K1. The stationary Leica RTC360 serves as the reference system; due to its high measurement accuracy it provides a valid basis for evaluating relative deviations.

The study combines quantitative and qualitative analysis methods to capture both metrological and visual quality parameters. The quantitative analysis covers numerical indicators such as point count, deviations, and noise. The qualitative analysis focuses on geometric completeness, object recognizability, and radiometric intensity of the point clouds. The goal is to provide an objective assessment of data quality and infer the suitability of each system for scan-to-BIM applications.

3.2 Evaluation criteria

Point clouds are assessed against six quality criteria aligned with established scan-to-BIM benchmarks (Valero et al., 2022; Salah et al., 2025). The criteria cover both geometric and visual aspects to enable a comprehensive evaluation of scan quality. Leica Cyclone 3DR (version 2025.1.6) was used for analysis.

1. **Total number of recorded points:** Indicates point-cloud resolution and thus geometric detail. Higher counts represent finer structures but increase storage and processing time.
2. **Geometric completeness and accuracy**: Describe how fully and correctly the object's true geometry was captured. High completeness avoids missing areas; high accuracy ensures points reflect the building's actual shape.
3. **Object recognizability**: Assesses whether components such as doors, stairs, or railings can be clearly identified. This is central to scan-to-BIM modeling because it determines how far point clouds can be converted into semantically structured models.
4. **Point-cloud intensity**: Reflectance strength indicating surface/material properties. Relevant where radiometric differences matter, e.g., identifying surface types or materials.
5. **Deviations between datasets**: Quantifies accuracy via cloud-to-cloud comparisons between the RTC360 reference and the mobile scans. The mean of these differences is used as the geometric deviation metric.
6. **Point-cloud noise**: Random deviations of individual points from the true surface. In Leica Cyclone 3DR, the *Noise* tool yields a cleaned cloud and a set of noise points to quantify the relative share.

3.3 Component-based assessment

In addition to general criteria, a qualitative component-based analysis was performed to determine to what extent typical building elements are captured and clearly identifiable.

The analysis used visual inspection in Leica Cyclone 3DR across selected building areas. Elements relevant for model-based applications were considered, including doors, door frames, walls, stairs, railings, floor surfaces, and smaller fixtures. For each element, we assessed whether the point cloud enables complete geometric capture and clear visual delineation.
Evaluation was qualitative and comparative across systems, focusing on capture feasibility, edge sharpness, and visual detail. A normative classification by scan-to-BIM standards or LOD levels was out of scope, as the focus was on practice-oriented data-quality appraisal.

This approach complements the quantitative analyses and enables an application-oriented judgement of point-cloud suitability for subsequent geometric modeling.

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3.4 Validation strategy

To ensure comparability, all point clouds were aligned to the same origin and orientation prior to analysis. Only original data were used—no additional filtering or manual corrections—so results reflect the systems' technical characteristics alone.
A standardized processing chain further minimized subjectivity. Analyses were performed with fixed parameters in identical software environments, allowing differences to be attributed directly to the tested systems' performance.

4. Results

4.1 Total number of points recorded

The three systems examined differ significantly in terms of the total number of points captured. As shown in Table 1, the XGRIDS L2 Pro generated the densest point cloud with 185,086,553 points, followed by the NavVis VLX2 with 163,670,178 points and the XGRIDS K1 with 137,969,809 points. These differences are due to different scan rates, ranges, and internal filter mechanisms.

Point density correlates directly with spatial detail, but at the same time leads to increased storage requirements and longer processing times. While the XGRIDS L2 Pro generated the highest amount of raw data in the test, the NavVis VLX2 was able to achieve a comparable level of detail despite a lower number of points, indicating more efficient sensor fusion and internal data optimization.

System	Total number of points	Scanzeit [min]	Note
XGRIDS K1	137,969,809	≈ 20	Compact unit, shorter range
XGRIDS L2 Pro	185,086,553	≈ 20	Higher scan rate, RTK-supported
NavVis VLX2	163,670,178	≈ 25	Cloud processing, 4 cameras

Table 1. Total number of points recorded

4.2 Geometric completeness and accuracy

The geometric analysis focused on the interior spaces of the first floor. Comparison of the point clouds in Leica Cyclone 3DR reveals significant differences in the completeness and precision of the captured surfaces. The XGRIDS K1 reliably captured light-colored surfaces, but there were significant gaps in dark or reflective materials (e.g., black floor tiles). The XGRIDS L2 Pro showed improved coverage, with approximately 75% of the dark tiles being fully reproduced. The point cloud of the NavVis VLX2 showed the highest geometric completeness: even low-contrast areas and dark materials were captured almost completely, with edges appearing particularly sharp and clearly defined.

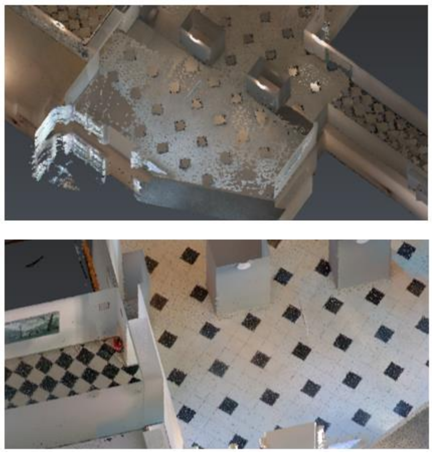

Figure 1. Comparison of tile representation in the point cloud between the XGRIDS K1 (top) and the NavVis VLX2 (bottom)

To quantify accuracy, three distances were measured within the point clouds: the length and width of a selected corridor and the dimensions of a fire extinguisher sign. The results are summarized in Table 2. The average deviations for all systems are less than 1 cm, with the XGRIDS L2 Pro having the lowest average value at 6.43 mm and the XGRIDS K1 having the highest at 9.86 mm.

Parameters	XGRIDS K1 [m]	XGRIDS L2 Pro [m]	NavVis VLX2 [m]	Reference RTC360 [m]
Corridor length	10.142	10.143	10.148	10.150
Corridor width	2.130	2.125	2.113	2.120
Sign width	–	0.140	0.140	0.141
Sign height	0.142	0.134	0.141	0.141

Table 2. Geometric completeness and accuracy

4.3 Component-related results and detectability in the scan-to-BIM context

The component-related analysis focused on the detectability and visual identifiability of model-relevant elements within the point clouds. Doors, door frames, stairs, railings, floor surfaces, walls, and selected fixtures such as fire extinguishers and wall pictures were examined.

Figure 2 below shows examples of sections of the three point clouds of a door. The evaluation shows clear differences in geometric clarity and depth of detail:

- XGRIDS K1: Doors and frames are only vaguely recognizable.
- XGRIDS L2 Pro: Doors and frames are fully rendered; door handles can be discerned.
- NavVis VLX2: provides the highest level of detail; handles, light switches, and material differences are clearly visible.

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Figure 2. Comparison of point clouds using the example of a door (from top to bottom: XGRIDS K1, XGRIDS L2 Pro, NavVis VLX2)

These differences have a direct impact on the modelability in scan-to-BIM workflows. While the NavVis VLX2 enables complete modeling, the XGRIDS L2 Pro provides a good basis for model-relevant components such as walls, doors, and stairs. The XGRIDS K1, on the other hand, is particularly suitable for overview-type inventory documentation.

Component	**XGRIDS K1**	**XGRIDS L2 Pro**	**NavVis VLX2**
Doors Frames	incomplete recognition	clearly identifiable	Fully captured
Stairs / Railings	well captured	well captured	Very well captured
Flooring	some areas missing	almost completely captured	Fully captured
Fire extinguishers / Small parts	not visible	recognizable	Clearly recognizable
Material contrasts	low	medium	High

Table 3. Component-related results and detectability in the scan-to-BIM context

These results illustrate that the detection quality of components does not depend solely on point density, but also on sensor fusion, camera properties, and surface reflectivity.

4.4 Intensity of point clouds

Intensity analysis adds a radiometric dimension to geometric evaluation. It describes the strength of the reflected laser beam and provides information about material properties and surface structures. The analysis was performed in Leica Cyclone 3DR, with the point clouds displayed in color-coded intensity mode.

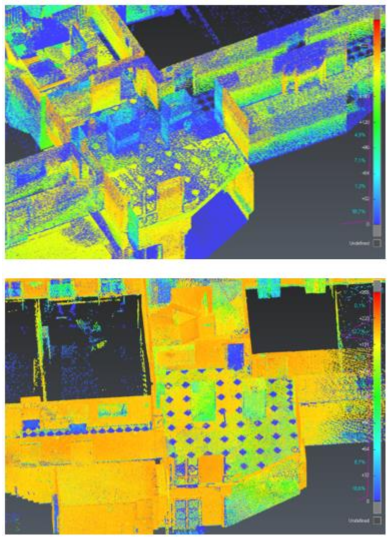

Figure 3. Intensity scale of the XGRIDS K1 (top) and the XGRIDS L2 Pro (bottom)

The point cloud of the XGRIDS K1 shows predominantly low intensity values without any discernible pattern. Dark areas of the floor appear with almost no backscatter. The XGRIDS L2 Pro shows higher intensity values overall. The tile pattern of the floor is clearly visible, as the dark areas show lower reflections. The NavVis VLX2 only provides isolated intensity values, as the LiDAR intensity is recorded internally but not output during export. Therefore, further quantitative evaluation of this parameter is only possible for XGRIDS devices.

System	**Intensity level**	**Visibility of material contrasts**	**Note**
XGRIDS K1	Low	Weakly pronounced	Irregular reflection distribution
XGRIDS L2 Pro	Medium to high	Clearly visible	Stable reflection, clear ground profile
NavVis VLX2	–	Not assessable	No exported intensity data

Table 4. Intensity of point clouds

4.5 Deviations between data sets

The cloud-to-cloud analyses quantify the geometric deviations between the mobile point clouds and the reference image from the Leica RTC360. To do this, the Inspect Cloud vs Cloud function was used in Leica Cyclone 3DR, with the RTC360 data set serving as a reference (see section “Deviations between the data” in the comparison document).

The average deviation values range between 6.43 mm and 9.86 mm (see Table 5). The XGRIDS L2 Pro showed the smallest average deviation, followed by the NavVis VLX2. The XGRIDS K1 showed the largest deviation. In all three cases, however, these values are considered very good in the context of typical building scans.

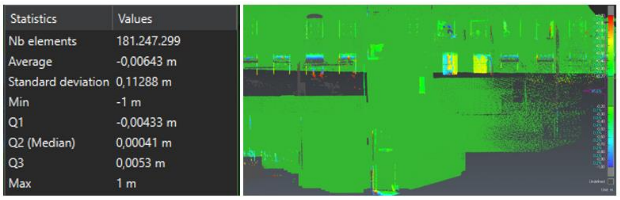

Figure 4. Graphical deviation analysis of the XGRIDS L2 Pro

System	Average deviation [mm]	Note
XGRIDS K1	9.86	Minor deviations in the stairwell
XGRIDS L2 Pro	6.43	Very high consistency, deviations only in reflections
NavVis VLX2	7.43	Minor deviations on windows and reflective areas

Table 5. Deviations between data sets

The results show that all systems exhibit high geometric consistency. The slightly higher deviations of the XGRIDS K1 can be attributed to the lower point density and range, while the NavVis VLX2 shows minor differences on reflective surfaces (windows, glass fronts).

4.6 Noise in the point cloud

The noise was determined in Leica Cyclone 3DR using the Noise Filter tool. The software generates a cleaned point cloud and a separate data set with the points classified as noise (see section "Noise in the point cloud" in the comparison document).
The analysis revealed significant differences between the systems (see Table 6). With the XGRIDS K1, 72,729,971 points were identified as noise, which corresponds to 52.7% of the total number of points. With the XGRIDS L2 Pro, the proportion was 131,016,747 points (70.8%). The NavVis VLX2 achieved the lowest noise percentage with 14,486,541 points (8.9%).

System	Total number of noise points	Percentage of total points	Main causes
XGRIDS K1	72,729,971	52.7%	Sensor movement, weak reflection on dark surfaces
XGRIDS L2 Pro	131,016,747	70.8%	Variable scan trajectories, high sensitivity
NavVis VLX2	14,486,541	8.9%	Reflections on windows and glass surfaces

Table 6. Noise in the point cloud

4.7 Interim conclusion

The results in sections 4.4 to 4.6 illustrate that the data quality of mobile systems depends heavily on the interaction between sensor configuration, motion control, and algorithm stability. While the NavVis VLX2 impresses with low deviations, low noise, and high homogeneity, the XGRIDS L2 Pro offers high point density and radiometry data for detailed surface analysis. The XGRIDS K1 shows good overall performance for simple inventories, but is only suitable for precise modeling to a limited extent due to higher noise levels and low range.

5. Conclusions

5.1 Interpretation of results

The analyses clearly show that the three mobile laser scanning systems examined have different strengths and weaknesses. The NavVis VLX2 achieves the most consistent overall performance, particularly in terms of geometric accuracy, homogeneity, and noise behavior. These results confirm the findings of Chrbolková et al. (2025) and Štroner et al. (2025), who describe SLAM-based systems such as NavVis as particularly stable in path reconstruction (Chrbolková et al., 2025; Štroner et al., 2025). The combination of a multi-camera system, stable sensor unit, and integrated cloud processing results in high point quality, even at low point density.

The XGRIDS L2 Pro achieved a higher overall score and dense coverage, but showed comparatively high noise levels. This suggests that real-time processing and RTK integration offer high sensitivity, but also greater susceptibility to local measurement errors. The observations are consistent with recent studies on mobile systems with open processing, which indicate that local SLAM solutions tend to exhibit increased point dispersion when motion guidance is unstable (Keitaanniemi et al., 2023; Urban et al., 2024).

The XGRIDS K1 showed solid results in almost all categories, but lagged behind the other two devices in terms of point density and deviation values. Nevertheless, its compact design and limited range make it interesting for simple inventories or quick on-site surveys. The higher noise levels are to be expected in relation to the size of the device and sensor capacity.

5.2 Relevance for scan-to-BIM applications

With regard to model-based applications, the component-related analysis confirms that scan quality significantly determines the extent to which point clouds can be transferred to BIM models. The NavVis VLX2 provides the geometric and visual detail required for LOD 200 to 300 models, while the XGRIDS L2 Pro provides a good basis for LOD 100 to 200 models. The XGRIDS K1 primarily meets the requirements of documentation and rough planning. This classification is in line with the recommendations of Valero et al. (2022), according to which point cloud quality should be evaluated depending on the application (Valero et al., 2022).

Furthermore, the results show that qualitative differences in object recognizability—for example, in doors, stairs, and smaller fixtures—have a direct impact on subsequent modelability. The visual completeness of the point cloud influences automatic segmentation and semantic classification, which are central to future AI-supported modeling methods (Malihi et al., 2023).

5.3 Comparison with previous studies

The average deviations of 6 to 10 mm determined in this study correspond to the results of current comparative studies on mobile SLAM systems (Chrbolková et al., 2025). This confirms that modern mobile scanners achieve a level of accuracy under suitable conditions that is sufficient for many construction and engineering applications. The significantly lower noise levels of the NavVis VLX2 are in line with the values described in the literature for systems with stable trajectory guidance (Gharineiat et al., 2024). Although the XGRIDS L2 Pro outperforms in terms of data density, it still lags behind established systems in terms of internal filtering and trajectory stability.

5.4 Methodological limitations

The study is based on publicly available data sets (RealityCapture Training, 2025) that were recorded under real but not fully controlled conditions. Therefore, external influencing factors such as lighting conditions, direction of movement, or GPS signal quality cannot be completely ruled out.

Furthermore, the evaluation was limited to indoor spaces; statements about performance in outdoor areas or with larger structures are therefore only transferable to a limited extent. The lack of independent registration of the point clouds could also lead to minor systematic distortions. Despite these limitations, the results provide a realistic picture of the practical performance of modern mobile systems.

5.5 Scientific contribution

The study contributes to the methodological evaluation of mobile laser scanning systems by applying six clearly defined quality criteria and supplementing them with a practice-oriented, component-related perspective. Of particular relevance is the fact that the XGRIDS L2 Pro and XGRIDS K1 systems have been analyzed from a scientific perspective for the first time, even though there is currently very little peer-reviewed literature on these devices. The results thus contribute to broadening the discussion on the accuracy, cost-effectiveness, and practicality of mobile scanning systems. In addition, the study shows that qualitative assessments such as object recognizability are a valuable addition to classic geometric parameters.

5.6 Outlook

Future work should aim to validate the findings under controlled laboratory conditions and systematically investigate the influencing factors of motion guidance, surface materials, and lighting conditions. It would also be useful to test AI-supported segmentation and classification methods in order to further quantify the connection between point cloud quality and automated model generation. Another research approach lies in the integration of mobile and stationary systems in order to achieve higher overall data quality through hybrid data sets.

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