Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 2, No.1, February : 2025

A SYSTEMATIC REVIEW OF ADVANCED AI-DRIVEN METHODS FOR TOPOGRAPHICAL SURVEYS TO ENHANCE COST

Prof. Patil B.S HOD Department of Civil Engineering, Abhinav Education Society's College of Engineering & Technology Polytechnic Wadwadi, Pune. - 412801
Shrinath Khanadale Diploma Student, Department of Civil Engineering, Abhinav Education Society's College of Engineering & Technology Polytechnic Wadwadi, Pune. - 412801
Supriya Kothari Diploma Student, Department of Civil Engineering, Abhinav Education Society's College of Engineering & Technology Polytechnic Wadwadi, Pune. - 412801
Siddhant Belose Diploma Student, Department of Civil Engineering, Abhinav Education Society's College of Engineering & Technology Polytechnic Wadwadi, Pune. - 412801

Abstract
This systematic review examines the application of advanced AI-driven methods in topographical surveys to enhance cost efficiency. Over the past decade, AI technologies such as machine learning, drones, LiDAR, and computer vision have revolutionized the surveying industry by improving data accuracy, reducing manual labor, and optimizing resource usage. Through a comprehensive literature search of peer-reviewed articles from databases, this review highlights how these technologies reduce survey costs by speeding up data collection, minimizing errors, and increasing operational efficiency. The findings demonstrate that AI-driven methods lead to cost savings, improve project timelines, and reduce the need for rework. This review provides insights into the transformative potential of AI in topographical surveying and offers recommendations for future research and practical implementation in the industry.

Keywords:
Artificial Intelligence (AI), Topographical Surveying, Cost Efficiency, Geographic Information System (GIS), Surveying Technologies

INTRODUCTION
Topographical surveys play a crucial role in understanding a site's physical features and conditions, which is particularly important when working with existing buildings. These surveys involve detailed measurements of the land's contours, elevation, and other geographical features necessary for planning, design, and renovation. In the context of existing buildings, accurate topographical data is vital for assessing structural integrity, planning modifications, and ensuring compliance with local regulations. However, obtaining and analyzing topographical data for existing buildings can be a complex and costly process. Traditional methods, including manual surveys and outdated technology, often lead to inefficiencies, errors, and inflated costs. As a result, there is a growing demand for innovative solutions that can reduce costs while improving the accuracy and efficiency of data collection.
This study examines how modern topographical surveying methods, enhanced by technological advancements such as AI, machine learning, and digital tools, can significantly reduce costs associated with gathering and processing data for existing buildings. By incorporating these technologies, it is possible to streamline the survey process, optimize resource usage, and minimize human errors, leading to more cost-effective outcomes. This research aims to demonstrate the potential for enhancing cost efficiency through the integration of advanced techniques in topographical surveying, ultimately providing valuable insights for architects, engineers, and developers involved in building management and renovation projects.

1.1 The Importance of Topographical Surveys
Before starting any land development project, it's essential to understand the land's topography to create an effective plan. Topographical surveys provide detailed, accurate information that helps to reduce risks and prevent costly mistakes once construction or excavation begins. Similar to

underground utility mapping, topographical surveys help avoid delays and unexpected expenses, ensuring the project moves forward smoothly without major setbacks.
The more data collected by the surveyor, the better equipped you are to make informed decisions. Here are some of the key things a topographical survey can help identify:

- **Vegetation**: For projects in areas with dense forests or specific vegetation types, topographical surveys can identify the size, type, and location of trees and plants. This helps determine what vegetation can be best suited for the area and whether certain trees need to be preserved or removed.
- **Contour Levels**: Topographical maps show the shape of the land through contour lines, which represent elevation changes. These lines help to highlight the steepness of slopes, the height of mountains, or the depth of valleys, giving a clear picture of the landscape. There are three types of contour lines: intermediate, index, and supplementary.
- **Natural Features**: Topographical surveys can easily identify natural features like mountains, valleys, lakes, and oceans. They record the elevation of these features, typically about sea level, providing important information for planning development.
- **Man-made Structures**: Topographical surveys also map out human-made structures such as buildings, roads, bridges, and other infrastructure. This ensures accurate positioning and helps avoid conflicts with existing structures during construction.
- **Streams and Water Bodies**: Whether you need to locate a stream’s centerline, its banks, or the lowest point (called the thalweg), a topographical survey can define these features with precision. This information is key when planning drainage systems, flood management, or other water-related aspects of a development project.

1.2 Techniques for Cost-Effective Topographical Surveying
Topographical surveying plays a crucial role in gathering precise and comprehensive data about both natural and man-made features of a specific area. Various techniques are employed to achieve accurate topographic data collection, each offering distinct benefits and applications.
1. Field Surveying: Field surveying is a conventional method where direct measurements are taken using instruments like total stations, theodolites, and leveling tools. This technique is essential for obtaining highly accurate data, especially in areas with complex terrain.
2. GPS/GNSS Surveying: GPS or GNSS surveying uses satellite signals to determine positions on Earth with high accuracy. This method is ideal for large-scale topographic surveys, enhancing both speed and precision across vast areas.
3. LiDAR (Light Detection and Ranging): LiDAR is an advanced technology that uses laser beams to capture detailed, three-dimensional terrain models. Its ability to penetrate vegetation makes it especially useful for mapping hard-to-reach areas and providing detailed topographic data, including buildings and vegetation.
4. Aerial Surveying: Aerial surveying utilizes aircraft equipped with cameras or LiDAR sensors to collect topographic data from the sky. It is highly effective for surveying large areas rapidly, providing a broad overview of landscapes, and facilitating infrastructure planning.
5. Photogrammetry: This technique involves using overlapping aerial photos to create accurate three-dimensional models of the terrain. When combined with other methods, photogrammetry enhances the level of detail and accuracy in topographic data collection.
6. **Satellite Imagery**: Using satellites to capture images from space, this method provides a wide-scale view of vast areas. It is useful for regional mapping and tracking changes in the landscape over time, thanks to advances in satellite technology that improve resolution and accuracy.
7. Terrestrial Laser Scanning (TLS): TLS uses stationary laser scanners to capture precise point cloud data of the environment. This method is especially effective for detailed surveys of buildings and landscapes, as well as for monitoring changes or structural deformations.
This array of techniques provides diverse approaches to topographical surveying, each contributing to improving efficiency and cost-effectiveness in mapping and data collection.

Table 1: Technological Innovations in Topographical Surveying for Cost Optimization and Data Management of Existing Buildings

Aspect	Method/Technology	Impact on Cost	Benefits	Data Collected
Surveying Method	LiDAR (Laser Scanning)	Moderate cost, faster than traditional	High precision, reduced fieldwork	3D data, point clouds, building geometry
Technology for Data Capture	Drones (UAVs)	Moderate cost requires skilled operators	Reduces fieldwork, access hard-to-reach areas	Aerial imagery, 3D models
Data Processing Software	AI-based Survey Analysis	Low to moderate cost, reduces time and errors	Automated analysis, faster processing	Topographic maps, surface models
Data Management	Cloud-Based Platforms	Subscription costs, but efficient	Real-time data access, collaboration	Centralized data storage, real-time updates
Building Condition Analysis	AI & Machine Learning Models	Low cost once setup, helps predict costs	Detects potential issues early	Condition reports, predictive analysis
Cost Optimization	BIM (Building Information Modeling)	High initial cost, long-term savings	Streamlined project planning, maintenance	3D building model, material quantities

This table covers various methods, technologies, and tools used in topographical surveying for existing buildings and their impact on cost efficiency. Each method or technology offers unique benefits in terms of speed, precision, and overall cost reduction.

1.3 Objectives of the Study

1. Evaluate the impact of AI-driven methods on topographical survey accuracy and efficiency.
2. Explore AI technologies for optimizing resources and reducing costs in surveying.
3. Investigate the role of AI in promoting sustainable practices and long-term cost savings.

1.4 Scope of the Study

This study focuses on exploring how topographical surveys can enhance cost-efficiency in managing data related to existing buildings. It aims to examine various surveying methods and technologies that contribute to reducing costs and improving the accuracy, speed, and reliability of data collection. The scope includes the evaluation of traditional and advanced techniques, such as ground surveying, GPS/GNSS, LiDAR, drones, and AI-based data processing tools. The study further investigates the application of Building Information Modeling (BIM) and cloud-based platforms to streamline the management, analysis, and storage of survey data. Additionally, the research explores the role of artificial intelligence (AI) and machine learning in identifying potential cost-saving opportunities by improving the accuracy of building condition analysis and optimizing future building maintenance and renovation projects. The study will analyze how these innovations can lead to significant reductions in operational costs, minimize human errors, and provide a more efficient approach to the planning and management of construction projects involving existing buildings.

1.5 Statement of the Problem

In the context of construction and infrastructure management, efficient management of topographical survey data for existing buildings plays a critical role in minimizing costs and improving project outcomes. Traditional surveying methods, although accurate, often involve high labor costs, time-intensive processes, and limitations in data precision, especially when dealing with complex or deteriorating structures. Modern technologies such as LiDAR, drones, and AI-based data processing offer significant potential to enhance the accuracy, speed, and cost-efficiency of topographical surveys.

However, there is a lack of comprehensive understanding regarding how these technologies can be fully integrated into existing building data management systems. This knowledge gap often leads to inefficiencies, mismanagement of resources, and increased costs in building renovation, maintenance, and development projects. Therefore, the need exists to explore and evaluate advanced topographical surveying methods to optimize costs and improve the accuracy of data related to existing building structures.

REVIEW OF LITERATURE

Table 2: Summary of Topographic Surveying Studies

Author(s)	Year	Findings	Conclusion
L. C. Luh et al.	2014	TLS provides high-speed data collection (50,000 to 1,000,000 points per second). The field test for the topographic survey was completed with 1st class survey standards. Proposed procedure for using TLS in topographic surveys.	TLS is efficient for topographic surveys. A procedural guideline for TLS-based topographic data acquisition was established.
Sara G. Bangen	2013	TS and rtkGPS are reliable for wetted channel topography. TLS is ineffective in-channel, and ALS is not reliable in the wetted channel but works well for floodplain topography.	TS and rtkGPS are the most reliable for wetted channel topography. TLS and ALS have limitations, especially in channels.
Reine Maria Basse et al.	2014	CA and ANN techniques are effective in modeling land use changes. ANN can help in calibrating cellular automata models with big data for better accuracy in land use predictions.	ANN techniques improve the calibration of land use models. CA and ANN are suitable for land use change analysis in cross-border areas.
Ioannis A. Pissourios	2023	The survey methods evolved in three phases. The key contributions to urban land use surveys were identified, with an emphasis on discussing survey methodology.	The evolution of urban land use survey methods can be periodized into three phases, laying the foundation for future research.
Márcia Macedo et al.	2023	UAV provided centimeter accuracy (1.93044 cm), while TLS offered millimetric accuracy. UAV could replace TLS, but more efficient imaging techniques are needed for higher accuracy.	UAVs can replace TLS for planimetric surveys in civil construction, but further improvements in accuracy are necessary.
Okwuenu C. M et al.	2024	The survey produced a topographic map using conventional surveying methods. The school area is approximately 1707 hectares.	The study concluded the need for a topographic map for planning and land management at the school.

. **Paul Sestras et al. (2023)** This paper explores the application of UAV-based surveying methods in civil engineering, particularly in topographic mapping. The authors discuss the advantages and limitations of using UAVs for capturing high-resolution digital elevation models (DEMs) compared to conventional surveying methods. Their research highlights the benefits of UAVs in providing detailed topographic representations, overcoming challenges posed by traditional methods, and expanding the scope of deliverables in construction planning. The study also includes case studies and an accuracy assessment of UAV-based data. **Rosmadi Fauzi et al. (2008)** This study involved a GIS and topographic survey of Jarak Island to map the natural and geological features. The authors used field surveys and GIS software to create accurate topographic maps of the island, including elevation data. Through GIS analysis, the study identified key natural and topographic features, enhancing the understanding of the island's terrain. The results provide detailed spatial data useful for environmental and land development applications. **Raju Ahmed (2022)** The study investigates the effectiveness of UAVs in topographic surveys for mapping Earth's relief features. The research highlights UAVs' ability to capture accurate topographic data quickly and cost-effectively compared to traditional methods. The study uses UAVs and advanced software to create high-resolution elevation models, demonstrating their potential for efficient and precise mapping of complex terrain. The findings emphasize the significant benefits of UAVs in topographic surveying, particularly for large-scale projects.

Westoby, M. J. (2012) Author presents a low-cost photogrammetric technique, "Structure-from-Motion" (SfM), for creating high-resolution topographic datasets. Unlike traditional photogrammetry, SfM simultaneously solves the camera pose and scene geometry, using overlapping images to construct detailed 3D models. The study compares SfM with terrestrial laser scanning and demonstrates its potential to achieve decimeter-scale accuracy. The paper advocates for SfM as a cost-effective and flexible approach for capturing complex topography, especially for geoscience applications involving diverse landforms. **C. H. Lim et al. (2021)** This study evaluates the feasibility of using UAV-based photogrammetry as a replacement for traditional EDM surveys in topographic mapping. The authors compare survey data from UAVs and total stations over a highway stretch, finding that UAVs produce similar results to traditional methods, with some discrepancies in elevation. The study suggests that UAV-based surveys are accurate for large-scale projects but may require adjustments for specific features. It provides insights into the benefits and limitations of UAVs in topographic surveying. **Hubert T. Samboko (2022)** The study explores the use of UAVs, photogrammetry, and low-cost RTK GNSS for river monitoring and hydraulic modeling. The study focuses on the combination of UAV-based data with ground control points (GCPs) to improve the accuracy of digital elevation models (DEMs) for hydraulic applications. Results from the Luangwa River in Zambia show that UAVs and RTK GNSS can provide accurate geometries for hydraulic simulations, with open-source software producing results comparable to commercial tools. The study highlights the importance of GCPs for vertical accuracy in hydraulic modeling.

Mr. Rohit Ghode et al. (2024) Research examines the application of advanced topographical surveying technologies, such as LiDAR, GPS, and UAVs, to improve cost efficiency in land development projects. The study emphasizes how these technologies can streamline survey processes, reduce costs, and accelerate timelines. Through case studies, the research demonstrates how advanced surveying methods, combined with Geographic Information Systems (GIS), can enhance project planning, risk mitigation, and resource optimization, contributing to more sustainable and economically viable land development. **Yang Zhou et al. (2023)** study analyzes the spatio-temporal changes in cultivated and construction land in China from 1996 to 2019. Using statistical analysis and a two-way fixed effect model, the study identifies regional trends in land use, with increases in cultivated land in certain regions and decreases in others. The research also highlights the expansion of construction land driven by urbanization and population growth, emphasizing the inefficiencies in rural land use and the mismatch between urban growth and population trends. The findings inform land policy adjustments. **Sara G. Bangen (2014)** study compares various topographic survey methods, such as total stations, GPS, LiDAR, and UAVs, for their effectiveness in generating high-precision digital elevation models (DEMs) in fluvial geomorphology. The study evaluates the accuracy and precision of DEMs derived from different methods and discusses the trade-offs between survey time, cost, and data quality. Results show that UAVs offer a cost-effective alternative with superior aerial coverage, while LiDAR and total stations provide more precise elevation data. The study provides practical insights into choosing survey methods for specific applications.

Table 3: Comparative Analysis of Traditional vs. AI-driven Methods for Topographical Surveys to Enhance Cost Efficiency

Aspect	Before (Traditional Methods)	After (AI-driven Methods)
Accuracy	Relatively less accurate, prone to human error and inconsistencies.	High precision with AI algorithms minimizing errors in data collection.
Efficiency	Time-consuming with manual data collection and analysis.	Faster data processing and real-time analysis, reducing survey time.
Cost	Higher operational costs due to manual labor, equipment, and rework.	Reduced costs through automation, optimization, and fewer rework requirements.
Resource Utilization	Suboptimal resource allocation, often resulting in inefficiencies.	Optimized resource usage through AI-driven automation and real-time adjustments.
Data Analysis	Manual interpretation of complex data, prone to delays and errors.	AI-powered algorithms for immediate data analysis and actionable insights.
Project Timeline	Longer project durations due to slower, manual survey methods.	Shortened project timelines due to quicker data gathering and processing.
Sustainability	Limited integration of sustainable practices.	AI-driven methods can promote sustainable surveying by minimizing waste and reducing the environmental footprint.
Long-term Cost Savings	Higher long-term maintenance costs due to inaccurate or outdated data.	Reduced long-term costs through accurate data that aids in better planning and decision-making.
Error Reduction	Frequent errors and inaccuracies in measurements and data collection.	AI reduces human error, ensuring more reliable data.
Automation	Manual data entry and survey processes.	Extensive automation in data collection, processing, and analysis.

AI-driven methods significantly improve topographical surveys by enhancing accuracy, efficiency, and cost-effectiveness. They reduce errors, optimize resource use, shorten project timelines, and promote sustainability. These advancements lead to long-term cost savings through more reliable data and better decision-making.

METHODOLOGY

This systematic review aimed to evaluate the role of advanced AI-driven methods in topographical surveys, with a focus on enhancing cost efficiency. A thorough literature search was conducted across databases such as IEEE Xplore, Google Scholar, and Scopus, targeting peer-reviewed studies published over the past decade. Key data on the AI technologies used, their applications in surveying, and their impact on cost were systematically extracted. The review found that technologies like machine learning, drones, and LiDAR significantly reduce survey costs. These technologies improve accuracy, minimize errors, optimize resource use, and speed up data collection, which leads to faster project completion, fewer reworks, and ultimately lower costs. These findings highlight the potential of AI to transform surveying practices and enhance overall efficiency in the industry.

3.1 Limitations of this study

Limitations of this study involve several factors that may impact the feasibility and generalizability of the findings:

- High-cost technologies like LiDAR and drones may be beyond the reach of many surveyors and organizations.

- Adverse weather conditions, such as heavy rain or fog, can significantly hinder data collection, especially for aerial surveys.
- Advanced surveying methods require specialized knowledge, potentially limiting their widespread adoption across various surveying professionals.
- Local regulations and surveying practices can influence the effectiveness and applicability of certain methods in different regions.
- The high upfront costs of advanced technologies may discourage adoption, particularly for smaller-scale or budget-limited projects.

CONCLUSION

Topographical surveys play a critical role in enhancing cost efficiency when managing data related to existing buildings. By leveraging advanced technologies such as LiDAR, drones, AI-based analysis, and Building Information Modeling (BIM), significant improvements in data accuracy, processing speed, and overall cost optimization can be achieved. These innovations allow for more precise mapping, reduce the need for time-consuming fieldwork, and enable the early detection of potential issues, ultimately lowering maintenance costs and improving decision-making processes. The integration of AI and machine learning further enhances predictive capabilities, helping to forecast costs and identify opportunities for savings. Overall, adopting modern surveying methods is essential for achieving cost-effective and efficient management of existing building data.

Key Insights:

1. **Balance between Accuracy and Efficiency**: The trade-offs between accuracy and efficiency in survey technologies are crucial in selecting the right method for a project (Sara G. Bangen, 2013).
2. **Effectiveness of HDS and Total Station**: High-definition surveying (HDS) and Total Station are proven to be highly effective for detailed topographic surveys, offering reliable data for analysis (L.C. Luh, 2014; Okwuenu C. M, 2024).
3. **Selection of Survey Techniques**: Choosing the most suitable survey technique based on site-specific conditions and research goals is vital for achieving the desired results (Sara G. Bangen et al., 2014).
4. **Advanced Modeling Methods**: Technologies such as Cellular Automata (CA) and Artificial Neural Networks (ANNs) are effective in modeling land use changes and enhancing predictive capabilities (Reine Maria Basse, 2021).
5. **UAVs as Alternatives to TLS**: Unmanned Aerial Vehicles (UAVs) have emerged as a promising alternative to Terrestrial Laser Scanning (TLS) in civil construction surveys, providing efficient and cost-effective solutions (Márcia Macedo, 2023).
6. **GIS in Landscape Mapping**: Geographic Information Systems (GIS) are invaluable for landscape mapping and visualizing changes in land use, significantly improving planning and analysis (Rosmadi Fauzi, 2008; Ioannis A. Pissourios, 2023).
7. **Conventional vs. Photogrammetric Surveys**: Photogrammetric surveys show a high correlation with traditional methods in land development, making them a valuable tool in surveying practices (Yaguba Jalloh, 2018).

In conclusion, these studies highlight the critical role of adopting innovative and site-appropriate surveying techniques. By tailoring methods to specific project needs, they contribute to better planning, management, and decision-making in land development and related sectors.

References

1. Ahmed, R., & Mahmud, K. H. (2022). Potentiality of high-resolution topographic survey using unmanned aerial vehicle in Bangladesh. *Remote Sensing Applications: Society and Environment*, *26*, 100729. https://doi.org/10.1016/j.rsase.2022.100729

2. Bangen, S. G. (2013). *Comparison of Topographic Surveying Techniques in Streams*. https://doi.org/10.26076/7E1E-3C6F
3. Bangen, S. G., Wheaton, J. M., Bouwes, N., Bouwes, B., & Jordan, C. (2014). A methodological intercomparison of topographic survey techniques for characterizing wadeable streams and rivers. *Geomorphology*, *206*, 343–361. https://doi.org/10.1016/j.geomorph.2013.10.010
4. Basse, R. M., Omrani, H., Charif, O., Gerber, P., & Bódis, K. (2014). Land use changes modelling using advanced methods: Cellular automata and artificial neural networks. The spatial and explicit representation of land cover dynamics at the cross-border region scale. *Applied Geography*, *53*, 160–171. https://doi.org/10.1016/j.apgeog.2014.06.016
5. Dawid, L., Tomza, M., & Dawid, A. (2019). Estimation of Usable Area of Flat-Roof Residential Buildings Using Topographic Data with Machine Learning Methods. *Remote Sensing*, *11*(20), 2382. https://doi.org/10.3390/rs11202382
6. Fauzi, R., Russin, A., Ghani, A. A., & Ismail, K. (2008). *Making the Most of Maps: GIS and Topographical Survey on the Island of Jarak*.
7. Ghode, M. R., Shinde, M. R. D., & Shende, R. (n.d.). *Using Advance Methods for Topographical Survey to Achieve Economy*.
8. Lim, C. H. (2021). Topographic Survey and Modelling using Photogrammetry: A Comparison against Electronic Distance Measurement (EDM) Method. *ASM Science Journal*, *16*, 1–9. https://doi.org/10.32802/asmscj.2021.720
9. Luh, L. C., Setan, H., Majid, Z., Chong, A. K., & Tan, Z. (2014). High resolution survey for topographic surveying. *IOP Conference Series: Earth and Environmental Science*, *18*, 012067. https://doi.org/10.1088/1755-1315/18/1/012067
10. Macedo, M., & Ferreira, B. (2023). Use of Advanced Technologies for Topographic Surveys in Civil Construction. *Journal of Management and Sustainability*, *13*(2), 17. https://doi.org/10.5539/jms.v13n2p17
11. Pissourios, I. A. (2023). Urban Land Use Survey Methods: A Discussion on Their Evolution. *Urban Science*, *7*(3), 76. https://doi.org/10.3390/urbansci7030076
12. Samboko, H. T., Schurer, S., Savenije, H. H. G., Makurira, H., Banda, K., & Winsemius, H. (2022). Evaluating low-cost topographic surveys for computations of conveyance. *Geoscientific Instrumentation, Methods and Data Systems*, *11*(1), 1–23. https://doi.org/10.5194/gi-11-1-2022
13. Sestras, P., Roșca, S., Bilașco, Ștefan, Șoimoșan, T. M., & Nedevschi, S. (2023). The use of budget UAV systems and GIS spatial analysis in cadastral and construction surveying for building planning. *Frontiers in Built Environment*, *9*, 1206947. https://doi.org/10.3389/fbuil.2023.1206947
14. *Topographic Survey of Comprehensive Secondary School Nawfia, Anambra State*. (2024). *5*(2).
15. Westoby, M. J., Brasington, J., Glasser, N. F., Hambrey, M. J., & Reynolds, J. M. (2012). 'Structure-from-Motion' photogrammetry: A low-cost, effective tool for geoscience applications. *Geomorphology*, *179*, 300–314. https://doi.org/10.1016/j.geomorph.2012.08.021
16. Zhou, Y., Zhong, Z., & Cheng, G. (2023). Cultivated land loss and construction land expansion in China: Evidence from national land surveys in 1996, 2009 and 2019. *Land Use Policy*, *125*, 106496. https://doi.org/10.1016/j.landusepol.2022.106496