Accuracy Assessment of Horizontal Measurements from LiDAR Available in Mobile Phones

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***Abstract*: The Apple Company has added LiDAR to mobile phones for the iPhone 12 Pro and iPhone 12 Pro Max camera systems. This addition makes various applications, including Measure and Photos, run better and faster. A typical LiDAR sensor sends out pulsed light waves into the surrounding environment. These impulses bounce off surrounding objects and return to the sensor. The sensor uses the time it takes each pulse to return to the sensor to calculate the distance traveled.**

In this study, LiDAR technology added to I phone Pro-Max 12 was used to measures interior 2D plan of small building, nearly 85 square meters using polycam software which is commercial software available in apple store, interior scanning for the building walls done using LiDAR in I phone mobile in kinematic mode, while moving in hand, at distance nearly 3m far from each wall side. The same building was observed by Leica total station for its partition corners getting their coordinates. 4 minutes is the duration to scan all building partitions using I phone LiDAR scanner, while the same job took 2 hours using Leica total station. After scanning by iPhone LiDAR and measuring coordinates by total station instrument for building interior, a 2D plan was draw from the produced point cloud from I phone LiDAR after exporting into PTS, Position and Trunk Scanner, which imported to Autodesk Recap, RCP, real capture project. Also, another 2D plane was illustrates from the total station measurements. The two 2D plans were compared together against, partition side lengths, Areas, and angles. Taking the time of observation into consideration, and the resulted used statistical parameters, it is remarkable that, horizontal measurements using the available LiDAR technology in iPhone mobiles is acceptable to some extent especially in limited extension jobs. Side lengths and areas measurements have root mean square error 0.08m and 0.28 m² respectively. While little differences in angle occur, the calculated root mean square error was 2.02 degrees. Measurement errors resulting using iPhone scanner was little compared with measurements by Leica total station. Therefore, the measurements using this technique are useful and not harmful, at least for projects similar with the study area used in the research.

***Keywords:* iPhone, LiDAR, total station, Accuracy, Assessment:**

1. INTRODUCTION

Since the 2000s, ground laser scanning has become an increasingly important method of recording a detailed feature like historic buildings in protected areas. This is to reduce the difficulty of working in large areas, save time, and at the same time better understand the details of the area [1]. Laser scanner instruments are based on the principal of light detection and ranging LiDAR. LiDAR is a popular remote sensing method used for measuring the exact dimensions of an object on the earth’s surface. Even though it was first used in the 1960s when laser scanners were mounted to aero planes, LiDAR didn’t get the popularity it deserved until twenty years later [2]. Today it has become a very important technology in many engineering and non-engineering fields. Even though it was first used in the 1960s when laser scanners were mounted to airplanes, LiDAR didn’t get the popularity it deserved until twenty years later [3]. Today, LiDAR popularity has increased and obtained the importance it deserves; now it is available in mobile phones; giving more chance to public users for simple and quick access to measurements and calculating the distances between objects. LiDAR also become important key factor in gamming because it simulates nature and makes the objects and tools used more realistic.

With LiDAR technology, it is possible to acquired 3D point data (point cloud) on surface of an object with high accuracy. In addition, this 3D point group data can be transformed into 3D mapping, modeling and quantitative using appropriate software, this products may be useful in several applications. LiDAR systems are classified into two types based on its functionality — Airborne LiDAR & Terrestrial LiDAR. Airborne LiDAR is installed on a helicopter or drone for collecting 3D data. As soon as it’s turned on, Airborne LiDAR send light towards the objects on the ground surface, and then, this emitted light returns to the sensor immediately after hitting the object, giving an exact measurement of its true dimensions. Airborne LiDAR divided into two types — Topological LiDAR and Bathymetric LiDAR. Unlike Airborne, Terrestrial LiDAR systems are installed on moving vehicles or fixed in static mode on tripods on the earth surface for collecting accurate 3D data points. Terrestrial laser scanner devices today represent one of the most widely and important instruments in the field of surveying engineering and environmental applications. Laser scanner instruments can collect irregular 3D point clouds of land areas, rivers, and roads, constructions, analyzing infrastructure or

even collecting point clouds from the inside and outside of buildings in a fast and cheap way. LiDAR principal has followed a simple idea— emitting laser light at an object on the earth's surface then calculating the time it takes to return to the emitting source of LiDAR . Given the speed at which the light travels (approximately 300,000 km per second), the process of measuring the exact distance through LiDAR appears to be incredibly fast. However, it’s very technical. The formula that analysts use to arrive at the precise distance of the object is as follows:

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 11, November-2021

$d = \frac{C*t}{2}$ Equation (1)

The distance of the object = (Speed of Light x Time of Flight) / 2, where,

D, is distance of the object to the emitting source

C, is the Speed of Light in space

T, is time of Flight

A laser scanner consists of an emitting diode that produces a light source at a specific frequency. A mirror directs the laser beam horizontally and vertically towards the surface of the object then reflects the laser beam [4]. Using the principles of pulse time of flight, the distance to the object can be determined by the transit time, with a precision of –4 mm [5]. The result of a scan produces a collection of points in space, 3D, commonly known as "point clouds,"

Which can be processed and combined into accurate 3D models; figure 1 shows the principle of the laser scanners.

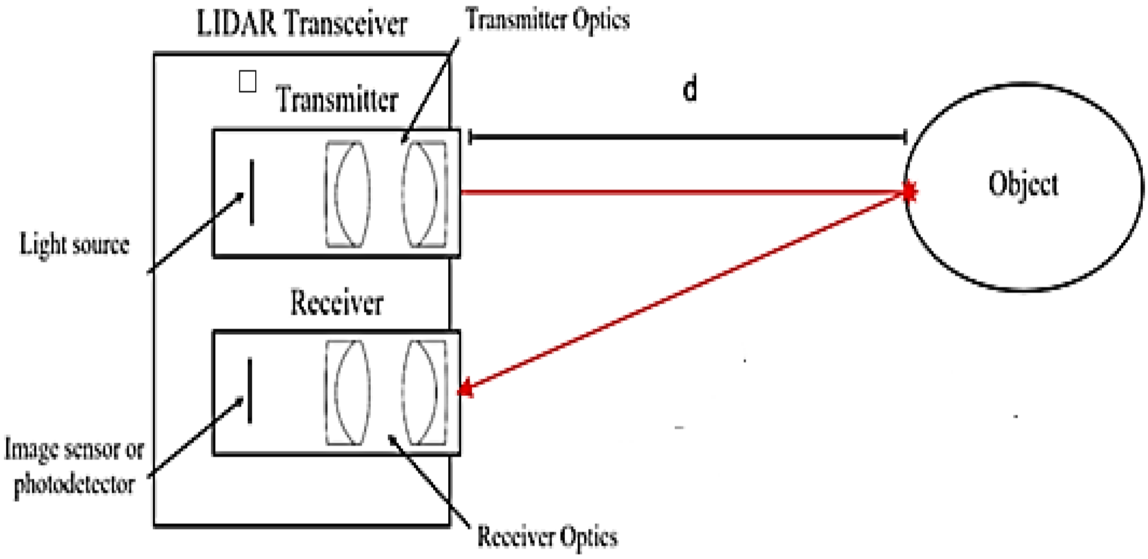

Figure 1: principal of laser scanner

LiDAR can be used to accomplish many developmental objectives, some of which are: depth of the ocean's surface to locate any object submerged in oceans or seas due to accident or for research purposes, they use LiDAR technology to accomplish their mission. Terrain elevations play a crucial role during the construction of roads. Small and large buildings and bridges. LiDAR technology has 3 D coordinates, which makes it incredibly easy to produce the 3D representation of elevations or 2D plans to ensure that concerned parties can draw necessary conclusions more easily. Typical applications of LiDAR technology in agriculture are used. Besides this, it is also used for campaign planning, mapping under the forest canopy.

2. DATA SETS

Three tools were used in this experiment, I phone pro max mobile provided with LiDAR scanner, poly cam software used in data collection, and Leica total station instrument. The used iPhone 12 pro max comes with an 8GB RAM and 256GB storage. The rear camera consists of a 12MP (wide) + 12MP (telephoto) 5x optical zoom + 12MP (ultra-wide) sensors and a LiDAR scanner for night mode. The front camera has a 12 MP (wide) + SL 3D (depth/biometrics) camera sensor. An image is posted showing a diagram of Three tools were used in this experiment, iPhone pro-max mobile provided with LiDAR scanner, poly cam software used in data collection, and Leica total station instrument. IPhone 12 pro max has 8GB RAM and 256GB storage. The rear camera consists of a 12MP (wide) + 12MP (telephoto) 5x optical zoom + 12MP (ultra-wide) sensors and a LiDAR scanner for night mode. The front camera has a 12 MP (wide) + SL 3D (depth/biometrics) camera sensor (1). An image is posted showing a diagram of the rear of an iPhone in figure 2, sniped to show the camera bump and the standby button. as shown in the drawing, three of the camera lenses are normal, while a fourth is indicated to be different, something the tweet describes as LiDAR in the "iPhone 12 Pro" and "iPhone 12 Pro Max" models [6].

Figure 2: LiDAR scanner location in I phone mobile.

Polycam software is a leading 3D capture application for iPhone Creates high-quality 3D models from photos, and rapidly generates scans of spaces with the LiDAR sensor. Polycam software has the capability to export 3D capture to many extensions [7]. in this paper, polycam software used in scanning the interior walls for the building and then used to

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 11, November-2021

process the collected point cloud for producing the 3D modeling.
Leica total station instrument TS03 model with 3 seconds accuracy and distance accuracy 1mm +1.5ppm used to measure the x,y coordinates for the interior of the building using single laser beam reflector less option without using any prism. Figure 3 shows the Leica TS03 instrument and figure 4 shows the instrument datasheet. The study area is chosen to be a small building (apartment), its area is about 85 square meters, 8m by 10.5 m, it contains 8 partitions.

Figure 3: TS03 Leica instrument

3. METHODOLOGY

Iphone ProMax 12 used to collect measurements data for the small building. 3D Point cloud was collection using Kinematic mode as the mobile phone handheld. Using the polycam software, interior scanning for the building were done. Raw data in the form of point cloud were collected while the mobile phone moving nears the walls, nearly 3 meters apart. Raw data from mobile phone in the form of Point cloud (174.6 MB) exported to dxf formal to be used by Autodesk software, the storage capacity after exportation is
262.2 MB included 389,500- 3D points. The collected data was 2*2 mm to 5*5 mm grids using iPhone mobile (ProMax 12) with the aid of polycam software. As discriped, the 3D data were collected in kinematic mode, the mobile phone moving near the walls catching in hand, so, lidar beam transmitted directed to the objects (walls) surrounding it by mesh, then the raw data (point cloud) were transformed to 3D object using the same software. Data process by polycam taking about 3 minutes to transform. The lidar rays are emitted from the mobile, and within the range of three to five meters, they can surround the targets with a two-dimensional mesh, this mesh appears clearly on the mobile screen, and the person conducting the survey can move in the direction of the scanning line when all the visible targets are covered by this mesh. it is remarkable that, during the collection of LiDAR data from the mobile phone, the 2D mesh traced on the mobile screen more extensively and density in the corners and deep places, as well as on the ground line of all wall's elevations. Figure 4 shows the collected LiDAR mesh size compared with a fixed target has 8 * 8 centimeters. Also, the traced mesh was uniform; twice the size of the fixed target for the objects has the same pattern, nearly, sixteen centimeters. In all cases, after the data process with polycam software, the final mesh size of the produced point cloud was 2*2 mm to 5*5 mm with different pattern as measured from AutoCAD program, figure 5.

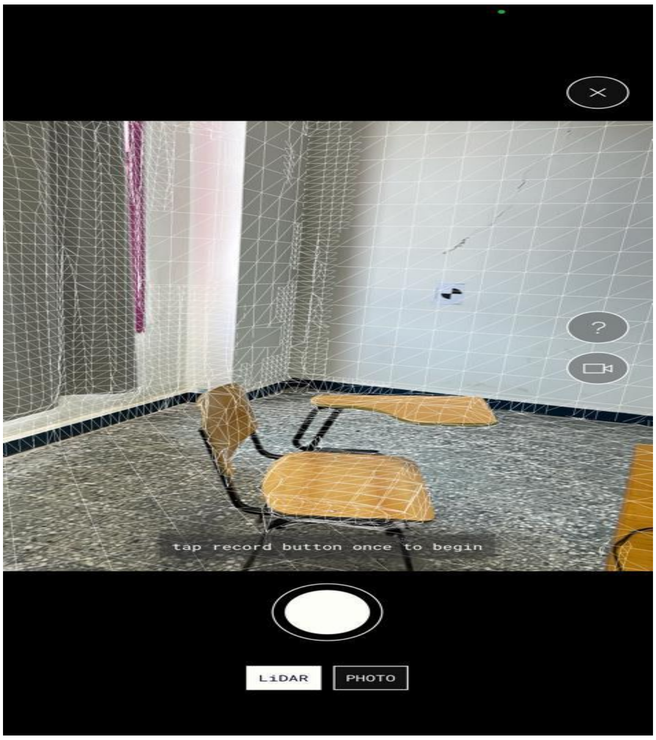

figure 4: LiDAR mesh while data collecting with a fixed target.

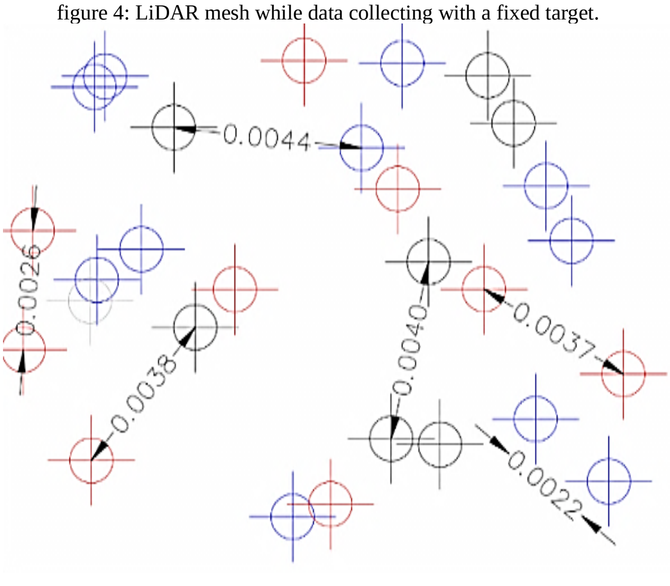

figure 5: Point cloud as obtained from iPhone Mobil LiDAR scanner

The same raw data – point cloud- figure 6 are then proceeding using the same software – polycam - to be visualized in 3D modeling as object. Figure 7 shows the 3D modeling produced from the point cloud after process. The dxf file then used by AutoCAD software and all walls are manually digitized and traced as 2D plane using Autocad software.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 11, November-2021

Measurements obtained from LiDAR Iphone mobile were used to know at what extent this measurement useful and the possibility of using them for simple tasks quickly without affecting the accuracy, this is the objectives of this paper, so scanning wall faces of the sectors or partitions forming the whole building also, the openings represented in doors and windows only without taking into consideration any internal details are followed. Nearly 3 meter was the distance from which all walls were scanned without affecting any problems in coverage. Therefore, it was the approved distance that was followed in data collection throughout. The scanning duration for all partitions with an approximately 85 square meters was nearly four minutes using iPhone LiDAR. The product from this process is a three-dimensional point cloud represents a detailed survey of the component parts of the building walls. The obtained 3D point cloud was used by AutoCAD program to produce 2D plan for the building.Polyline tool command from AutoCAD tools was used to digitize building walls which appeared clearly in the 3D point cloud manually. walls appear somewhat clearly represented by dense points on both sides of the walls, and the width of these walls ranged from 12 to 20 cm. Figure 8 shows the methodology flowchart, while, Figure 9 shows the extracted 2D map from both iPhone and total measurements included partition areas. Figure 10 shows the extracted 2D map included side lengths. Figure 11 shows the extracted 2D map included point numbers for the selected angles and coordinates. After finalizing tracing the 2D plan for the building, dimensions and angels for the building walls were extracted, and the areas of all partitions are calculated. The same building was observed using Leica instrument total station. Building corners for all partitions were observed and x,y coordinates are collected, then the 2D plan was traced by AutoCAD, then dimensions and partitions interior angles were extracted from the drawing also the partition areas were calculated. The two 2D plans are then identically Geo-referencing together using one common point as a base point has the same coordinates and the coordinates of corner for all building were extracted. Four items were computed and compared from the two 2D planes, angels, side lengths, areas, and coordinates of all model points.The methodology that was followed in the research starts from using LiDAR on the iPhone for scanning the interior parts of the selected building represented in included door openings and windows, as well as making a two-dimensional survey observation using the Total Station device. The raw data generated by the iPhone are then exported to 3D point cloud. The 3D point cloud was processed to produce a 3D modeling for the building. The point cloud was used by the AutoCAD program to draw the two-dimensional plan by deducing the outer limits of the partitions of the building, as it appears in the form of dense point clouds ranging in width from 12 cm to 20 cm and is easy to distinguish and draw using the Polyline tool from AutoCAD. Also, the observations from the Total Station device were used directly to draw a two-dimensional horizontal plan. The two 2D plans resulting from the hand-held iPhone mobile scanning and the Total Station observations were used together to in evaluation process. The elements of evaluations were, areas of the partitions, the lengths of the sides for the entire walls of the building, the interior angles, and the point's coordinates of the 2D plan corners.

Figure 1: 3D point cloud as produced from iPhone scanning

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 11, November-2021

Figure 2: 3D modeling produced from point cloud after process.

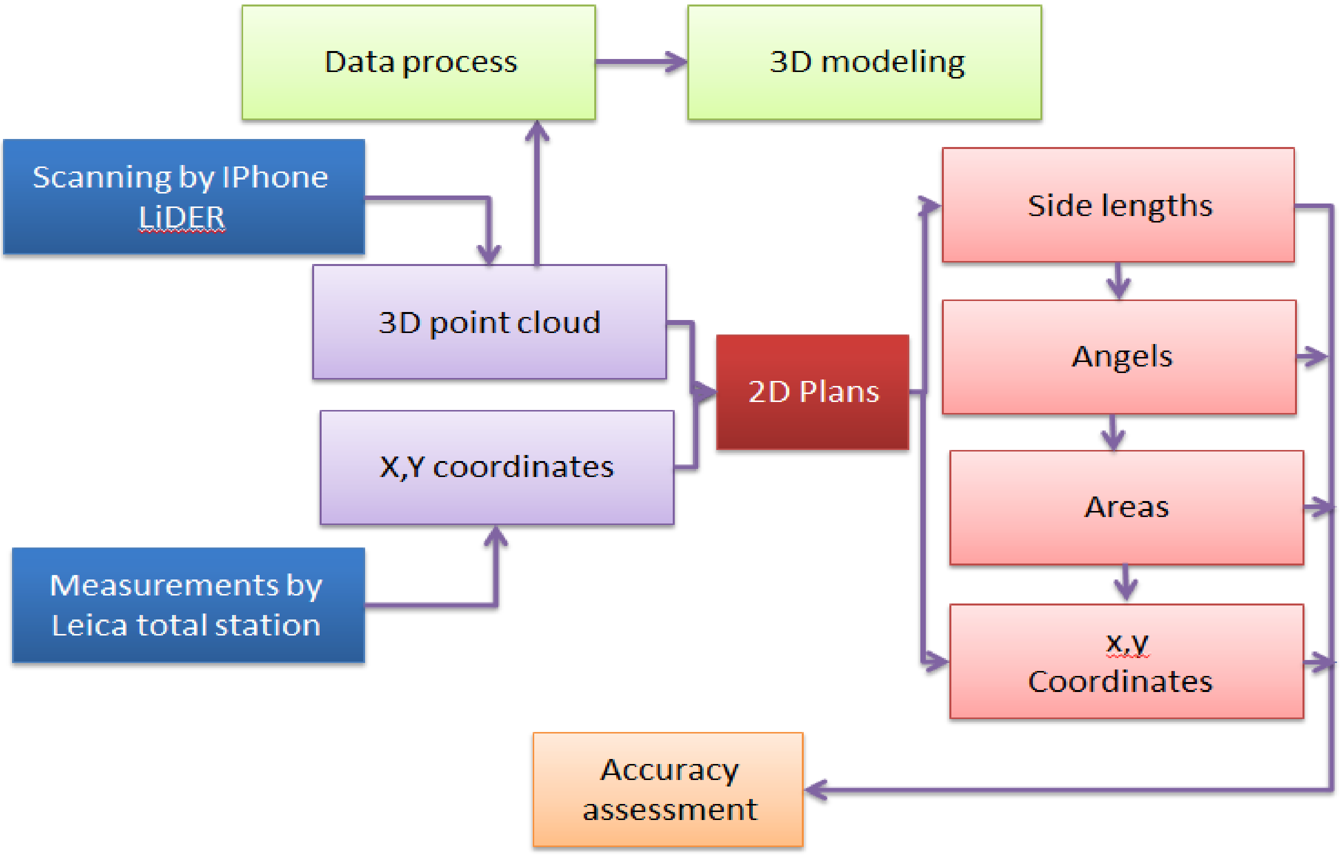

Figure 3: Methodology flowchart

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 11, November-2021

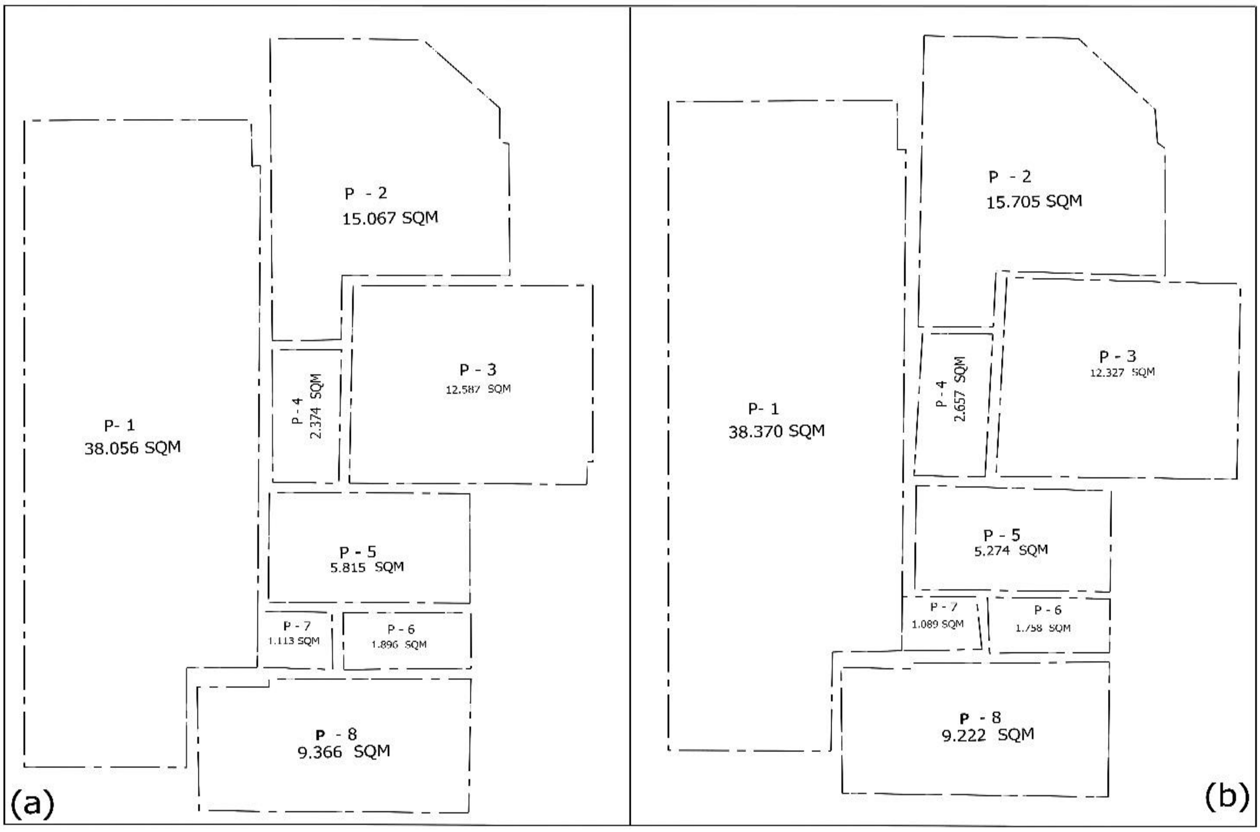

Figure 9: 2D plan indicates partitions areas, (a) produced from I phone and (b) produced from total station.

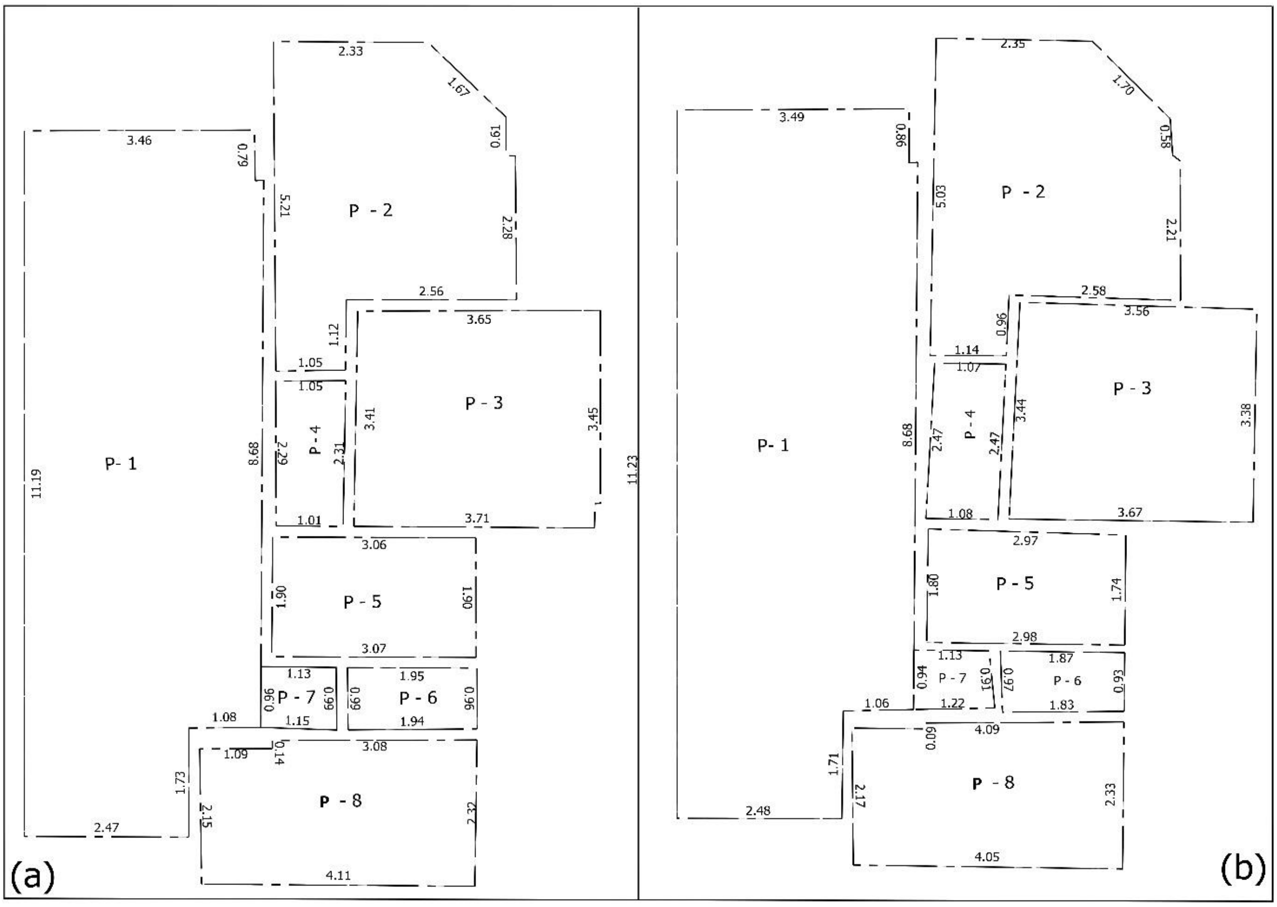

Figure 10: 2D plan indicates side lengths, (a) produced from I phone and (b) produced from total station.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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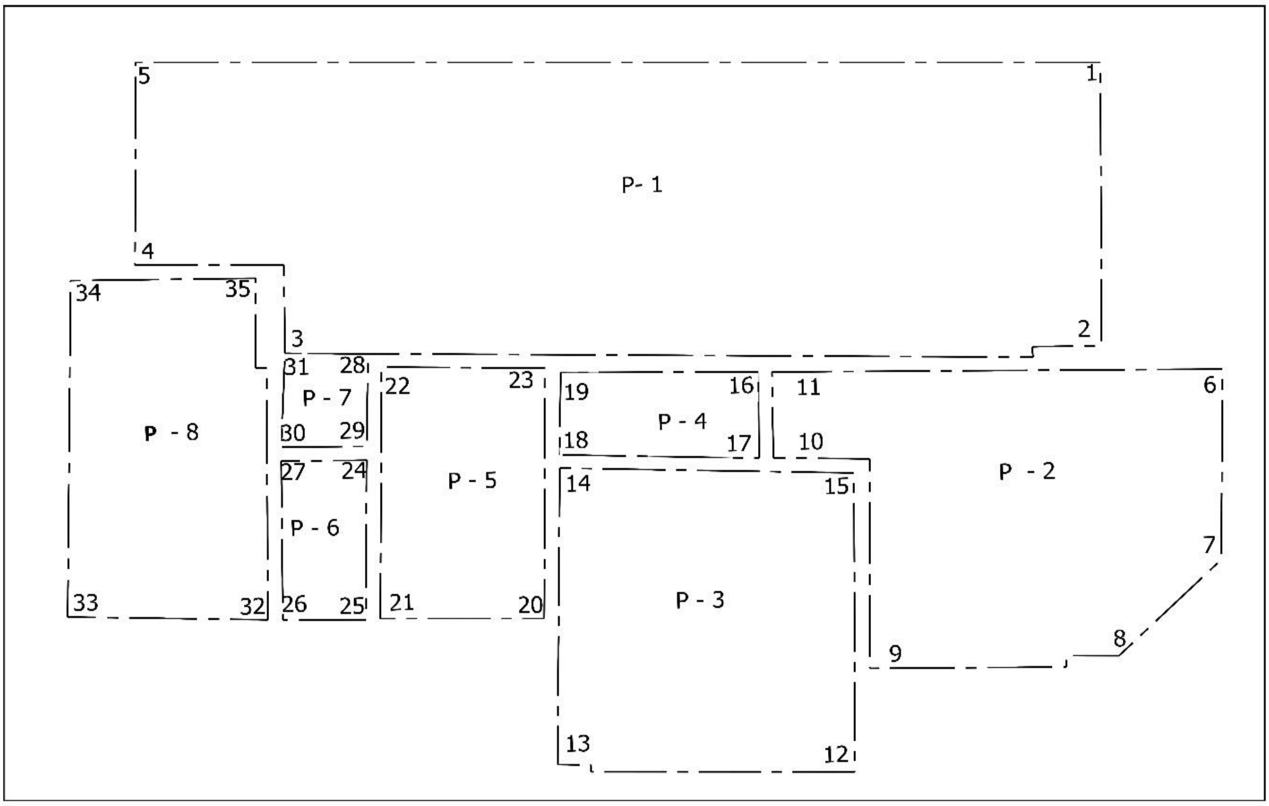

Figure 11: 2D plan indicates selected points id for coordinates and angles.

4. RESULTS

The evaluation of the data produced from total station observations and iPhone measurements are done using four elements. The two 2D plans from the two equipment's are used for elements extraction the following, (1) Area of each partition, (2) side lengths, (3) interior angles, and (4) corner coordinates. Four statistical parameters were used; (1) the minimum error, (2) maximum error, (3) the mean error, and (4) root mean square error. The coordinates of 35 selected points and interior angle around these points were measured from the two 2D planes of the total station observations and LiDAR scanning from iPhone mobile. The coordinates and the interior angles are tabulated in table 1. The differences in angles and coordinates between the two equipment are given in the same table, table 1. RMSE, the most widely used statistics as a measure of accuracy [3] was calculated and used to evaluate the quality of iPhone mobile measurements against total station measurements, equation 2.RMSE can be given by,

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{k=1}^{n}(\boldsymbol{V_k})^2} \qquad (2)$$

Where,

$\boldsymbol{V_k = H_k - H'_k}$.

n, is the number of checkpoints

H_k Are iPhone measurements of point k,

H_k'. Are the total station measurements of point the point k.

Table 2 descripts the values of partitions area and their differences produced from the two data sources. The partition areas range 38.55 to 1.76 square meters. Statistics (min, max, mean and RMSE) for coordinates of the 2D plan of iPhone and total station are given in table 3, it is remarkable from this table that, the maximum error in x-coordinates is 0.02m, while it is 0.04 m for y-coordinates, the RMSE are 0.05 and 0.06 meters for x and y-coordinates respectively. The mean error was 0.02 and 0.01 for x and y-coordinates respectively. Little Deformation in the shape of the 2D plan produced from iPhone was remarkable. It was also noticeable that there was a big distortion in angle 8. The value of the distortion was 4.854 degrees, the reason maybe it was considered as obtuse angle. Angles 19,29, and 31 are also have big errors to some extent , the errors included in these angle ranges 4 to 6 degrees the reason maybe existing these angles in small partitions. All the remaining angles has differences not exceeds 2 degrees, table 1. Overall, the minimum, maximum and mean errors in angles of the 2D plan are (-6.88, 3.35, and -0.42) degrees while the root mean square error was 2.01 degree, table 4. Statistics for the side lengths of the 2D plan of iPhone and total station are given in table 5, form this table, it is noted that small differences exist between the two types of the data, few centimeters differences exist between side lengths in the two plans. The minimum, maximum and mean error for 27 side are (-0.18, 0.18, and 0.01) m with RMSE 0.08 m. error in Areas are small like the error in lengths, there was little differences between the two sources of the data, the minimum, maximum and mean error for 8 partitions were (-0.31, 0.54, and 0.04) m² with RMSE 0.28 square meters, table 6.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 11, November-2021

TABLE 1: Coordinates and angels of the 2D plan measured from the two data sources.

Po-id	(coordinates)						angles/degrees			Side- length /m		
	I phone		T.S		Diff /m							
	x	y	x	y	dx	dy	I phone	T.S	Diff	I phone	T.S	Diff
1	5353.52	4089.5	5353.48	4089.47	0.042	0.02	90.296	90.19	-0.10	3.46	3.49	-0.03
2	5353.55	4087.355	5353.49	4087.32	0.055	0.02	89.908	90.66	0.75	0.79	0.86	-0.07
3	5357.66	4087.321	5357.60	4087.26	0.055	0.05	91.677	90.93	-0.74	8.68	8.68	0
4	5357.69	4089.641	5357.65	4089.58	0.04	0.05	90.593	89.81	-0.78	1.08	1.06	0.02
5	5354.44	4089.839	5354.40	4089.80	0.04	0.03	90.118	90.19	0.072	1.73	1.71	0.02
6	5355.58	4089.797	5355.54	4089.75	0.04	0.04	89.898	89.26	-0.629	2.47	2.48	-0.01
7	5355.57	4090.788	5355.54	4090.74	0.034	0.04	134.7	135.0	0.36	11.19	11.23	-0.04
8	5354.44	4090.803	5354.41	4090.76	0.034	0.03	139.994	135.1	-4.854	2.33	2.35	-0.02
9	5355.75	4089.798	5355.71	4089.75	0.04	0.04	87.998	89.62	1.622	5.21	5.03	0.18
10	5357.70	4089.815	5357.66	4089.76	0.039	0.05	92.447	91.51	-0.933	1.67	1.7	-0.03
11	5357.69	4090.777	5357.66	4090.72	0.034	0.05	89.526	89.52	0.002	0.61	0.58	0.03
12	5354.62	4092.857	5354.60	4092.82	0.021	0.03	90.819	89.81	-1.007	2.28	2.21	0.07
13	5354.60	4090.96	5354.57	4090.92	0.033	0.03	90.169	90.77	0.608	2.56	2.58	-0.02
14	5357.68	4090.948	5357.64	4090.89	0.032	0.05	88.071	89.4	1.329	1.12	0.96	0.16
15	5357.67	4092.846	5357.65	4092.79	0.021	0.05	90.941	91.15	0.215	1.05	1.14	-0.09
16	5354.67	4093.037	5354.65	4093.00	0.02	0.03	92.17	90.19	-2.041	1.05	1.07	-0.02
17	5355.68	4093.023	5355.66	4092.98	0.02	0.04	88.076	88.68	0.604	2.29	2.47	-0.18
18	5355.72	4095.337	5355.71	4095.29	0.006	0.04	91.881	90.20	-1.679	2.31	2.47	-0.16
19	5354.66	4095.331	5354.66	4095.29	0.006	0.03	97.873	90.98	-6.884	1.01	1.08	-0.07
20	5355.90	4096.438	5355.90	4096.39	-0.00	0.04	91.357	90.26	-1.096	3.41	3.44	-0.03
21	5355.84	4093.026	5355.82	4092.98	0.021	0.04	89.744	89.70	-0.039	3.71	3.67	0.04
22	5359.46	4093.001	5359.44	4092.93	0.02	0.06	90.045	89.80	-0.238	3.45	3.38	0.07
23	5359.55	4096.448	5359.55	4096.38	-0.00	0.06	88.855	90.22	1.373	3.06	2.97	0.09
24	5354.66	4095.487	5354.66	4095.45	0.006	0.03	87.446	89.07	1.625	1.9	1.8	0.1
25	5355.71	4095.503	5355.71	4095.46	0.005	0.04	90.277	90.41	0.133	1.9	1.74	0.16
26	5358.29	4096.62	5358.29	4096.56	-0.00	0.05	90.97	90.38	-0.581	1.13	1.13	0
27	5358.13	4099.513	5358.15	4099.45	-0.02	0.05	91.307	90.13	-1.177	0.96	0.94	0.02
28	5356.96	4100.698	5356.98	4100.65	-0.02	0.04	89.685	89.54	-0.141	0.99	0.91	0.08
29	5354.63	4100.712	5354.66	4100.67	-0.02	0.03	96.109	91.38	-4.724	1.95	1.87	0.08
30	5350.88	4088.109	5350.83	4088.09	0.051	0.01	85.723	87.24	1.519	0.96	0.93	0.03
31	5353.36	4088.101	5353.31	4088.07	0.051	0.02	88.482	91.82	3.347	2.15	2.17	-0.02
32	5354.44	4089.839	5354.40	4089.80	0.04	0.03	89.138	88.96	-0.176	2.32	2.33	-0.01
33	5354.34	4099.308	5354.36	4099.27	-0.01	0.03	89.646	90.35	0.706	4.11	4.05	0.06
34	5350.88	4099.308	5350.90	4099.29	-0.01	0.01	91.388	91.21	-0.172	2.15	2.17	-0.02
35	5353.52	4089.5	5353.52	4089.5	0	0	88.702	89.33	0.633	3.08	3.09	-0.01

TABLE 2: Area from 2D plan measured from the two data sources and their differences.

partition / Area	Area / m² - T.S	Area/ m² - I phone LiDAR	Difference / m²
partition 1	38.235	38.558	-0.314
partition 2	15.067	15.213	-0.151
partition 3	12.688	12.308	0.226
partition 4	2.374	2.658	-0.283
partition 5	5.815	5.274	0.541
partition 6	1.896	1.761	0.024
partition 7	9.251	9.221	0.137
Total Area	**85.326**	**84.993**	**0.324**

TABLE 3: Statistics for coordinates of the 2D plan measured from the two data sources.

Statistics (coordinates)	X,m	Y,m
Min error	-0.027	0.011
RMSE	0.055	0.064
Max error	0.02	0.04
Mean error	0.02	0.01

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 11, November-2021

TABLE 4: Statistics for angels of the 2D plan measured from the two data sources.

Statistics (angels)	**Angle difference (degree)**
Min error	-6.88
Max error	3.35
Mean error	-0.42
RMSE	2.01

TABLE 5: Statistics for side length of the 2D plan measured from the two data sources.

Statistics (side length)	side length difference (m)
Min error	-0.18
Max error	0.18
Mean error	0.01
RMSE	0.08

TABLE 6: Statistics Areas of the 2D plan measured from the two data sources.

Statistics (partition area)	partition area difference (m^2)
Min error	-0.31
Max error	0.54
Mean error	0.04
RMSE	0.28

Profiles for some verification elements were illustrated in figure 12 and 13; figure 12 shows the relation between the two types of the data from total station and iPhone LiDAR for partition areas, side lengths and angels. Regarding this figure, areas and side lengths profiles are systematic and same pattern, while the angle

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 11, November-2021

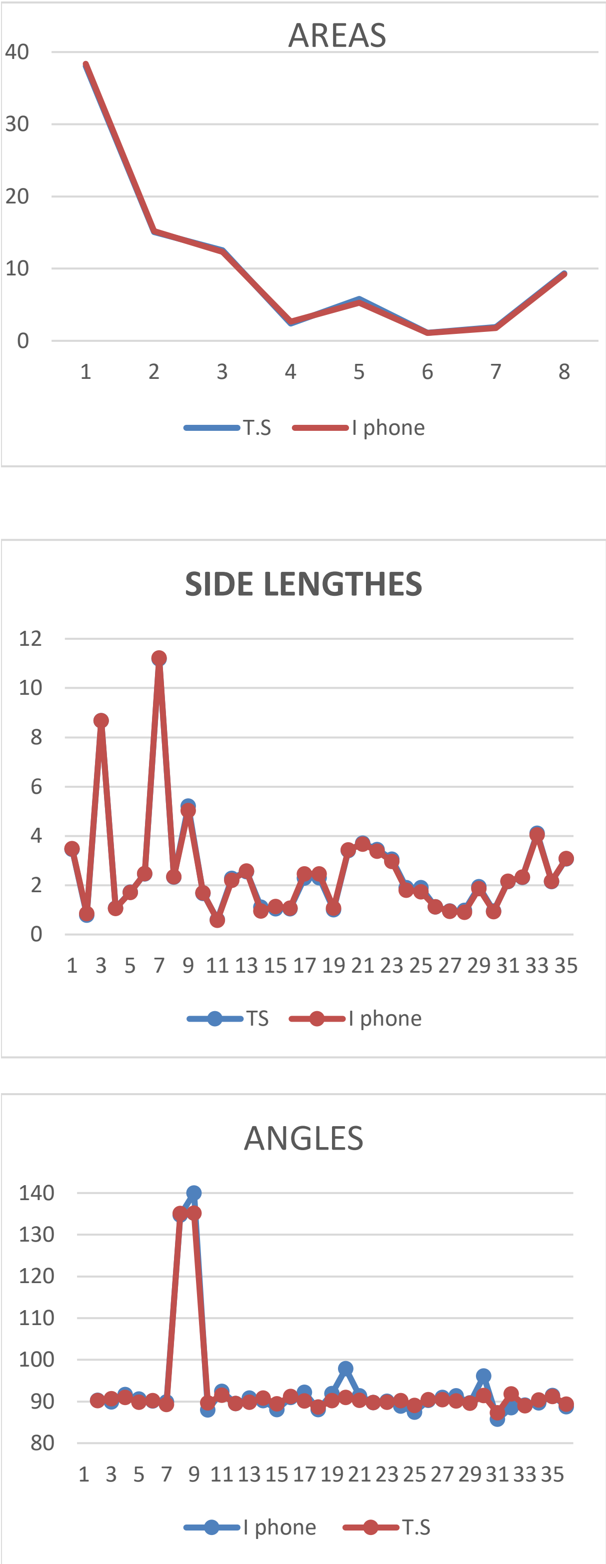

Fig. 12: A profiles for Areas, Side lengths and Angles for the 2D plan produced from TS and iPhone LiDAR.

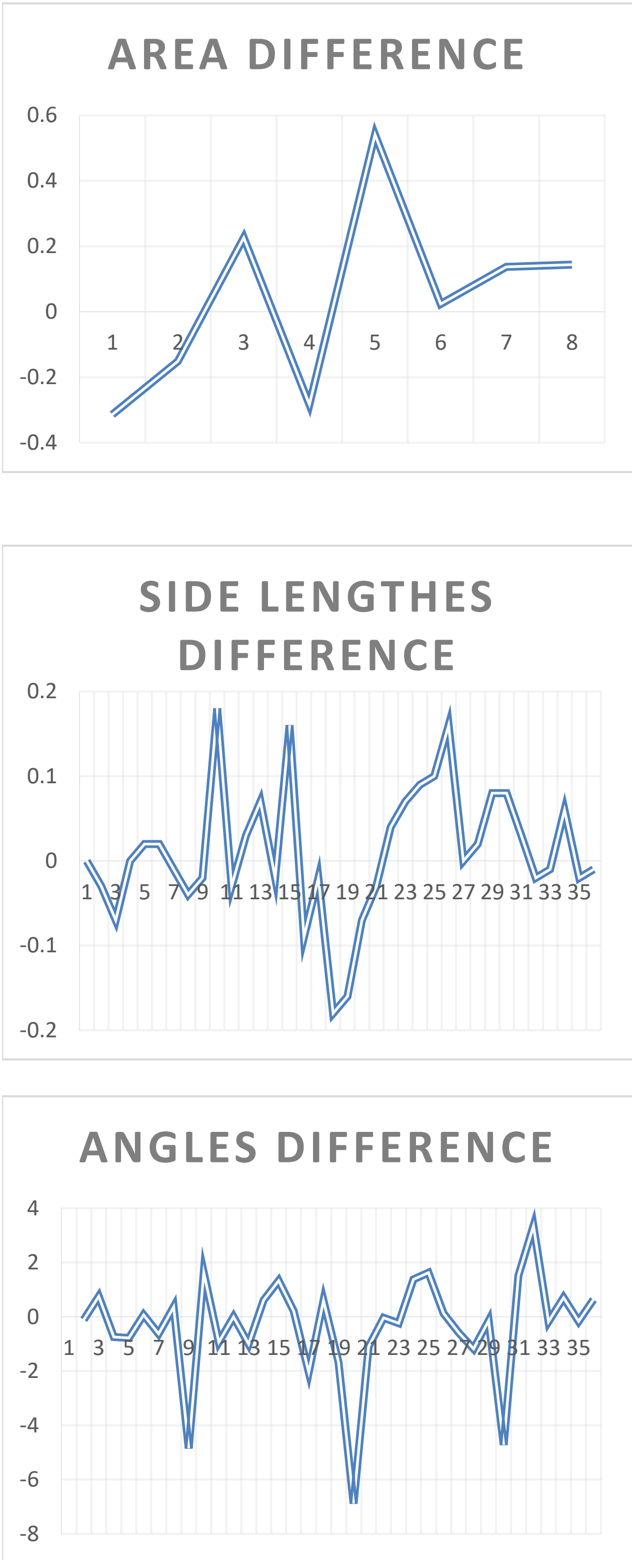

Fig. 13: A profiles of differences for Areas, Side lengths and Angles for the 2D plan produced from TS and iPhone LiDAR.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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5. CONCLOUSION

The availability of LiDAR technology in mobile phones became very important to know the extent of reliance on this technology without making serious mistakes. Where it is considered as new technology added in Mobil phones nowadays, also it is very saving time and effort as well as cost. Therefore, the aim of the research was to evaluate the performance of LiDAR available in these mobile phones for simple surveying work need in our daily life to show is this technology useful or not and at what extent can use it? To answer these questions, Two-dimensional interior 2D plans for a small building with an area of approximately 85 square meters were observed by total station instrument and used as reference data to evaluate the same production from LiDAR scanner available in iPhone Mobiles. Some statistical parameters were used to achieve this evaluation. The mean, minimum, maximum differences and the root mean square error (RMSE) used as four assessment parameters. While the evaluation items used were, the angles, the side lengths, the areas and the point coordinates from the 2D plans produced from the two equipment. Results showed that the measurements accuracies from iPhone are useful to some extent at least for the study case. Measurements using liDAR available in mobile iPhones were compatible with the corresponding measurements from total station instrument. RMSE were (2.01degree, 0.08 m, 0.28m^2) for angles, side lengths and partition areas respectively. While the RMSE for point coordinates were (0.02 m and 0.01 m) for x and y coordinates respectively.

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