EVALUATING PRECISION IN LAND SURVEYING: TECHNIQUES AND BEST PRACTICES

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***Abstract**: Land surveying is very important in many areas like building, town planning, and managing natural resources, where exact measurements matter a lot for good decisions. This introduction will look at basic ideas about precision in land surveying and explain why it is important to use strong techniques and best practices. Understanding this topic well not only helps improve measurement accuracy but also reduces possible mistakes that can happen from poor methods. Thus, carefully assessing modern surveying methods is necessary to find effective ways that ensure top precision levels. By including relevant examples and case studies, this essay aims to offer a clear framework for those working in the field. To back this discussion, the ADDIE model offers a structure that helps with a methodical approach to improving the practices used in land surveying, which helps promote more accuracy and reliability in the results obtained. In land exploration and management, land surveying means measuring and mapping land and what is below the surface to set property limits and help with land use. It uses various methods to find where points are on the Earth's surface, often using advanced tools like GPS and laser scanning. Getting these measurements right is very important because they affect decisions about city planning, building, and protecting the environment. Additionally, land surveying is key in legal matters, as marking property edges helps avoid conflicts and clarifies ownership. Knowing efficient surveying techniques, as shown in the model in [citeX], is important because it shows the best ways to improve accuracy and efficiency in the field, encouraging sustainable development and better land use choices.*

Key words: Land surveying, ADDIE, Earth's surface, Technology on Precision,

INTRODUCTION

Accuracy in surveying is very important, as it affects the results related to land management and development projects. The precision of survey data not only affects the trustworthiness of legal boundaries but also aids important decision-making in various areas, such as farming and city planning. For example, as noted in (Betts et al. 2014), using aerial mapping technologies has improved high precision farming data, showing that accurate data collection improves resource management and helps farming methods. Moreover, these advancements reveal a move towards data-based approaches that promote sustainability and efficiency. Without accurate surveying, the chance of mistakes increases, which can cause serious financial issues, disputes about land ownership, and poor resource distribution. Therefore, focusing on accuracy in surveying methods is crucial for effective land use and building stakeholder confidence in the data provided, ultimately supporting the larger goals of environmental protection and responsible development. For visual aid, the ADDIE model diagram gives a clear view of the ongoing process of survey design that emphasises accuracy.

To get precision in land surveying, it is very important to choose and use different techniques along with best practices in the industry. One key method is using advanced data collection methods like laser scanning. Although some professionals were slow to adopt this, it offers unmatched speed and precision in gathering spatial data. By adding laser scanning into surveying tasks, the quality of the results can improve a lot, meeting what clients expect, as noted by (Christiaen et al. 2012; Pascalau et al. 2021). Additionally, using new technologies, such as Geographic Information Systems (GIS), improves spatial analysis and decision-making. Following a clear method that includes careful analysis, planning, strong development, effective execution, and ongoing assessment can help apply these techniques well (Table 1). This ensures

that surveying practices not only follow the rules but also improve how things work. Supporting graphics, like, show how this process repeats itself and highlight its significance in achieving precision in surveying.

Table 1

Land Surveying Techniques and Accuracy Comparison

Technique	**Accuracy (cm)**	**Cost (USD)**
Differential GPS	1-5	2000-5000
Total Station	1-3	3000-15000
LiDAR	5-15	25000-100000
GNSS	5-10	5000-20000
Photogrammetry	1-5	5000-30000

The history of land surveying is closely linked to the social and political situations of old civilisations, as the need for good land measurement was often due to farming, taxes, and disputes over land. For example, in ancient Egypt, the yearly flooding of the Nile required accurate surveying methods to set boundaries again, which was crucial for their farming success. Similarly, the Romans used advanced tools and techniques, like the groma and chorobates, which improved their urban planning and infrastructure building. In modern times, big technological changes in the 20th and 21st centuries have improved surveying methods, shown by the use of satellite positioning and underwater acoustic systems in maritime archaeology (Thompson et al. 2023). The shift from simple tools to high-tech digital methods shows how surveying has constantly adapted to meet changing human needs. This evolution lays the foundation for today's surveying practices that focus on precision and accuracy (Ter Huurne et al. 2024; Smuleac et al., 2023). This discussion clearly outlines the key evaluation methods that have come from this rich history, highlighting their significance in the current surveying field.

Evolution of Surveying Techniques

Technological improvements have been important in changing surveying methods over time. In the past, land surveying depended a lot on manual tools and simple instruments like theodolites and chains, which offered low accuracy and efficiency. The introduction of satellite technology and Global Positioning Systems (GPS) marks a big step up in precision. As explained in (Cina et al. 2023), modern GPS (Smuleac et al., 2022) receivers improve both pseudorange and carrier phase measurements, making accurate positioning possible even in difficult situations. This development has allowed professionals to take on complicated tasks, from land mapping to georeferencing, with better reliability. Furthermore, the use of geographic information systems (GIS) has greatly changed the field, enabling thorough spatial analysis and data handling. As new techniques arise, it is crucial for surveying experts to follow best practices to maintain high accuracy and reduce possible errors, as seen in discussions about effective methods in earlier sections of this document. To visually display these improvements, refer to, which summarises the structured, repetitive nature of current surveying methods.

Impact of Technology on Precision

Technological progress has changed how land surveying is done, making it more accurate and reducing human mistakes. New tools like total stations and GPS help surveyors get very detailed measurements, often as precise as a few millimetres. This change is not just small; it is a big shift in how surveying is carried out. For example, using hyperspectral imagery allows for a full analysis of coastal areas, going beyond older methods and making it easier to evaluate the shoreline (Gardner et al. 2011; Pascalau et al 2023). Also, the use of satellite-based earth observation systems is crucial for creating environmental policies, where accurate data is vital

for identifying issues and making rules (Alfred De Gier et al. 2010; Smuleac et al. 2013). Therefore, these technologies highlight the need for accuracy in surveying, which helps improve decision-making. The effect of these advancements is significant, especially for managing the environment and carrying out policies. As shown in the related visual, the ADDIE model can also be used to create training programs that utilise these technologies, making sure that surveyors are prepared to use precision in their jobs (Table 2).

Table 2

Impact of Technology on Precision in Land Surveying

Technique	Precision (cm)	Year Introduced
Total Station	1-5	1980s
GPS Surveying	1-10	1990s
Laser Scanning	0.1-1	2000s
Drones (UAVs)	3-5	2010s
LiDAR (Light Detection and Ranging)	2-10	2000s
3D Modeling Software	Variable	2010s

Key Historical Figures and Their Contributions

The growth of land surveying is closely tied to the efforts of important historical people who developed methods and tools that improved how measurements are made. For example, Eratosthenes, who figured out the Earth's circumference very accurately, established key standards for surveying. His approach shows the early use of careful thinking and observation, which helped shape today's surveying techniques. Likewise, John Harrison's work on the marine chronometer in the 18th century changed navigation at sea, leading to more accurate land surveys from ocean locations. This progress is vital to understanding how farming and city planning changed as surveying methods improved. Therefore, bringing together these historical achievements into modern practices is vital for continuing to boost accuracy in surveying, showing the need to learn from past advances (Brunet et al. 2011). In this regard, using systematic evaluation methods highlights the lasting importance of these historical figures.

MATERIALS AND METHODS

Recent changes in land surveying have really changed the ways we work in this important area. The use of technology, especially Geographic Information Systems (GIS) and remote sensing, has improved both the accuracy and speed of surveying methods. These new techniques make it easier to map large areas, getting around the limits of older surveying methods that often depended on manual measurements.

For example, Geoinformatics Engineers are becoming more important in using spatial data for good land management choices, particularly in developing countries like Ghana, where this approach can greatly affect sustainable resource use (Bale et al., 2010; Finkbeiner et al., 2001). Moreover, using drones for aerial surveys is changing how data is collected, enabling detailed ground analyses with less human effort. As these technologies keep progressing, they challenge land surveying experts to change and enhance their methods, making sure they meet current needs (Alfred De Gier et al. 2010). The chances for new ideas in this area are huge, suggesting further improvements in the accuracy and trustworthiness of land surveying results. To demonstrate these advancements, [extractedKnowledge1] can act as a visual example of the methods that support modern surveying practices (Figure 1).

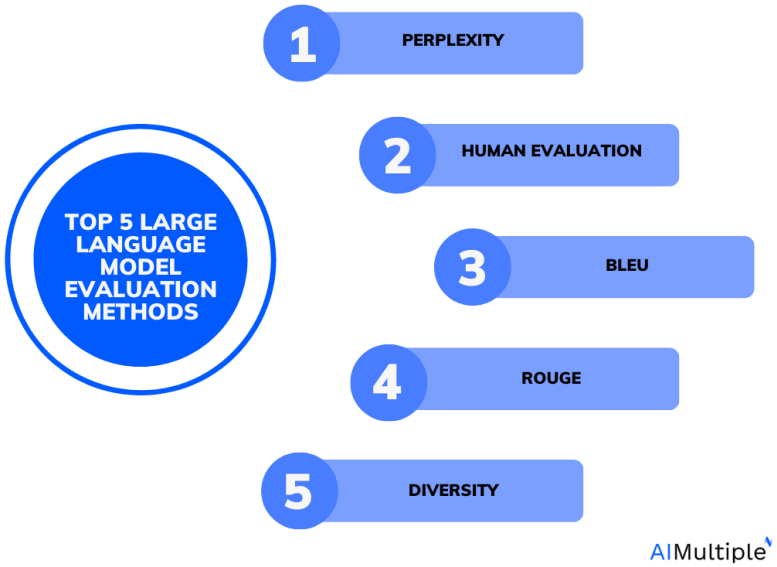

Fig. 1. Top Five Evaluation Methods for Large Language Models

Use of GPS and GNSS Technologies

The use of GPS and GNSS technologies has changed how land surveying is done today, making it more accurate and efficient. These technologies collect exact location data, which helps surveyors create detailed maps and define boundaries correctly. Thanks to better receiver technology, it is now possible to get real-time positioning, which improves decision-making in fields like engineering and construction (Cina et al. 2023). Using GNSS along with traditional surveying methods helps improve workflows, making it easier to monitor projects and meet legal standards (et al.). Still, problems like signal interference and data integrity need to be dealt with to make the most of these systems. Following best practices in using GPS/GNSS is essential to overcome these issues and ensure the accuracy needed for successful land surveying. The importance of clear communication in these tasks is shown in, demonstrating the systematic approach of the technical methods used.

The Role of Total Stations in Precision Measurement

In land surveying, Total Stations are very important for getting precise measurements. These tools combine electronic theodolites and electronic distance measurement (EDM) technology, which helps surveyors measure distances and angles accurately. In modern surveying, Total Stations allow for the collection of complex geospatial data, which is essential for things like construction management and environmental research. The ability to capture three-dimensional coordinates also improves the accuracy of topographical maps, making planning and decision-making better. Research, like studies on the use of geoinformatics in the oil industry (Jonathan et al., 2013), shows how useful Total Stations are for complicated projects that need careful execution. Therefore, Total Stations represent a key technology for achieving accuracy and dependability in land surveying, highlighting the importance of measurement tools in this area.

Advancements in Laser Scanning and Photogrammetry

Recent changes in laser scanning and photogrammetry have significantly changed land surveying, boosting both accuracy and efficiency. The use of mobile Light Detection and Ranging (LiDAR) technology allows for thorough data gathering in different terrains, enabling surveyors to make detailed three-dimensional surface models with high accuracy. For example, studies show that mobile terrestrial LiDAR scanning can effectively produce accurate digital pavement surfaces, which greatly enhances pavement management systems (Famili et al., 2020).

RESULTS AND DISCUSSIONS

Furthermore, the ability to evaluate and process LiDAR data in geographic information systems (GIS) improves the assessment of road cross slopes and material calculations, highlighting the flexibility of these methods. While traditional surveying methods depended a lot on manual measurements, improvements in these technologies not only make workflows faster but also reduce human error, raising accuracy standards in surveying practices. The clear potential for innovation in this area is shown in both research and practical use (Balado Frías et al., 2024). The visual representation of these advancements, as outlined in the structured overview of AI in education, reflects the systematic growth and use of these technologies in improving survey precision and efficiency (Figure 2, Table 3).

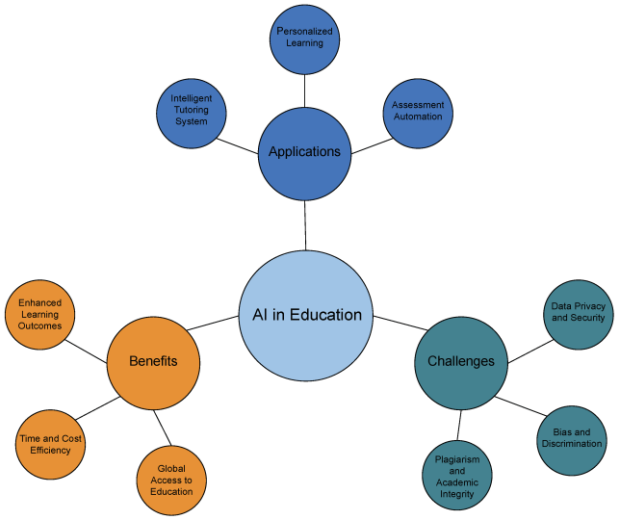

Fig. 2. Conceptual Framework of AI in Education: Applications, Benefits, and Challenges

Table 3

Advancements in Laser Scanning and Photogrammetry

Technique	Year	Accuracy (mm)	Application Areas
Laser Scanning	2023	1-3	Civil Engineering, Topography
Photogrammetry	2023	10-50	Architecture, Forestry
Terrestrial Laser Scanning	2022	2-5	Historical Preservation, Mining
UAV Photogrammetry	2023	5-20	Agriculture, Environmental Monitoring
Mobile LiDAR	2022	2-6	Transportation, Urban Planning
Aerial Laser Scanning	2023	10-15	Land Cover Mapping, Hydrology

In the search for accuracy in land surveying, a careful method is very important. Among good practices, thorough planning and using new technologies are key factors. Using methods like laser scanning greatly boosts data precision, as shown by some Belgian land surveyors who are hesitant to use this technique due to concerns about effectiveness and handling data (Christiaen et al. 2012). Also, using accurate GPS technology can greatly improve location accuracy, making it an essential instrument for today's surveyors. The significance of this technology use is highlighted by recent advances in remote sensing, which allow for high-quality mapping with little need for ground verification, particularly in farming (Betts et al. 2014). Moreover, ongoing training and skill enhancement for surveyors are necessary to effectively use these tools and understand the data they produce, thereby maintaining the reliability of the surveying process.

Importance of Calibration and Maintenance

To make sure surveying data is correct and dependable, it is necessary to have strict calibration and upkeep of tools. Calibration is an important step that creates a clear link between measurements and their real values, helping to avoid differences that could affect the outcome of projects. Regular inspections and timely maintenance are very important, as they lower the chances of equipment drifting over time due to wear or outside factors. The significance of these actions is highlighted by the need for stakeholders to trust the accuracy of the data gathered, which is crucial for smart decision-making in land development and conservation. Not following strict calibration and maintenance procedures could lead to expensive mistakes and weaken the reliability of geodetic surveys, as shown in many studies about marine geodesy (Frazier et al. 2020.; Fubara et al. 2021). Also, the development of the ADDIE model in instructional design shows useful methods that can be used to train surveyors in precision techniques.

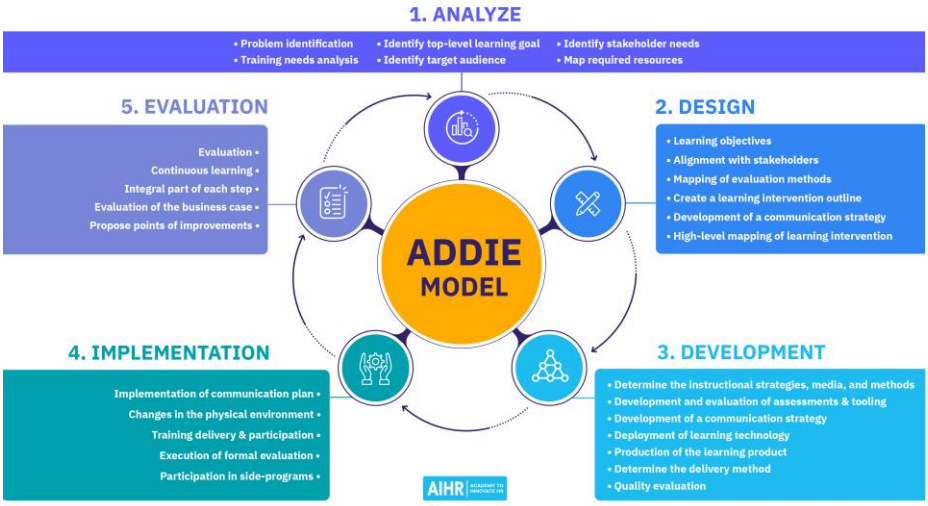

Fig. 3. ADDIE Model Framework for Instructional Design

Data Collection Protocols and Standards

Strict data gathering rules and standards are very important for keeping the accuracy and correctness of measurements in land surveying. These rules shape the methods used in different parts of data collection, which helps to achieve similar results in various projects. For

example, using recognised Best Management Practices (BMPs), as mentioned in (Mesner et al.), is vital to reduce nonpoint source pollution that can negatively influence land survey quality and environmental evaluations. Furthermore, new technologies, especially drones, provide fresh ways to improve data collection standards. As pointed out in (Abdul Aziz et al. 2019), drones can take detailed aerial photographs and cover large areas quickly, linking traditional surveying with modern needs. Thus, following strict data collection rules not only ensures precision but also aligns with new technological developments, strengthening the dependability of land surveying practices as a whole. instruction for surveying techniques (Mesner et al., 2011; Jonathan et al., 2013) (Figure 4).

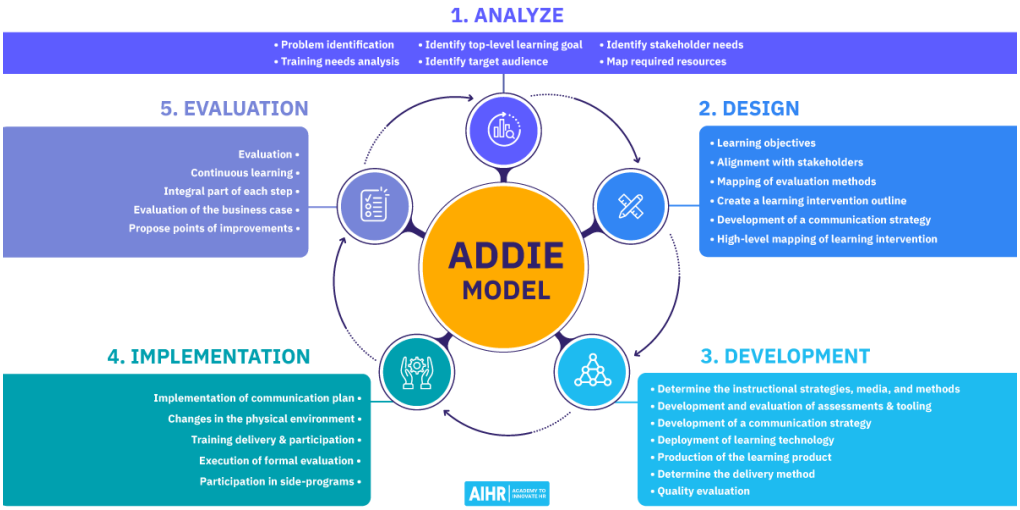

Fig. 4. Overview of the ADDIE Model in Instructional DesignReferences

Quality Control Measures in Surveying

To ensure accuracy in land surveying, strong quality control measures are needed, which are crucial for reducing mistakes and improving the trustworthiness of survey results. Good quality control includes thorough checks at every stage of the surveying process, starting from data gathering and ending with the final analysis. Detailed pre-survey checks, like assessing sites and calibrating instruments, are essential steps that lay the groundwork for precision. Furthermore, using review methods, such as evaluations by peers and verifying measurements with known reference points, helps ensure that every measurement is examined for accuracy and consistency. Ongoing training and learning for surveying professionals, keeping up with new technologies, are also vital for upholding high quality standards. This supports the idea that focusing on both proper procedures and the skills of the operators is important for effective quality control in surveying ('MDPI AG'). These combined methods not only improve the reliability of the data but also build trust among those involved in land management (Abdelfatah et al. 2019).

CONCLUSIONS

In conclusion, looking at precision in land surveying shows how important it is to use different methods and good practices to improve accuracy. The analysis shows that using new technologies like drones provides real benefits for monitoring the environment and collecting data, filling gaps between field work and remote sensing (Abdul Aziz et al. 2019).

The results of this study highlight the essential need for using accurate methods in land surveying to improve precision and trustworthiness in different uses. A detailed look at current methods shows that techniques like direct observations and camera trap-based capture-recapture surveys provide the most dependable estimates since these methods are less likely to result in population overestimation (Adams et al. 2024). Additionally, new technological developments, particularly hyperspectral imagery, offer major possibilities for better seafloor and habitat characterisation, which affects coastal management and environmental evaluations (Gardner et al., 2011). By combining these insights, the research shows the necessity for unified approaches that not only improve data gathering but also encourage consistency in outcomes, thus bolstering conservation efforts. Ultimately, these findings promote the use of new technologies and strong methods, making sure that land surveying practices effectively tackle the changing challenges in the field, as demonstrated by.

Fast improvements in technology are about to change land surveying, making it much more precise and efficient. With new tools like drones (UAVs) and laser scanning, surveyors can collect data over large areas in amazing detail, leading to better data collection and analysis. New developments in artificial intelligence and machine learning will help make processing this data easier, allowing surveyors to quickly gather insights. For example, using hyperspectral imagery, as mentioned in (Gardner et al., 2011), helps in understanding the seafloor much better, which expands traditional surveying methods into difficult areas. Moreover, the role of Geoinformatics Engineers in the changing oil and gas industries, highlighted in, shows how crucial accurate geospatial data is for managing resources. As these technologies combine, the future of land surveying is expected to reach accuracy levels that were once considered impossible, changing how industries operate and their results. These claims are supported by showing the structured methods that back these advancements in precision technology.

In conclusion, following set best practices and methods is very important for improving accuracy in land surveying. Careful use of the ideas discussed in this essay—like using new technology and strict evaluation techniques—helps surveyors deal with the complex challenges of today's surveying. Adding regular quality checks and using new tools and software makes survey data more reliable. Also, being aware of possible errors and biases in data gathering and analysis helps professionals protect the quality of their work. By combining theory with real-world use, professionals can meet the needs of stakeholders while maintaining industry standards. In the end, a focus on ongoing improvement and adapting to new technologies will lead to better land surveying methods. This flexible approach is well shown in the ADDIE model, which is important in designing

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