ECONOMIC EFFICIENCY OF METHODS FOR SURVEYING RURAL INFRASTRUCTURE: ASSESSMENT OF ACCURACY, COST AND DURATION

Ivan Openko, Oleksandr Shevchenko, Yanina Stepchuk,
Ruslan Tykhenko, Olha Tykhenko, Anastasiia Horodnycha
National University of Life and Environmental Sciences of Ukraine, Ukraine
ivan_openko@ukr.net, shevchenko_ov90@ukr.net, stepchuck.yanina@gmail.com,
rvtyhenko@ukr.net, olgavfrank@ukr.net, 777nastya10@gmail.com

Abstract. The study delves into a pivotal realm of rural infrastructure management by scrutinizing the efficacy of diverse building survey methodologies. The assessment encompassed laser scanning, total station surveying, and smartphone-enabled LiDAR, encompassing a meticulous evaluation across key dimensions: accuracy, economic cost, and time efficiency. The overarching objective was to pinpoint the most optimal surveying approach tailored for rural landscapes, considering the delicate equilibrium between cost-effectiveness and precision. The study findings illuminate a multifaceted landscape of trade-offs inherent in these methodologies. The findings revealed that the Total Station method, utilizing the GEOMAX ZOOM 10 (2”), emerged as the most expensive among the building measurement techniques, with a cost of 185.04 euros. However, it demonstrated the highest accuracy with an RMS (Root Mean Square) value of 0.0135 m. In contrast, Laser scanning employing the Leica ScanStation C10 had a cost of 149.85 euros, with an RMS value of 0.0205 m. The Lidar method using the iPhone 13 Pro, while being the third most expensive at 128.48 euros, exhibited a comparatively lower accuracy with an RMS value of 0.1694 m. By navigating the intricate interplay between economic considerations and the imperative for precise infrastructure management, this study endeavours to foster sustainable, efficient, and economically viable approaches in rural infrastructure development. The insights garnered herein endeavour to bridge the gap between precision and financial prudence, fostering a pragmatic balance in survey method selection for rural infrastructure initiatives.

Keywords: economic assessment, surveying, rural infrastructure, comparative analysis, LiDAR technology.

Introduction

The economic efficiency of surveying methods in the context of rural infrastructure is a focal point in contemporary research, as the need for optimized resource utilization and sustainable development becomes increasingly imperative. This article delves into the intricate interplay of accuracy, cost, and duration assessment, seeking to provide a comprehensive understanding of the economic viability of surveying techniques deployed in rural infrastructure projects.

Some scholars have delved into the intersection of economic considerations and surveying methodologies, contributing valuable insights to this evolving discourse. Notably, Martyn A., Openko I., Ievsiukov T., Shevchenko O., Ripenko A. [1] pioneered research in economic feasibility of implementation of topographic and geodetic works, laying the groundwork for subsequent investigations into the economic dimensions of surveying practices. In their study, the researchers examined the delicate relationship between accuracy and economic viability in a rural context, in particular: definition of the dependence of the cost of topographic and geodetic works in the field of land management on the accuracy of these works; estimation of the efficiency of using modern satellite technologies for the purpose of the real estate cadastre (especially, when installing (fixing) the turning points of the land plot within the permissible error of 0.5 meters), and determining the prospects for using the mobile gadgets for these purposes; establishment of acceptable accuracy of topographic and geodetic surveys in the real estate cadastre depending on the market value of the land plot.

The integration of cutting-edge technologies in surveying, such as laser scanning and LiDAR, has been a focal point of exploration for researchers like He G. B., Li L. L. [4], Lam N., Nathanson M., Lundgren N., Rehnström R., Lyon S. W. [5]. Their work has illuminated the potential of these technologies to enhance both accuracy and cost-effectiveness in rural infrastructure surveys. Additionally, Chumachenko O. M., Kryvoviaz E. V. [6] have made significant contributions in assessing the economic implications of surveying durations, providing crucial insights into time efficiency considerations in rural projects.

The study by Tran H., Khoshelham K., Kealy A. delves into techniques for detecting changes in building structures over time, employing Lidar data and BIM for accurate and efficient analysis [8], 9]. Kuçak, R. A., Erol, S., & İşiler, M. [10] evaluated the precision and reliability of different lidar systems,

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providing insights into their performance and applicability in various domains such as remote sensing, geospatial analysis, and environmental monitoring.

It is common in research to prioritize accuracy assessments without delving into the cost-effectiveness of measurement methods. This often occurs due to the complexities involved in quantifying economic factors and the focus on technical aspects in many studies. However, incorporating cost-effectiveness analysis alongside accuracy assessments can provide a more comprehensive understanding of the practical implications and feasibility of different measurement methods in real-world applications.

The scientific novelty of our study lies in the comprehensive assessment of building measurement techniques, considering both accuracy and cost-effectiveness. While previous research has often focused solely on accuracy evaluations, our study uniquely integrates economic considerations into the analysis. By comparing the accuracy and costs associated with Total Station, Laser scanning, and Lidar methods, we provide valuable insights into the trade-offs between precision and economic efficiency.

Materials and methods

The study was conducted within the 6-th academic building of the National University of Life and Environmental Sciences of Ukraine in Kyiv (Fig. 1). The choice of this particular building as a research object was based on its significance and ease of access for geodetic measurements under martial law. The main focus of the analysis was on the façade of the building, chosen because of its typicality to stone buildings, infrastructure in rural areas, which serves as an appropriate benchmark for comparing different geodetic methods and assessing their effectiveness.

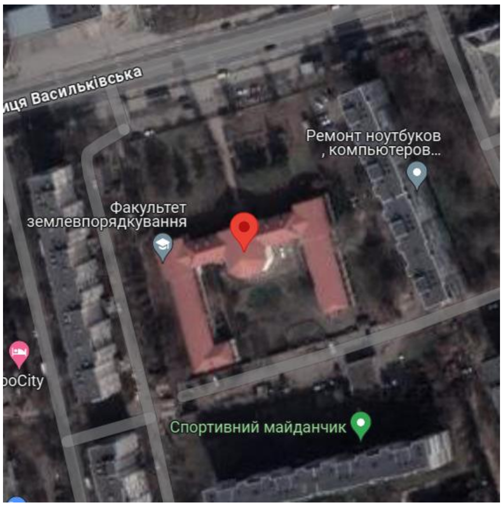

Fig. 1. **National University of Life and Environmental Sciences of Ukraine in Kyiv, 6-th academic building, source: created by the authors Google maps**

In order to guarantee the precision and dependability of the diverse surveying techniques, numerous control points were strategically positioned on the exterior of the educational building. These control points served as benchmarks, enabling a comprehensive scrutiny of the data acquired through each survey method. The meticulous positioning of these control points facilitated the examination of measurement discrepancies and calibration variations among the distinct survey instruments.

Three distinct surveying methodologies were employed to acquire in-depth information about the building.

- Lidar survey (Fig. 2): The lidar survey was conducted using an iPhone 13Pro smartphone equipped with lidar technology. This cost-effective alternative to traditional lidar systems allowed for the collection of point cloud data on the building facade, as illustrated in Fig.2. The smartphone lidar capabilities provided an affordable yet efficient means of obtaining detailed information about the structure.

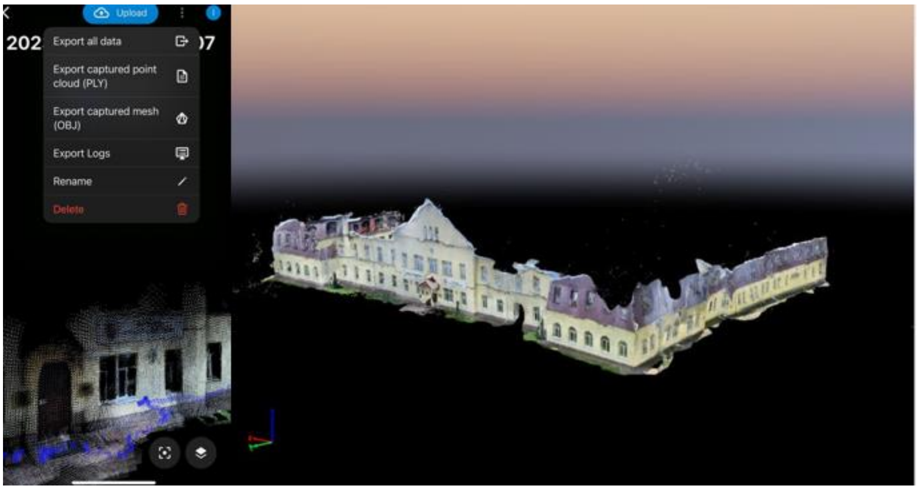

Fig. 2. **Building model using the iPhone 13Pro smartphone lidar, source: created by the authors using specialized software tools (PIX4Dcatch, Pix4Dmapper)**

- Laser scanning: Utilizing a Leica ScanStation C10 laser scanner, the study captured a comprehensive 3D representation of the facade through the generation of a point cloud. The laser scanner, strategically positioned at various stations around the building, facilitated the creation of an intricate 3D image (Fig. 3).

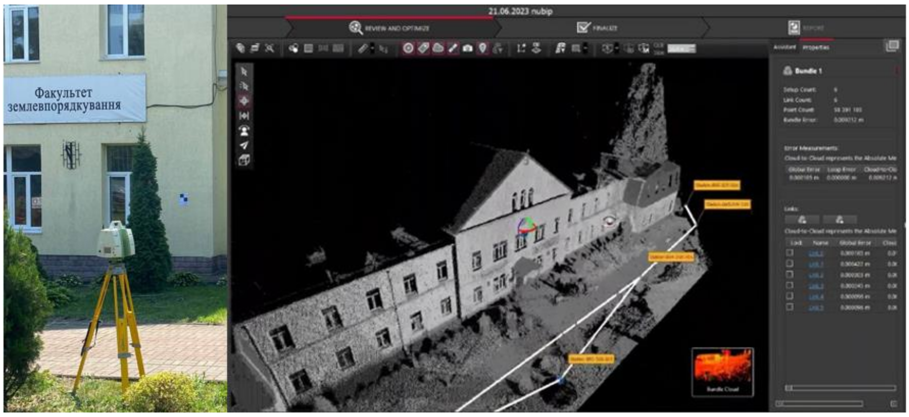

Fig. 3. **3D model of the building created by using laser scanning source: created by the authors using specialized software tools (Leica Cyclone, CREDO 3D)**.

- Total station survey (Fig. 4): Employing a GEOMAX ZOOM 10 (2”) total station in conjunction with a GNSS receiver, a contour of the building facade was meticulously outlined. This surveying method provided precise measurements of both angles and distances, resulting in generation the model of the building.

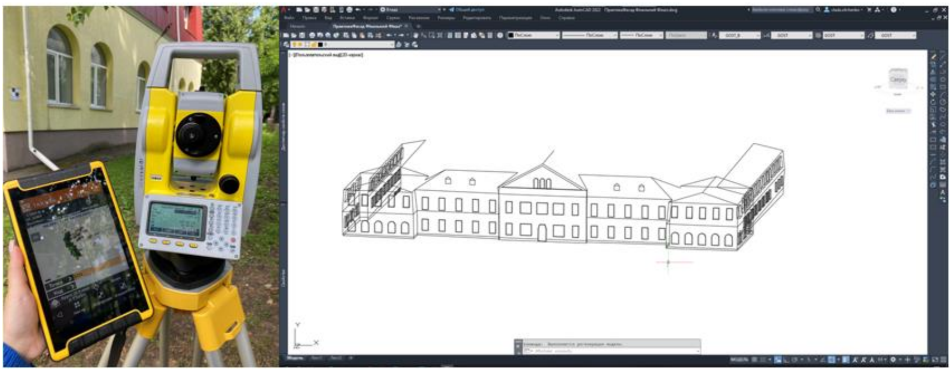

Fig. 2. **Building model created by total station survey source: created by the authors using specialized software tools (AutoCAD)**

Results and discussion

During the initial stage of our research, we assessed the precision of surveying techniques in measuring distances between control points on the stone structure of the 6th academic building at the National University of Life and Environmental Sciences of Ukraine in Kyiv. Subsequently, the distances obtained were juxtaposed with control measurements to gauge the accuracy of the three distinct survey methods (Table 1).

Table 1

Evaluation of measurement techniques

Lines between the control points	**Control measurements, m**	**Laser scanning, m**	**Δ*L*, m**	**Total Station, m**	**Δ*L*, m**	**Lidar (iPhone 13 Pro), m**	**Δ*L*, m**
1-2	10.4300	10.4427	-0.0127	10.4399	-0.0099	10.3967	0.0333
4-5	16.4700	16.4593	0.0107	16.4840	-0.0140	16.5503	-0.0803
7-8	12.7700	12.8014	-0.0314	12.7860	-0.0160	13.0502	-0.2802
		Total	-0.0334	Total	-0.0399	Total	-0.3272
		Mean	-0.0111	Mean	-0.0133	Mean	-0.1091
		RMS (Root mean square)	0.0205	RMS	0.0135	RMS	0.1694

The second stage of the study focused on ascertaining the economic efficacy of various building measurement methods. This stage aimed to determine the economic value associated with the use of different building measurement methods (Table 2) [5], 6].

Table 2

Economic assessment of the cost of building measurements

Indicators		**Laser scanning (Leica ScanStation C10)**	**Total Station (GEOMAX ZOOM 10 (2”))**	**Lidar (iPhone 13 Pro)**
RMS (Root mean square), m		*0.0205*	*0.0135*	*0.1694*
Lead time, hour	- field measurements, hour	3	48	1
	- cameral processing, hour	24	24	72
	Total, hour	27	72	73
Number of employees, persons		1	1	1
Average salary in Ukraine (Surveyor), EUR·hour^{-1}		1.26	1.26	1.26
Rent for the necessary surveying equipment, EUR·hour^{-1}		4.05	1.01	0.11
Fee for the use of special software, EUR·hour^{-1}		0.24	0.30	0.39
Total of measurement, EUR		149.85	185.04	128.48

Source: own calculations based on the data from: the State Statistics Service of Ukraine, official distributor of surveying equipment System Solutions

The findings revealed that the Total Station method, utilizing the GEOMAX ZOOM 10 (2”), emerged as the most expensive among the building measurement techniques, with a cost of 185.04 euros. However, it demonstrated the highest accuracy with an RMS (Root Mean Square) value of 0.0135 m. In contrast, Laser scanning employing the Leica ScanStation C10 had a cost of 149.85 euros, with an RMS value of 0.0205 m. The Lidar method using the iPhone 13 Pro, while being the third most expensive at 128.48 euros, exhibited a comparatively lower accuracy with an RMS value of 0.1694 m. The decision on which method to employ should thus consider the specific requirements and constraints of the project, aiming to achieve the optimal balance between economic efficiency and measurement accuracy.

The Total Station method emerges as the most expensive yet highly accurate option, whereas Laser scanning offers a slightly lower cost with respectable accuracy. On the other hand, Lidar, while the most cost-effective, sacrifices some accuracy compared to the other methods.

Conclusions

In conclusion, the study underscores a significant trade-off between measurement accuracy and costs, with the Total Station method exhibiting the highest precision but at a correspondingly elevated cost. The Laser scanning method, while offering commendable accuracy, comes at a lower cost compared to Total Station. Notably, the Lidar method emerges as the most cost-effective, being up to 30% cheaper than the Total Station.

The study found a discernible relationship between measurement accuracy and cost, where higher precision tends to be associated with increased expenditure. The correlation coefficient for this relationship was calculated as -0.81, indicating a strong negative correlation between the accuracy of measurement methods and their respective costs. Moreover, a robust correlation was observed between the Root Mean Square (RMS) values and the expenses related to software for processing measurement results, denoted by a correlation coefficient of 0.90. This implies a substantial positive relationship, indicating that higher costs for software are associated with increased precision in measurement results. Furthermore, a notable correlation coefficient of 0.64 was identified between RMS values and equipment rental costs. This correlation suggests a positive relationship, indicating that the expenditure on equipment rental is moderately associated with the accuracy of the measurement methods – higher rental costs are correlated with greater precision in measurements.

The affordability of the Lidar method positions it as a viable alternative, particularly in cases where financial considerations are paramount. This technology proves advantageous in scenarios where a balance between accuracy and cost efficiency is crucial, such as geodetic surveys of rural infrastructure. Lidar's cost-effectiveness makes it an attractive option for projects with budget constraints, without compromising substantially on the precision required for assessing and managing rural infrastructure. Its potential applications include topographic mapping, land surveying, and infrastructure development in less economically affluent regions, contributing to the sustainable and cost-efficient management of rural areas.

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Author contributions:

Conceptualization, I.O., O.T.; methodology, I.O. and R.T.; software, validation, O.S.; formal analysis, O.S.; investigation, I.O. and Ya.S.; data curation, I.O., Ya.S., A.H.; writing original draft preparation, I.O. and O.S.; writing – review and editing, I.O. and O.S.; visualization, Ya.S.; project administration, I.O.; funding acquisition, O.S., A.H. All authors have read and agreed to the published version of the manuscript.

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