VOL 4, NO.1 (2024) 43-64
https://jagst.utm.my

JAGST
Journal of Advanced Geospatial
Science & Technology

Comparison of As-Built Surveys Using Handheld Laser Scanner and Conventional Method

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***Abstract* -** With the advent of laser scanners in general, handheld laser scanners have become a tool used by surveyors to capture point clouds. The handheld laser scanner is useful for tight and confined spaces where a terrestrial laser scanner or a human cannot enter. Many surveyors still rely on the conventional method, which involves using a distometer and measuring tape for their strata as-built surveys. This is due to the simplicity and cost-effectiveness of the equipment. However, the conventional method is highly susceptible to human errors, unlike the laser scanner, which captures all features in point clouds without human intervention. In this research, data collected from both handheld laser scanners and conventional methods are compared. The handheld laser scanner captured a total of three levels. After collecting data at the site, the GeoSLAM Hub software processed the point clouds. This software helps convert the 3D point clouds into a 2D plan, with dimensions listed for the subsequent comparison process. The comparison focuses on the X and Y dimensions of the unit, with a tolerance of ±0.1m as per the circular KPUP-1-2015-JILID-I-v2016 provided by JUPEM. Following the comparison, the Root Mean Square Error (RMSE) is determined, with the lowest and highest values being 0.018m and 0.024m, respectively. In conclusion, the results show a minimum difference of 0.001m and a maximum difference of 0.049m, which falls within the provided tolerance. The handheld laser scanner offers visual aids to surveyors, enabling them to identify discrepancies' locations quickly. However, its drawback lies in the equipment's cost. Ultimately, the strata as-built plan is prepared for the three surveyed levels.

Keywords *– Handheld Laser Scanner, Strata Survey, Strata As-built Plan, Point Cloud, Dimensional*

Article History: Received 20 January 2024, Accepted 24 February 2024, Published 31 March 2024

How to cite: Yong, C. Y. A., Ariff, M. F. M., Omar, A. H. and Amim, Z. M. (2024). Comparison of As-Built Surveys Using Handheld Laser Scanner and Conventional Method. Journal of Advanced Geospatial Science and Technology. 4(1), 43-64.

1.0 Introduction

Sung et al. (2022) states that a handheld laser scanner is a portable scanner equipped with an Inertial Measurement Unit (IMU) and positioning system. The handheld laser scanner is crucial for capturing and collecting geospatial data. Majid et al. (2023) stated that terrestrial laser scanning (TLS) has become a popular method to acquire and document object spatial data. Before the existence of the laser scanner, a distometer and a measuring tape were used to measure the dimension in an as-built survey. Zakaria et al. (2019) stated that TLS can also provide data at unreachable places; hence, the handheld laser scanner is a more direct and efficient approach to capturing data in challenging areas such as confined spaces, underground, narrow passages, etc. According to Mat Adnan et al. (2019), 3D scanning is mapping an object, structure or area and describing it in the form of x, y, and z coordinates – a format known as a "point cloud". The GEOSLAM handheld laser scanner has the SLAM technology to localize and map an area ten times quicker than the conventional methods. This approach is carried out during a strata as-built survey.

According to Razali et al. (2020), as-built surveying is a survey technique in which position and geometrical attributes are observed and presented in a survey plan. A strata as-built survey is required before the submission of CPS to JUPEM, which is also the process of obtaining a strata title. A strata title determines ownership of such or land parcels, and a document is issued to the purchaser stating ownership. This document is a strata title (Strata Titles Act 1985). The surveyors still apply the conventional method of measuring the dimension, floor height and wall thickness using the distometer and measuring tape. When the building reaches the superstructure stage, the surveyors may start to do the strata survey. A building superstructure stage is the portion of the building above ground level, encompassing the framework, floors, walls, and roof. Although the distometer may provide the distance in 3 decimal places, the distance shown in the plan is only one decimal place, whereas the fieldbook will display it in 2 decimal places. According to Razali et al. (2020), as-built surveying is a technique in which position and geometrical attributes are observed and presented in a survey plan. A strata as-built survey is one of the processes conducted before submitting the Proposed Strata Plan to the survey department; thus, it shall be done using an efficient method. Strata as-built survey often involves high-rise buildings with many floors. If surveyors use the conventional method of a distometer and measuring tape, it would take a significant amount of time and labour to complete the whole building, and the time taken for resolving construction errors is included in the time frame.

Every unit dimension must be measured and rectified before preparing the CPS plan. The floor height of the unit is also presented in the CPS plan as a section plan. The items that need to be submitted are the CPS plan, fieldbook, strataXML and other documentation. The accuracy of the distance is ±0.1m. This is based on the circular issued by JUPEM. After submitting CPS to JUPEM, JUPEM shall arrange a site visit to the mentioned site.

Figure 1 is a sketch describing the difference between the building plan and the actual constructed unit. Ebrahim (2014) stated that a 3D scanner is a device that analyzes a real-world object or environment to collect data on its shape and appearance. This is one of the scenarios surveyors might encounter during strata as-built surveys. The surveyors may be unable to identify the differences immediately as the conventional method does not provide a clear visual. Jaafar et al. (2017) stated monitoring will be challenging without previous knowledge. If the handheld laser scanner is used, surveyors may directly know the root cause of the difference. Surveyors are responsible for monitoring the overall progress and performance of the building before preparing for submission work. Jaafar et al. (2017) stated that one of the duties of engineers is to monitor the performance of structures against design criteria.

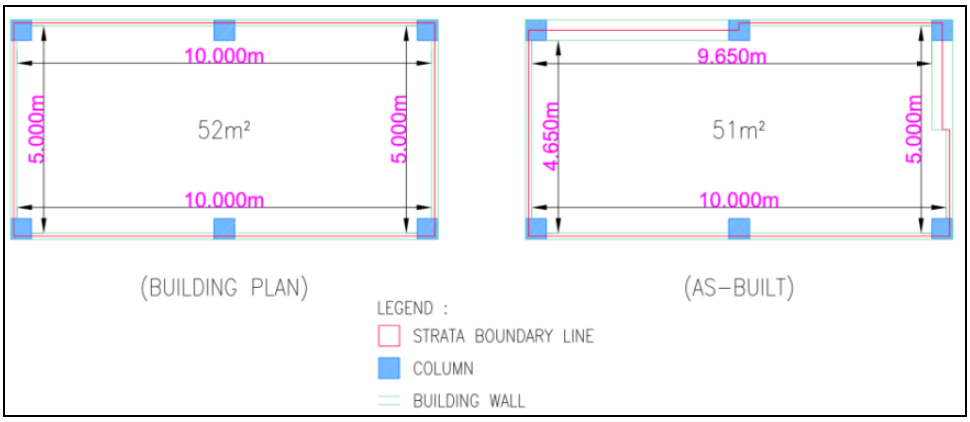


Figure 1. Comparison between Building Plan and As-built

Figure 1 shows a few discrepancies between the building plan and as-built: the wall thickness, area, shape and dimension. If hundreds of units encounter the same problems, rectifying them would take time. With the help of a 3D laser scanner, especially a handheld laser scanner, in this case, it would significantly reduce the time it takes for a surveyor to identify all the discrepancies. The visual may give the surveyor all the information crucial to the as-built survey. This research aims to produce the strata as-built plan and evaluate the accuracy of the strata as-built plan produced by the handheld laser scanner.

2.0 Materials and Methods

2.1 Study Area

The study area was conducted at a construction site at D'Quince Residence (Figure 2). This development is still in the construction stage and is suitable for collecting raw data as no additional renovation is applied.

Figure 2. Study area (D'Quince Residence)

2.2 Equipment & Software

2.2.1 GeoSLAM Zeb-Revo

According to Wei et al. (2019), the suitable 3D laser scanner that is used significantly depends on an object's level of detail and size. The GeoSLAM ZEB Revo is a compact and portable handheld 3D LiDAR scanner. It captures 43,000 points per second and achieves a relative accuracy of one to three cm for high-quality scans in the shortest possible time. The ZEB Revo has a range of 30 m and can be used in areas with poor GPS, including indoors, underground and outdoors. It has a rotating LiDAR sensor for the broadest possible field of view and is IP64 protected. Data collected with the ZEB Revo can be processed with GeoSLAM Hub. As Razali et al. (2021) stated, laser scanning technology offers relevant and reliable data representation of Earth features and infrastructures on the ground.

Figure 3. GeoSLAM Zeb-Revo

2.2.2 Distometer

This small device is known as a distometer. It provides all significant measurement modes in one standard length, surface and volume calculation. It is equipped with a display that shows the last three measurement results for easy reference. The distance measurements can be provided in 3 decimal places. According to Russhakim et al. (2019), a distometer has been used widely to measure distance because of its small and handy size.

Figure 4. BOSCH GLM 40 Laser Range Finder

2.2.3 Measuring Tape

The measuring tape is a flexible tool for measuring the distance. It is made from fibreglass, cloth, metal ribbon and plastic. Hence, it is a flexible ruler. Centimetres and inches are marked on the tape's surface to determine the measurements' length.

Figure 5. Measuring tape

2.2.4 GeoSLAM Hub

Hub was GeoSLAM's primary processing platform until September 2021, when Connect was introduced. It can turn three-dimensional data into actionable information and valuable results in minutes. Hub combines industry-leading SLAM (Simultaneous Localization And Mapping) technology with powerful post-processing capabilities to provide complete end-to-end solutions. Hub users can take advantage of the Adjust to Control feature. Control points are marked during scanning and imported into Hub.

Figure 6. GeoSLAM Hub (GeoSLAM, 2023)

2.2.5 AutoCAD

AutoCAD is computer-aided design software (CAD) for precise 3D and CAD design and modeling with solids, surfaces, mesh objects, documentation features, etc. It includes features to automate tasks and increase productivity, such as comparing drawings, counting, adding objects and creating tables. It also has seven industry-specific toolsets for electrical design, plant engineering, architectural layout drawings, mechanical design, 3D mapping, adding scanned images and raster image conversion. AutoCAD allows users to create, edit and annotate drawings from desktop, web and mobile devices.

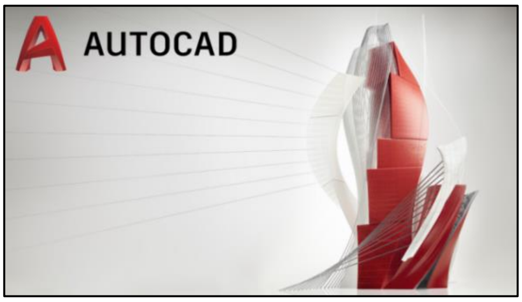


Figure 7. AutoCAD (Autodesk)

2.3 Methodology

The flowchart represents a more detailed workflow for this research. Flowcharts may give the reader a more straightforward and understandable work procedure. It involves four main stages: Preparation Stage (Stage 1), Data Collection Stage (Stage 2), Data Processing Stage (Stage 3) and Data Assessment Stage (Stage 4). Each stage plays an essential role in achieving the expected result at the end of this research. This flowchart was also used to safeguard the quality of this research. The details for each stage will be described in the following sub-chapters.

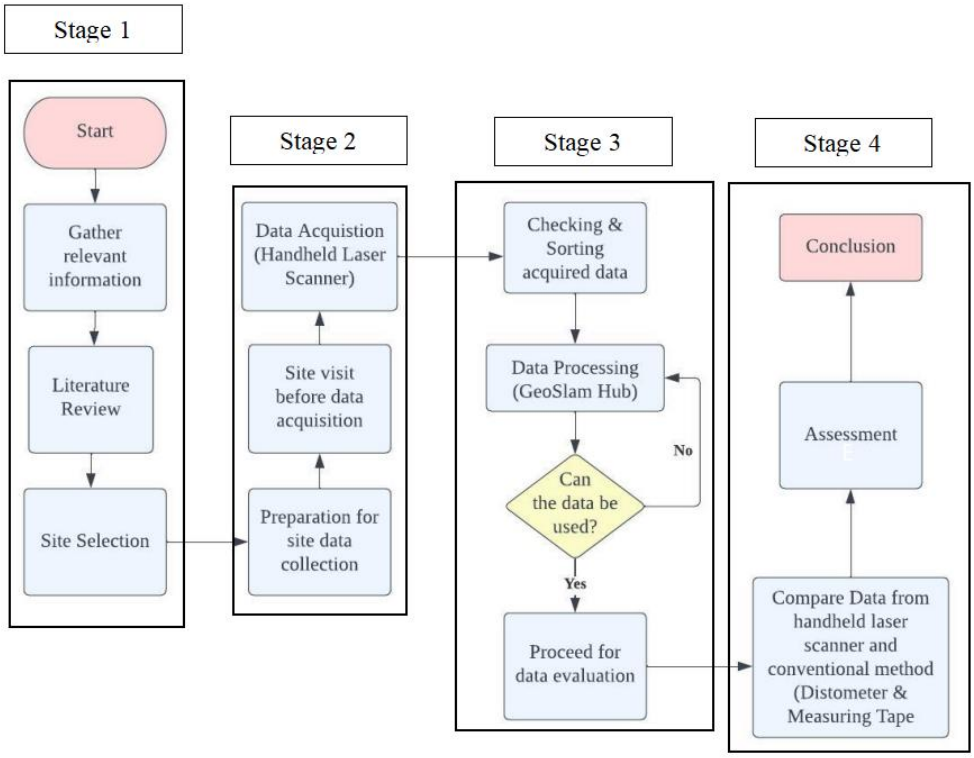


Figure 8. Flowchart for Research Methodology

2.3.1 Stage 1: Preparation

This stage involves planning and identifying which instrument shall be used to carry out this research. With the help of the literature review, the principles and fundamentals of using a handheld laser scanner can be understood and applied on-site. A residential high-rise building has been selected, D'Quince Residences, located at Damansara Perdana, Selangor. The building has a total floor level of eighty-five, including the basement level. The reason for selecting this building is because it is one of the high-rise buildings in the Damansara area and is still under construction. It is the most suitable place to collect the data before it begins renovation. Three levels from Block B were chosen for data collection: levels 10, 25 and 38. These three levels are selected because some high-rise buildings may have different wall sizes. For instance, level 10 has a 0.25m wall width, level 25 has a 0.20m wall width, and level 38 has a 0.15m wall width. These differences may affect the strata demarcation line and area. This is also to expand the coverage for the whole tower.

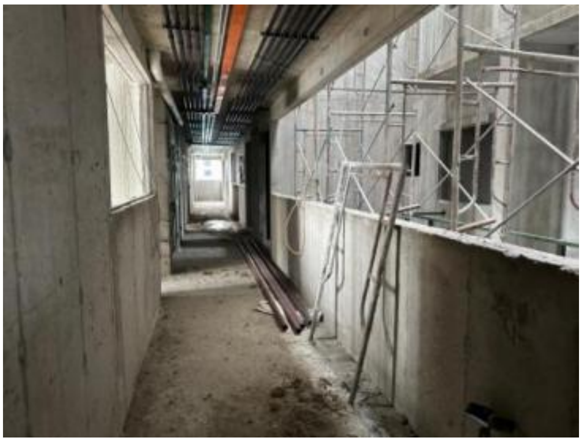


Figure 9. D’Quince Residence site location and condition

2.3.2 Stage 2: Data Collection

GeoSLAM ZEB-Revo, BOSCH GLM 40 Laser Range Finder and architect’s building plan have been selected as the tools in this research. Before the actual day for data collection, a site visit shall be conducted to understand that building better. Safety equipment such as a safety helmet, safety vest and safety boot must be equipped before entering the site. During data collection at the site, the handheld laser scanner (GeoSLAM) will scan and distometer (BOSCH GLM 40) measure the 2D dimension for three levels which are levels 10, 25 and 38. Each of the levels consists of fifteen service apartment units. In the end, a total data of forty-five units shall be collected. Since there are fifteen units on one level, two to three scan trips will occur. This is to prevent data distortion and device overload in the scanning process. During the post-processing stage, all the data from the same level will be merged. Ismail et al. (2022) stated the accessibility of state-of-the-art remote sensing technologies grants comprehensive and up-to-date data collection over a wide area.

Figure 10. Data collection using HLS (Left) & As-built using distometer (Right)

2.3.3 Stage 3: Data Processing

All data from the handheld laser scanner and distometer will be gathered and sorted in this stage. According to Razali et al. (2022), point clouds are a digital representation of physical objects or buildings in the real world. The point clouds from the handheld laser scanner will be downloaded from the data logger and copied to a computer for the post-processing phase using GeoSLAM Hub. If things go well, a black and white 2D plan shall be exported, and the wall structure for the whole level will be shown. Mok (2021) stated the point cloud model is the raw data output from laser scanners. Autodesk Recap shall be used to view the point clouds. A .laz file containing all the point cloud data can be exported from GeoSLAM Hub. Then, the file can be opened in Autodesk Recap. If the data processed from GeoSLAM Hub is unusable, reprocessing shall be done. Bolkas and Martinez (2018) stated the point-cloud coordinate information derived from terrestrial Light Detection And Ranging (LiDAR) is important for several applications in surveying and civil engineering.

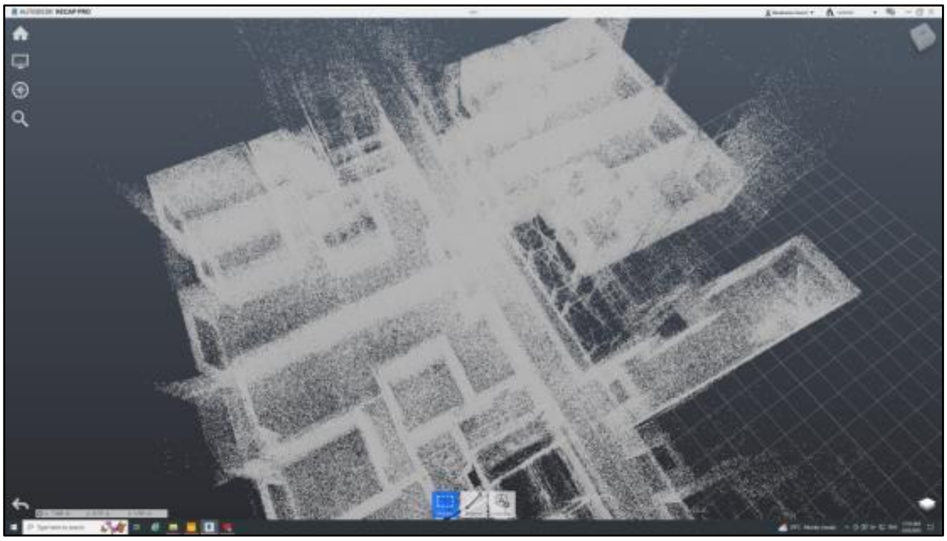
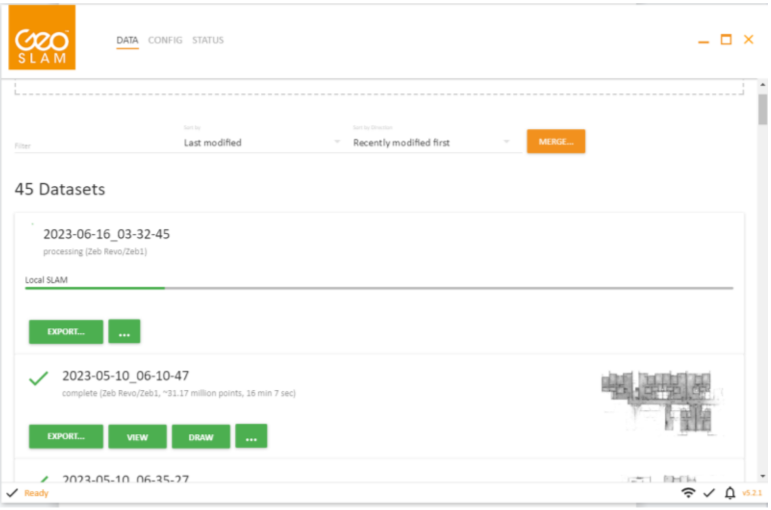


Figure 11. Viewing Point Clouds in Autodesk Recap

2.3.4 Stage 4: 3-D Model Point Clouds to 2-D Plan

The point clouds are exported into a 2-D plan, which can be superimposed with the approved building plan. Since there are two to three scan trips per floor, data merging of the 2-D Plan (Figure 11) is required before superimposing with the approved building plan. After that, the assessment with the superimposed plan shall be conducted. If all the data goes well, an as-built strata plan will be produced. As stated by Wang et al. (2019), LiDAR can provide accurate distance information and is not affected by light conditions.



Last modified

Recently modified first

45 Datasets

2023-06-16_03-32-45
processing (Zeb Revo/Zeb1)
Local SLAM

2023-05-10_06-10-47
complete (Zeb Revo/Zeb1, ~31.17 million points, 16 min 7 sec)

2023-05-10_06-35-27

Ready

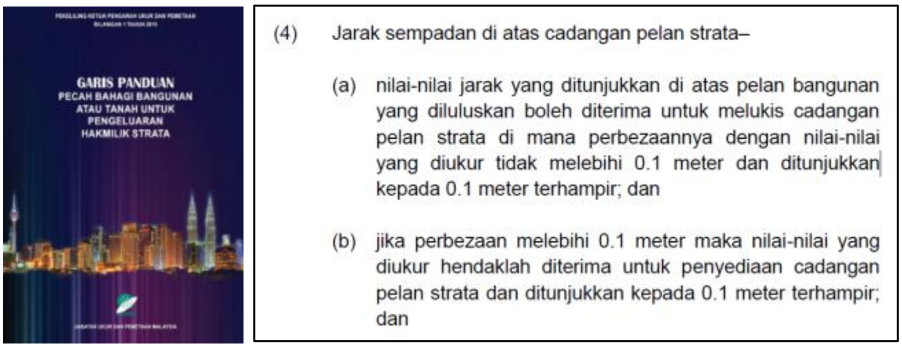
Figure 12. Point Cloud Processing By Using GeoSLAM Hub

3.0 Result and Analysis

This section shall analyze and discuss the results of this research. The data will be compared between the handheld laser scanner and the conventional method (distometer). Forty-five (45) units from levels 10, 25 and 38 will be compared and analyzed. In the end, an as-built strata plan will be produced. The data are evaluated by comparing the distance obtained from the handheld laser scanner, the building plan, and the conventional method. A 2-D plan shall be produced after GeoSLAM Hub processes the data. From there, the dimension of the space can be determined and compared with the distance listed by the architects and the distance obtained from the distometer and measuring tape. The results will be assessed to decide whether or not they meet the designated requirements. The X and Y dimension for each of the units is compared. The distance will be listed in the 2-D plan processed from GeoSLAM Hub. Then, the distance will be compared with the distance measured by the distometer and measuring tape. After that, the RMSE will be calculated.

3.1 Data Benchmarking (Conventional Method)

The measured distances are recorded in a hardcopy plan. Hence, the data are all in 2-dimensional format. The tolerance is referred to in the JUPEM circular section 7.2.2. (4).



(4) Jarak sempadan di atas cadangan pelan strata–

(a) nilai-nilai jarak yang ditunjukkan di atas pelan bangunan yang diluluskan boleh diterima untuk melukis cadangan pelan strata di mana perbezaannya dengan nilai-nilai yang diukur tidak melebihi 0.1 meter dan ditunjukkan kepada 0.1 meter terhampir; dan

(b) jika perbezaan melebihi 0.1 meter maka nilai-nilai yang diukur hendaklah diterima untuk penyediaan cadangan pelan strata dan ditunjukkan kepada 0.1 meter terhampir; dan

Figure 13. JUPEM Circular (KPUP-1-2015-JILID-I-v2016)

Referring to Figure 13, the distance shown in the CPS can follow the approved building plan provided the tolerance is within ±0.1m. Any distance that exceeds the tolerance shall not be acceptable. This shall serve as the benchmark to check the accuracy of the data using the conventional method.

3.1.1 Result (Conventional Method)

Referring to Figures 14, 15 and 16, the distance has been checked, and no distance has exceeded the ±0.1m tolerance. This proves that the building was built according to the approved building plan. The surveyor community has widely used this method to this day. This is because this method is more direct than an HLS. However, this method can be easily affected by human errors, such as the distance not being taken in a straight line, which will cause the distance to be different from the building plan.

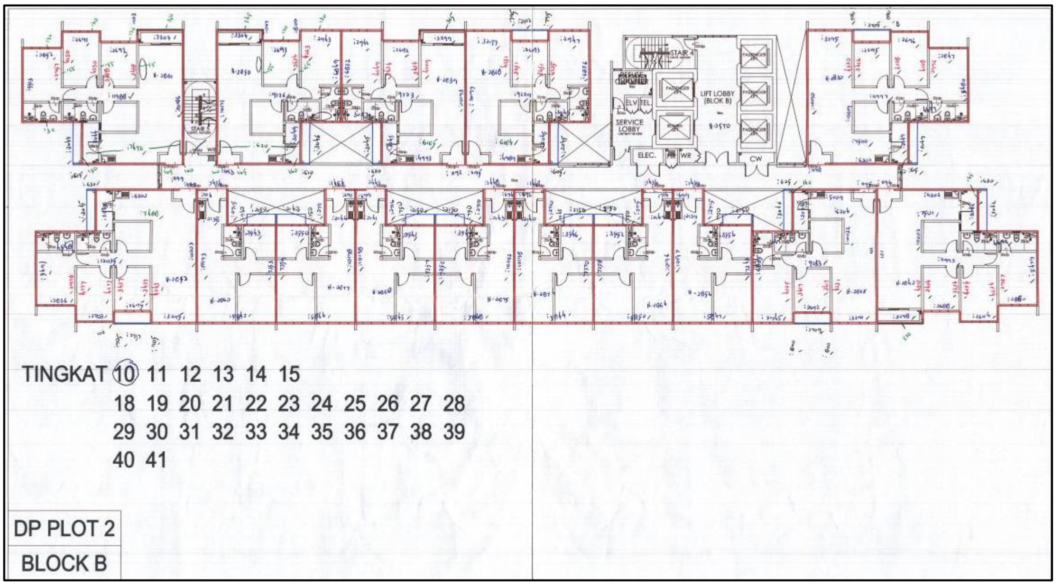


Figure 14. Conventional method result (Level 10)

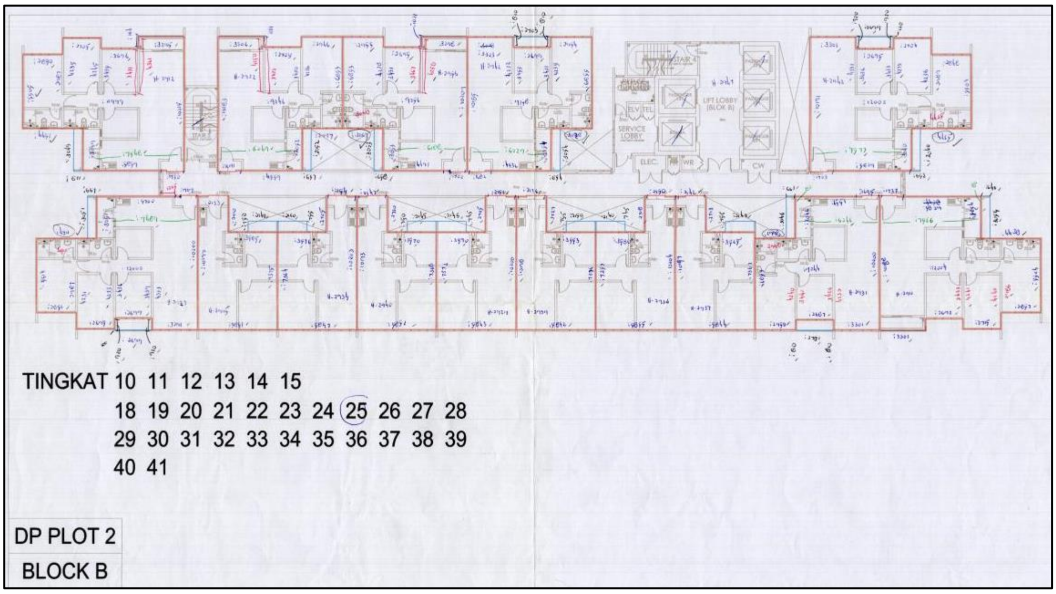


Figure 15. Conventional method result (Level 25)

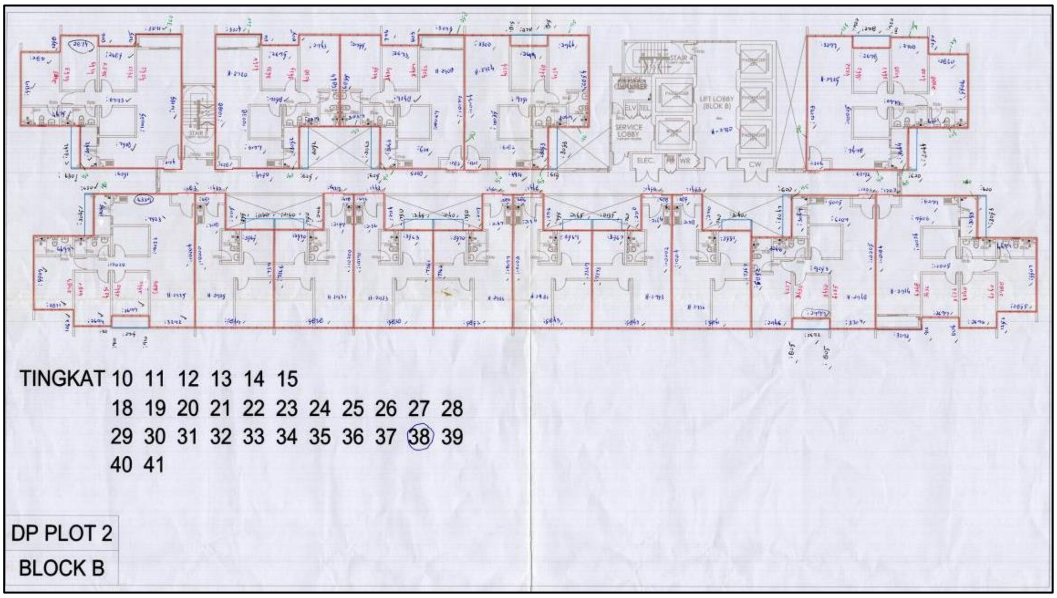


Figure 16. Conventional method result (Level 38)

3.1.2 Strata As-built Plan (HLS)

As stated by Al Khalil (2020), laser scanners allow for the acquisition of a huge amount of 3D point cloud, which can often be combined with high-resolution colour digital images, and Razali et al. (2023) also stated that the development of the 3D model effectively conserves data digitally. The Strata As-built Plan is based on the processed point clouds from the GeoSLAM Hub, which the HLS also collects. The Strata As-built Plan serves as the outcome of this research. Moreover, the Strata As-built Plan consists of the layout's dimensions, wall structure, project title, north arrow, scale, grid line, and others. These are the main components inside a strata as-built plan. Besides that, every room has been labelled with its function. The strata as-built plan shall be plotted in an A1 size paper for submission to the land office. Once the plan is checked, an endorsement from the land office will be issued. Not every project requires a strata as-built plan submission; a strata as-built plan submission shall occur when the existing building has no certified building plan and strata title. To obtain a strata title, surveyors must submit a Schedule of Parcel first, based on the architect's building plan, but in this case, it shall be the strata as-built plan to the land office to determine the shared unit. After that, the surveyor may proceed to the CPS stage.

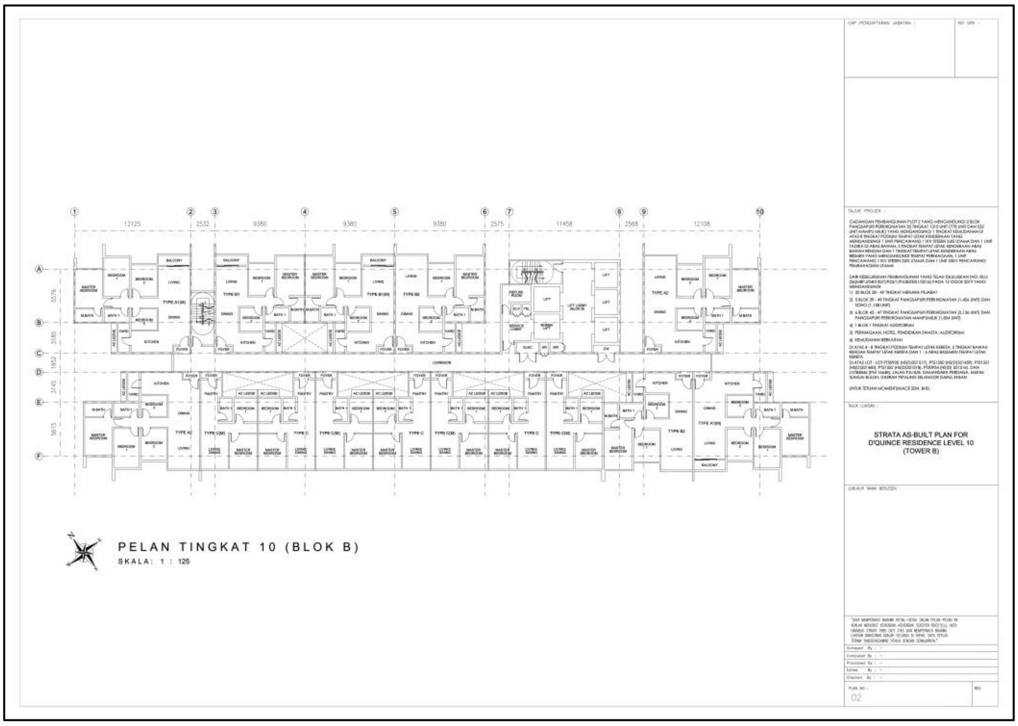


Figure 17. Final Strata As-built Plan (Level 10)

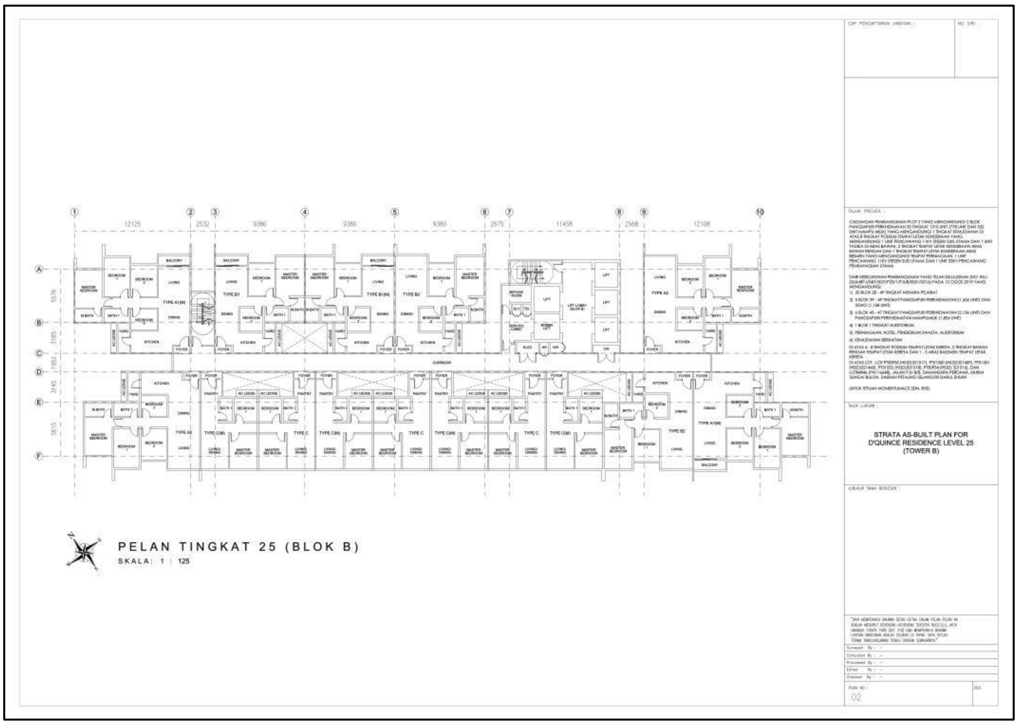


Figure 18. Final Strata As-built Plan (Level 25)

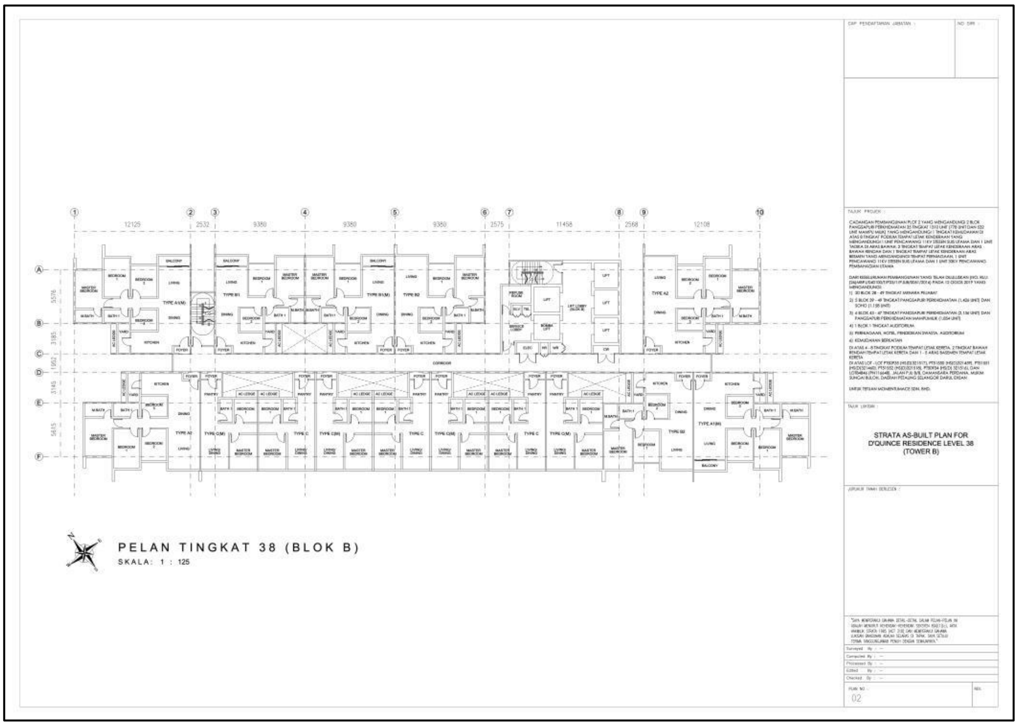


Figure 19. Final Strata As-built Plan (Level 38)

3.2 Evaluation and Verification

The data from the HLS and conventional method shall be compared and analyzed. The tolerance for this comparison is ±0.1m. The item that is being compared is the X and Y Dimension. X is the horizontal dimension, and Y is the vertical dimension. This comparison is to monitor the dimensions of the unit.

Figure 20. X and Y Dimension

Next, the Root Mean Squared Error (RMSE) shall be calculated. The RMSE of a set of observations is calculated using the formula:

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} \left(P_i - O_i \right)^2}{n}}$$

Figure 21. RMSE formula (gisgeography.com, 2021)

P_i is the data value from conventional methods;
O_i are the data values from the HLS method;
$\sum$ is a Greek letter called sigma, which represents ‘sum’ and
n is the sample size (the number of units).

3.2.1 Level 10

The result shows that all the distance still maintains within the tolerance of ±0.1m. The highest difference for X Dimension is 0.049m for unit B-10-03. The lowest for X Dimension is 0.002m at unit B-10-08. As for the Y Dimension, the highest difference is located at unit B-10-13, which has a difference of 0.040m, while the lowest is located at unit B-10-06, with an outstanding difference of 10mm. The MSE and RMSE for the X dimension are 0.0005m and 0.023m, respectively, while the Y dimensions are 0.0006m and 0.024m, respectively. The highest difference is caused by human error; the surveyor may not place the distometer horizontally, resulting in the difference.

Table 1. Data comparison for level 10

Unit No.	Conventional Method		Handheld Laser Scanner		Difference (m)	
	Orientation (m)		Orientation (m)			
	X	Y	X	Y	X (±)	Y (±)
B-10-01	11.997	10.190	11.992	10.179	0.005	0.011
B-10-02	11.993	10.002	11.967	10.024	0.026	-0.022
B-10-03	9.253	10.032	9.204	9.996	0.049	0.036
B-10-3A	5.847	10.197	5.835	10.168	0.012	0.029
B-10-05	5.850	10.196	5.839	10.186	0.011	0.010
B-10-06	5.844	10.198	5.826	10.197	0.018	0.001
B-10-07	5.848	10.202	5.833	10.166	0.015	0.036
B-10-08	5.845	10.198	5.843	10.165	0.002	0.033
B-10-09	5.844	10.198	5.835	10.176	0.009	0.022
B-10-10	5.842	10.193	5.837	10.194	0.005	-0.001
B-10-11	12.035	10.203	11.990	10.218	0.045	-0.015
B-10-12	11.988	10.186	11.955	10.156	0.033	0.030
B-10-13	9.226	10.171	9.206	10.131	0.020	0.040
B-10-13A	9.223	10.193	9.234	10.186	-0.011	0.007
B-10-15	9.229	10.197	9.231	10.178	-0.002	0.019

	X (m)	Y (m)
MSE	0.0005	0.0006
RMSE	0.023	0.024

3.2.2 Level 25

The X Dimension has the highest value of 48mm at unit B-25-13A, and the lowest of 0.0030m is at unit B-25-02. Next, the Y Dimension has the lowest of 0.001m at unit B-25-10 and the highest at unit B-25-3A with a value of 0.043m. All of the distance is within the tolerance. The MSE and RMSE for the X dimension are 0.0003m and 0.018m, respectively, while the Y dimension obtained 0.0004m for MSE and 0.019m for RMSE. Similar to level 10, the highest discrepancy is caused by human error; the distometer is not placed horizontally when measuring the distance.

Table 2. Data comparison for level 25

Unit No.	Conventional Method		Handheld Laser Scanner		Difference (m)	
	Orientation (m)		Orientation (m)			
	X	Y	X	Y	X (±)	Y (±)
B-25-01	12.002	10.191	11.996	10.181	0.006	0.010
B-25-02	12.004	10.188	12.001	10.207	0.003	-0.019
B-25-03	9.244	10.200	9.217	10.173	0.027	0.027
B-25-3A	5.844	10.187	5.832	10.144	0.012	0.043
B-25-05	5.855	10.204	5.844	10.167	0.011	0.037
B-25-06	5.842	10.198	5.849	10.195	-0.007	0.003
B-25-07	5.843	10.200	5.848	10.205	-0.005	-0.005
B-25-08	5.852	10.193	5.833	10.199	0.019	-0.006
B-25-09	5.847	10.203	5.828	10.197	0.019	0.006
B-25-10	5.851	10.199	5.830	10.200	0.021	-0.001
B-25-11	12.000	10.200	11.986	10.212	0.014	-0.012
B-25-12	11.999	10.215	12.012	10.197	-0.013	0.018
B-25-13	9.246	10.183	9.258	10.182	-0.012	0.001
B-25-13A	9.256	10.209	9.208	10.195	0.048	0.014
B-25-15	9.258	10.185	9.262	10.201	-0.004	-0.016

	X (m)	Y (m)
MSE	0.0003	0.0004
RMSE	0.018	0.019

3.2.3 Level 38

Unit B-38-13A has the highest difference in the X and Y Dimension, with a value of 0.047m and 0.039m for the X and Y Dimension, respectively. The lowest X Dimension is at unit B-38-01 with a value of 10mm, which is a fantastic result of a handheld laser scanner. Besides that, unit B-38-10 has the lowest value of 0.002m in terms of Y Dimension. The MSE and RMSE for the X dimension are 0.0005m and 0.022m respectively. Y dimension obtained 0.0004m for MSE and 0.019m for RMSE. As with levels 10 and 25, human error causes the highest difference; the distance measured from the distometer is not horizontally aligned.

Table 3. Data comparison for level 38

Unit No.	Conventional Method		Handheld Laser Scanner		Difference (m)	
	Orientation (m)		Orientation (m)			
	X	Y	X	Y	X (±)	Y (±)
B-38-01	11.999	10.193	12.000	10.182	-0.001	0.011
B-38-02	12.005	10.184	11.997	10.205	0.008	-0.021
B-38-03	9.253	10.205	9.225	10.180	0.028	0.025
B-38-3A	5.841	10.214	5.827	10.199	0.014	0.015
B-38-05	5.847	10.202	5.825	10.205	0.022	-0.003
B-38-06	5.843	10.203	5.826	10.193	0.017	0.010
B-38-07	5.852	10.197	5.836	10.182	0.016	0.015
B-38-08	5.838	10.191	5.845	10.180	-0.007	0.011
B-38-09	5.838	10.200	5.833	10.191	0.005	0.009
B-38-10	5.849	10.200	5.832	10.198	0.017	0.002
B-38-11	12.020	10.204	11.985	10.186	0.035	0.018
B-38-12	11.993	10.185	11.981	10.219	0.012	-0.034
B-38-13	9.258	10.188	9.211	10.149	0.047	0.039
B-38-13A	9.248	10.179	9.210	10.198	0.038	-0.019
B-38-15	9.251	10.194	9.240	10.187	0.011	0.007

	X (m)	Y (m)
MSE	0.0005	0.0004
RMSE	0.022	0.019

3.3 Comparison Method Analysis

Referring to Figure 22, the bar chart compares levels 10, 25 and 38 in the X-Orientation measurement. The blue chart represents level 10, the orange one represents level 25, and the grey one represents level 38. The data in the bar chart shows the difference between the conventional and HLS methods in data comparison. The data in the bar chart shows inconsistency between all the levels. The contractor's construction work causes this. For instance, the walls at levels 10 and 25 are plastered, which will cause some discrepancies in the data. The highest difference is located at unit 3, level 10, discussed in section 3.2.1.

In comparison, the lowest is located at unit 1, level 38, as discussed in section 3.2.3. The data from units 3A and 5 at levels 10 and 25 has obtained the same result. This is because both units have similar characteristics in terms of the wall. Both units are considered completed units; hence, the same result can be obtained. Although the data is inconsistent, all of the data is still within the tolerance based on the JUPEM Circular (KPUP-1-2015-JILID-I-v2016).

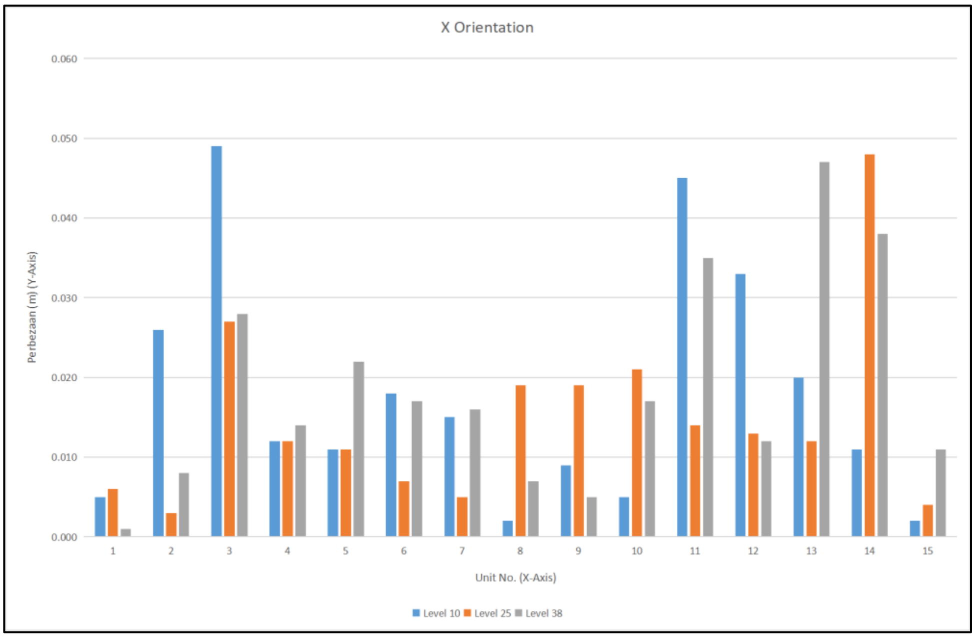


Figure 22. Bar Chart for X-Orientation (Dimension Difference)

Next, Y-Orientation is shown in Figure 23, and the data for unit 10 at level 10 and level 25 obtained the same result. This is because both units have similar characteristics, such as plastering and completing the wall. When the time for data collection is, levels 10 and 25 can be considered completed. Only level 38 is still under construction, and this causes a significant difference in the result. Ultimately, all the data is within the tolerance based on the JUPEM Circular (KPUP-1-2015-JILID-I-v2016).

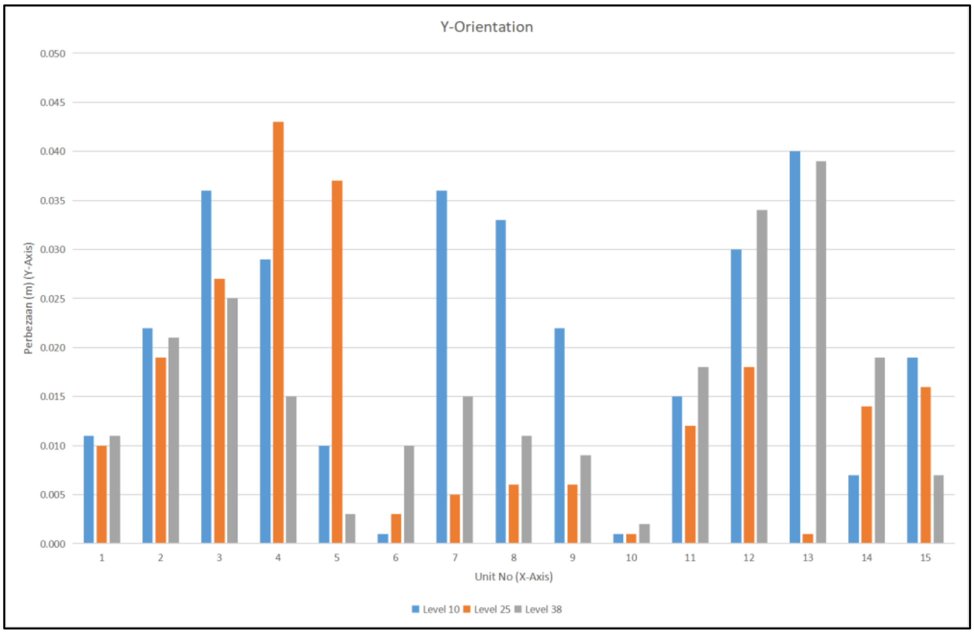


Figure 23. Bar Chart for Y-Orientation (Dimension Difference)

4.0 Conclusion

The handheld laser scanner and conventional method have been assessed and evaluated throughout this research. The final strata as-built plans are also prepared for levels 10, 25 and 38. The strata as-built plan is produced by illustrating the wall based on the 2-D plan generated from GeoSLAM Hub. By simply overlapping with the 2-D plan, a wall line can be drawn according to the dimension of the respective unit. From the analysis, the lowest difference was achieved at an outstanding amount of 0.001m. Not only was the data from HLS compared with the data from the conventional method but it was also used to compare with the ABP, which served as the benchmark for this research. Surveyors are advised to operate the instrument more often to strengthen their knowledge and skills in operating the HLS. This is to avoid low confidence towards the scanner. Secondly, a backup battery is crucial when scanning. This ensures that the scanning work is not interrupted in the process. Finally, the processing software should be explored to increase efficiency in processing the data from the HLS. Although the HLS cannot replace the existing conventional method, it can serve as a checker's tool to evaluate the data collected by the traditional method. It is crucial to understand the fundamentals of the HLS to extract the most function from it. Although HLS cannot operate for an extended period compared to a distometer, it can be used as a checking tool to evaluate the accuracy of the distance measured by a distometer. Lastly, the point cloud data can also provide BIM information to the database for future usage, which shall expand this device's usability.

Acknowledgements

The authors highly acknowledge the Ministry of Higher Education Malaysia (MoHE) and Universiti Teknologi Malaysia (UTM) for the financial support under the Fundamental Research Grant Scheme FRGS/1/2021/WAB09/UTM/02/1.

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