Metric Reliability and Operational Adaptability in the context of the Integrated 3D Metric Survey of the Genete Leul Palace (Addis Ababa, Ethiopia)

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Abstract

This paper presents the 3D metric survey of the Genete Leul Palace in Addis Ababa, carried out by the Geomatics Group of Politecnico di Torino within an international cooperation project aimed at supporting the restoration of this significant heritage site. The research explores the application of an integrated and rapid survey methodology combining Terrestrial Laser Scanning (TLS), SLAM-based Mobile Mapping Systems (MMS), and UAV photogrammetry, adapted to a context characterized by logistical, regulatory, and infrastructural constraints. Despite challenges such as customs delays, limited equipment availability, and restricted UAV operations, the survey was successfully completed within a short timeframe while ensuring metric accuracy suitable for restoration purposes. A topographic control network enabled the integration of multi-sensor datasets into a consistent reference system, supporting the generation of reliable 3D models and 2D architectural drawings. The results demonstrate that hybrid workflows can effectively balance accuracy and efficiency, even in complex and time-constrained environments. The study highlights the importance of context-aware strategies and collaboration with local partners as key factors for success. Ultimately, the project confirms that advanced geomatic methods can provide sustainable, replicable solutions for cultural heritage documentation in developing countries, thereby promoting knowledge transfer, preservation, and socio-economic development.

1. Introduction

The Genete (or Guenete) Leul Palace, an early 20th-century royal residence within the former imperial compound of Addis Ababa, is a landmark of Ethiopian modern heritage. It currently hosts the Ethnographic Museum of Ethiopia and the Department of Linguistics of Addis Ababa University. Within the cooperation programme promoted by the Italian Ministry of Foreign Affairs and International Cooperation (MAECI), the Politecnico di Torino, through its Department of Architecture and Design (DAD), was commissioned to develop preliminary studies for the restoration project of this heritage site.

In this context, the Geomatics Group of DAD, operating within the Laboratory of Geomatics for Cultural Heritage (G4CH Lab), conducted a comprehensive 3D metric survey to support the restoration and valorization project by collecting accurate, reliable data.

The main goals of the research, in the field of geomatics, are to:

- provide a reliable geometric dataset as a basis for the restoration project of the palace;
- demonstrate the feasibility of advanced metric surveying in a low-infrastructure context, where customs restrictions and limited local equipment availability affect planning;
- deliver results within one intensive week of fieldwork, ensuring both the needed accuracy for the use of metric data and speed;
- foster collaboration between the Politecnico di Torino and the University of Addis Ababa;
- work within an interdisciplinary team composed of geomatics specialists, restorers, and structural engineers, linking the digital survey to design decisions.

In this regard, the purpose of this paper is not only to illustrate how modern digital methods of 3D metric documentation can serve as powerful tools to support restoration and conservation processes — driving cultural and economic development even in developing countries — but also, consequently, to affirm 3D metric survey methods as sustainable tools in support of these processes. The project thus contributes not only to 3D documentation but also to capacity-building in heritage management for developing countries, emphasizing how accurate yet rapid surveying can promote knowledge transfer, cultural preservation, and tourism development. Furthermore, the full paper will describe not only the rapid survey strategies employed to document the palace under study, but also the logistical and operational limitations encountered, which are common when planning 3D metric survey operations abroad.

The restoration of Guenete Leul Palace is framed within the context of a broader international cooperation project funded by AICS (Italian Agency for Development Cooperation), formally titled "Restoration and enhancement of the historical and cultural heritage of the University of Addis Ababa" (Italian: "Restauro e miglioramento del patrimonio culturale e storico dell'Università di Addis Abeba"); the project is coordinated by prof. Francesca De Filippi and Prof. Michele Bonino (Department of Architecture and Design, Politecnico di Torino), with Elena Rudiero serving as Project Manager.

1.1 State of the art: 3D metric survey in developing countries

The use of 3D metric survey for documenting cultural heritage has increased significantly in recent years. Technologies such as Terrestrial Laser Scanning (TLS), photogrammetry, and Mobile Mapping Systems (MMS) are widely used to generate accurate geometric data, supporting restoration purposes, structural analysis, and HBIM applications (Conti et al., 2024). Recent evaluations have further demonstrated the effectiveness of various LiDAR technologies for documenting forgotten or complex cultural heritage, even in challenging environments (Maté-González et al., 2022). Studies show these methods are highly effective in well-equipped environments, where access to advanced tools, infrastructure, licensed software, and expertise is easily available and affordable. However, in underdeveloped

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countries, the application of these kinds of technologies has some limitations.

Many studies have highlighted photogrammetry as a low-cost alternative to TLS, owing to its flexibility and lower equipment requirements (Cruz & Albuerne, 2025). Similarly, multi-sensor approaches, such as combining TLS and photogrammetry, have been applied to document archaeological sites abroad, damaged historic structures in post-disaster scenarios, and also in underdeveloped countries (Shrestha et al., 2017). Also, other similar research in integrated workflows combining TLS and photogrammetry for heritage documentation mainly focus on improving geometric accuracy and data quality (Alshawabkeh et al., 2020; Baik, 2017), while these works are conducted under controlled conditions and do not investigate the logistical and practical challenges associated with fieldwork in real-world data acquisition deeply, especially in underdeveloped countries. In this field, the integrated application of multi-scale 3D digital technologies is emerging as a robust solution for comprehensive heritage conservation (Tian et al., 2025). Furthermore, works conducted by our Laboratory of Geomatics for Cultural Heritage (Chiabrando et al., 2022; Lippolis et al., 2024) describe metric analysis and focus on rapid mapping approaches applied to heritage conservation in international contexts.

Despite these efforts, significant logistical and regulatory challenges are largely underdiscussed in the literature. For example, in international projects, importing survey equipment can be problematic due to strict customs regulations and administrative delays. Furthermore, obtaining flight authorisations for UAV (Unmanned Aerial Vehicle) photogrammetry by foreign teams is a complex, time-consuming process. To overcome this, this project relied on local UAV operators in collaboration with UNICEF and African Drone Academy, and it has proven to be a highly effective and affordable solution for delivering highly accurate data, because local entities usually have immediate access to equipment, and they can have the necessary legal permits more easily than foreign teams. Such collaborations have proven highly effective, as capacity-building projects and UAS-based mapping in developing countries enable more sustainable, legally compliant data acquisition (Calantropio et al., 2021). In addition to the legal and logistical context, limited time is also a critical issue during fieldwork abroad. Traditional static surveys (TLS), while highly accurate, are usually time-consuming and impractical when the operational period is limited to a few days. In this case, SLAM-based Mobile Mapping Systems (MMS) provide a solution to this problem. MMS enables experts to acquire data rapidly and maintain continuous spatial coverage, particularly in complex or restricted indoor environments. In Conclusion, despite these technological advancements, existing studies typically focus on isolated case studies under ideal conditions. There is a clear lack of literature on adaptive, multi-scale workflows that effectively respond to the realities of international fieldwork, such as unpredictable delays, time constraints, and strict customs restrictions. This research addresses these gaps by proposing a survey methodology that will balance TLS accuracy with MMS speed and local UAV collaboration, ultimately supporting restoration needs.

2. The mission: 3D metric survey in Addis Ababa

This section outlines the mission's primary phases and the challenges encountered during fieldwork.

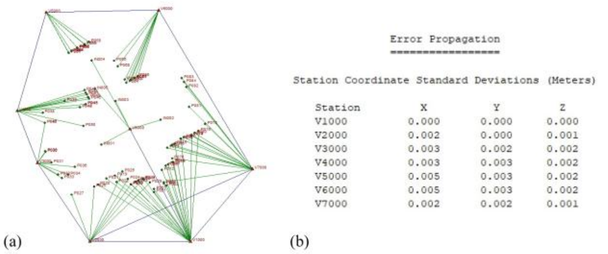
2.1 Field organisation and logistics

The survey mission was carried out in September 2025. The import procedures for the instruments posed a major challenge, as customs restrictions delayed their release by 2 days. In addition, it was not possible to operate UAV (Unmanned Aerial Vehicles) systems for aerial photogrammetry due to flight authorisation constraints. The aerial dataset was later acquired with support from UNICEF and the Africa Drone Academy, enabling completion of the external documentation. Language barriers and initial coordination challenges complicated the organisation; however, thanks to the support of local collaborators from the University of Addis Ababa and the DAD research team, field activities began a few days after arrival. Once the equipment was released, all data collection was completed within 5 operational days, demonstrating that it is possible to conduct an integrated metric survey with rapid acquisition by combining both new and legacy instruments. The acquisition team consisted of the authors, although not all were present every day due to health-related issues. Given these conditions, the standard survey workflow had to be adapted. A total of 7 external vertices and 1 internal vertex were installed on site to establish the control network. The external points were later measured with GNSS (Geomax Zenith 35), while internal and façade control points were acquired using a Total Station to ensure a consistent local reference frame. As illustrated in the following section, these points proved fundamental for registering both TLS (terrestrial laser scanner) and MMS (Mobile Mapping System) datasets, thereby linking indoor and outdoor acquisitions into a unified system.

2.2 Accuracy strategy: the metric survey

Despite the survey's rapid, time-constrained nature, a topographic control network was established. This choice was made to ensure that datasets acquired through the different detailed surveying techniques employed (TLS, SLAM, and UAV photogrammetry) could be processed within a common coordinate system. At the same time, it helped to limit error propagation, providing metric control and validating the acquired measurements.

The network, consisting of seven topographic vertices outside the building and one inside (Figure 1), was measured with a total station and adjusted by least-squares. The standard deviation observed at each vertex is on the order of a few millimetres (≤ 5 mm).



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                Error Propagation
                =================

Station Coordinate Standard Deviations (Meters)

   Station        X          Y          Z
   V1000        0.000      0.000      0.000
   V2000        0.002      0.000      0.001
   V3000        0.003      0.002      0.002
   V4000        0.003      0.003      0.002
   V5000        0.005      0.003      0.002
   V6000        0.005      0.003      0.002
   V7000        0.002      0.002      0.001
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Figure 1. (a) Topographic network scheme (vertices and control points); (b) Standard deviations observed on the topographic vertices after the least-squares adjustment.

Approximately 90 control points were also surveyed, both inside and outside the building, to support the registration and validation of the point clouds subsequently acquired using different detailed survey techniques.

As mentioned earlier, the detail survey utilised Terrestrial Laser Scanning (TLS) with a FARO Focus^{3D} X330 and a Mobile Mapping System (MMS) based on SLAM technology (Stonex X120GO) (Figure 2). The main specifications of the two adopted devices are shown in Table 1.

Figure 2. (a) Faro Focus^{3D} X 330; (b) Stonex X120GO SLAM laser scanner.

Faro Focus^{3D} X 330	
Distance range	0.6-330 m
Horizontal and vertical range	305/360 °
Distance accuracy	± 2 mm @ 10 m
Acquisition speed	up to 976,000 pt/s
Stonex X120GO SLAM laser scanner	
Distance range	0.5-120 m
Horizontal and vertical range	360/260 °
Relative accuracy	6 mm
Acquisition speed	320,000 pts/s

Table 1. Main specifications of Faro Focus^{3D} X 330 and Stonex X120GO SLAM laser scanner.

The hybrid approach was not conceived as a technological comparison but as a pragmatic response to contextual constraints—limited time, restricted visibility, and the impossibility of performing dense static scans due to access limitations. Each scan, whether static or mobile, was linked to the control network, ensuring a coherent and georeferenced 3D framework. A clear distinction was maintained between survey accuracy (metric control during acquisition and registration) and the accuracy of derived products (architectural drawings and HBIM outputs at 1:100 scale). The achieved level of detail and reliability is fully appropriate for restoration-oriented applications. TLS was used to acquire high-precision static scans of large halls and façades, while MMS enabled rapid, continuous coverage of narrow corridors, staircases, and basement areas.

The planning phase played a crucial role in the success of the fieldwork. Since the surrounding area is densely vegetated, a colleague acquired a series of 360° panoramic photographs prior to the mission, which were subsequently used in Italy to plan the scanning positions and trajectories. This pre-visualisation step significantly optimised on-site operations, especially considering the short working timeframe.

The survey activities and the subsequent processing operations related to the registration and metric validation of the point clouds were carried out as follows:

1) TLS acquisitions.

Regarding the TLS survey, 86 scans were acquired (with a resolution of 1 pt/6 mm at 10 m distance) to document the façades and external areas of the Genete Leul Palace. The scan planning ensured a high degree of overlap between adjacent scans, facilitating subsequent registration using the Iterative Closest Point (ICP) algorithm.

The registration of the 86 point clouds was performed following a consolidated workflow consisting of an initial ICP-based registration and, subsequently, a rigid roto-translation using control points to transform the TLS point clouds into the desired reference system, while simultaneously validating the metric accuracy of the registration. During the first phase (ICP-based registration), discrepancies of approximately 2 mm were observed; in the second phase (target-based registration), the observed accuracy on the control points (47 points measured with a total station) is approximately 0.014 m. This value represents the mean 3D deviation between the coordinates measured on the TLS point cloud and the reference coordinates acquired with the total station (Lachat et al., 2018). The final point cloud, derived from the registration of the 86 static scans, consists of more than 1,500,000,000 points (Figure 3). Given the intended scale of representation, the point cloud was filtered to achieve a 1 cm resolution to improve data management.

Figure 3. TLS point cloud after registration.

2) SLAM acquisitions.

Given the building's high geometric and morphological complexity and the need for a rapid, efficient survey, most indoor environments were surveyed using a SLAM-based MMS system. To limit potential drift or misalignments, the acquisitions were performed in closed loops (with coincident start and end points).

A total of 27 scans were acquired (covering both outdoor and indoor environments, Figures 4 and 5), ensuring sufficient overlapping areas to enable co-registration of the point clouds, using the TLS dataset as reference ground truth (ICP registration) or, when possible, by acquiring known coordinates control points (previously measured with the total station). This second strategy enables more robust trajectory estimation and, consequently, reduces the likelihood of drift and misalignment.

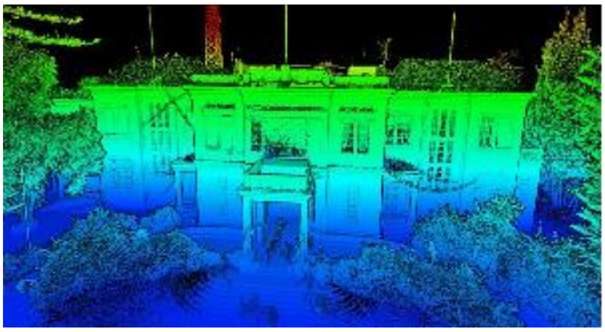
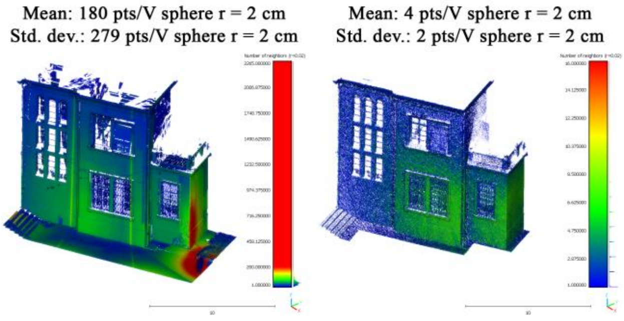


Figure 4. MMS point cloud of the main facade of the building.

Figure 5. Outdoor and indoor mixed SLAM-based acquisition.

As regards the SLAM scans, no subsampling was required, considering that (a) an initial filtering is already performed during the preliminary processing to remove less reliably reconstructed points, and (b) there is a significant difference in terms of density between the SLAM point cloud and the TLS one, as shown in Figure 6.



(a) (b)

Figure 6. Number of neighbours density analysis on (a) TLS point cloud and (b) SLAM point cloud, evidencing significant differences in terms of density.

As illustrated in the image below (Figure 7), the architectural complexity of the building, together with the fact that the basement serves as storage for immovable artworks, greatly complicated the acquisition process.

Moreover, most museum rooms were locked and could only be opened individually with separate keys, which, combined with the previously mentioned language barriers, made coordination and workflow continuity particularly challenging. Another difficulty was the presence of visitors and museum staff, as the museum remained open to the public throughout the survey. These moving elements were later removed in post-processing by filtering out outliers from the point clouds.

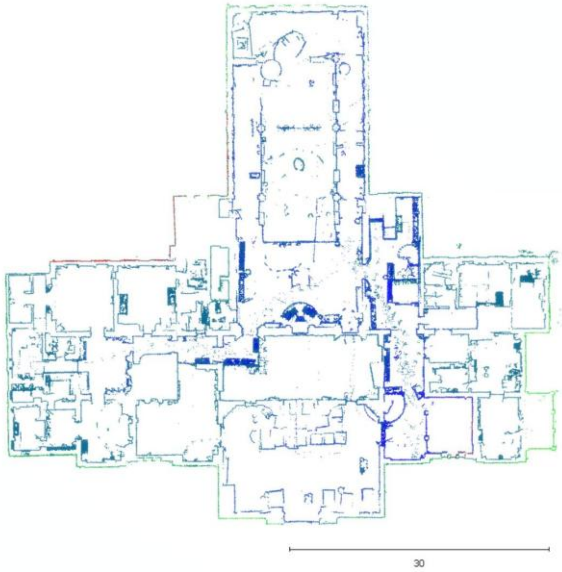


Figure 7. Horizontal section of a point cloud derived from the SLAM-based acquisition.

2.3 The UAV photogrammetric acquisition by African Drone Academy and UNICEF

The flight was planned by the geomatics group of Polito at an altitude of approximately 40 m, corresponding to a Ground Sampling Distance (GSD) of ≈1 cm/pixel. This resolution was selected to support the generation of a three-dimensional model at architectural scale (1:100).

The African Drone Academy operator adopted a cross-grid acquisition geometry comprising five longitudinal and five transverse flight strips. The flight plan included both nadir images, aimed at documenting horizontal surfaces (e.g., roofs), and oblique images with the camera tilted between 30° and 45° relative to vertical surfaces. This configuration enabled the acquisition of the upper portions of the façades, particularly in areas not adequately captured by terrestrial LiDAR. In ground-based laser scanning, the acquisition geometry typically results in increasingly oblique incidence angles for elevated surfaces, which in turn leads to a reduction in point density and measurement quality in the upper parts of the building.

Additional limitations were caused by partial occlusions from vegetation or protruding architectural elements (e.g., balconies, canopies).

High image overlap was ensured, with 80–90% forward overlap and 70–80% side overlap. A total of 419 images were acquired.

The UAV platform employed was a DJI Mavic 2 Pro (Figure 8), equipped with a high-resolution digital camera, whose main specifications are reported in Table 2.

Figure 8. DJI Air 2S.

UAS Model	DJI Air 2S
Sensor type	1'' CMOS
Camera model	FC3411
Sensor size	13.2 × 8.8 [mm]
Effective pixel	20 [MP]
Pixel size	2.4 [µm]
Focal lenght	8.1 mm; 35 mm Format Equivalent: 22 mm
Lens field	88°
Image size	5472 × 3648 [pixel]

Table 2. Main specifications of the used camera (FC3411).

The dataset was processed using the well-known photogrammetric software Agisoft Metashape, following a standard Structure-from-Motion (SfM) and Multi-View Stereo (MVS) workflow. Camera internal orientation parameters were estimated through a self-calibration procedure within a bundle block adjustment. Image alignment allowed the extraction of tie points and the generation of a sparse point cloud, based on relative orientation. The absolute orientation of the block was achieved using 26 Ground Control Points (GCPs) manually collimated from the images. The GCPs consisted of natural features clearly identifiable on the façades (e.g. corners or points characterised by radiometric or material discontinuities) and were measured using a total station. The adopted reference system corresponds to the survey control network, ensuring consistency with other geomatic datasets (terrestrial laser scanning and SLAM acquisitions). A further set of 15 points was used as Check Points (CPs) to evaluate the metric accuracy of the photogrammetric model. Accuracy assessment was carried out using Root Mean Square Error (RMSE) at the checkpoints. The obtained values are fully consistent with the architectural scale of representation (1:100) and are reported in Table 3.

	RMSE [m]			
	X	Y	Z	XYZ
GCPs [26]	0.013	0.009	0.012	0.019
CPs [15]	0.011	0.008	0.021	0.025

Table 3. RSME observed on GCPs and CPs.

At the end of the photogrammetric process, standard photogrammetric products were generated to support vector-based restitutions, including a dense point cloud (Figure 9), a Digital Surface Model (DSM) and an orthomosaic of the roof surfaces (Figure 10).

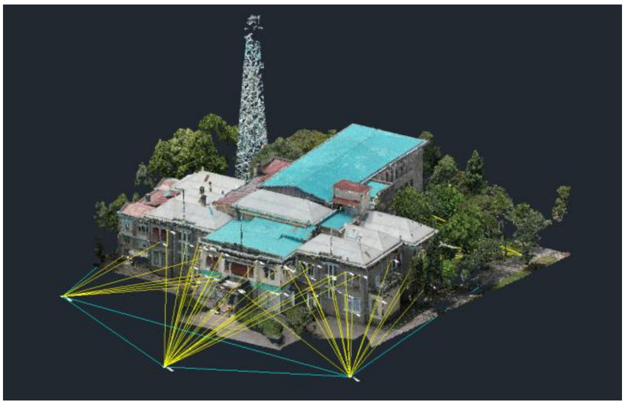
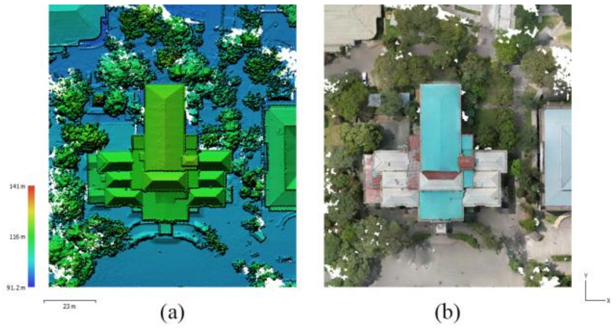


Figure 9. Photogrammetric dense point cloud with topographic network (light blue vectors) and GCPs/CPs (yellow vectors).



(a) (b)

Figure 10. (a) DSM; (b) Orthomosaic.

2.4 Challenges in MMS and TLS alignment

Despite the rapid nature of the survey campaign described in this paper, several metric control strategies were adopted to verify and validate the acquired point clouds. Indeed, a rapid approach must be supported by robust metric control that ensures the survey-generated metric products are consistent with the required specifications (in this case, those of the restorers and the professionals involved in the enhancement project).

On the one hand, as described in the previous sections, topographic control was implemented; on the other hand, a series of cross-sections was carried out between the TLS point cloud (assumed as the ground-truth reference model) and the SLAM point cloud to verify the presence of misalignments (Figure 11 and 12). Furthermore, discrepancy analyses were performed on the 3D point clouds to assess co-registration and the absence of local drift (Figure 13).

Figure 11. Cross-sections were generated from the TLS and SLAM point clouds to verify the absence of misalignments.

Figure 12. Cross-sections performed on the TLS and SLAM point clouds to verify the presence of any misalignments, evidencing a 3 cm discrepancy.

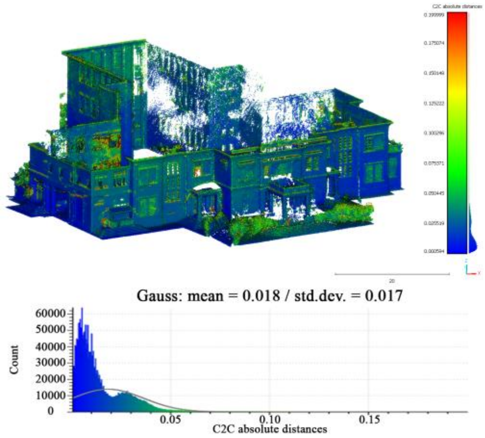


Figure 13. Discrepancy analysis between TLS point cloud (reference) and SLAM point cloud (compared) evidencing an average discrepancy of ca. 0.020 m.

Following these checks, local misalignments of 7–9 cm were detected on upper floors due to weak geometry and reflective surfaces; however, net of these local deviations, the discrepancies observed for the registration between TLS and MMS data remain acceptable for nominal scales of approximately 1:50 (TLS data) and 1:100/200 (MMS data).

Mean residuals between TLS and MMS datasets remained below 1-2 cm in most areas, validating the adopted workflow. Observed deviations on upper levels were consistent with architectural irregularities confirmed by restorers rather than instrumental errors. This demonstrates that metric reliability and operational efficiency can coexist effectively when survey design is adapted to contextual conditions.

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Integration of TLS, MMS and UAV datasets was subsequently performed in CloudCompare, generating a unified, georeferenced point cloud comprising approximately 640 million points. The dataset was subsequently sectioned in the PointCab platform to extract floor plans, elevations, and cross sections, which form the geometric foundation for vectorisation and modelling (Figure 14).

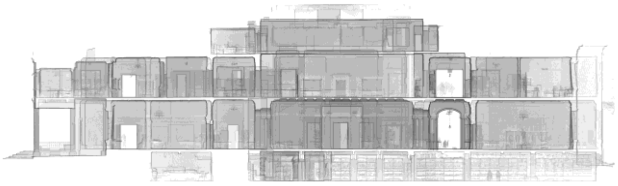

Figure 14. PointCab cross-sections of the SLAM point cloud for the production of vector drawings and 2D representations.

3. First results: architectural drawings

The integrated dataset documents the entire building volume, from the basement to the upper roof level (excluding the roof itself, which is awaiting integration with UAV photogrammetry). This provides a complete and metrically validated 3D representation. Key outcomes include:

- Orthophotos, plans, and sections directly supporting the restoration project;
- 2D vector drawings including façade drawing (Figure 15), sectional view (Figure 16), and floor plan (Figure 17).

Figure 15. 2D drawing of main facade derived from Orthophotos generated from the TLS and UAV point cloud and vectorized in AutoCad

Figure 16. 2D drawing of Cross-section of the building obtaind from the SLAM and UAV point cloud through section extraction in PointCab and vectorized in AutoCad

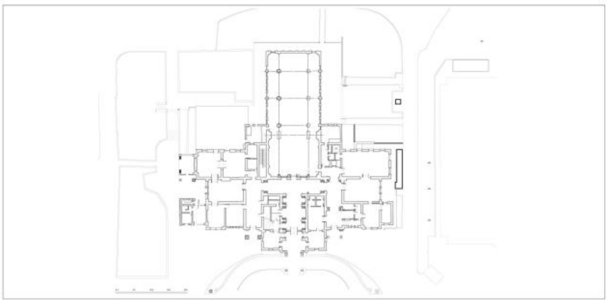

Figure 17. 2D drawing of Ground floor plan of the building obtaind from the SLAM point cloud through section extraction in PointCab and vectorized in AutoCad

4. Discussion

Following the research experience described in the previous sections, it can be emphasized that the different 3D metric survey techniques employed for the documentation of the Genete Leul Palace were able to generate value-added metric products at a scale consistent with the architectural requirements. This highlights how Geomatics nowadays represents a fundamental pillar in the documentation of historical and architectural heritage, as well as an indispensable support for restoration projects (specifically, the case presented in this paper: enhancement initiatives aimed at supporting developing countries within the framework of international collaboration).

It is also worth reflecting on the sustainability of the operations carried out during field activities and, subsequently, on the processing of the acquired data. On the one hand, it is important to emphasise that the rapid development of new survey solutions has enabled the effective 3D metric survey of a morphologically complex and stratified building such as the Genete Leul Palace within an extremely short time frame (approximately 3 days) as illustrated in (Figure 18). This would not have been possible until relatively recently, and it is now feasible thanks to the development not only of more effective instrumentation but also of increasingly powerful algorithms (such as SLAM algorithms, which have revolutionised several aspects of 3D metric surveying at the architectural scale). The opportunity to reduce the time of occupation of a historical/cultural site is of undeniable value, as survey activities are often not compatible with the ordinary functions of a building (in the case of the Genete Leul Palace, the presence of visitors to the ethnographic museum and the regular activities of Addis Ababa University).

However, it is also necessary to highlight several logistical challenges associated with conducting a survey campaign of this scale in a foreign country. In addition to the significant language barrier, there are logistical difficulties with the export of equipment through customs. With regard to the use of UAV systems for photogrammetric purposes, the challenges are even greater, both in importation and in actual operation, due to the different regulations governing the use of aerial systems across countries. A viable alternative may be to rent equipment locally or to rely on local professionals and institutions with the necessary expertise (as in the case of the research experience described for the photogrammetric flight); however, this solution entails additional costs.

A second bottleneck is represented by the storage and processing of the acquired data. In this paper, particular emphasis has been placed on the survey's rapid nature; however, data processing required several weeks and the full-time commitment of an experienced operator for tasks related to point cloud and photogrammetric data processing. Indeed, despite the high level of automation currently achieved in processing this type of data, these procedures remain time-consuming and require continuous supervision; the level of expertise required from the operator is therefore high and cannot be delegated to fully automatic solutions.

Moreover, while the amount of data acquired during the campaign was approximately 70 GB (distributed as follows: TLS ~17 GB; SLAM ~49 GB; UAV data ~4 GB), it is important to note that, at the end of the processing phase, the total data volume exceeded 600 GB. This introduces significant complexity, both in storing the derived data generated during processing and in classifying and cataloguing it for future use.

Another aspect that should be underlined is the high cost of the adopted solutions. While UAV photogrammetry and digital photogrammetry in general can be considered low-cost techniques, LiDAR systems (both TLS and MMS systems based on SLAM technology) are characterised by high costs, which can reach several tens of thousands of euros. This becomes even more significant in the context of technology transfer to developing countries.

In addition to the hardware aspect, the software component must also be considered: most of the software used in this research consists of commercial solutions that require paid licenses. As for photogrammetry and point cloud management, numerous open-source alternatives exist; however, platforms for primary processing, such as TLS or SLAM scan registration, are often proprietary solutions developed by instrument manufacturers, which can introduce additional costs.

Nevertheless, it can be observed (as discussed in the previous sections) that the fact that these solutions are increasingly rapid and efficient also represents an economic advantage, as reduced site occupation ultimately translates into lower overall costs.

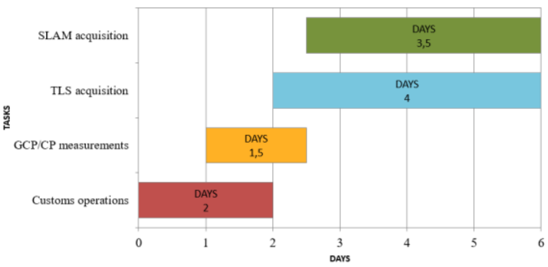

Figure 18. GANTT Chart of the on-site survey workflow showing the duration of each task

5. Conclusions and Next Steps

The Genete Leul Palace mission illustrates how geomatic methods can be adapted to complex operational environments. In developing countries, temporary import restrictions, limited power supply, and tight working schedules often make standard survey protocols impractical. By prioritizing operational efficiency, the team struck a balance between precision and feasibility: TLS ensured reference accuracy, while MMS guaranteed completeness in confined spaces. The achieved accuracy is entirely adequate for restoration analysis and architectural documentation. Equally important was the interdisciplinary collaboration among architects and designers, geometricians, restorers, and structural engineers, which allowed a pragmatic balance between metric ambition and project needs. This synergy demonstrated that even under constrained conditions, rigorous spatial data can effectively support design, planning, and long-term monitoring. The experience confirms that context-aware geomatic strategies can deliver high-quality documentation in areas with limited infrastructure. The project proves that:

- Rapid hybrid workflows can achieve the required metric standards for restoration;
- Speditivity and accuracy are not conflicting concepts but parameters to be balanced according to scale, context, and project priorities;
- Metric documentation is a fundamental asset for heritage preservation and socio-economic development, offering reusable 3D data for education and tourism.

Future steps include establishing a monitoring protocol for the long-term structural evolution of the palace. This phase of the study will be conducted with the structural and restoration team of POLITO (from DAD and DISEG).

This methodology provides a replicable model for heritage documentation projects across Africa and other developing regions.

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