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POSSIBILITIES OF APPLYING 3D LASER SCANNING TECHNOLOGY IN MODERN ENGINEERING AND ARCHITECTURAL PROJECTS

Tashkent State Transport University

Kazakbaeva Mukhabbat Turabaevna,

Asanova Madina Asqar kizi,

Xudoyquliyeva Nozima Hamid kizi,

Ergasheva Vasila Olim kizi

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Abstract: As the demand for accuracy, speed, and efficiency in modern engineering and architecture continues to grow, advanced digital technologies — particularly 3D laser scanning methods — are playing an increasingly important role. This technology makes it possible to measure the spatial structure of real objects with high precision, and to create and analyze their three-dimensional digital models. The article examines the technical principles and advantages of 3D laser scanning, the types of static and mobile scanning, and the practical aspects of their application in engineering and architectural projects. The role of this technology in saving time and resources, improving safety, and optimizing BIM processes in construction is also highlighted.

Keywords: 3D laser scanning, mobile scanning, static scanning, point cloud, LiDAR technology, BIM, CAD systems, engineering, architecture, digital modeling, construction efficiency, spatial measurement.

1. Introduction

The demand for high accuracy, speed, and efficiency in modern engineering and architecture is growing steadily. In fields such as construction, industry, geodesy, and cultural heritage preservation, the need to precisely measure complex objects and create their digital replicas is driving the widespread adoption of advanced technologies. One such innovative technology is 3D laser scanning, which enables the measurement of geometric parameters of real-world objects and structures with high precision and the creation of their three-dimensional digital models.

3D laser scanning operates remotely, without direct contact with the object. In this process, laser beams are directed at the surface of an object and, based on the returning signal, the spatial coordinates of points are determined. The result is a "point cloud" consisting of millions of points. This data is then processed using specialized software to create an accurate three-dimensional model of the object, providing detailed information about its geometric shape, dimensions, and technical condition.

In engineering, 3D laser scanning is widely used for designing and monitoring industrial facilities, energy structures, transport infrastructure, and construction sites. For example, creating accurate digital models of existing buildings and industrial installations enables the efficient organization of reconstruction and modernization works. The technology is also highly valuable for monitoring the condition of complex engineering systems, detecting deformations, and assessing

safety levels. While traditional measurement methods are time- and labor-intensive, laser scanning allows large volumes of data to be collected in a short time.

In architecture and construction, 3D scanning is used for building design, construction process control, and quality assessment of completed structures. When used in conjunction with BIM (Building Information Modeling) technology, it enables the identification of discrepancies between the design and the actual state of the structure. This helps reduce construction errors, optimize material usage, and shorten project timelines.

3D laser scanning is also an important tool in the preservation and restoration of cultural heritage sites. Creating accurate digital replicas of historic buildings, architectural monuments, and archaeological sites is crucial for passing them on to future generations. Digitized models document the current condition of objects, monitor changes over time, and provide a scientific basis for restoration projects. Furthermore, virtual museums and digital tours allow cultural heritage to be presented to a wider public.

The key advantages of 3D laser scanning include high accuracy, fast data collection, the ability to fully capture complex geometric shapes, and the reduction of human error. The ability to study hazardous or difficult-to-access areas remotely is another important benefit. However, the need for powerful computing hardware and specialized software to process large volumes of data is considered one of its limitations.

In recent years, advances in artificial intelligence, cloud computing, and digital twin technology have further expanded the capabilities of 3D laser scanning. Automated data analysis, virtual modeling of objects, and real-time monitoring are improving the efficiency of industrial and construction processes. In the future, the precision and speed of this technology are expected to increase further, broadening its range of applications.

2. Methods

During the study, the main types of 3D laser scanning technology, their technical characteristics, and practical applications were examined in detail. Laser scanning systems used in modern geodesy, construction, industry, and architecture are generally divided into two types based on their operating method:

- Static 3D laser scanning;
- Mobile 3D laser scanning.

In static 3D laser scanning, the scanner is placed at a fixed point and measures the coordinates of surrounding objects with high accuracy. The laser beams, reflected from object surfaces, generate a spatial dataset — a point cloud — consisting of millions of points. Data collected from multiple scanning positions are merged using specialized software, resulting in a complete three-dimensional model of the object or area. Static scanning is widely used for engineering structures, historic buildings, industrial facilities, and complex constructions that require high accuracy. Its main advantage is the high precision and reliability of the measurement results.

Mobile 3D laser scanning allows for fast data collection, with the scanner operating while in motion. Mobile systems can be mounted on handheld devices, wheeled platforms, vehicles, backpacks, or unmanned aerial vehicles. An operator can move freely throughout an area, scanning large spaces in a short time. This method is especially effective for documenting transport

infrastructure, urban planning objects, industrial zones, and complex indoor spaces. A key advantage of mobile scanning is the ability to collect large volumes of data quickly; its disadvantage is that accuracy may be slightly lower than static scanning in some cases.

The study also examined the integration of 3D laser scanning with modern digital construction and design systems — in particular, integration with BIM (Building Information Modeling). BIM systems incorporate not only the geometric model of a building or structure, but also its technical, economic, and operational data. Point clouds obtained from laser scanning can be imported into a BIM environment, enabling the creation of accurate digital replicas of existing objects. This allows for the identification of discrepancies between the design and reality, control of construction processes, and efficient organization of reconstruction works.

The compatibility of mobile scanning systems with CAD (Computer-Aided Design) software was also investigated. It was found that integrating scanner data into platforms such as AutoCAD, Civil 3D, Revit, and ArchiCAD allows for the creation of engineering drawings, three-dimensional models, and technical documentation, reducing the need for additional measurements and saving time and financial resources.

Cloud-based data storage and sharing were also examined. Cloud platforms allow large point cloud datasets to be stored remotely, processed, and quickly shared among various specialists, ensuring effective collaboration and unified data management.

Additionally, real-time monitoring capabilities were analyzed. Mobile laser scanning systems can be used for regular monitoring of construction sites, industrial facilities, and transport infrastructure, enabling rapid detection of deformations or changes, improving technical safety, preventing emergencies, and reducing operating costs.

The results showed that both static and mobile 3D laser scanning technologies have their own distinct advantages, and their application depends on the project's objectives, the complexity of the object, and the required level of accuracy. Integrated with modern BIM, CAD, and cloud technologies, these systems are becoming an essential component of the digital transformation of engineering and architecture.

3. Results

In recent years, 3D laser scanning technology has been recognized as one of the fastest-growing digital geospatial technologies on the global market. The acceleration of digitization processes, the rise of automation in construction and industry, and the growing demand for accurate spatial data have significantly increased interest in this technology. According to analyses, the total market volume of 3D laser scanning reached approximately $4 billion USD by 2025 — a figure reflecting its widespread use not only in engineering and construction, but also in geodesy, industry, transport, energy, architecture, and the digitization of cultural heritage sites.

A key driver of market growth has been the increasing popularity of mobile 3D scanning systems. While traditional static scanning ensures high accuracy, mobile technologies stand out for their speed of data collection, processing, and practical application. Modern mobile scanners combine laser sensors, high-resolution cameras, inertial navigation systems (IMU), GNSS receivers, and artificial intelligence algorithms, enabling users to digitize complex objects and large areas in a short time.

One of the key advantages of mobile scanning systems is the ability to create colorized three-dimensional images. Modern scanners integrated with digital cameras attach real color information to the point cloud obtained via laser. The result is an accurate representation of not just the geometric shape, but also the visual appearance of objects — of great value in architecture, cultural heritage documentation, and construction monitoring.

Another important advantage is the technology's adaptability. Mobile scanners can effectively scan narrow corridors, complex industrial structures, underground utilities, interior spaces of historical monuments, and areas that are difficult for humans to access — a significant advantage over traditional geodetic methods. Particularly in hazardous or restricted areas, the ability to collect data remotely improves worker safety.

Mobile systems also provide operators with considerable freedom of movement. During scanning, specialists can move freely around an object, significantly reducing data collection time. SLAM (Simultaneous Localization and Mapping) algorithms track the operator's movement trajectory and bind all data to a unified coordinate system, resulting in a complete and continuous digital model of complex areas.

Fast data processing is another key advantage. Modern software can process data, form point clouds, and display preliminary results during the scanning process itself, allowing project participants to assess the condition of an object on-site and make decisions quickly. As a result, this technology is increasingly used in construction monitoring, industrial surveillance, and emergency assessment.

Ease of use and intuitive interfaces are also contributing to the technology's growing adoption. While laser scanning systems once required highly specialized operators, today many devices are equipped with automated software tools, allowing new users to learn and effectively use the technology in a short time.

A vivid example of the popularization of mobile scanning technology is the introduction of a LiDAR sensor in Apple's iPad Pro. This innovation brought laser scanning from professional environments to the mass consumer market. With the LiDAR sensor, users can create 3D models of rooms and small objects, use augmented reality (AR) applications, and perform basic measurement tasks — giving further impetus to the broader adoption and cost reduction of laser scanning technologies.

Research in the construction industry also confirms the economic efficiency of 3D laser scanning. Studies indicate that project delays and cost overruns are among the most pressing problems in large construction projects — with timelines extending an average of 20% beyond planned schedules and costs exceeding initial estimates by up to 80%. One of the main causes of such problems is insufficient accuracy of object data and errors arising during the project process.

Integrating 3D laser scanning into construction processes is helping to significantly reduce these problems. Scanning accurately records the actual state of objects, discrepancies between the design and the real situation are detected early, and construction processes are effectively monitored. As a result, rework is reduced, resources are used more rationally, and project timelines are better adhered to. Research shows that in some cases, 3D scanning technology can reduce time expenditure by up to 10 times compared to traditional measurement methods.

4. Discussion

The results of the research and analysis show that 3D laser scanning technology is one of the strategically important innovative technologies in the modern AEC (Architecture, Engineering and Construction) sector. By creating opportunities to collect, process, and analyze spatial data about objects and structures with high accuracy, it significantly improves the quality of design, construction, and operational processes. Particularly in complex engineering objects and large construction projects, the use of 3D scanning plays a crucial role in ensuring data reliability, improving decision-making, and minimizing project errors.

The research results showed that the transition from static scanning systems to mobile 3D scanning technologies is a natural and inevitable stage in the industry's digital development. Static scanners, initially used to ensure high accuracy, are increasingly being replaced by more mobile, flexible, and fast systems. Mobile scanning technologies allow users to digitize large areas in a short time, process data on-site, and analyze results in real time — an important factor in improving the efficiency of construction and engineering projects.

The integration of mobile 3D scanning systems with Internet of Things (IoT) technologies is also opening up new possibilities. Scanning equipment connected to various sensors, smart devices, and monitoring systems creates the ability to exchange data in real time, continuously monitor the technical condition of objects, and quickly detect emerging changes. As a result, construction sites, industrial structures, and transport infrastructure are continuously monitored, significantly improving safety levels. This approach also serves as an important foundation for implementing the Digital Twin concept in practice.

Current trends show that mobile 3D laser scanning technologies are being applied ever more broadly in construction and architecture. This technology is not only a tool for improving project quality, but also for achieving economic efficiency. By creating accurate digital models of objects, rework is reduced, errors in construction processes are identified in advance, and project costs can be optimized — resulting in more efficient use of time and financial resources.

The significance of 3D laser scanning is also growing in infrastructure projects. For designing and monitoring roads, bridges, railway networks, tunnels, and engineering utilities, this technology serves as a source of highly accurate data. The role of laser scanning is equally invaluable in the preservation and restoration of historical and cultural heritage sites. Digitized models make it possible to document the current condition of monuments, track deformations, and develop scientifically grounded restoration projects.

In urban planning and regional planning, 3D laser scanning is also gaining importance. Within the framework of modern "Smart City" concepts, high-accuracy three-dimensional data are widely used for developing transport systems, managing land resources, conducting ecological monitoring, and performing urban analyses — contributing to more efficient and sustainable development of future urban infrastructure.

In general, 3D laser scanning technology is an integral part of the digital transformation being carried out in engineering and architecture. It creates the opportunity to increase measurement accuracy, accelerate work processes, reduce human error, and make effective management decisions based on data. The development of mobile scanning systems and their integration with

BIM, IoT, artificial intelligence, and cloud technologies is laying the groundwork for construction and engineering to become even more automated and digitized in the future.

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