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LASER SCANNING AND CREATION OF A BIM MODEL OF THE BUILDING No. 1 NTUU "IGOR SIKORSKY KPI" AS A METHOD OF VISUALIZING HISTORICAL AND ARCHITECTURAL HERITAGE

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Abstract. *The article describes a comprehensive approach to obtaining and processing data after terrestrial laser scanning of an architectural monument and* *creating a BIM model of a fragment of the facade of a historic building – the First Building of the Igor Sikorsky Kyiv Polytechnic Institute. In the course of this work, modern methods of spatial fixation of the object under study were used, including high-precision 3D scanning with a Leica ScanStation C10 scanner, point cloud registration, data filtering, and the results of their further processing in Leica Cyclone REGISTER 360 and Autodesk ReCap software, and the construction of an informational 3D model of this building in the Autodesk Revit environment.*

Foreign and domestic experience in performing such work has been analyzed. It has been shown that one of the most effective methods of spatial documentation is terrestrial laser scanning (TLS), which provides a high-precision point cloud that reflects the actual shape of an object with an accuracy of several millimeters. International studies show that Scan-to-BIM technology is key in the processes of digital restoration and planning of reconstructions of historical objects. It is noted that Ukraine lacks systematic applied research that would combine these technologies into a comprehensive algorithm for specific historical and architectural objects. This circumstance indicates the practical importance of this research and the need for further development of methods for documenting historical facades using modern geodetic and geoinformation technologies.

The article pays particular attention to ensuring high data accuracy, station registration algorithms, scan parameter selection, and the potential for further use of the model in restoration work, technical condition monitoring, and digital conservation of cultural heritage objects. The LOD 300 model confirms the possibility of high-quality reproduction of the geometry of historical objects using Scan-to-BIM technology in the Ukrainian context.

Keywords: *terrestrial laser scanning, point cloud, TLS, BIM model, Scan-to-BIM, digital preservation, historic building, architectural heritage, Autodesk Revit, Leica ScanStation C10, point cloud registration, Cyclone REGISTER 360, HBIM, facade restoration, 3D modeling, geodetic documentation, information modeling, measurement accuracy, LOD 300, digital reconstruction.*

Relevance of the study. In today's world, preserving Ukraine's architectural and historical-cultural heritage is super important. Russia's military aggression, the physical deterioration of buildings, not enough money for restoration work, and the lack of systematic digital documentation are leading to the loss of unique architectural sites that are part of our national cultural heritage. The high risk of destruction of buildings under the influence of external factors requires the introduction of new technologies for recording their actual condition, which are capable of ensuring the long-term preservation of information about the geometry, structural features, and architectural details of historical objects.

One of the most effective methods of spatial documentation is terrestrial laser scanning (TLS). It provides a highly accurate point cloud that reflects the actual shape of an object with an accuracy of several millimeters. The collected data allows for the digital preservation of monuments, the creation of comprehensive information models, the analysis of deformation processes, and the planning of restoration measures. In conditions of military action, such digital models can become the only source of information about the original appearance of an object in the event of its partial or complete destruction [4; 5].

The use of BIM technologies significantly expands the possibilities for analyzing and recreating architectural objects. The combination of point clouds with parametric modeling allows you to create 3D models of LOD 300 and above, which not only reflect geometry but also provide the ability to add information attributes, integrate design data, and further use the model for restoration, scientific, or design purposes. International studies indicate that Scan-to-BIM technology is key in the processes of digital restoration and planning of reconstructions of historical objects, especially those with complex architectural plasticity, numerous decorative elements, and surface irregularities [9; 10].

In the context of the growing need for digital inventory of architectural monuments in Ukraine, the development and practical application of methods for creating BIM models of historical facades based on laser scanning is relevant and in line with global trends in the industry. The use of such technologies contributes to the efficiency of repair work, ensures the reliability of geometric information, and creates a solid foundation for the preservation of cultural heritage in the face of modern threats.

Review of recent studies and publications. In global scientific literature, the issue of three-dimensional documentation of historical objects and the creation of their digital models based on laser scanning has been studied for over two decades. A significant contribution to the formation of the theoretical and methodological foundations of digital recording of architectural heritage was made by the works of M. Murphy, S. Pavia, and E. McGovern, in which the concept of HBIM (Historic Building Information Modeling) was proposed and the use of BIM modeling for the reconstruction and restoration of historical buildings was justified [1].

The studies by F. Remondino and A. Rizzi examine in detail the processes of combining terrestrial laser scanning and photogrammetry, which allow the creation of high-precision digital copies of architectural objects, including complex facade structures, decorative elements, and cultural heritage objects [2]. The authors emphasize that the use of point clouds in combination with modern modeling algorithms provides the accuracy required for restoration work.

R. Volk, J. Stengel, and F. Schultmann made a significant contribution to the study of the possibilities of BIM technologies for modeling existing buildings. They systematized the advantages and limitations of BIM application in the reconstruction of various types of structures and emphasized the importance of using TLS data to create as-built models [3]. These works emphasize that the accuracy of the initial geodetic data is a key condition for further parametric modeling.

The studies by C. Dore and M. Murphy separately emphasize the importance of automating the processes of detecting facade elements in point clouds and transforming them into BIM objects [4]. The authors point out that the creation of algorithms for recognizing architectural forms is of great importance for speeding up the modeling process and increasing the accuracy of digital reconstruction.

The works of S. Fai, N. Graham, and their co-authors focus on the practical application of laser scanning to create high-precision digital copies of historic buildings, museums, and architectural complexes, emphasizing the importance of complete coverage of the object, correct adjustment of the scanning density, and accuracy of recording the obtained data [5].

Among the works devoted to the use of BIM in cultural heritage preservation, a significant place is occupied by the review by S. Bruno, M. De Fino, and F. Fatiguso, which examines the possibilities of HBIM as a tool for comprehensive documentation and management of historic buildings [6]. The authors note that HBIM models can combine geometric and attributive information, providing a holistic approach to the reconstruction of architectural objects.

Recent studies in 2024 have focused on integrating HBIM with methods for analyzing damage and the state of preservation of historical objects. For example, L. Zhuo and co-authors propose a multidimensional approach to analyzing damage to architectural heritage objects based on combining TLS data, optical images, and structural parameters in an HBIM environment [13]. The authors demonstrated that combining geometric and attributive data allows for a much more accurate assessment of the condition of historical facades and prediction of their further deterioration.

Another important area of recent research is presented in the work of M. Aricò (2024). It proposes a Scan-to-BIM workflow focused on creating facade degradation maps in the HBIM environment [14]. The author emphasizes the importance of automated detection of masonry defects, texture changes, and cracks based on point cloud density analysis, which is promising for restoration approaches.

A significant contribution to the standardization of digital reconstruction processes was also made by a group of researchers, M. Avena, G. Patrucco, F. Remondino, and A. Spanò, who in 2024 proposed a scalable algorithm for automating key stages of Scan-to-BIM for cultural heritage objects [15]. The work demonstrates that automatic point cloud segmentation and the generation of basic BIM model elements significantly reduce modeling time and minimize the human factor, which is particularly relevant for complex facades of historic buildings.

The issue of applying laser scanning and BIM in the context of historical heritage research is actively developing among Ukrainian scientists. In particular, recent publications have examined the possibilities of digital documentation of architectural monuments, the reproduction of objects of historical significance, and the creation of 3D models for museums and restoration projects [9–11]. These works emphasize the importance of adapting international experience to Ukrainian conditions, particularly in terms of inventorying architectural objects that are at risk of destruction.

Summarizing the data from the analysis of literary sources, we have grounds to state that TLS and BIM technologies are an integral part of modern approaches to digital modeling and preservation of architectural heritage. However, Ukraine lacks systematic applied research that would combine these technologies into a comprehensive algorithm for specific historical objects. This determines the practical importance of this study and the need for further development of methods for documenting historical facades using modern geodetic and geoinformation technologies.

Research objective. The purpose of the study is to develop and justify a methodology for creating a high-precision BIM model of the facade of an architectural monument – the First Building of the Igor Sikorsky Kyiv Polytechnic Institute – based on ground-based laser scanning data, as well as to determine the effectiveness of using TLS technology for digital recording of architectural objects. The study includes an analysis of the accuracy of the point cloud obtained, an assessment of the conformity of the BIM model with the actual state of the object, and the formation of an algorithm for the practical application of Scan-to-BIM technology for the tasks of restoration, monitoring, and digital conservation of architectural heritage.

Materials and methods of scientific research. The research materials consist of ground-based laser scanning data of the historic building's facade, obtained using a Leica ScanStation C10 scanner, as well as the results of their further processing in Leica Cyclone REGISTER 360, Autodesk ReCap, and Autodesk Revit software. Field work was carried out in urban conditions, which required the use of several scanning stations to ensure complete coverage of the facade area.

The research algorithm included the following steps and types of work:

- obtaining a point cloud using ground-based laser scanning;

- registering scans using the Cloud-to-Cloud algorithm with subsequent manual correction;
- cleaning the point cloud of extraneous objects and noise;
- exporting data in E57 and RCP formats for further work;
- creating a BIM model of the facade in Autodesk Revit by modeling the main architectural elements based on the point cloud;
- checking the accuracy of the model by superimposing the geometry on the point cloud and analyzing deviations;

The research conducted and data obtained made it possible to create a digital model of LOD 300 and perform further analysis of the geometric characteristics of the facade of the scanned architectural monument.

Research results and discussion

The research materials are presented in the form of initial geodetic measurements, point clouds obtained as a result of terrestrial laser scanning of the historic building, as well as data generated during the processing of scans in the specified specialized software. This work was carried out on the facade of a historic building, which is a valuable example of architectural heritage and has a complex geometric structure characteristic of buildings from the late 19th and early 20th centuries (Fig. 1).

Figure 1. «Facade of the first building of Igor Sikorsky Kyiv Polytechnic Institute»

Field work was carried out in conditions of limited urban space, parked vehicles, and difficult viewing angles. With this in mind, the optimal placement of scanning stations was determined taking into account the need to ensure maximum visibility of decorative elements and minimize “dead zones” on the facade (Fig. 2).

A Leica ScanStation C10 terrestrial laser scanner (Fig. 3) was used to collect primary data. This scanner is widely used in architectural and deformation surveying. The main technical characteristics of the scanner used in our work are listed below:

- Working range – up to 300 m;
- Actual measurement accuracy – up to 6 mm per 50 m;
- Scanning speed – up to 50,000 points/s;
- Color imaging capability when using an external camera.

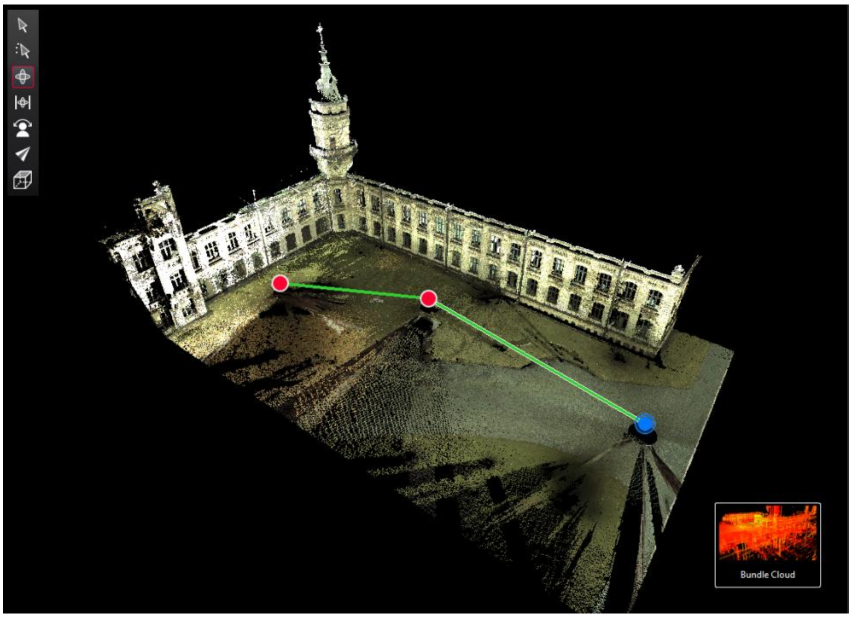

Figure 2. Location of scanning stations in the field

Scanning was performed at a standard density suitable for modeling the facades of historic buildings, with an emphasis on the detailing of small architectural forms [7; 8].

Figure 3. Leica Total ScanStation C10

During field surveys, several stations were set up and the object was scanned from them. This approach ensured complete coverage of the facade and its spatial fixation from different angles. The location of the stations was based on the principle of overlapping the scanned surface by at least 30–40%, which ensured high-quality registration at the point cloud merging stage.

Initial registration and processing of scans were performed using Leica Cyclone REGISTER 360 software, which allowed:

- Perform automatic preliminary stitching of data from stations;
- Perform manual registration in areas with insufficient overlap;
- Optimize the point cloud by removing noise and artifacts;
- Check the accuracy of registration;
- Export data in E57 and RCP formats for further 3D modeling;

The connection between stations was checked using Cloud-to-Cloud registration tools. The average deviation was no more than 8–10 mm (Fig. 4), which meets the requirements for facade modeling at LOD 300 detail level [3, 6].

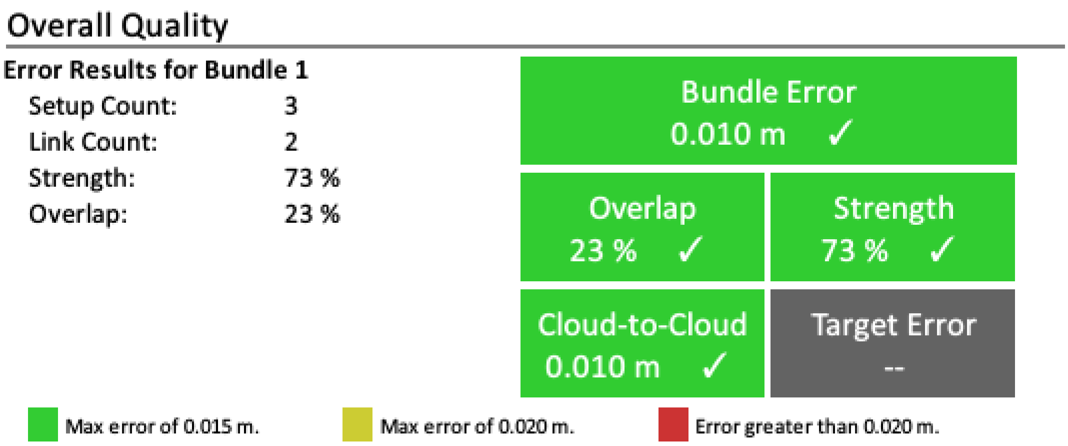

Figure 4. Excerpt from the final report on stitching quality results

After importing the point cloud in RCP format into Autodesk Revit, the basic spatial structure of the model was formed (Fig. 5):

- A grid of levels was created in accordance with the actual structural horizontal lines;
- The main axes of the facade have been determined;
- The model coordinates have been linked to the point cloud;

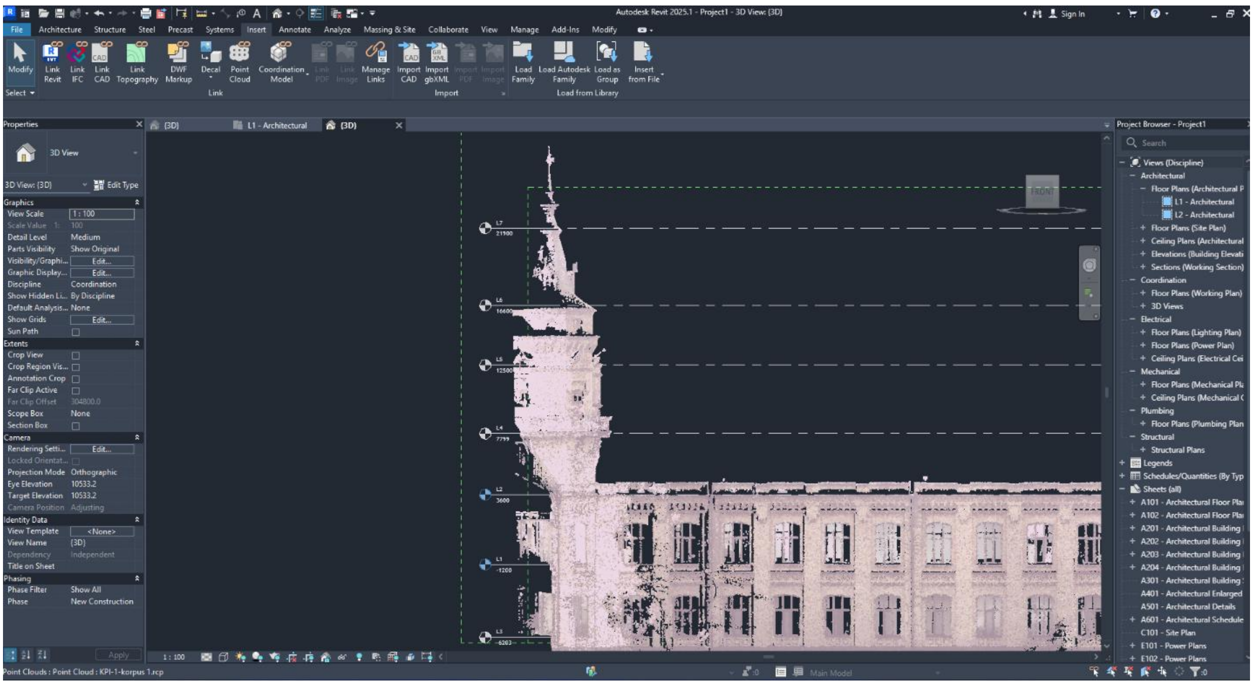

Figure 5. Elevation system in Autodesk Revit 2025

The main outline of the building walls was formed using the Wall tool, with the thickness and position of each wall refined based on a point cloud. Analysis of the graphic intersections showed deviations between the actual surface and the model not exceeding 5 mm, which meets the requirements for LOD 300 [6].

The facade architecture features numerous arched openings. The following were used to model them (Fig. 6):

- profile modeling tools;
- in-place families,
- simulation of arcs based on cloud points;

Complex building profiles were modeled using:

- Sweep,
- Extrusion,
- Construction of individual families;

Creating profiles required laying down a significant number of control cross-sections of the point cloud. This approach ensured accurate reproduction of curved architectural forms, which was one of the important tasks in improving the methodology for scanning buildings and creating their 3D models.

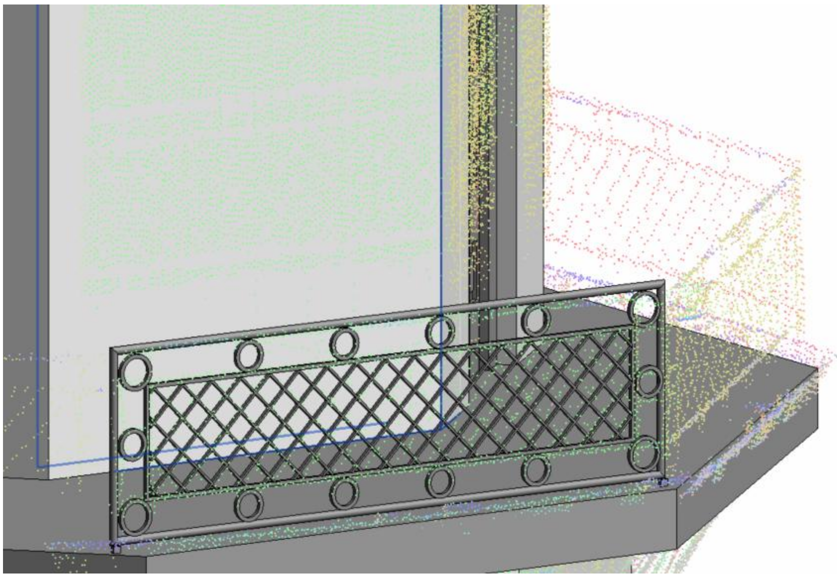

Figure 6. Parametric family of fences

To confirm the accuracy of the model, BIM elements were superimposed on the point cloud. Control sections showed that:

- The average deviation is 3.2 mm;
- The maximum deviation reaches 8 mm in areas of damaged masonry;
- The minimum deviation is 1.5 mm;

The results obtained comply with international standards for modeling historical facades (Figs. 7-8) [1; 4; 12].

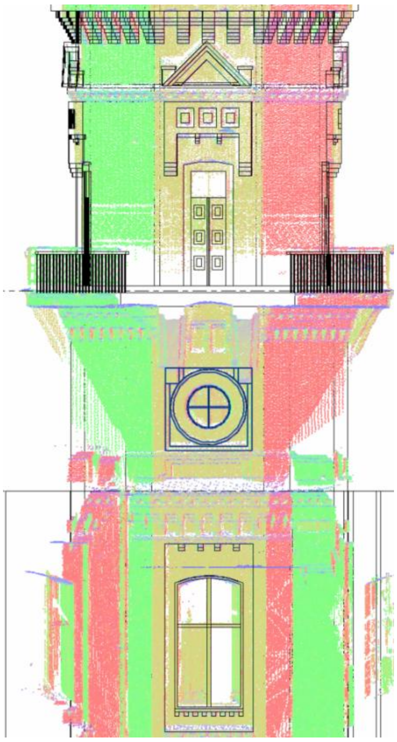

Figure 7. High-precision 2D drawing based on a BIM model

Figure 8. Current state of the first building of Igor Sikorsky Kyiv Polytechnic Institute (fragment – right tower)

Conclusions.

As a result of the study, a comprehensive analysis of the possibilities of using terrestrial laser scanning and BIM modeling technologies for documenting and digitally reconstructing historical architectural objects was carried out. Based on the data obtained, an information model of a fragment of the facade of a historic building was created, which made it possible to comprehensively assess the effectiveness of the Scan-to-BIM methodology in the preservation of cultural heritage.

Firstly, it has been established that the use of terrestrial laser scanning provides high-quality and informative point clouds with sufficient detail to reproduce complex architectural forms. The use of multiple scanning stations and scan overlap techniques has made it possible to achieve spatial consistency of data and reduce the number of “dead zones,” which is an important condition for working with historical objects that may contain numerous small details and surface irregularities. The average registration errors did not exceed the values acceptable in geodesy, which indicates the high accuracy of the obtained output data.

Secondly, the creation of a BIM model in Autodesk Revit confirmed the possibility of high-precision reproduction of the facade geometry based on a point cloud. The use of BIM tools made it possible to simulate the main structural elements: arched openings, cornices, profiled belts, and other decorative components of the building. The resulting LOD 300 model reproduces the actual state of the facade and can be effectively used in further restoration, design, and research work.

In general, the study confirms the high efficiency of laser scanning and information modeling technologies in the field of documentation and restoration of historic facades. The algorithm used can be adapted for research on a wide range of architectural objects and serve as a methodological basis for further scientific and practical work on the digital documentation of Ukraine's cultural heritage.

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ЛАЗЕРНЕ СКАНУВАННЯ І СТВОРЕННЯ BIM МОДЕЛІ КОРПУСУ № 1 НТУУ «КПІ ІМЕНІ ІГОРЯ СІКОРСЬКОГО» ЯК МЕТОД ВІЗУАЛІЗАЦІЇ ІСТОРИКО-АРХІТЕКТУРНОЇ СПАДЩИНИ

Анотація. *У статті охарактеризовано комплексний підхід до отримання та опрацювання даних після наземного лазерного сканування пам’ятки архітектури та створення BIM-моделі фрагмента фасаду історичної будівлі – Першого корпусу НТУУ «КПІ імені Ігоря Сікорського». У процесі виконання цієї роботи застосовано сучасні методи просторової фіксації досліджуваного об’єкта, включаючи високоточне 3D-сканування за допомогою сканера Leica ScanStation C10, реєстрацію хмар точок, фільтрацію даних та результати їх подальшого опрацювання у програмному забезпеченні Leica Cyclone REGISTER 360, Autodesk ReCap і побудову інформаційної 3D моделі цієї будівлі в середовищі Autodesk Revit.*

Проаналізовано зарубіжний та вітчизняний досвід виконання робіт такого змісту. Показано, що одним із найефективніших способів просторового документування є наземне лазерне сканування (TLS), яке забезпечує отримання високоточної хмари точок, яка відображає реальну форму об’єкта з точністю до кількох міліметрів. Міжнародні дослідження свідчать, що технологія Scan-to-BIM є ключовою у процесах цифрової реставрації та планування реконструкцій історичних об’єктів. Зазначено, що в Україні бракує систематизованих прикладних досліджень, які б поєднували ці технології у комплексний алгоритм для конкретних історико-архітектурних об’єктів. Ця обставина вказує на практичну важливість даного дослідження та необхідність подальшого розвитку методик документування історичних фасадів із використанням сучасних геодезичних і геоінформаційних технологій.

Особливу увагу у статті приділено питанням забезпечення високої точності набору даних, алгоритмам реєстрації станцій, вибору параметрів *сканування та можливостям подальшого використання моделі у реставраційних роботах, моніторинзі технічного стану та цифровій консервації об'єктів культурної спадщини. Модель рівня LOD 300 підтверджує можливість якісного відтворення геометрії історичних об'єктів із застосуванням технології Scan-to-BIM в українських реаліях.*

Ключові слова: *наземне лазерне сканування, хмара точок, TLS, BIM-модель, Scan-to-BIM, цифрова консервація, історична будівля, архітектурна спадщина, Autodesk Revit, Leica ScanStation C10, реєстрація хмар точок, Cyclone REGISTER 360, HBIM, реставрація фасадів, 3D-моделювання, геодезичне документування, інформаційне моделювання, точність вимірювань, LOD 300, цифрова реконструкція.*