

A Comparative Analysis of Reconstructive Crime Scene

Muhamad Fuad Emri¹, Lau Chong Luh^{1*}, Mohamad Hezri Razali¹, Ahmad Norhisyam Idris¹, Saiful Aman Sulaiman¹, Khairulnizam M. Idris², Muhammad Nasri Abdul Ghani³

¹*School of Geomatics Science and Natural Resources, College of Built Environment, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

²*Geospatial Imaging and Information Research Group, Faculty of Built Environment and Surveying, College of Built Environment, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia*

³*Bandwork GPS Solution Sdn. Bhd., Old Klang Road, 58200 Kuala Lumpur, Malaysia*

ARTICLE INFO

Article history:
Received 01 November 2024
Revised 20 November 2024
Accepted 15 May 2025
Online first
Published 31 July 2025

Keywords:
Crime scene
Three-dimensional
LiDAR
iPhone
Laser Scanning

DOI:
[10.24191/bej.v22iSI.6478](https://doi.org/10.24191/bej.v22iSI.6478)

ABSTRACT

In this new technology era, crime scene reconstruction should be enhanced with the latest technology instead of using conventional two-dimensional (2D) approach. This study expands our knowledge of how to employ iPhone LiDAR to speed up the process of gathering crime scene data. With the aim of revolutionising forensic efficiency, this study investigates the potential of iPhone LiDAR in crime scene reconstruction with conventional techniques. In this study, distometer, measuring tape, iPhone 14 Pro Max and Total Station were used for data collection. The objectives include creating a crime scene sketch by hand, converting point clouds data into a 2D drawing, and analysing measurements obtained from various techniques. In this study, Total Station was used to conduct the detail survey of the crime scene. In this study, the distometer was used for baseline measurements while the measuring tape was utilised for short distances measurements. iPhone LiDAR 14 Pro Max, which is equipped with a 3D Scanner App, was used as the proposed approach for data collection. The findings demonstrate that the manual measurements using a distometer and measuring tape are less accurate than LiDAR readings when compared with the readings acquired from the Total Station.

INTRODUCTION

A crime scene is any location that may provide potential evidence for a committed crime. Two types of crime scene include primary and secondary crime scene. A primary crime scene is where a crime took place. In contrast, secondary crime scene is an area that is related to the crime but is not where the crime

^{1*} Corresponding author. *E-mail address:* lauchongluh@uitm.edu.my
<https://doi.org/10.24191/bej.v22iSI.6478>

was committed. For example, in a murder case, primary crime scene is where the murder took place while secondary crime scene is where the body is moved to after the murder (Shorey, 2022).

Crime scene investigation (CSI) has been around more than 100 years back with the first formal CSI manual was published in 1893 by an Austrian professor in criminal law, Hans Gross. In 1910, the first police crime laboratory was established in Lyon, France by a French criminalist Edmond Locard. Locard has a theory of “exchange principle”, where it is impossible for a criminal not to leave behind trace evidence that can be used to identify them on a crime scene (Whetstone et al., 2023).

Since then, CSI has evolved new techniques such as taking mugshots, fingerprinting and photography by the end of the nineteenth century. These technologies paved the way to forensic science in the early decades of twentieth century. One of the latest innovations of crime scene thanks to the evolution of technology is 3D representation of a crime scene. This is called a crime scene reconstruction, where a 3D model is made based on photographs taken or 3D laser scanning. It will create an accurate 3D representation of a crime scene.

This study aims is to determine the practicability of iPhone LiDAR in crime scene data capture. The objectives are to produce a crime scene sketch from traditional methods data, process point clouds data into a 3D model, analyse the measurement comparison of different methods.

Problem Statement

The most important thing in a crime scene is the time. The time of a crime scene discovered and the time the crime scene is first access. The crime scene may not be first accessed by crime scene investigators (CSIs). This usually happens when in cases of assaults or murders, paramedics may have been present at the scene treating the victim that will create contamination. One of the greatest challenges in any crime scene is contamination.

Contamination is the unwanted alteration of evidence that could affect the integrity of the original exhibit or the crime scene (Gehl, 2016). Another important challenge to the physical evidence is the loss of continuity. Evidence must be presented to demonstrate the chain of continuity from the crime scene to the courtroom to be accepted in court. These two challenges can be overcome by a great 3D model reconstruction of a particular crime scene. This is because the 3D model shows the crime scene in detail, including the placement of evidence. The faster the crime scene is photographed or scanned, the less contamination will occur.

Traditional methods of forensic and crime scene documentation include digital media, hand sketches, manual measurements and paper documentation (Maneli & Isafiade, 2022). Hand sketches and manual measurements usually take a long time to be completed; therefore, are less practical for crime scene reconstruction because of evidence contamination. Evidence contamination has a higher chance of occurring with more time consumed.

In 1893, Austrian criminal law expert Hans Gross published the first official CSI manual. Criminal Investigation: A Practical Handbook, his ground-breaking book, was translated into English in 1906. Gross established the principles of contemporary crime scene investigation alongside the French criminalist Edmond Locard. Gross illustrates this in Figure 1 with the first step is to create a dimension with placing A, A', I and I' at right angles. Parallel lines are drawn to produce a predetermined number of squares of equal size. The more of the square drawn, the higher the accuracy will be (Burney & Pemberton, 2013).

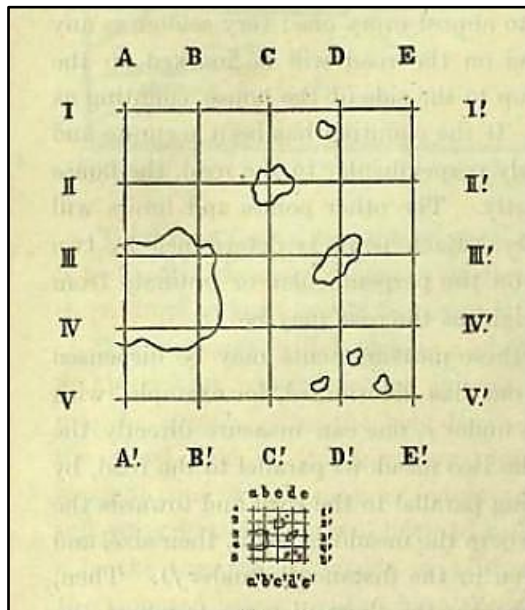


Fig. 1. Rough Crime Scene Sketch

Source: Burney & Pemberton (2013)

A crime scene is usually photographed which takes a long time to execute and less detail is taken. With new technology such as Terrestrial Laser Scanning (TLS) or LiDAR emerging these last two decades, crime scenes can be captured in more detail than ever. Since 2020, LiDAR has been incorporated with the iPhone, making it more accessible and affordable than a TLS device. The crime scene can also be captured with a manual measurement that involves distometer and measuring tape. This study concentrated on the analysis of the methods to capture the crime scene to create a 3D model reconstruction from the measurement aspects.

Past Studies

There are a few past studies that concentrate on LiDAR capturing crime scenes [7] have made a study to find the usability of Recon-3D, an iOS application. iPhone 13 pro was used to scan three different scenarios: a mock-up crime scene, a garage and a parked car. The study found Recon-3D to be a useful application for forensic investigators. This study uses mean absolute error for measurement analysis. The measurement obtained is compared to known distances using several metrics, such as mean Absolute error (MAE) and Standard Deviation (SD).

Another study uses the 3D LiDAR scanner made by Faro and the Leica Pegasus Backpack, a portable 3D LiDAR scanner combination to map a crime scene. Since both outputs a point clouds as well, they can be easily combined for visualisation. The result from point clouds data will then be used to create a visualisation in VR. The study found that while the crime scene can be accessed using VR, further study needs to be done with some important objects needing to be scanned separately to make it possible to pick up the object in VR (Nelis et al., 2018).

This next study uses iOS applications to measure the same evidence and distance that will be compared to manual measurements. The comparison and accuracy of various methods were calculated using a paired

sample t-test analysis. The study found that while mobile applications are better than manual measurement, consideration should be given to selecting the accurate starting point, stableness, motion, and angle to be selected. This study compared the various methods and calculated the accuracy using a paired sample t-test analysis.

A different study has been carried out by John et al. (2023) to compare the measurements between LiDAR data and actual measurements. The Canvas App was used in the study for crime scene recreation. The results indicate that the application can be used for the primary recreation of the crime scene and evidence collection. This study uses Relative Error to determine the magnitude of the error in terms of the actual size measurement.

METHODOLOGY

Figure 2 shows the flowchart of the methodology. The first section, preliminary stage includes the selection. The next section, data acquisition stage involves instrument testing and data collection. The third section is the data processing stage that includes data processing and measurement analysis.

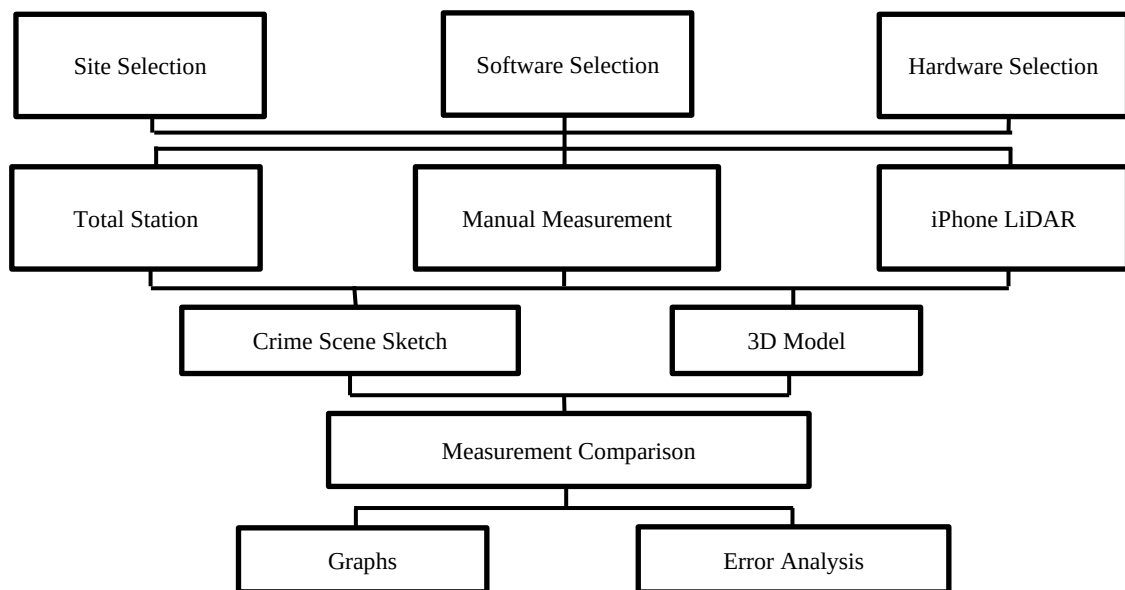


Fig. 2. Methodology Flowchart of This Study

Source: Authors (2024)

Site Selection

The preliminary stage involves thorough consideration of the research site selection. This involves identifying and selecting a site or location that corresponds to the study's unique objectives and goals. Accessibility, representativeness, and relevance to the research subject were all considered. The chosen location serves as the physical context for data collection and analysis, determining the overall validity and applicability of the study. Figure 3 shows the selected site, which is an indoor classroom. Several objects

were scattered around the classroom to portray the crime scene. These objects include a chair, a table, a bag, a hammer, a book, a water bottle and a victim.



Fig. 3. Site

Source: Authors (2024)

Hardware Selection

For the instrument selection, three instruments were selected as the three different methods of data acquisition. The first instrument is the total station. The total station data is important for validating the accuracy of the other instruments. It served as a baseline for comparison, ensuring reliability and consistency across different data acquisition methods. The next instrument is the distometer. This instrument was assisted by measuring tape. This instrument was selected because it is one of the traditional methods to create a crime scene sketch. The last selected instrument is the iPhone LiDAR. This instrument was chosen because it is an indication of the future technology for crime scene capturing. The inclusion of both traditional and advanced instruments acknowledges the importance of integrating proven methods with emerging technologies in crime scene investigations. It is supported by the easier and faster data capture of crime scenes, where time is one of the most important essences. While the total station acted as the benchmark, iPhone LiDAR representing future technology and the traditional method portrayed by distometer and measuring tape, this selection suggests a balanced approach that considers the adaptability of methods in crime scene scenarios.

Software Selection

The first software is the 3D Scanner App. This application can be found in the App Store. It was used to capture 3D data using the built-in capabilities of a smartphone. The next software is Clouds Compare. This software was chosen for its ability to process point clouds data. It enables advanced analysis,

visualisation, and manipulation of 3D data. The software is used for filtering the point clouds data. The next software is the Autodesk Recap Pro. This software was chosen to help further processing of the point clouds data. The next software is the Topcon Link. This software helps facilitate the transfer of data between Topcon instruments and processing software. The next software is the Autodesk AutoCAD. This software was chosen for its capabilities to process the total station data and the manual measurement data.

Total Station Data Acquisition

The first data collection method is by total station. This method started by establishing a network to serve as the station. Several stations are needed to reach full coverage of the scene. Four targets are used as the reference for easier registration in the processing stages.

Manual Measurement Data Acquisition

The second data collection method is the manual measurement, which includes the use of measuring tape and distometer. There are three measuring techniques for crime scene sketch, triangulation, polar coordinates and baseline or fixed line. The techniques used in this study are baseline or fixed line. A straight line was established between two fixed points. In this study, the walls are used as the baseline. The evidence was measured along the fixed line and at perpendiculars to the line.

Figure 4 shows the measuring techniques. The first step is to establish the baseline to be used as the reference for subsequent measurement. The next step is to create the dimension of the crime scene. Then, the measuring tape was used to collect the specific distances between objects. These measurements were recorded in a rough sketch that includes the layout of the crime scene and relevant measurements. Distometer was used for measuring longer distances where it is less prone to error compared to using measuring tape. Measuring tape is more flexible than distometer and can easily conform to the shape of the object being measured. It is beneficial when taking short measurements. The distometer was used to measure longer distances because it can read longer distance much quicker and there is less chance of misreading a measurement. In contrast, the measuring tape was used to cover the shorter distances that do not have a surface to reflect off the beam from distometer.

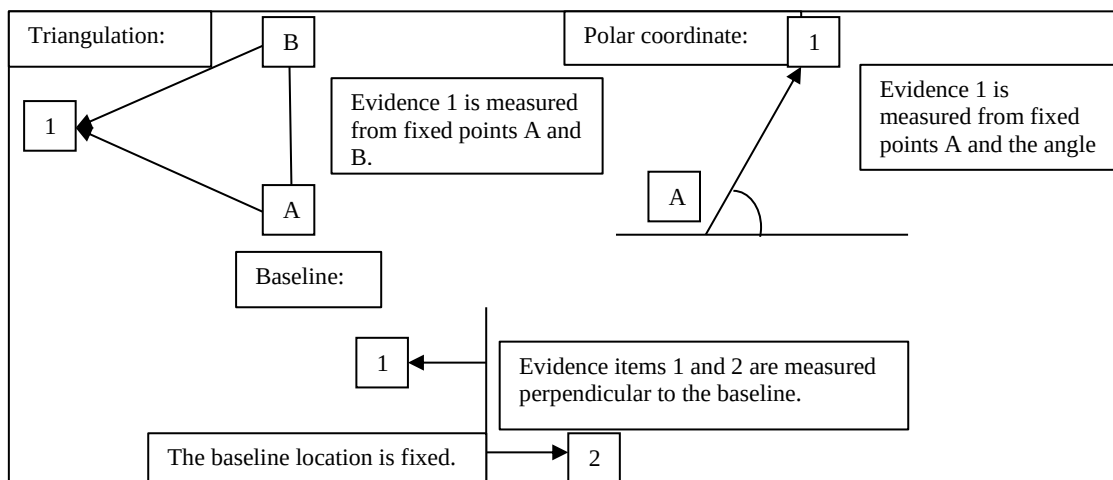


Fig. 4. Crime Scene Measurement Techniques

Source: Miller (2014)

iPhone LiDAR Data Acquisition

The last data collection was using the iPhone LiDAR. An iPhone 14 Pro Max was used to do the data collection. It moved around the mockup scene for full coverage. This technique is easier than other techniques as it shows where the data has been collected and where it needs to be collected. A 3D Scanner App was installed on the iPhone. The app was used to scan the site. The option used is the Point Clouds with default settings. The scan started by scanning the wall to create the dimension and finished by scanning the interior. The app will show the scanned area while scanning to avoid missing some areas.

Crime Scene Sketch

The total station data was processed using Topcon Link and AutoCAD. The process started by extracting the data from the instrument using Topcon Link. The raw data exported from the total station is imported into the software. The data was exported into a .dwg file format for further processing in AutoCAD. The extracted data will then be imported into AutoCAD. For registration, the four targets were used as the reference for aligning the data. The final product is a crime scene sketch. This product acts as the benchmark for comparing measurements from other methods. Figure 5 shows the crime scene sketch using AutoCAD for total station data. After finishing the sketch, measurement data will be extracted for measurement analysis use.

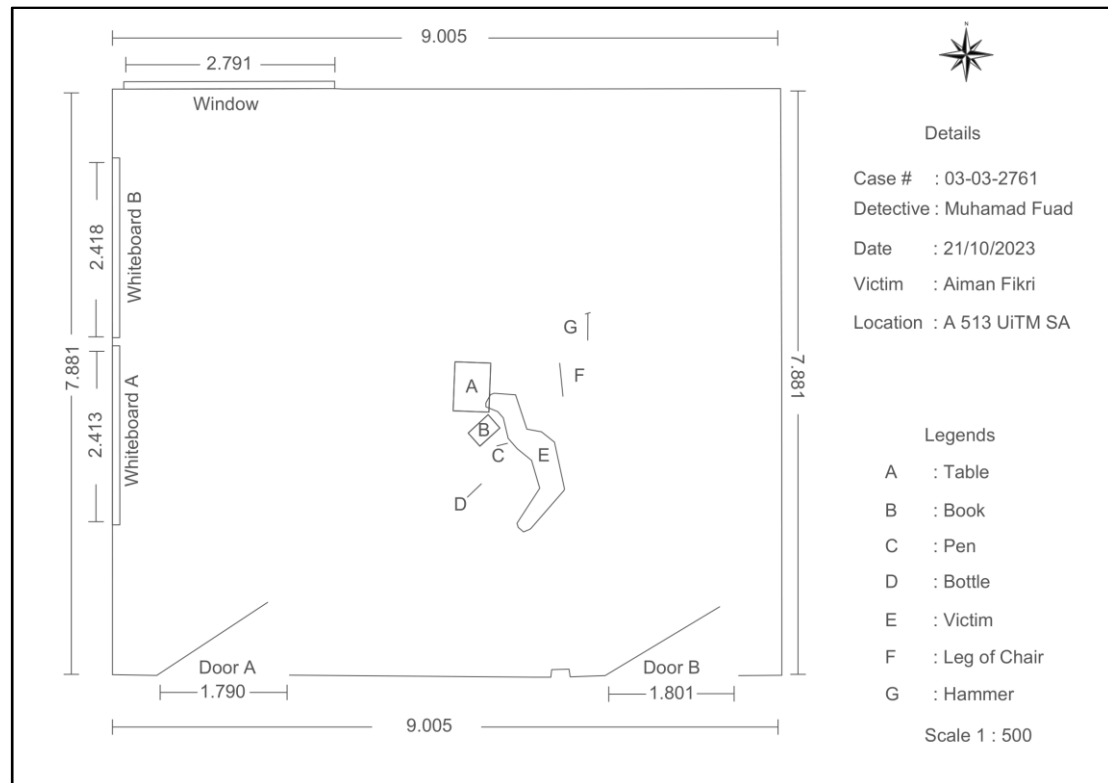


Fig. 5. Total Station Crime Scene Sketch

Source: Authors (2024)

The manual measurement data was processed using AutoCAD. The process will start by creating the dimension which has been acquired using distometer. The dimensions were used as the baseline for other distometer readings. Different colours were used for easier recognition. The data was based on the baseline that is established during data acquisition stages. Figure 6 shows the crime scene sketch using AutoCAD for manual measurement. After finishing the sketch, measurement data was extracted for measurement analysis use.

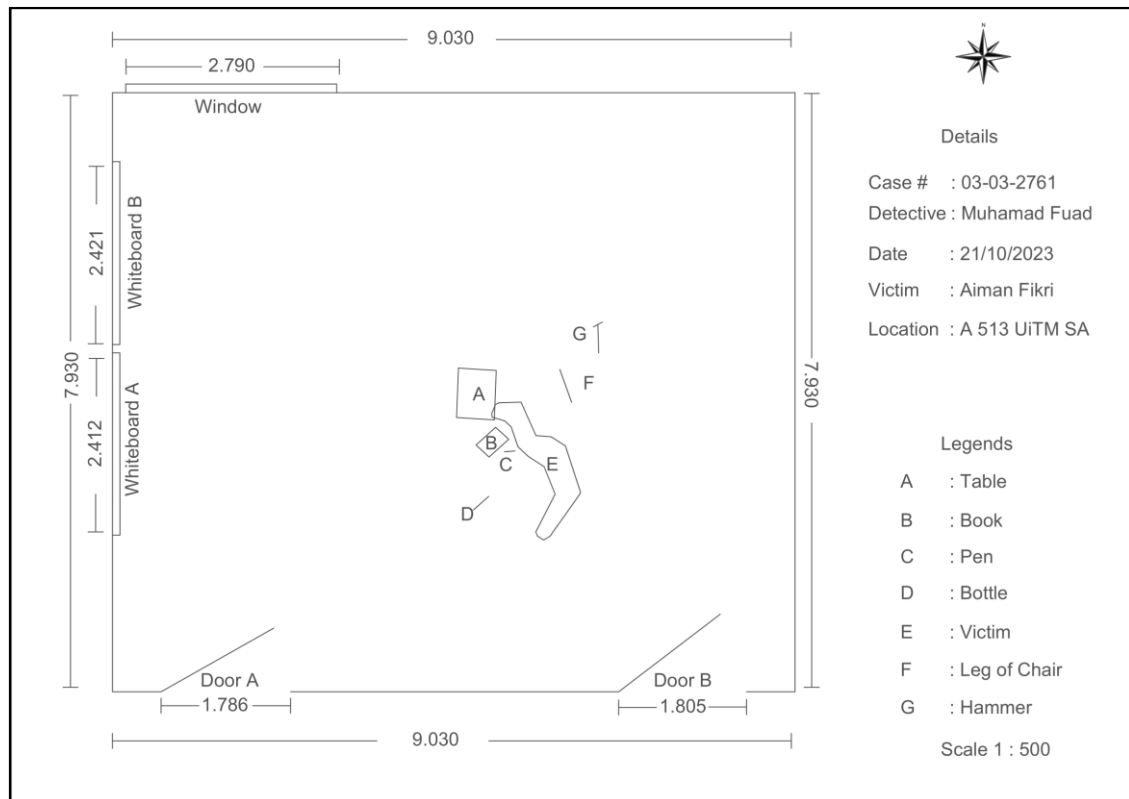


Fig. 6. Manual Measurement Crime Scene Sketch

Source: Authors (2024)

3D Model

The iPhone LiDAR data capture was processed using Cloud Compare. The process started after capturing the crime scene, with the first step being to clean up the data. This step includes removing the noises or unwanted points from the point clouds data. The process starts with cross-section feature. It was used to remove any unwanted data. Next is the segmentation function that helps remove unwanted data outside of the baseline. The next step was to generate the 3D mesh. The mesh product can be used for further processing if needed. Figure 7 shows the processed 3D model of the crime scene from the top view. This model was used to compare measurements.



Fig. 7. Crime Scene 3D Model Top View

Source: Authors (2024)

Measurement Analysis

Once all final products of each method have been generated, the measurement analysis stage begins. It involves differentiating the physical evidence measurement between the selected methods. The first measurement analysis involves the total station final sketch and manual measurement. The total station final sketch will be used as a benchmark for measurement because of the high dependability of the data. The second measurement involves the total station final sketch and 3D model of iPhone LiDAR. This helps to illustrate the idea of usability of the iPhone LiDAR method. The last analysis is the comparison between the manual measurement and the iPhone LiDAR 3D model. This is useful for determining whether the iPhone LiDAR method can be used for capturing crime scenes. A bland-Altman plot was generated to visualise the error analysis for the measurement. Error metrics used were Mean Absolute Error (MAE) and Mean Relative Error (MRE) analysis. Histogram graph also was generated for visualising the difference between the datasets.

RESULTS AND DISCUSSION

This chapter presents the findings of the study and interprets their significance. This chapter systematically presents the results obtained from the previous chapter, utilising visual aids such as tables and graphs for clarity. Following the presentation of results, the analysis phase begins to explore the meaning and implications behind the results. This chapter laid the groundwork for drawing conclusions and making recommendations based on the results obtained.

Measurement Analysis

The measurement analysis includes MAE, MRE and graphs to visualise the differences. MAE was used because it is a pivotal metric in regression analysis, representing the average absolute difference between true and observed values. Another metric is MRE. It assesses the proportional accuracy of values. It is particularly useful for understanding the percentage-wise difference between datasets. The last is histogram graphs. It offers a visual representation of the difference in distributions between datasets. Table 1 shows the data from the total station method and manual measurement method. The data is being compared with the total station data act as the true value of the measurements. *W* stands for width; *L* is for length and *P* is for perimeter.

Table 1. Dimensions from three (3) different techniques

Object	Total Station (m)	iPhone LiDAR (m)	Manual Measurement (m)
Room W	7.881	7.905	7.930
Door A W	1.790	1.784	1.786
Door B W	1.801	1.803	1.805
Whiteboard A W	2.413	2.420	2.412
Whiteboard B W	2.418	2.421	2.420
Window W	2.791	2.791	2.790
Room L	9.005	9.005	9.030
Bottle L	0.260	0.259	0.273
Hammer L	0.361	0.371	0.377
Leg of Chair L	0.448	0.441	0.464
Pen L	0.152	0.148	0.164
Table P	2.289	2.310	2.309
Book P	1.206	1.203	1.171

Source: Authors (2024)

Total Station and Manual Measurement Error Analysis

The equation 1 shows the formula of mean absolute error while equation 2 shows the formula of mean relative error percentage.

$$MAE = \sqrt{\frac{1}{n} \sum_{i=1}^n |y_i - \hat{y}_i|} \quad (1)$$

$$MAE = 0.015$$

A low MAE value of 0.015 indicates that the absolute differences between the total station and manual measurements are relatively small on average.

$$MRE = \frac{1}{n} \sum_{i=1}^n \left| \frac{y_i - \hat{y}_i}{y_i} \right| \times 100 \quad (2)$$

$$MRE = 2.00\%$$

An MRE of 2.00 % designates that the manual measurement and total station method are relatively small in relative differences. An MAE of 0.015 and MRE of 2.00% shows a consistent low value which strengthen the confidence in the reliability and accuracy of the manual measurement method.

Figure 8 shows the differences between total station and manual measurement using a histogram. The highest difference is room width on 0.049m and lowest are window width and whiteboard A width on 0.001m. Figure 9 shows the Bland-Altman plot of the total station and manual measurement. The Bland-Altman plot indicates two outliers that deviate significantly from the overall trend, indicating a significant measurement disagreement.

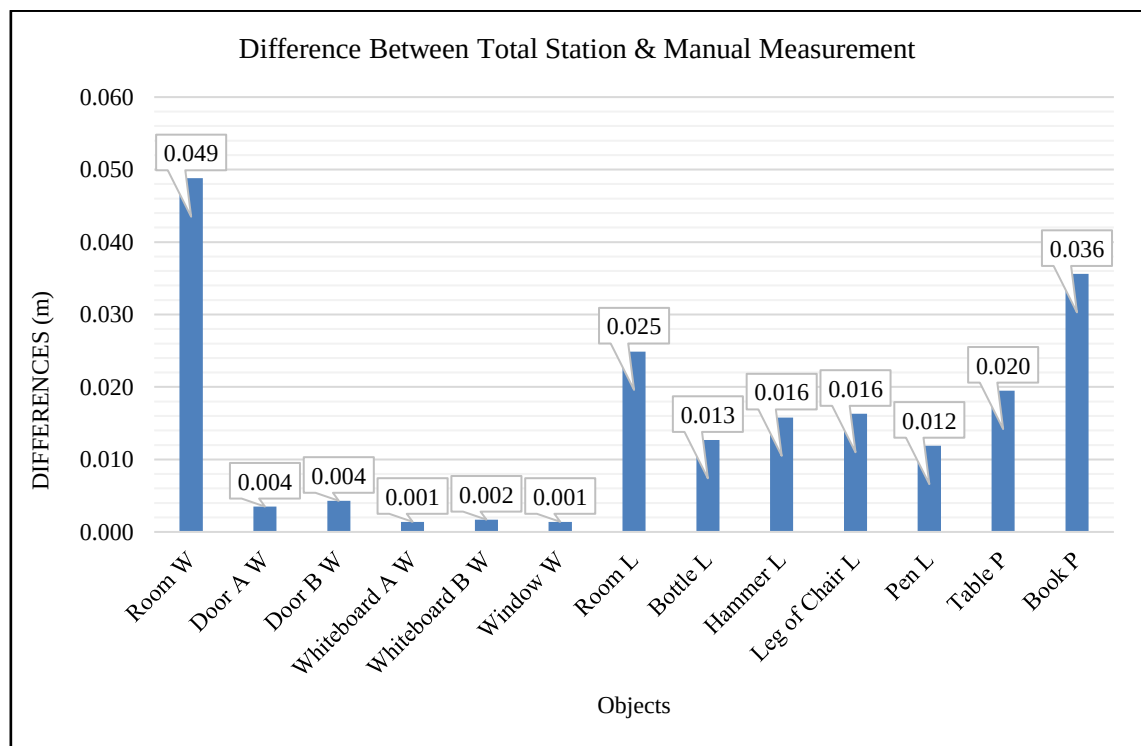


Fig. 8. Histogram of Differences between Total Station and Manual Measurement

Source: Authors (2024)

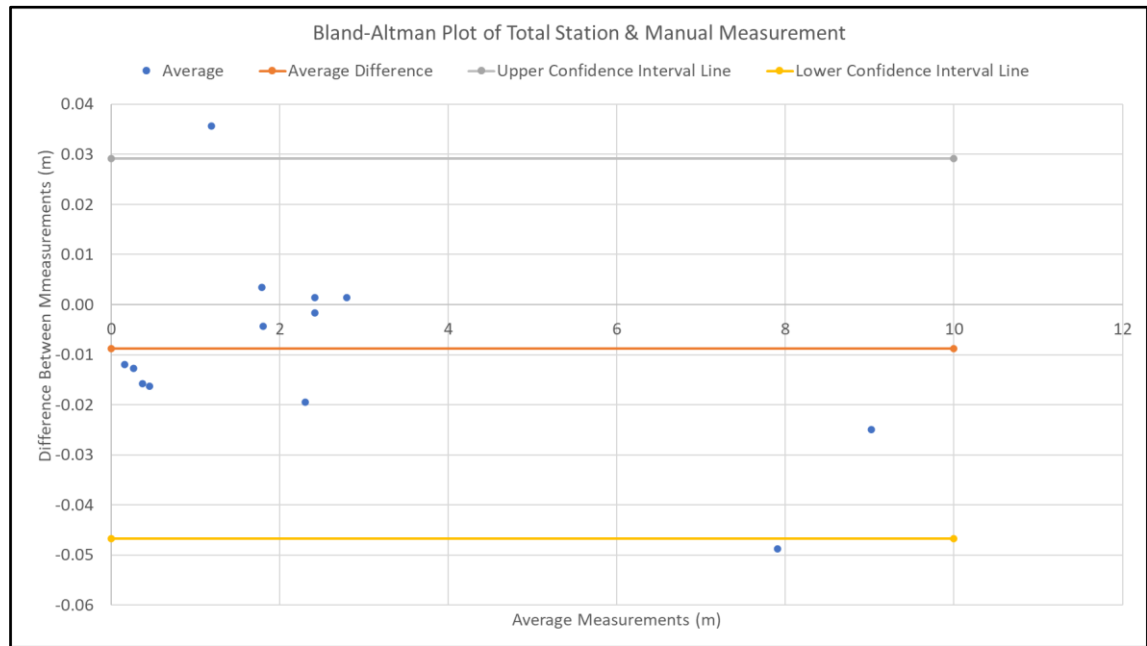


Fig. 9. Bland-Altman Plot of Total Station and Manual Measurement

Source: Authors (2024)

Total Station and iPhone LiDAR Error Analysis

A low MAE value of 0.007 indicates that the absolute differences between the total station and iPhone LiDAR are relatively small on average. An MRE of 0.76 % designates that the iPhone LiDAR and total station method are relatively small in relative differences. An MAE of 0.007 and MRE of 0.76 % shows a consistent low value which strengthen the confidence in the reliability and accuracy of the iPhone LiDAR method. This indicates that iPhone LiDAR data is better than manual measurement as it is closer to the true values, which is the total station data. Figure 10 shows the differences between total station and iPhone LiDAR using a histogram. The highest difference table perimeter on 0.081m and the lowest is 0 on multiple data. Figure 11 shows the Bland-Altman plot of the total station and iPhone LiDAR. The Bland-Altman plot only exhibits a single outlier that deviate notably from the overall trend.

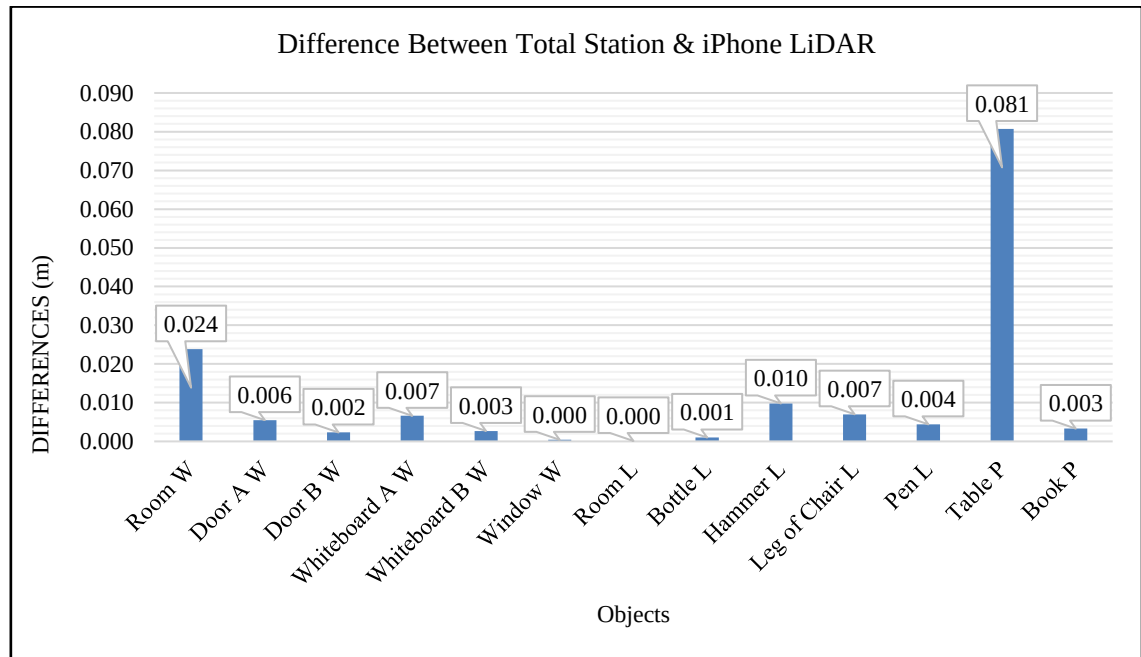


Fig. 10. Histogram of Differences between Total Station and iPhone LiDAR

Source: Authors (2024)

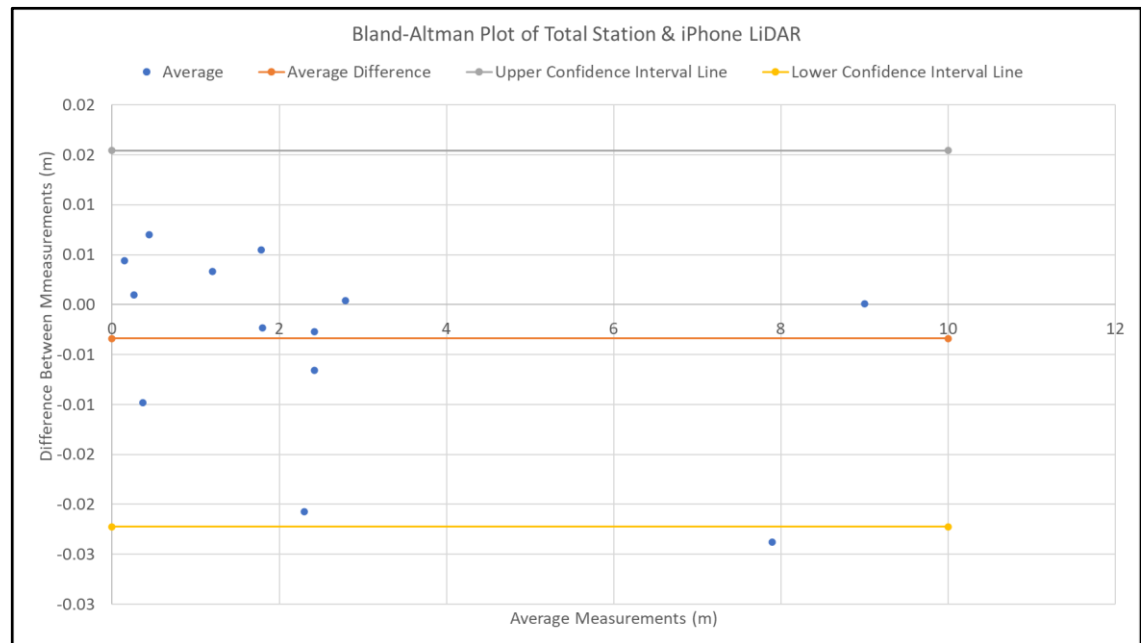


Fig. 11. Bland-Altman Plot of Total Station and iPhone LiDAR.

Source: Author (2024)

Manual Measurement and iPhone LiDAR Error Analysis

A low MAE value of 0.012 indicates that the absolute differences between the manual measurement and iPhone LiDAR are relatively small on average. An MRE of 2.09 % designates that the iPhone LiDAR and manual measurement methods are relatively small in relative differences. An MAE of 0.012 and MRE of 2.09 % shows a consistent low value which strengthen the confidence in the reliability and accuracy of the iPhone LiDAR. These results strengthen the ability to use iPhone LiDAR for capturing crime scenes. Figure 12 shows the differences between manual measurement and iPhone LiDAR using a histogram. The highest difference is the table perimeter on 0.061m and lowest are 0.001 on whiteboard B width and window width. Figure 13 shows the Bland-Altman plot of manual measurement and iPhone LiDAR. The Bland-Altman plot only exhibits a single outlier that deviate notably from the overall trend.

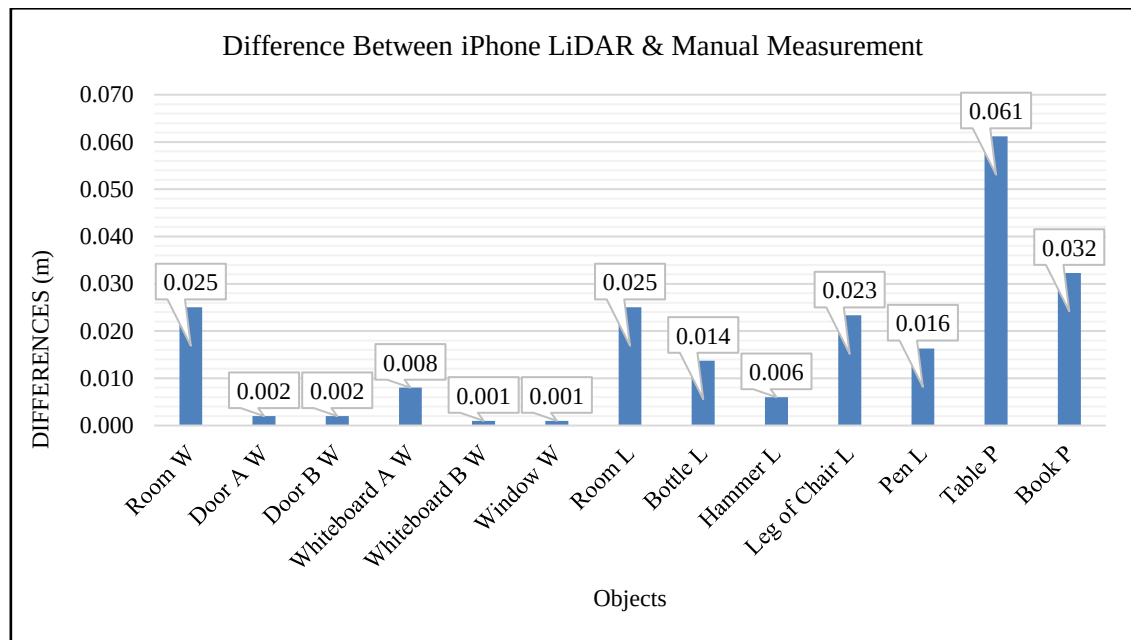


Fig. 12. Histogram of Differences between Manual Measurement and iPhone LiDAR

Source: Authors (2024)

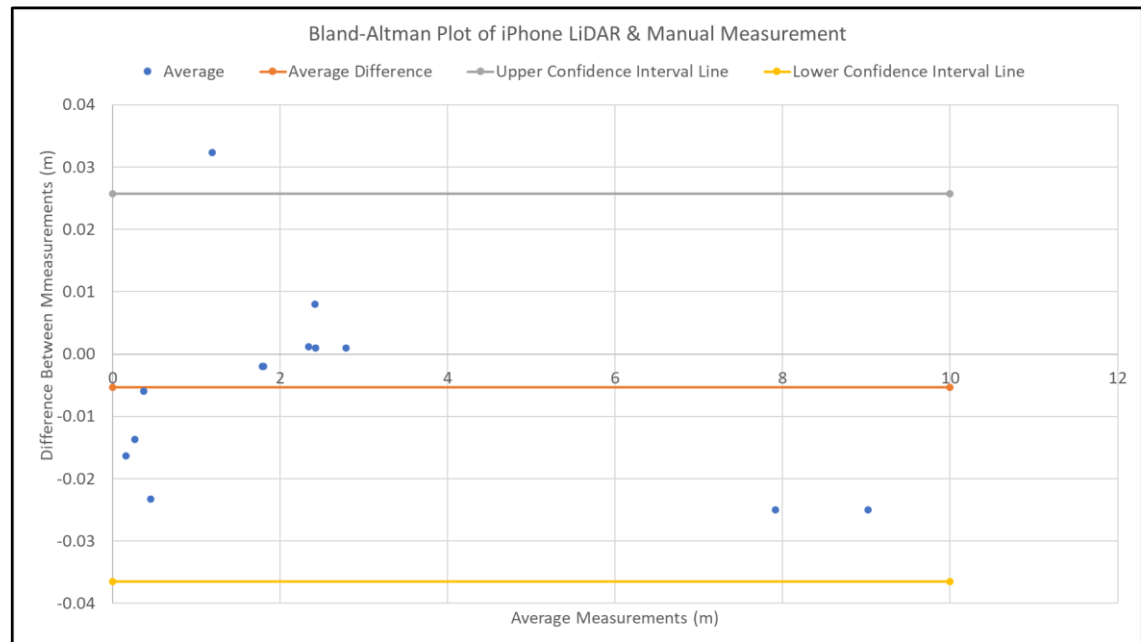


Fig. 13. Bland-Altman Plot of Manual Measurement and iPhone LiDAR

Source: Authors (2024)

CONCLUSION

In conclusion, this study aimed to assess the feasibility of utilising advanced technology, which is iPhone LiDAR for crime scene capture by comparing it with the established method of total station which considered as true value and with manual measurement, a traditional method for crime scene capture. The results demonstrated that, iPhone LiDAR compared to total station exhibited promising accuracy, with an MAE of 0.007 and MRE of 0.76 %. On the other hand, when comparing the manual measurements and total station, it is less accurate as it has a higher MAE of 0.015 and MRE of 2.00 %. This indicates that the result from iPhone LiDAR is better than manual measurement when compared to the true value. When comparing iPhone LiDAR and manual measurement, it shows compelling results, showing an MAE of 0.012 and an MRE of 2.09 %. These findings suggest that iPhone LiDAR technology holds the potential for crime scene capture, offering a viable alternative which is faster than other methods.

While the study fulfilled its objectives to find out if iPhone LiDAR is appropriate for crime scene capture, there still lie several recommendations that can further enrich and strengthen the exploration of iPhone LiDAR technology in crime scene capture. To enhance the robustness and generalisability of the findings, the first recommendation is to expand the dataset by including more diverse crime scene scenarios and increasing the number of surveyed sites. This will provide a more thorough understanding of iPhone LiDAR's performance across different forensic contexts. Considering the rapid advancements in surveying technologies, the second recommendation is to explore the integration of TLS alongside iPhone LiDAR for a comparative analysis. While iPhone LiDAR provides portability and accessibility, TLS is known for its high-resolution and precise measurements. To ensure the practical applicability of iPhone LiDAR in forensic investigations, the third recommendation is to collaborate with forensic experts and law

enforcement agencies. Engaging in partnership with professionals in the field will provide valuable insights into the nuances of crime scene analysis.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the assistance of the School of Geomatics Science and Natural Resources, College of Built Environment, Universiti Teknologi Mara (UiTM) throughout the entirety of this study.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

AUTHORS' CONTRIBUTIONS

Muhamad Fuad Emri and Lau Chong Luh carried out the research and wrote and revised the article. Mohamad Hezri Razali and Ahmad Norhisyam Idris conceptualised the central research idea and provided the theoretical framework. Lau Chong Luh, Saiful Aman Hj Sulaiman and Khairulnizam M. Idris designed the research, and supervised the research progress; Muhammad Nasri Abdul Ghani provided advice on the 3D crime scene data collection and review the article.

REFERENCES

- Burney, I., & Pemberton, N. (2013). Making Space for Criminalistics: Hans Gross and Fin-de-siècle CSI. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences*, 44(1), 16-25. <https://www.sciencedirect.com/science/article/pii/S1369848612000969>
- Gehl, R., & Plecas, D. (2016). *Introduction to Criminal Investigation: Processes, Practices and Thinking*. New Westminster, BC: Justice Institute of British Columbia. <https://pressbooks.com>
- John, S., Philip, S., Singh, N., Hari, P. B., & Khokhar, G. S. (2023). Economic Solution for Spatial Reconstruction Using LiDAR Technology in Forensic Sciences. In *2023 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)* (pp. 252-256). IEEE. <https://ieeexplore.ieee.org/abstract/document/10131861>
- Kottner, S., Thali, M. J., & Gascho, D. (2023). Using the iPhone's LiDAR Technology to Capture 3D Forensic Data at Crime and Crash Scenes. *Forensic Imaging*, 32, 200535. <https://www.sciencedirect.com/science/article/pii/S2666225623000040>
- Maneli, M. A., & Isafiade, O. E. (2022). 3D Forensic Crime Scene Reconstruction Involving Immersive Technology: A Systematic Literature Review. *IEEE Access*, 10, 88821-88857. <https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9858116>

- Nelis, J., Desmet, S., Wauters, J., Haelterman, R., Borgers, E., & Kun, D. (2018). Virtual Crime Scene. In *2018 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR)* (pp. 165-168). IEEE. <https://ieeexplore.ieee.org/abstract/document/8613654/>
- Shorey, J. (2022). Crime Scene Definition, Investigation & Examples. Study.com. <https://study.com/learn/lesson/crime-scene-overview-components.html>
- Whetstone, T., Brodeur, J. P., Walsh, W. F., Kelling, G. L., & Banton, M. P. (2023). Crime-scene Investigation and Forensic Sciences. Britannica. <https://www.britannica.com/topic/police/Crime-scene-investigation-and-forensic-sciences>
- Miller, M. T. (2014). Crime Scene Investigation Laboratory Manual. ELSEVIER. <https://www.caeducatorstogether.org/cabinet/file/2d807c40-f41d-45ae-ae61-c44d85f01daa/Crime-Scene-Documentation-Sketching.pdf>



© 2025 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY-NC-ND 4.0) license (<http://creativecommons.org/licenses/by-nc-nd/4.0/deed.en>).