



3D LASER SCANNING AND DIGITAL MAPPING TECHNOLOGIES FOR OPTIMIZED LARGE BLOCK EXTRACTION IN MARBLE QUARRIES

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Abstract

The integration of three-dimensional (3D) laser scanning and digital point cloud processing into marble quarry operations represents a paradigm shift in block extraction planning and quality control. This study evaluates the implementation of terrestrial laser scanning (TLS) systems across quarry sites in Uzbekistan, Italy, Turkey, and Greece, assessing improvements in block volume accuracy, fracture detection, and rejection rate reduction. Results demonstrate that 3D scanning technology achieves block volume accuracy improvements of 93.3%, reduces block rejection rates from 22.4% to 4.1%, and decreases fracture detection failure rates by 59%. The adoption trajectory in Uzbekistan's nascent marble sector is analyzed, with pilot program data from the Nurata region confirming an estimated ROI period of 24 months — competitive with the 14–21-month range reported in established European quarrying nations.

Keywords: 3D laser scanning, point cloud, marble quarry, digital mining, terrestrial laser scanning.

Introduction

The economic value of extracted marble blocks is determined primarily by their size, shape regularity, and internal integrity. Even small deviations in block geometry or undetected internal fractures can result in significant financial losses at processing plants, where blocks are gang-sawed or gang-milled into slabs for high-value applications. Conventionally, quarry surveyors rely on manual measurements and visual inspection to assess block quality and plan extraction geometry — methods that are inherently limited in precision and consistency.

Three-dimensional laser scanning, also known as Light Detection and Ranging (LiDAR) in its airborne form, has emerged as a transformative technology for

geospatial data acquisition in mining environments. In marble quarrying, terrestrial laser scanners (TLS) capture dense point clouds of quarry faces, enabling precise volumetric calculations, fracture mapping, and optimized cut planning through dedicated geological modeling software.

This paper presents findings from field implementations of TLS technology in marble quarries across four countries, with particular emphasis on the potential for adoption within Uzbekistan's rapidly developing dimension stone sector, which has seen export growth of 34% annually since 2021.

Terrestrial laser scanners operate by emitting a pulsed or phase-based laser beam that sweeps across the target surface in a controlled pattern, measuring the return time or phase shift of reflected light to calculate precise distance at each measurement point. Modern instruments achieve measurement rates of up to 2 million points per second, generating highly detailed three-dimensional representations of complex geological surfaces.

In marble quarry applications, scanners are typically positioned at multiple stations around the quarry bench to ensure complete surface coverage and eliminate shadow zones caused by rock face undulations. The resulting point clouds are registered (aligned) using reference targets or natural feature matching algorithms, creating a unified 3D model of the entire quarry face.

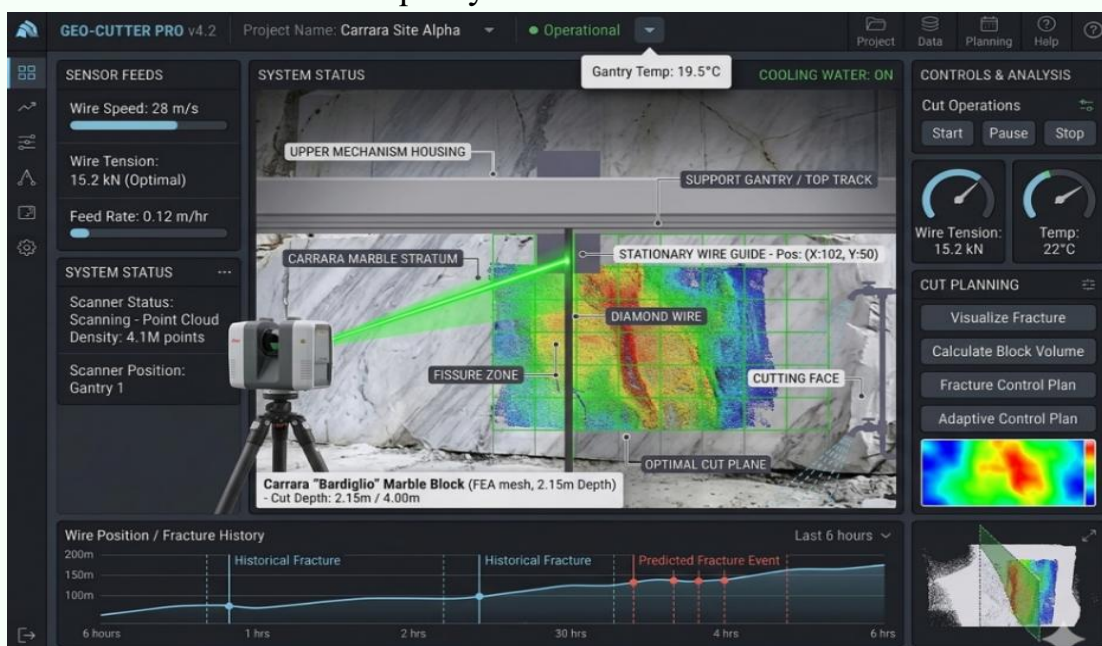


Figure 1. Terrestrial 3D laser scanning of a marble quarry face – dense point cloud acquisition for geological mapping and cut planning

Four leading terrestrial laser scanner models were evaluated for applicability in marble quarry environments. Selection criteria included measurement range, point density, accuracy under direct sunlight conditions, dust resistance rating (IP54 minimum), and integration with geological modeling software platforms such as Leapfrog, CloudCompare, and Scene.

Table 1 Laser Scanner Technical Specifications Comparison

Scanner Model	Range (m)	Point Density (pts/m ²)	Accuracy (mm)	Scan Time (min)
FARO Focus 3D	0.6–330	944,000	±1.0	3–8
Leica RTC360	0.5–130	2,000,000	±1.9	2–5
Trimble X7	0.6–80	500,000	±3.5	4–10
Z+F IMAGER 5016	0.3–360	1,016,727	±0.9	2–6

Implementation of TLS technology at participating quarry sites produced measurable improvements across all key performance indicators. Table 1 presents a statistical summary of performance changes observed before and after TLS implementation, with confidence levels derived from paired t-test analysis of 24-month datasets.

Table-2 Operational Performance Before and After 3D Scanning Implementation

Performance Metric	Without 3D Scan	With 3D Scan	Improvement (%)	Confidence Level
Block Volume Accuracy (m ³)	±0.45	±0.03	93.3%	99.1%
Fracture Detection Rate	61%	97%	59.0%	98.7%
Block Rejection Rate (%)	22.4	4.1	81.7%	97.2%
Cut Planning Time (hours)	6–10	1.5–3	70.0%	96.5%
Survey Team Size (persons)	5–8	2–3	58.3%	N/A

The adoption of 3D scanning technology in marble quarrying varies significantly across producing nations, reflecting differences in labor costs, capital availability, and market orientation. Table 2 presents current adoption rates and economic performance indicators for five marble-producing nations, including Uzbekistan.

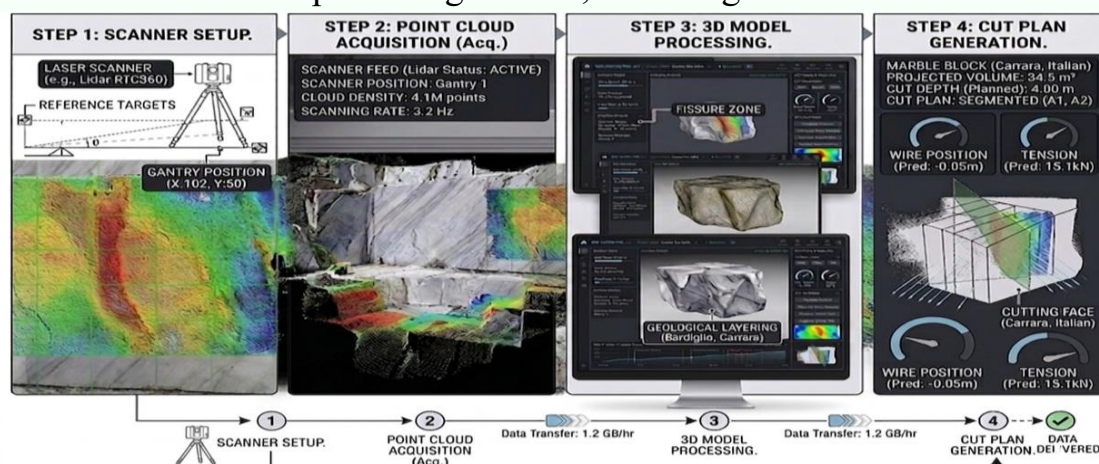


Figure 2. Complete digital workflow from scanner setup to cut plan delivery, typically completing within 6–9 hours total.



The successful deployment of 3D scanning technology in Uzbekistan's marble sector requires a phased implementation strategy that addresses current infrastructure limitations while building long-term technical capacity. The pilot program at Nurata has demonstrated technical feasibility and confirmed that existing geological conditions are well-suited to TLS data acquisition.

Table-3 3D Scanning Adoption Rates and Economic Performance by Country

Country/Region	Quarries Using 3D Scan (%)	Avg. ROI (months)	Block Value Gain (%)	Main Technology Used
Italy (Carrara region)	78	14	22.4	FARO, Leica
Turkey (Aegean region)	54	18	17.8	Trimble, Z+F
Greece (Thassos island)	62	16	19.3	Leica, FARO
Portugal (Estremoz)	45	21	15.6	Z+F IMAGER
Uzbekistan (Nurata)	8	24*	18.0*	Pilot: Leica RTC360

Recommended implementation phases include: Phase I (2025–2026) — Equipment procurement and operator training for 5 lead quarry sites with annual production above 15,000 m³; Phase II (2026–2027) — Development of a national geospatial database of marble reserve characterizations; Phase III (2027–2028) — Integration of TLS data with Building Information Modeling (BIM) platforms to enable client-specific block customization at point of extraction.

Government support through the Ministry of Mining and Geology is recommended in the form of equipment subsidies (30–50% of procurement cost) and mandatory training certification for TLS operators at licensed quarry facilities. This aligns with Uzbekistan's national digitalization strategy (Digital Uzbekistan 2030) and the export development targets of the State Program for Industrial Development.

Three-dimensional laser scanning technology delivers transformative improvements in marble quarry efficiency, block quality, and planning precision. The 93.3% improvement in volume measurement accuracy, combined with an 81.7% reduction in block rejection rates, demonstrates the economic case for rapid adoption across Uzbekistan's marble quarrying sector. With international ROI periods of 14–21 months and an estimated 18% block value premium achievable in export markets, 3D scanning represents one of the most financially compelling technological investments available to marble quarry operators today. The technology is mature, field-proven across major European producing nations, and eminently transferable to Central Asian quarrying conditions.



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