THE SUITABILITY OF TERRESTRIAL LASER SCANNING FOR STRATA BUILDING

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ABSTRACT:

During the recent years, the used of terrestrial laser scanning (TLS) is becoming rapidly popular because of its ability in several applications, especially the ability to observe complex documentation of complex building and observe millions of point cloud in three-dimensional in a short period. Users of strata plan usually find it difficult to translate the traditional two-dimensional (2D) data on maps they see on a flat piece of paper to three-dimensional (3D). The TLS is able to record thousands of point clouds which contains very rich of geometry details and made the processing usually takes longer time. In addition, the demand of strata survey work has made the surveyors need to obtain the data with full of accuracy and time saves. Therefore, the aim of this study is to study the limitation uses of TLS and its suitability for strata building survey. In this study, the efficiency of TLS Leica C10 for strata building survey was determined in term of its accuracy and comparing with Zeb-Revo Handheld Mobile Laser Scanning (MLS) and the distometer. The accuracy for scanned data from both, TLS and MLS were compared with the Distometer by using root mean square error (RMSE) formula. Then, the 3D model of the building for both data, TLS and MLS were produced to analyze the visualization for different type of scanners. The software used; Autodesk Recap, Autodesk Revit, Leica Cyclone Software, Autocad Software and Geo Slam Software. The RMSE for TLS technique is 0.001m meanwhile, RMSE for MLS technique is 0.007m. The difference between these two techniques is 0.006m. The 3D model of building for both models did not have too much different but the scanned data from TLS is much easier to process and generate the 3D model compared to scanned data from MLS. It is because the scanned data from TLS comes with an image, while none from MLS scanned data. There are limitations of TLS for strata building survey such as water and glass window but this study proved that acquiring data by TLS is better than using MLS.

1. INTRODUCTION

1.1 Terrestrial Laser Scanner

The popularity of Terrestrial Laser Scanner (TLS) has been introduced into a field of surveying and has increased dramatically especially in producing the 3D model of the building. Other than the ability to collect data of land and object of various shape and sizes in a quick way, it is also very useful to obtain high accuracy measurement while include the images in real time (Abellán et al., 2009). TLS is one of instrument that can provide efficiency in surveying. According to Arayici, 2007, TLS can also provide data at unreachable place. Even though the shape of the building is complex yet the TLS able to produce detail of the 3D point cloud. Instead of measuring the complex design by conventional method which is using the distometer, TLS is the new method that can be implemented to provide the accurate dimension of complex design for each parcel.

The conventional system provide information in single point only compare to TLS which able to record huge numbers of point. Moreover, TLS gives more advantages in understanding the scanned data especially when dealing with complex building. The TLS is not using any physical method while collecting the data. According to Fröhlich et al., 2004, TLS is using remote sensing technique because individual to hold the sign of the target in process of collecting data is not required.

Most of the different industrial sector such as engineering and architecture today require the 3D model of building especially for multi-storey building (Abdul-Rahman et al., 2005). In addition, they also needs precise data in order to be able to have an as-built analyzation especially for indoor mapping. Thus, it is important to obtain accurate data for preparation of strata plan and by using the laser scanner can fulfil their requirements. The laser scanner can gives the data with full of accuracy and increase the speed of Three Dimensional (3D) data acquisition of digital as-built generation process (Aziz et al., 2016).

The scanner can record thousands of points per second and each point has their location coordinates and elevation information. According to Sepasgozar et al., 2014, TLS can go for the rays up to 4000 meters and rated to have their best accuracy at distances out to 130 meters which means, it is capable to scan the whole areas and all object within the distance. The ray also safe for the eyes, and have multi target to take the reading.

Furthermore, the application field that involved with the laser scanner are topography, industrial, engineering and also in forensic field. The market of laser scanners for terrestrial applications has developed quite successfully and the laser scanners are seen as one of the surveying instruments that meet the requirements of industrial applications (Fröhlich et al., 2004). At first, the invention of the laser scanning is just suitable for short-range only. However, the uses of this laser scanning is keep increasing, and have pushed the development of the technology to invent the new updated laser scanner. Thus, the mid-range and long-range laser scanner has been introduced

(Pelagotti et al., 2009). Figure 1 shows the applications of TLS using dynamic and static laser scanning.

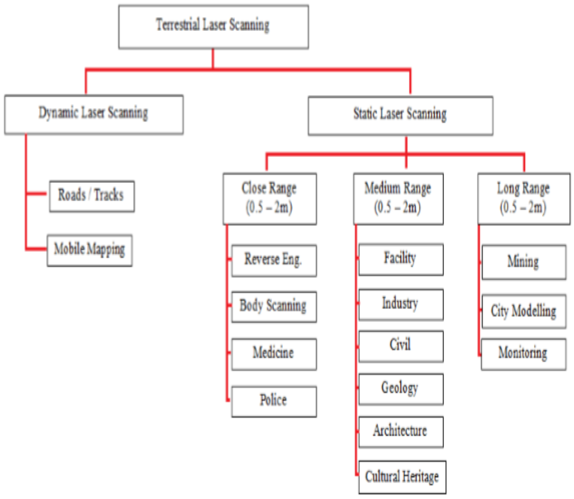

Figure 1. Applications of Terrestrial Laser Scanning (Giussani et al., 2004).

1.2 Strata Building

Strata title survey is a one method of measurement in Cadastral Surveying, and involved a land parcel, and a building which has at least more than two floors. This system will be used in process of acquisition of ownership and it is important to do the strata survey because it will determine the ownership and the right of the ownership of a parcel (Jamila, 1994). Strata Title formed an individual ownership for multi-level building such as apartment block and horizontal subdivision with shared areas (Arayici, 2007). It will be registered on the name of the proprietor, but the title of the land is still remained. If the strata title has been not transferred, the ownership of the parcel and the land are still owned by the developer and it will make unit owner faces a lot of trouble if they want to do any business on it (Jamila, 1994). Since the strata title is on high demand nowadays due to the increasing of the multi-level building project, so it is important to have the title for each of the parcel of the property, and make it as ultimate proof of property (Kitsakis et al., 2018).

Conventional method for as-built strata survey for measuring the distance of each parcel in the building is by using Distometer. It has been used widely to measure the distance because of its size which is small and handy. But it also has the weaknesses. The reading from Distometer cannot be recorded like TLS, and all the measurement needs to be written on the paper or on the map. It also unable to provide the three-dimensional (3D) model of the building. The handling of this instrument is same as the application of total station or Theodolite and GPS. User needs to find the suitable station to set up this instrument, and wait to collect the data. For this study, the Terrestrial Laser Scanning which is Leica C10 was tested to know the capability of TLS in strata building. The GeoSlam Zeb-Revo handheld mobile laser scanning were also compared with the data collected by Leica C10, together with data collected by Agatec distometer as conventional method. The aim of this research is to study the limitation uses of Terrestrial Laser Scanning and its suitability for strata building survey.

1.3 Highlighted of Study

The new technology in surveying field has been implemented and widely used by the surveyor. The demand of strata survey work has made the surveyor needs to obtain the data with full accuracy and time saves. Besides that, undertaking measured surveys and providing plans, elevations and sections of existing buildings and sites remains at the heart of the Building Surveyors. Most surveyors still used the conventional method when taking measurements on site which is by using measuring tape. In addition, Distometer was used to measure the dimensions of each parcel and the building but it still considered not relevant because these has to rely on accuracy, completeness and neatness of the sketches and notes made on the field. The recording of information on site is traditional undertaken on paper and surveyor plot the plan in the office by using Computer Aided Design (CAD) Software. It may lead to a few problems such as missing the paper that contain the information and misunderstanding the sketches that has been drawn at the site

It is visualized that by using the laser scanner for taking the internal measurement can provide the accurate plan in far less time than using present methods. Thus, this research will be carried out to improve the conventional method in collecting the detail for the purpose in strata work by using the terrestrial laser scanner. By using the different type of laser scanner which is Terrestrial Laser Scanning (TLS) and Mobile Laser Scanning (MLS), the accuracy elevation of both systems will be carried out. Both of laser scanners can detect thousands of point clouds data in a second. Thus, this strata survey will analyze the accuracy of data obtained from both laser scanner and it will be compared with the building plan. The recommended method for most efficiency way in undertaking strata building survey will be determined.

The terrestrial laser scanning (TLS) is not using any physical method when obtaining the data but the user needs to move the scanner to other area for scanning to complete the image of all area. It is because the TLS can scan only what is visible. Hence, the time taken for acquiring the data will be compared for both laser scanner which is Terrestrial Laser Scanner and Mobile Laser Scanner. Then justification about the issues and limitation of Terrestrial Laser Scanner in strata survey will be carried out in this research. Users of strata plan usually will translate what they see on a flat paper from 2D to 3D, and it is inconvenience for them because it required a high imagination and skill in understanding the plan (Dredge and Coiacetto, 2011). Thus, to make the work efficiency, the 3D model of the building must be developed. Even though TLS able to record thousands of point clouds at one time, but in order to get the 3D model, it still needs to be processed.Point cloud contains very rich of geometric details and a large number of polygonal elements, so it can cause the problems to generate the 3D model (Manferdini et al., 2010). 3D scanned point clouds for both laser scanner will develop unstructured sets of data so its need skill and knowledge to produce a good result. The point cloud processing usually takes a longer time compare to its data capturing.

Therefore, surveyor needs to do a lot of study to improve the way in obtaining the data and the efficiency of TLS in strata survey will be compared with the MLS. Different type of software will require different skill and knowledge to generate the 3D model and different format data will be produce. The comparison of the 3D model format was carried out to study the ability of the result for other user from different field.

1.4 Significance of Study

These days, as the strata development has quite increasing in development sector, the demand of the accurate strata title plan is increasing. Requirement for obtaining data with full of accuracy is necessary to produce strata title plan. The importance of Strata Title Survey is to make sure that every parcel has its own title and all the maintenance work and new development for that building are under control. Thus, this research is carried out to implement and study whether the Terrestrial Laser Scanning is capable to obtain data for strata survey with full accuracy and time saves.

The technique in obtaining the data makes us understand the principle of terrestrial laser scanner and the limitation usage of TLS for strata work. Study about terrestrial laser scanner for data acquisition, register and process the point cloud, modelling, generalization and visualization were conducted in this research. The dimensional of measurement from different type of laser scanner with conventional method will be made including the general comparison such as time consuming. Other than evaluate the ability of Leica Cyclone software to process the point cloud data in term of accuracy, relevance and the implications to the user, this research also will evaluated the ability of Autodesk Revit to form the 3D model for indoor building. The analysis from the measurement by Terrestrial Laser Scanning and Mobile Laser Scanning were compared. The visualization of 3D model of the building from different types of measurement instrument was made.

The 3D work especially for strata development in gaining the accurate data got higher demand in the important profession like engineering, architectural and most important in surveying field. The application for 3D laser scanning in these types of industries also seems to be virtually limitless and the benefits of the technology need to be continually applied to new and different industries so that more people can understand the usefulness of 3D Laser scanning. Therefore, this study can give the comprehensive discussion on improving the new method of gathering strata data in term of accuracy for two different types of measurement instrument and the limitation of the terrestrial laser scanner in strata survey.

2. METHODOLOGY

2.1 Flowchart of Study

There were four (4) phases in this study which comprises of preliminary study, data acquisition, data processing, result and analysis as shown detailed in Figure 2. These four phases set out the way this study needs to be conducted and is designed to assist in the implementation of the study. In phase one (1), the literature review and the understanding about TLS need to be done. The problem statements were determined followed by the aim and scopes of study to ensure this study done as planned. The study area of this study as shown in Figure 3. This study covered the whole 3D GIS Research Laboratory located at level 2, Block C05, Faculty Geoinformation and Real Estate, UTM, Johor

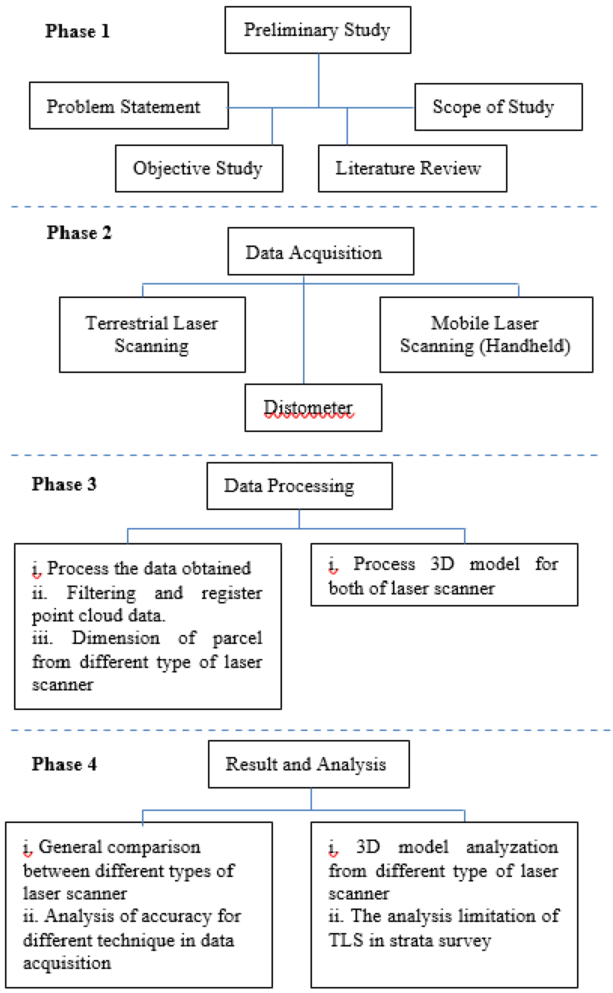

Figure 2. Flowchart of study


Figure 3. Area of study

In phase two (2), all the raw data from different technique were collected. The data included point cloud data from Leica C10 and GeoSlam Zeb-Revo handheld. All the collected point cloud data then were compared with the data dimensions collected by Agatec distometer as the conventional method. The flow of methodology for Leica C10 is shown in Figure 4. All these flows were discussed in following points.

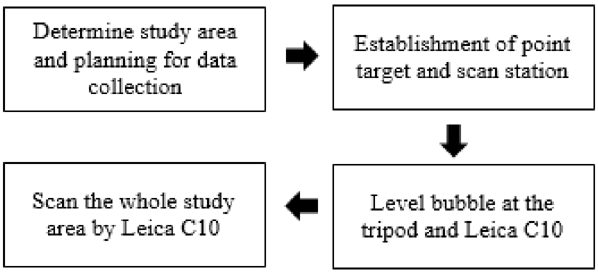

Figure 4. Leica C10 method procedures

2.1.1 Determine study area and planning for data collection: Before data collection proceed, the determination of scanned area needs to be done to ensure that area is suitable for this study while survey planning is to define the uses of scanner, position of scanner and target position.

2.2 Establishment of point target and scan station

A plan of survey area was sketch on paper to determine the location of scanner and the target (Figure 5). It is to ensure that all the information and detail of the building was covered. This research used only one scanner to scan the whole survey area so it needs to move to another scan station to scan the next part of the area. 6 units of sphere targets and 7 black and white targets with diameter ± 15 centimeter respectively were used. The placement of targets should be considered with the position of scanner because it acts as a control point for point cloud registration. At least three targets should be clearly seen by each other and can be scanned by scanner for each station.

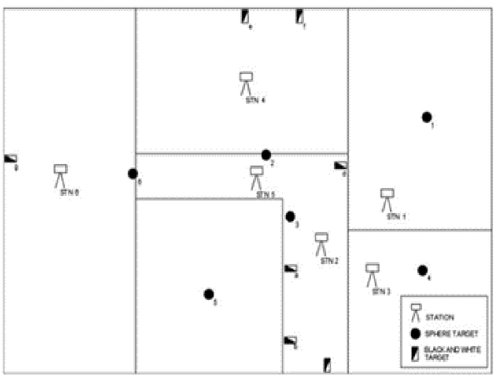

Figure 5. Position of the scanner and targets during data collections

2.2.1 Level bubble at the tripod and Leica C10: The Leica C10 must be set up and its bubble must be adjusted. Leica C10 was placed on a tripod during scanning process to ensure the stability of the scanner itself. The bubble was adjusted until below 30 seconds. It must be done for every station same like the Total Station.

2.2.2 Scan the whole study area by Leica C10: The scanning procedures can be proceeds after the file project was created. Set up the scanning parameters. Medium resolution is chosen due to its capability in scanning average data. This resolution needs 10 to 18 minutes to scan one area together with the image. It is scanned by grid with point spacing 1m x 1m (horizontal spacing x vertical spacing) and scan range is 100 meter. The data given is point cloud, and an image with coloured point cloud. Medium resolution is chosen for scanning the whole one area, while highest resolution was chosen to scan every target that can be seen and scanned from the scan station. Different types of resolution selected because it can differentiate the whole scanned area with the targets during registration and processing. To scan only the selected target, the "field of view" needs to be determined and "quick scan" must be selected on the Scan Parameter page. After the scanning process completed, the scanned data can be seen automatically at the MMI screen on the Leica C10 (Figure 6). Only then, the scanner can be moved to the next station. The standard set up must be done before moves the Leica C10 scanner. It is a must to ensure the new station folder has been created up to avoid the overlay data. All the raw data then were downloaded to the computer for data processing.

Figure 6. Scanned data of one area

The flow of methodology for GeoSlam Zeb-Revo as shown in Figure 7. All these flows were discussed in following points.

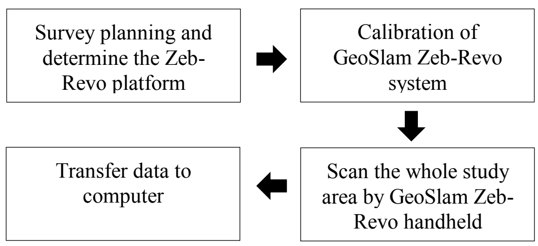

Figure 7. GeoSlam Zeb-Revo method procedures

2.2.3 Survey planning and determine the platform: The survey area was identical as Leica C10 study area which is 3D GIS Research Laboratory. The GeoSlam Zeb-Revo is handheld mobile laser scanning system. It does not involve the sphere or black and white target. It just needs to determine the suitable spot with flat surface as the platform. It is to place the Zeb-Revo rover for the calibration process.

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2.2.4 Calibration of Zeb-Revo rover: The calibration process for this Zeb-Revo rover is done automatically. During the initialization, the scanner must remain stationary as if the Zeb-Revo rover was disturbed during initialization process, it will revert to flash the LED in red color and need to wait to reinitialize. The Zeb-Revo rover in the scanning model when the LED has switch to green color and it is ready to collect the data.

2.3 Scan the whole study area by GeoSlam Zeb-Revo

This technique is easier compared to the Leica C10 method. When the rover was in scanning mode, press the start button at the side of Zeb-Revo head scanner and start button on Go-Pro Camera. The Zeb-Revo rover scanned the whole area by rotating the head scanner in 270 degree and range up to 15 meter. After completing scanning process for the whole study area, the Zeb-Revo rover needs to be put back on the same platform for initialization. Press stop button and let the rover in stationary mode for approximately 5 to 10 seconds. The LED flash is switched to orange color for de-initialized.

2.3.1 Transfer data to the computer: Once the rover finish the de-initialization, all the scanned data can be transferred right away from the scanner to the computer as shown in Figure 8. All the data were in las.* and laz.* format and image was in Jpeg.* format. The software used for transferring from Zeb-Revo rover to the computer is Geo Slam software.

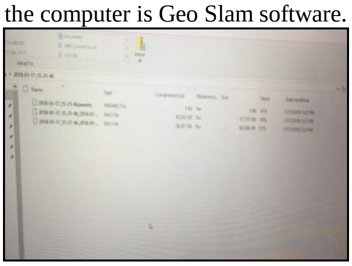

Figure 8. Raw data from rover transferred to the computer

As for conventional method, the Agatec Distometer was used. The flow of methodology for Agatec Distometer as shown in Figure 9. All these flows were discussed in following points.

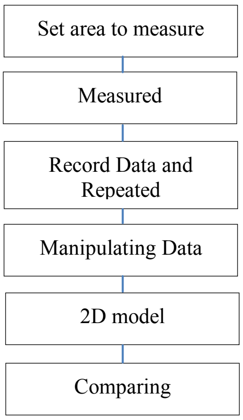

Figure 9. Agatec Distometer method procedures

2.3.2 Area to measure: This study used Agatec Distometer as for the conventional method. The study area was same as the Leica C10 and Zeb-Revo rover which is 3D GIS Research Laboratory. All the dimensions must be measured and obtained. Every parcel and every corner was measured to obtain the distance from the edges of the building to other corner.

2.3.3 Measure the study area by using Agatec Distometer: For this technique, measurement process was more detail. Any parcel and angle of the study area needs to be measured. The measurements were taken three times and the average was calculated. It was recorded manually on the paper. When all the parcels have been completely measured, the dimensions will be proceeds to next step which is processing data.

In phase three (3), all the raw point cloud data were transferred to the specifics software. Different software has been used due to different technique of data acquisition. For TLS Leica C10, Leica Cyclone Software was used for registration data process. While for Zeb-Revo handheld mobile laser scanner doesn't required to register the point cloud. Figure 10 below shows the flowchart for data processing process in this research.

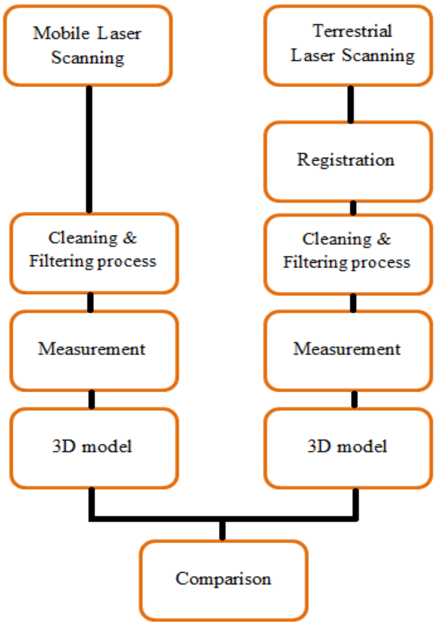

Figure 10. Flowchart for data processing.

All the point clouds data acquired from TLS need to undergo registration process. It is to match data of two scans with different position tied up together and be in one image. This research has 6 different position of the scanner, so registration process is a must to combine all the point cloud data to be in one image of the study area (Figure 11).

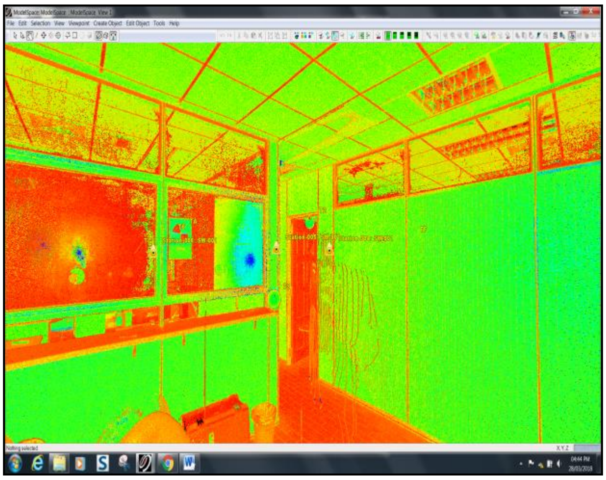

Figure 11. Result after completing TLS data registration

The unwanted point cloud data that can disturb the measuring process needs to be removed. It is because the measuring process is an important process to get the dimensions of the parcel for each different technique. Hence, cleaning and filtering process for TLS Leica C10 and Zeb-Revo handheld MLS data was done by using Autodesk Recap. Thus, the indoor building can be viewed clearly as shown in Figure 12 and Figure 13.

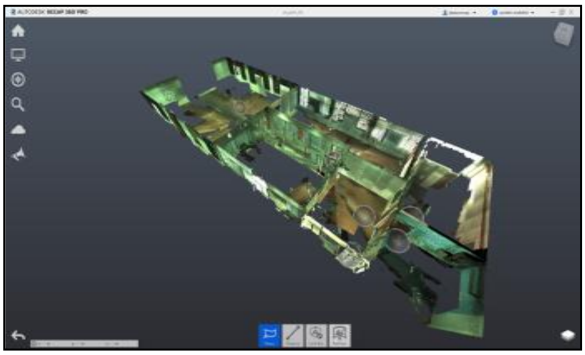

Figure 12. Cleaned data from TLS

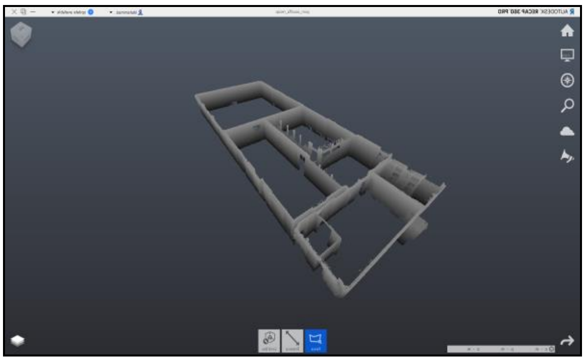

Figure 13. Cleaned data from MLS

Then, the measurement process can be proceeds. Data from TLS and MLS were processed by using Autodesk Revit Software. Raw cleaned data from both scanners were import directly from Autodesk Recap to Autodesk Revit by Point Cloud Tool in *.rcp format. Measuring process start by clicking at the point cloud which appear in the interface at the Revit Software. For TLS data it is easier to do the dimension measurement process because the point cloud data comes with an image. The image is a coloured point cloud data that can give real visual at the scanned area. Meanwhile, the scanned data from MLS does not provide the image.

The 'linear dimension' tool was used for dimensioning the parcel. Select the length which needs to be measured, and the dimension will be given automatically. Skill and knowledge in selecting the point cloud is very important since it involves the dimension of the length itself.

The process to produce the 3D model of the study area also was done by using Autodesk Revit. The cleaned point cloud data was imported into the Revit through 'Point Cloud tool. The wall needs to be created. In order to add the wall, the architectural wall has been selected because this type of wall is suitable for interior and exterior wall. The height of the wall is 10 feet which ±3 meter. Make sure the 'chain' box was ticked to connect each wall. Place the wall based on the true dimensions that has been measured during the measurement processing before this. Continue this step to place the wall until complete all the parcel. Figure 14 and Figure 15 show the dimensioning for TLS and MLS in Revit software respectively. Meanwhile, Figure 16 shows the dimensioning for Distometer in Autocad software.

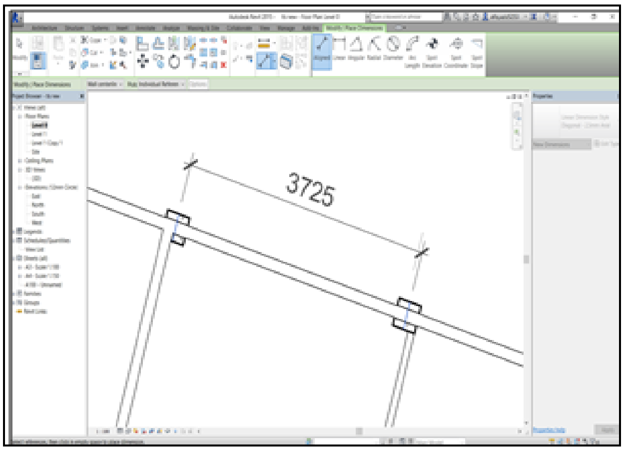

Figure 14. Dimensioning for TLS data in Revit software

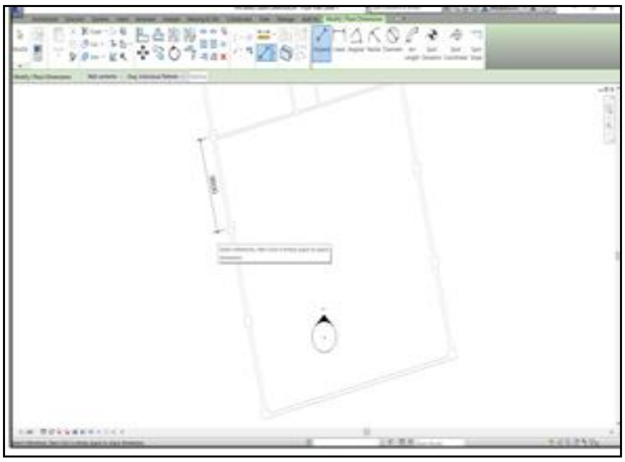

Figure 15. Dimensioning for MLS data in Revit software

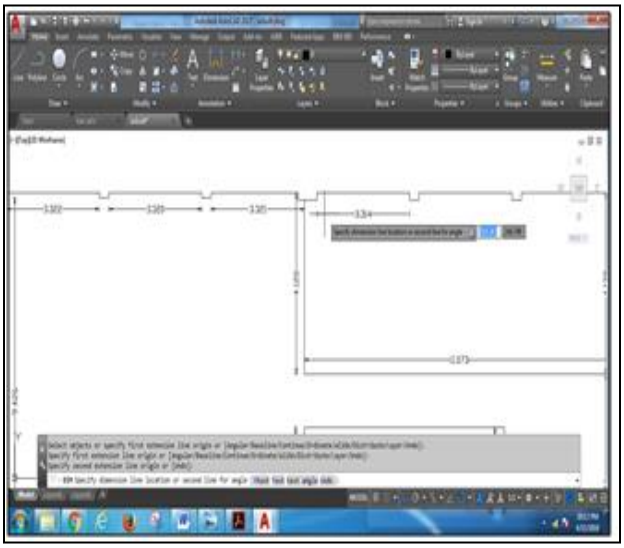

Figure 16. Dimensioning for Distometer in Autocad software

Next step in generating the 3D model is to create the section box as shown in Figure 17 which has control button that can be used to crop off the model to give user clearly view at the inside of the model especially for the complicated model. It also useful when processing involved only in specific room or specific wall. Thus, it can ensure that the model can be generated with accurately.

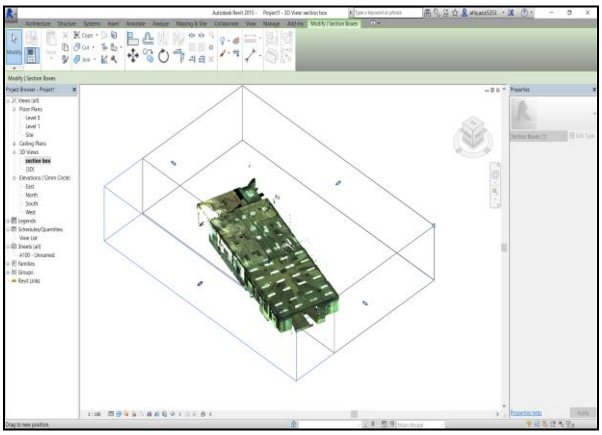

Figure 17. Section box in 3D model process

The dimensions from three different techniques were analyzed. Both data from TLS and MLS were compared with Distometer data to analyze the capability of laser scanner systems for strata building. The visualization of 3D model from both laser scan were analyzed.

3. RESULTS AND DISCUSSION

The 3D modeling analysis and 3D visualization analysis was made to study the suitability of TLS for strata building. The 3D modeling analysis consisted of measurement analysis between Terrestrial Laser Scanning, handheld Mobile Laser Scanning and Distometer. The results were compared for accuracy evaluation. Meanwhile, the 3D visualization analysis is a comparison of the presentation of model that was produced from TLS and MLS collected scanned data.

3.1 3D Modeling analysis

A total of 8 dimensions of a parcel were compared by using three different techniques which are by TLS, MLS and Distometer. The analysis was made to compare the accuracy of measurement and determine the suitability of the TLS for strata survey and the best technique that should be used in strata work. The comparison was made based on the same parcel, and the same point. Figure 18 shows the point of distance measurement that been referred. Meanwhile, Table 1 shows the point of distance measurement result for three different techniques of TLS, MLS and Distometer.

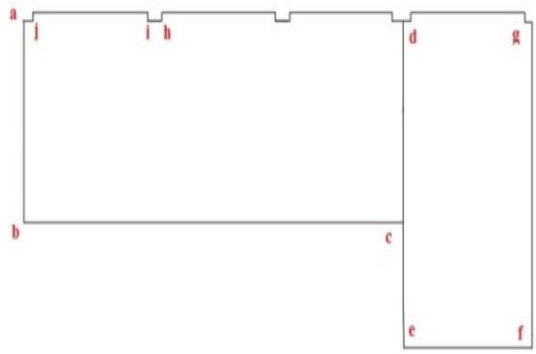

Figure 18. Point of distance measurement that been referred.

POINT	TLS (meter)	MLS (meter)	Distometer (meter)
a – b	4.150	4.200	4.180
b – c	11.000	10.850	11.073
d – e	6.500	6.500	6.475
e – f	3.500	3.510	3.541
f – g	6.500	6.490	6.505
g – d	3.500	3.510	3.520
h – i	0.350	0.340	0.348
i – j	3.300	3.250	3.319

Table 1. Result of distance measurement

Based on the result above, the graph comparison was made (Figure 19). From the graph below, it shows only slightly different between the distance measurements. The maximum distance difference between Distometer is 0.223m in point b – c by using MLS, while the minimum distance difference is 0.002m in point h – i by using TLS.

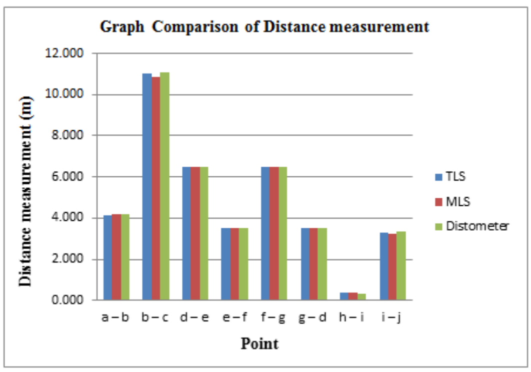

Figure 19. Graph comparison of distance measurement

The maximum difference of dimension from MLS and Distometer is because of human error during measurement process between two points or error during cleaning and filtering phase. While the minimum difference of dimension from TLS and Distometer is because of the TLS ability to give more accurate position up to millimeter level at a certain point. Table 2 shows the comparison measurement between Distometer, TLS and MLS. Meanwhile, Figure 20 show graph comparison of error between Distometer, TLS and MLS respectively.

POINT	Δ Disto – TLS (X) (m)	X^2 (m)	Δ Disto – MLS (X) (m)	X^2 (m)
a - b	0.030	0.001	-0.020	0.000
b – c	0.073	0.005	0.223	0.050
d – e	-0.025	0.001	-0.025	0.001
e – f	0.041	0.002	0.031	0.001
f – g	0.005	0.000	0.015	0.000
g – d	0.020	0.000	0.005	0.000
h – i	-0.002	0.000	0.008	0.000
i - j	0.019	0.000	0.069	0.005
SUM	∑	0.009	∑	0.057
RMSE	**∑8**	**0.001**	**∑8**	**0.007**

Table 2. Comparison measurement between Distometer with TLS and MLS

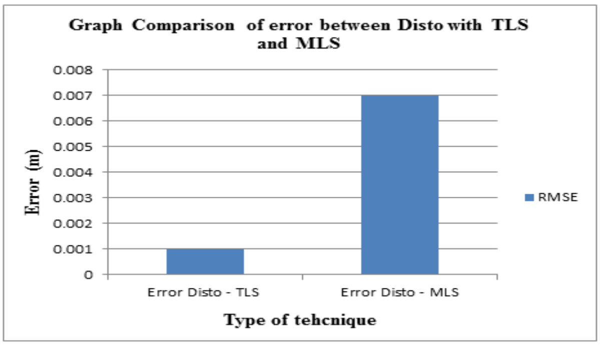

Figure 20. Graph comparison of error between Distometer with TLS and MLS

The RMSE value was used on the Table 2 to compare the error between Distometer with TLS and Distometer with MLS. The RMSE value of Distometer with TLS is smaller than RMSE value of Distometer with MLS, which is 0.001m compared to 0.007m. The smaller the RMSE value with distometer value is better. The graph shows huge difference between both RMSE with 0.006m. It is proved that TLS technique is better than using MLS technique in acquiring data for strata building. TLS can give good better accuracy with small RMSE value rather than MLS.

3.2 Visualization analysis

The analysis of 3D visualization was done by comparing the model of indoor study area which were produced by the same software, Autodesk Revit Software but different in technique acquisition which is by Terrestrial Laser Scanning Leica C10 and GeoSlam Zeb-Revo Handheld Mobile Laser Scanning.

The main focus for this analysis is to know the capability of different laser scanning in obtaining point cloud data to generate the 3D model. The 3D model for data from TLS Leica C10 is much easier to process compared with the data from Geo Slam Zeb-Revo handheld MLS.

It is because the scanned data from the TLS Leica C10, comes with the image, whereas the scanned data from MLS did not provide the image. The image can be used as a reference to the user in generating the 3D model processing. Figure 21 and Figure 22 show the 3D model from MLS and TLS.

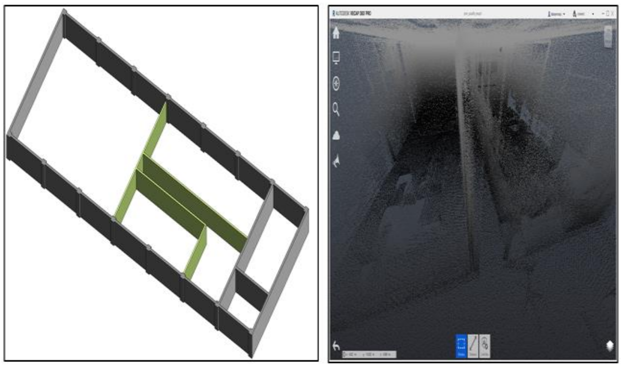

Figure 20. 3D model from MLS

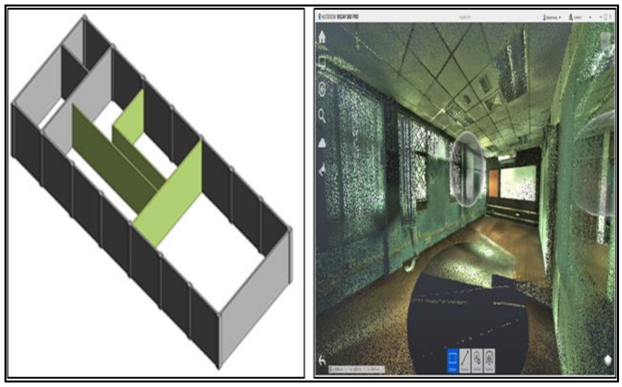

Figure 21. 3D model from TLS

The 3D models that were generated from both of laser scanners did not have too much difference. The difference in dimension gave impact to the model of the building. So it is important to scan the whole of survey area to achieve a good model. The skill and knowledge in processing also can affect the data.

3.3 General comparison between TLS, MLS and Distometer

The time taken for measuring the survey area between three devices was recorded (Table 3). The time factor took on the role because it involved speed during data acquisition process. It is to determine the accuracy of the instrument in terms of time. The time was taken by using watch.

Study Area	TLS	MLS	Distometer
For whole study area	60 minutes	30 minutes	70 minutes
For one parcel	10 minutes	4 minutes	13 minutes

Table 3. Time taken for study area based on different technique

Item	TLS	MLS	Distometer
Manpower	3 persons	1 person	2 persons
Scan point per second	50 000 points	43 200 points	One point per second
Time taken	120 hours	72 hours	48 hours

for data processing	(5 days)	(3 days)	(2 days)
Cost of instrument	RM100 000	RM95 000	RM 2500

Table 4. General comparison between different methods

From the result, analysis that can be drawn is the time taken for Distometer is bit longer than TLS, and may be influenced by several factors, among which are: (1) the need to measure from one edge to another edge of the parcel; (2) the need to record the data on the paper or books and needs to understand the shape of the parcel to get the idea during measuring process.

Since the TLS also needs to scan at least three targets to combine the data of different station, hence it also took longer time compared to the MLS. Based on Table 4, the time taken for data processing from both of laser scanner system took longer time compared to Distometer. It is because Distometer views the data in 2D, while point cloud data from laser scanner system can be processed and viewed in 3D model.

However, the processing needs high skill and knowledge. For the beginner it would be difficult to do the modelling and dimension measurement. Unlike the expert it will take lesser time to do the processing. For this research, it takes 5 days to process the data. Therefore, the user needs a good training not just handling the equipment but to process the data. There are a lot of software that can process this point cloud data, however the surveyor needs to study whether that software is good enough for them according to their objective of work and its accuracy.

3.4 Analysis of suitability of TLS for strata building

The TLS system is still considered as an early phase of development compared with the existing technique in obtaining strata data, which is by using Distometer, all the dimension data needs to write on the paper. The dimension could be wrong due to carelessness of the surveyor during data collection, and the needs to make sure that paper must always be in its placed for the next processing to avoid missing data. While TLS system automatically will record and save the scanned data. So it made the data more trusted, and can avoid missing data.

However, due to law of strata that has been set in Malaysia, TLS can be inconvenience. TLS might have limitations in strata survey due to the law of strata survey itself. For strata survey work, the accuracy of dimensions of every parcel is important. It is because the area of parcel can affect the price of the maintenance fee, the selling price and etcetera. So, the implementation of TLS for strata building should has more consideration and discussion according the law. TLS cannot penetrate into the wall. The wall thickness is important to determine the boundary of the parcel and that is the reason the Distometer still becomes a good choice in strata survey because Distometer can get all the dimension of the parcel including the thickness of the wall other than easy to handle since it is in small size. While for TLS systems, it required an additional handheld laser scanner to measure the thickness of the wall. And of course it also required an additional cost and time to combine and process the data.

With the recorded data, client can use the data for further work. And with the high accuracy dimensions of the parcel, the developer can create the Building Information Management (BIM) to ease their management of the strata building. They can use the information of every parcel to establish the database of the building to maintain the safety of the parcel owner and maintaining the facilities of the strata building. But due to the high price of TLS, most of the surveyor and the developer will choose the Distometer because it is more affordable compared to the TLS system.

There are some limitations of laser scanner and may be influenced by several factors, which are: (1) The existence of water and glass window, because the laser cannot penetrate through the water due to different density; (2) The laser can be refracted when contacted with the glass window; (3) During the processing, skill and knowledge will be very important to ensure the dimension is accurate.

But from the measurement analysis, the measurement difference between all three techniques has only slight differences. The dimension from both laser scanners still can be used for making measurement for strata survey since the strata plan calculation using one decimal point. For example, dimension showed in Strata Plan is 4.2 meter, and dimension at point a-b from MLS is 4.2 meter, from TLS 4.150 meter and Distometer 4.18 meter. When the values are rounded up to the nearest decimal point will be 4.20 meter same as in the Strata Plan.

4. CONCLUSION

The new invention in strata survey is a good thing in order to replace the conventional method with the new idea. It is because technological requirement always needed not just in the construction field, but also in most of the field. This study was carried out to study the limitation and suitability of the TLS for strata building survey. The 3D modeling analysis and 3D visualization analysis was produced. The 3D modeling analysis consists of the accuracy evaluation for TLS, MLS and Distometer technique. The maximum distance difference between Distometer is 0.223m which is in point b-c by using MLS and the minimum distance difference is 0.002m in point h – I by using TLS. The RMSE for TLS technique is 0.001m while the RMSE for MLS technique is 0.007m. The difference value of these two technique is 0.006m. It shows the accuracy between three techniques not much different in the form of decimal point. Meanwhile, the 3D visualization analysis that compare the presentation of the model was produced which shows the data from TLS is easier to process and generate the 3D model because it comes with an image and it can be as a references and helps user in generating the 3D model of the building processing compared with MLS data.

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