VOL 4, NO.2 (2024) 205-230
https://jagst.utm.my

JAGST
Journal of Advanced Geospatial Science & Technology

Utilizing Terrestrial Laser Scanning Dataset for Cadastral Surveying

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***Abstract* –** In the Fourth Industrial Revolution (4.0 IR) era, the adoption of Terrestrial Laser Scanning (TLS) has seen a remarkable upsurge in its application within land development contexts. TLS, a surveying method harnessing laser technology to gauge distances between objects and generate intricate three-dimensional representations of the immediate environment, has become increasingly pivotal in ensuring the precise delineation of property boundaries and establishing dependable land records. This research delves into a crucial aspect of this technological shift, investigating the potential disparities in area measurement accuracy when comparing conventional cadastral techniques Total Station (TS) to TLS, specifically in the Malaysian context. For data collection and processing, the BLK 360 laser scanner and the ES 105 TS were chosen for their capacity to capture high-resolution point cloud data and provide precise angle and distance measurements. The study's findings unveil TLS as a promising alternative for cadastral surveys in Malaysia, effectively maintaining boundary vector displacement well within the acceptable threshold of 0.050 meters at specified locations. On average, the discrepancies in northing and easting coordinates are impressively low at 0.004 meters and 0.002 meters, respectively. This research highlights the potential of TLS to enhance the accuracy and efficiency of cadastral area calculation in Malaysia, contributing to the establishment of more reliable land records and improved land development practices within the 4.0 IR framework.

Keywords *– Cadastral, Comparison Analysis, LiDAR, Terrestrial Laser Scanning (TLS), Total Station*

Article History: Received 28 November 2023, Accepted 1 August 2024, Published 31 August 2024

How to cite: Zakaria, F. A., Mohd Yatim, M. H., Mohd Ariff, M. F., Razali, A. F., Tan, L. C. and Abdul Hamid, H. (2024). Utilizing Terrestrial Laser Scanning Dataset for Cadastral Surveying. Journal of Advanced Geospatial Science and Technology. 4(2),205-230.

1.0 Introduction

Cadastral surveys play a crucial role in the administration and management of land in Malaysia, as they serve as the foundation for the country's land tenure system and land governance, which facilitate the official registration of land ownership and record the associated rights, limitations, and obligations related to land by employing accurate surveying techniques (Ismail, 2023). Typically, the conventional method of cadastral surveying, characterized by utilizing human measurements and established surveying procedures, has been a cornerstone of reliance. For example, in a study by Tata (2019), field observations, traverse measurements, and total stations delineate the boundaries of the parcels in their research. Subsequently, there is a burgeoning interest in cadastral surveys to explore novel methodologies that can enhance the precision and effectiveness of area measurement. This interest has been sparked by the remarkable progress achieved in technical capabilities. TLS, a technology that has garnered significant attention, is currently being explored for possible uses. TLS utilizes laser scanners to capture precise and very detailed data of the three-dimensional point cloud of the scanned region. Subsequently, the data can be analyzed for precise measurements and comprehensive insights into the underlying geometry (Razali et al., 2020). The functioning principle of TLS involves the emission of laser pulses and subsequent measurement of the time taken for these pulses to return. This enables the calculation of distances and the generation of highly detailed point clouds (Scaioni et al., 2018). The utilization of this technology presents a prospective alternative to the traditional cadastral approach for area measurement, resulting in improved levels of accuracy and efficiency due to its inherent capabilities.

In the context of cadastral surveys, the utilization of this technology necessitates the resolution of certain obstacles and issues, notwithstanding the significant advantages TLS offers (Yang et al., 2020). According to Neza et al. (2022), various aspects can influence the accuracy of measurements. These elements encompass the complexity of data processing, the presence of registration complications, and the efficacy of management strategies for vast quantities of data. According to Puniach et al. (2018), various parameters, including scanning angles, can influence the quality of the gathered data. It is vital to comprehend these concerns and devise resolutions for them to ensure the reliability and precision of the TLS implementation in cadastral surveys. The main focus of the issue statement revolves around assessing the potential disparities between the

TLS approach and the conventional cadastral method with the precision of their area measurements.

The implementation of TLS in cadastral surveys presents a range of benefits. The first phase entails generating point cloud data demonstrating a significant level of intricacy, facilitating delineation of boundaries and the precise calculation of areas (Cai et al., 2021). According to a study conducted by Yang et al. in the year 2020, TLS possesses the potential to effectively capture intricate geographical features, uneven shapes, and variations in elevation. These aspects are sometimes challenging to document accurately using alternative methodologies. Moreover, implementing TLS technology reduces fieldwork duration and eliminates the need for manual measurement, enhancing efficiency and productivity levels (Damięcka-Suchocka et al., 2022). This study aims to assess the accuracy and reliability of the TLS method compared to TS (conventional techniques) for quantifying property areas and determining their presence in Malaysia. This enabled the researchers to ascertain the feasibility of integrating TLS into current cadastral systems. The method offered has significant potential to improve cadastral surveys' accuracy, streamline data management processes, and enhance data collection capabilities.

The utilization of TLS in cadastral surveys has several notable benefits, such as enhanced precision, heightened productivity, and enhanced data administration. To provide meaningful results, addressing the challenges associated with implementing TLS, including errors in data processing and registration, is imperative. These issues have the potential to undermine the validity of the results. It is expected that doing this research on comparisons will lead to deeper comprehension and effective utilization of TLS in cadastral surveys. Consequently, this enhances the practices of land administration and management. Hence, the study delves into a crucial aspect of this technological shift, investigating the potential disparities in area measurement accuracy when comparing conventional cadastral TS to TLS, specifically in the Malaysian context.

1.1 Modernization of Cadastral in Malaysia

Cadastral surveying in Peninsular Malaysia and the Federal Territory of Labuan is under the federal government's jurisdiction, whereas land management is exclusively within the states' authority. The modernization initiative of the Department of Survey and Mapping Malaysia (DSMM) has been underway since 1995, as noted by Noor et al. (2018). The implementation of this plan has led to a substantial augmentation in the level of computerization employed in the department's administrative operations and fieldwork. Surmeneli et al. (2022) assert that the Malaysian Cadastral System is founded upon assessing parcel measures and their spatial relationships with adjacent parcels. Over the past few years, Malaysia has made significant advancements in its cadastral surveying system, which have involved the adoption of technological innovations such as the Global Navigation Satellite System (GNSS) and TLS (Abdullah & Yusof, 2022).

TLS surveys are commonly employed in a diverse range of fields, encompassing the digital restoration of historical landmarks, Earth sciences, environmental sciences, geodesy and surveying, structural deformation monitoring, crime scene preservation for forensic purposes, reverse engineering, manufacturing and assembly of engineering components, as well as architectural, engineering, and construction (AEC) applications (Liu & Li, 2024). Gawronek and Makuch (2019) posit that utilizing TLS technology within the AEC sector presents several potential benefits. These advantages encompass swift and comprehensive data acquisition, precise measurements without physical touch, financial efficiency, and enhanced safety.

The Malaysian government has introduced an extensive computerized system to supplant the former manual, paper-based method used for land administration in Malaysia. The administration of cadastral surveying and cadastral land registration is under the Department of Survey and Mapping Management (DSMM) and the Land Offices, respectively (Choon et al., 2022). The purpose of the system is to provide consistency between the cadastral information acquired from these two sources (Choon et al., 2022). Surmeneli et al. (2022) assert that the cadaster and land registration system in Malaysia, specifically in peninsular Malaysia, plays a pivotal role in expediting the provision of land administration services. This system utilizes qualified and final titles, optimizes business operations, and effectively integrates information communication technology (ICT). The modernization of Malaysia’s cadastral system has seen significant progress by adopting computerization, TLS technology, and a comprehensive electronic land administration system, as illustrated in Figure 1. In this regard, the government has made it possible to query land parcels based on attributes stored in the 3D database. It is an open platform for sharing information with other users because it is a web-based application that can be accessed via any modern web browser (Rajabifard et al., 2021). As a result of these technological improvements, land administration services have witnessed enhanced accuracy and efficiency. Consequently, the land registration and management process has been more streamlined, facilitating private individuals and commercial entities to register and maintain their land holdings.

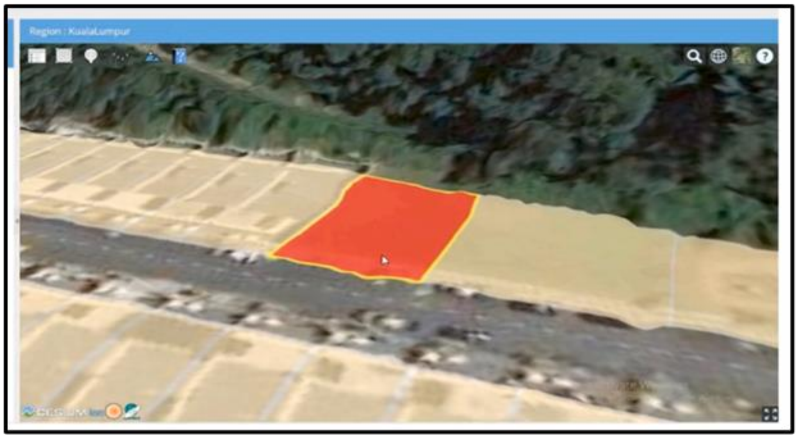

Figure 1. The Ladm Viewer's User Interface Allows for The Visualisation and Querying of 3D Parcels Based on Their Lot Number by Rajabifard et al. (2021).

1.2 Survey Perspective of Using TLS

Hassanein et al. (2023) define a TLS as an active imaging technique that operates from a ground-based position and swiftly captures three-dimensional point clouds of object surfaces by laser rangefinding. TLS surveys are employed in various fields, such as the digital reconstruction of historical landmarks, Earth sciences, environmental sciences, geodesy and surveying, structural deformation monitoring, crime scene preservation for forensic purposes, reverse engineering, manufacturing and assembly of engineering components, as well as AEC applications (Mengiste et al., 2022). Subsequently, applying TLS technology in the AEC industry offers several potential benefits, encompassing quicker and more comprehensive data collection, enhanced precision, non-contact measurement capabilities, cost-effectiveness, and improved safety measures Gawronek and Makuch (2019).

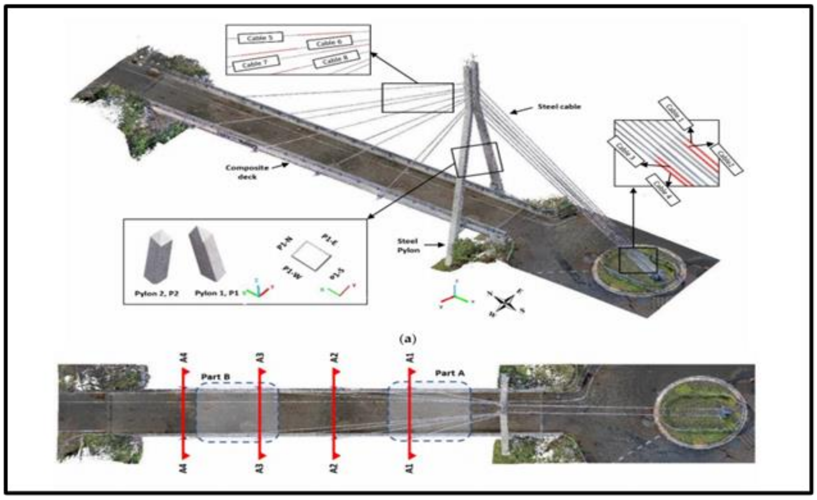

Figure 2. The objects and components of the bridge, including selected components and parameters, and the bridge's top view and cross-sections by Mohammadi et al. (2022).

Mohammadi et al. (2022) state that using TLS enables surveyors to ensure their safety by maintaining a secure distance during the process. This approach allows them to obtain a thorough and detailed site image. TLS provides a more comprehensive and intricate representation than earlier methods, ensuring the simultaneous capture of all relevant data. This is demonstrated in Figure 2, which showcases points along a cross-section overlaid on the composite shot. Prominent contributors to the current state of TLS include commercial instrument developers such as RIEGL, Leica Geosystems, Faro, Zoller and Frohlich, among others (Disney et al., 2019). TLS instruments have diverse capabilities regarding instrument range, size, mobility, scan speed, field of view, and the capacity to collect multi-return and entire waveform data (Baima & Robiglio, 2020). The attributes above enable a diverse range of Earth research endeavours to be conducted with TLS devices.

In summary, TLS serves as a valuable tool across a range of disciplines, encompassing the Earth sciences, environmental sciences, geodesy and surveying, structural deformation monitoring, forensics crime scene preservation, reverse engineering, manufacturing and assembly of engineering components, as well as AEC which enhanced precision, non-contact measuring capabilities, cost-effectiveness, and improved safety measures.

1.3 Concept of Terrestrial Laser Scanning

TLS is a commonly utilized survey methodology that entails the deployment of a laser scanner mounted on a tripod to capture a detailed three-dimensional point cloud of a specified scanned area (Altuntas, 2022). In simpler terms, TLS refers to applying a laser scanner to capture a series of data points that effectively represent the surface properties of an object or scene with precision. The term "point cloud" denotes a collection of discrete data points that faithfully represent the external surface of an object or scene. TLS is extensively utilized across various disciplines, including surveying, engineering, and architecture, among other pertinent domains.

As per the findings of Gurau et al. (2024), the laser scanner creates a laser beam that is precisely aimed at a specific target. Then, the scanner measures the time it takes for the laser beam to return to the sensor, thereby determining the duration of the round trip. The distance to the target can be determined by employing the established velocity of light. The technique described above is repeated multiple times within a unit of time, creating a condensed grouping of data points that accurately depict the specified area. A considerable volume of data points can be obtained using a scanning methodology characterized by the systematic traversal of the scanner across the subject or environment, creating a three-dimensional point cloud, as shown in Figure 3. Point cloud data facilitates the creation of three-dimensional models, digital terrain models, and other outputs that have practical uses in various disciplines, including architectural design, civil engineering, and resource management.

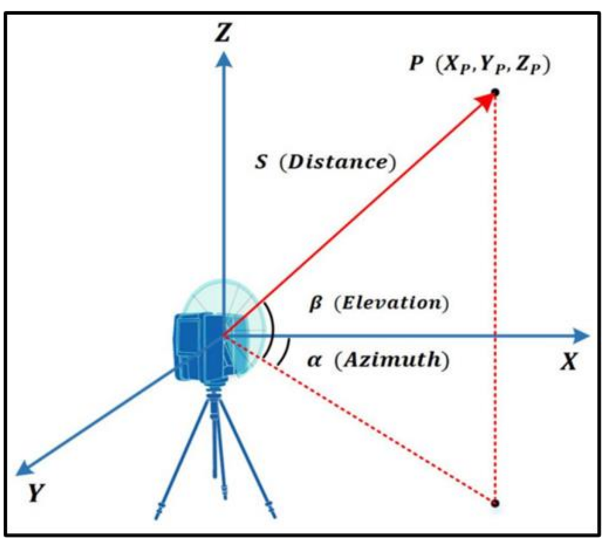

Figure 3. Working principle of a laser scanner by Wu et al. (2021).

Using TLS offers numerous advantages over traditional survey methods. One notable benefit is its non-contact nature, eliminating the need for direct physical interaction with the object under inspection. In addition, TLS has a noteworthy capacity for swift data acquisition, facilitating the collection of a significant amount of information within a restricted period (Šašak et al., 2019). Furthermore, TLS can administer surveys in arduous settings, such as areas characterized by rugged terrain or inaccessible structures. One of the key advantages of TLS is its remarkable level of accuracy and precision. Technology enables the capture of complex three-dimensional data, which can be employed to build accurate three-dimensional representations of an object or environment.

Additionally, this methodology is characterized by its non-invasive nature, making it suitable for use in sensitive environments. However, TLS is accompanied by notable budgetary ramifications. The procurement of the requisite equipment and software for implementing this approach may result in substantial expenses, and the effective execution of the strategy requires the availability of competent personnel who possess expertise in operating the equipment and interpreting the data. Furthermore, data acquisition can be laborious, particularly when confronted with large-scale and complex projects (Saptari et al., 2019).

In contemporary times, there has been a discernible increase in the implementation of TLS across various fields like architecture, civil engineering, and resource management. Several studies have been conducted to evaluate and compare the results obtained by TLS with various alternative surveying methods such as photogrammetry, Global Positioning System (GPS), and others.

1.4 Relationship Between Area and Land Tax

The correlation between land tax and land area is intricate as the tax burden imposed on property owners is often affected by multiple factors, such as the size and location of the property, as well as its designated function and zoning regulations. The process of calculating the appropriate amount of land tax to be levied and the methods of its collection in Malaysia are governed by the National Land Code. Figure 4 illustrates that Seremban, as the capital district of Negeri Sembilan, exhibits the highest land tax payable across various land classifications, except for village land. The state government establishes tax rates and regulations for all properties within a specific jurisdiction.

Land Classification	District/Locality	Land Plot Information	Rate (RM)	Calculation for Land Tax Amount (RM)
Town Land	Seremban	Land Usage Category: Building Land Use Type: Residential Land Area: 258 square metre	0.39 /sq metre (minimum RM84 /lot)	RM 0.38 X $258m^2$ = RM 98.04 ~RM 99.00
	Port Dickson and Town of Bahau (Jempol)		0.35 /sq metre (minimum RM81 /lot)	RM 0.35 X $258m^2$ = RM 90.30 ~RM 91.00
	Kuala Pilah, Tampin, Rembau, Jelebu and Sub-District of Gemas		0.34 /sq metre (minimum RM79 /lot)	RM 0.34 X $258m^2$ = RM 87.72 ~RM 88.00
Village Land	*single rate applies to all districts		0.32 /sq metre (minimum RM70 /lot)	RM 0.32 X $258m^2$ = RM 82.56 ~RM 83.00
Country Land	Seremban and Port Dickson		0.27 /sq metre (minimum RM58 /lot)	RM 0.27 X $258m^2$ = RM 69.66 ~RM 70.00
	Kuala Pilah, Jempol, Tampin, Rembau, Jelebu and Sub-District of Gemas		0.21 /sq metre (min RM47/lot)	RM 0.21 X $258m^2$ = RM 54.18 ~RM 55.00

Figure 4. Sample of Land Tax Calculation in Negeri Sembilan, Malaysia by Adnan et al. (2021).

The findings of these studies indicate that TLS exhibits promise in generating precise evaluations of property size, and it can be employed to detect properties that have been either undervalued or inflated for tax assessment objectives. The study by Mohammadi et al. (2022) serves as an illustrative case that demonstrates this phenomenon and presents additional supporting data. The researchers have made a significant finding indicating that using TLS leads to precise evaluations of property dimensions. This facilitates the identification of properties that have been either underestimated or overestimated in terms of their worth for tax assessment.

The study by Liu and Li (2024) offers another example for our contemplation. In contrast to conventional surveying techniques, the researchers utilized TLS to yield estimations of the overall land size of a property with a higher degree of precision, surpassing an accuracy level of less than 1%. In summary, terrestrial laser scanning technology offers a means to acquire precise measurements of property areas, primarily to facilitate tax assessment. This methodology has proven advantageous in discerning instances wherein properties have been underestimated or overestimated for taxation. Consequently, it assumes a significant role in facilitating fair and efficient land tax collection, aligning with one of the objectives of this approach.

2.0 Method

Accurate land area measurement is crucial for various applications, including land-use planning, property tax assessment, and land administration. In Malaysia, total stations (TS) are an industry-standard tool for property area calculations. This study aims to assess the accuracy and reliability of the TLS method compared to TS (conventional techniques) for quantifying property areas and determining their presence in Malaysia. The data-gathering process employed the TLS approach, while specialized software was utilized for analysis, accuracy assessment, and subsequent comparison of the results, as depicted in Figure 5. The methodology includes a study of relevant academic material and regulatory frameworks. The findings provide valuable insights into the TLS method's use for determining land use extent through coordinate measurements.

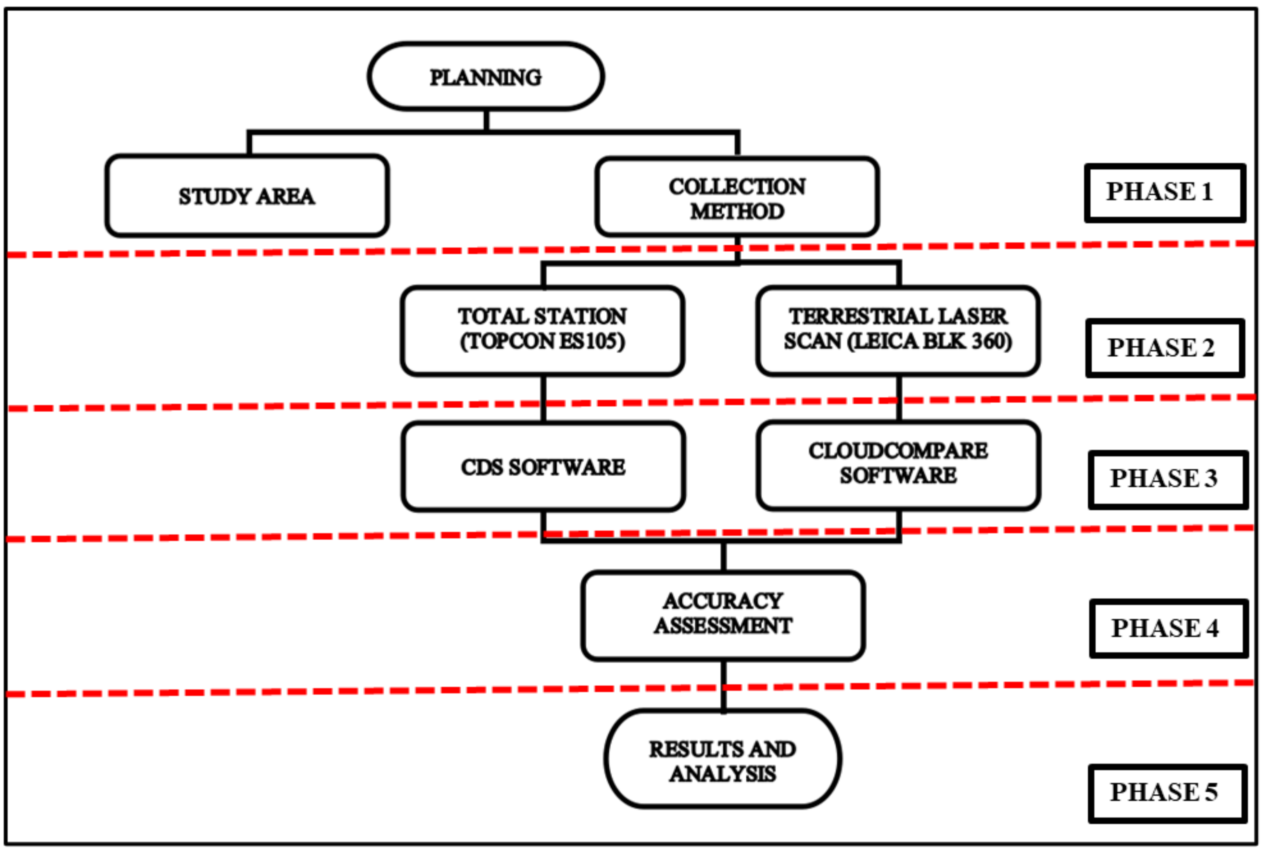

Figure 5. Flowchart of methodology.

2.1 Phase 1: Preliminary study

This preliminary inquiry compares the precision of area measurements taken using TLS and the Cadastral method using Total Station (TS), as depicted in Figure 6 and Table 1. The objective is to identify the potential of TLS to provide area measurements that closely align with those obtained through TS. UTM's Masjid Sultan Ismail was chosen as the study area, as depicted in Figure 7. This location was selected for accessibility, safety, and the surrounding environment. The BLK 360 laser scanner and ES 105 Total Station are best for data collection and processing. These sensors record point cloud data at high resolution and measure angles and distances accurately. Cloud Compare was chosen for TLS data processing. Civil Design and Survey (CDS) was used for TS measurements. This study can assist individuals in comprehending both approaches' pros and cons and provide valuable insights for future land surveying and measuring research.

Figure 6. Equipment used: TS and TLS.

Table 1. Specification of Equipment Used, TS and TLS.

Specifications	Terrestrial Laser Scan (Leica BLK 360)	Total Station (Topcon ES 105)
Performance	< 3min for a complete full scan	1sec / 5sec for each prism
Wavelength	830nm	635nm
Range	Min: 0.6m - up to 60m	500m
Dimension	Height: 165mm / Diameter: 100mm	19.1cm x 19cm x 34.8cm
Weight	1kg	5.6kg

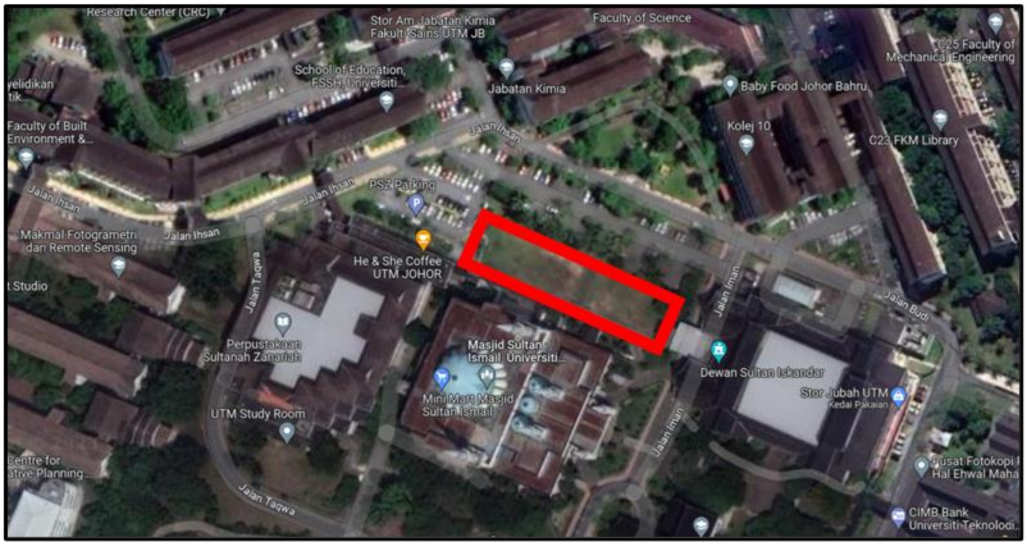

Figure 7. Study Area, Masjid Sultan Ismail, UTM by Google Maps.

2.2 Phase 2: Data Collection

The application of terrestrial laser scanning and total station techniques in the data-gathering phase involves accurately capturing measurements related to the boundaries of a designated area. There are various methods by which this task can be accomplished, as illustrated in Figure 8. By employing these methodologies, it becomes possible to gather a significant volume of data in three dimensions, which can then be used to construct a precise depiction of the targeted region.

Figure 8. Data acquisition work.

The initial step entails establishing a Global Navigation Satellite System (GNSS) that employs the static methodology for generating control points inside the designated region. CRM, an abbreviation for "cadastral reference mark," denotes this methodology. The control points function as reference points for subsequent measures. Once the control points have been established, the total station may be utilized to accurately measure the boundaries of the lot lines and calculate the area with a significant level of precision. This procedure can be executed after the establishment of the control points. Measurements are conducted using a prism at multiple places along the boundary to accomplish this task, and the info obtained from these sites is documented as depicted in Figure 9 and Figure 10.

Fnote	2,3,4,5,6,1,2				
Traverse	2	3	43°13'40"	90°00'00"	17.748
Traverse	3	4	116°45'30"	90°00'00"	25.141
Traverse	4	5	113°37'00"	90°00'00"	27.528
Traverse	5	6	191°52'30"	90°00'00"	15.643
Traverse	6	1	293°44'40"	90°00'00"	30.419
Traverse	1	2	293°26'40"	90°00'00"	31.353

Figure 9. Booking form on Civil Design and Survey (CDS) software.

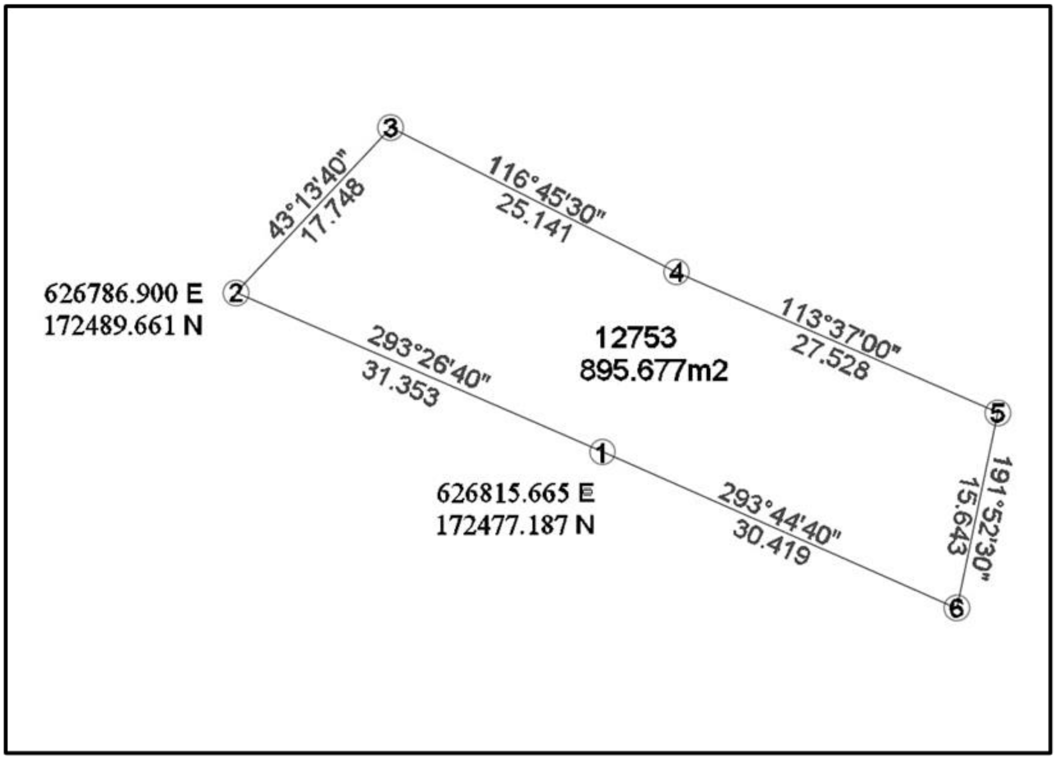

Figure 10. Traverse layout plan.

In the subsequent phase, the data acquired by the total station are juxtaposed with those obtained through terrestrial laser scanning. These comparisons occur in the following step. The Terrestrial Laser Scanner is a measurement instrument that employs laser technology to acquire data points on the surface of an object or within a three-dimensional environment. The data above points can be utilized to construct a three-dimensional model representing the object or area in question. This particular instrument is widely recognized for its exceptional precision. The scanning equipment emits laser beams that interact with the surface, leading to the reflection of the beams back towards the instrument. Due to the instrument's inherent capabilities, it can ascertain the X, Y, and Z coordinates of every data point scanned. Recording the X, Y, and Z coordinates of a given area makes it possible to construct a model that exhibits enhanced accuracy and facilitates more precise measurements of the area. The employed technique is the free scan approach, which entails manoeuvring the scanner throughout the region to gather data points from diverse perspectives.

2.3 Phase 3: Data Processing

In the data processing phase of conducting a survey using terrestrial laser scanning and total station techniques, several software tools, such as Cloud Compare and Civil Design and Survey, are commonly utilized. The software solutions facilitate the precise and efficient processing of extensive data obtained from terrestrial laser scanning and total station observations. This enables the effective handling of large volumes of data. In the data processing stage of area measurement techniques, such as terrestrial laser scanning and total station measurements, the commonly employed software includes Cloud Compare and Civil Design and Survey.

Anyone can calculate the area based on traverse data using specialized software such as Civil Design and Survey (CDS). Traverse data is a collection of interrelated survey measures systematically gathered along a predetermined course or route. In this article, the survey measures are denoted as “traversed”. The above data is commonly used to delineate boundaries or produce precise cartographic depictions. The predominant utilization of CDS software is observed within civil engineering and surveying domains. The software encompasses various functionalities, including analyzing traversing data and calculating geometric properties such as area, perimeter, and coordinates, among other capabilities. The programme often relies on the recorded locations and distances along the specified route to determine the region. This is achieved by employing traversal data within the CDS system. The simplification of the calculation for the enclosed area can be facilitated through the utilization of CDS software. This software allows users to input the gathered measurements and select an appropriate method for traverse closure, such as the Bowditch approach. It then generates the traverse adjustment report, depicted in Figure 11.

Additionally, this software enables users to expedite the calculation of the enclosed area. According to the provided diagram, it is evident that the conducted traverse is deemed acceptable, with a ratio of 1:98729, following the stipulated criteria established by the DSMM. This determination is based on the fact that the traverse has attained the initial measurement classification, surpassing the threshold of 1:8000.

Traverse Adjustment Report					
Northing Misclose:	-0.001				
Easting Misclose :	-0.001				
Bearing Misclose :	218.7366				
Distance Misclose:	0.001				
Area :	895.677				
Perimeter :	147.832				
Accuracy :	1:98729				
STN	Bearing	Distance	Latitude	Departure	Northing	Easting
2						
3	43.134	17.748	12.932	12.156	172502.593	626799.057
4	116.453	25.141	-11.319	22.449	172491.274	626821.506
5	113.37	27.528	-11.028	25.222	172480.246	626846.728
6	191.523	15.643	-15.308	-3.219	172464.938	626843.509
1	293.444	30.419	12.248	-27.844	172477.187	626815.665
2	293.264	31.353	12.474	-28.765	172489.661	626786.901

Figure 11. Traverse adjustment report.

The process of importing point cloud data must follow the chosen file format. After successfully completing the registration process, the data must be put into CloudCompare in LAS format. Subsequently, it is crucial to establish clear delineations for two discrete geographical points, followed by a meticulous computation of the spatial distance that separates these points. It is advisable to iterate this approach for each subsequent set of data points. By employing the acquired coordinates obtained from the measurements, individuals can perform the essential calculations to ascertain the area of the segment. The determination of the area of a particular section can be achieved by utilizing the software programme CloudCompare, which has been used to generate a three-dimensional model, as depicted in Figure 12. When determining the area of a segment, it is important to consider its distinctive shape and geometric characteristics, such as its resemblance to a rectangle or square. In such circumstances, the computation of the area can be ascertained by multiplying the length by the width of the respective region. The Shoelace area formula is a mathematical technique that can be employed to compute the area of a triangle. Utilizing the coordinates of the points constituting the boundaries of a polygon enables a precise and dependable computation of the area encompassed by the polygon.

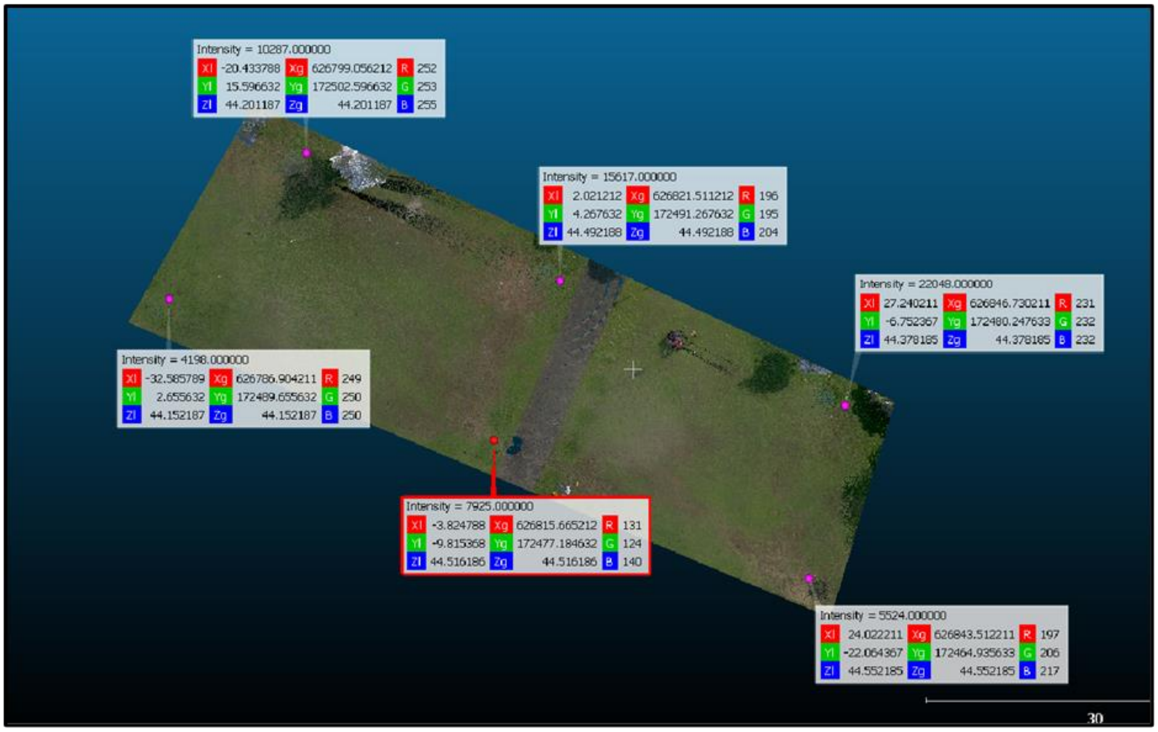

Figure 12. 3D Model.

2.4 Phase 4: Accuracy Assessment

The precision of TLS land surveys is crucial. First, the accuracy and precision of the TLS system are evaluated. Then, a comparison is made between the TLS system and the traverse data obtained from a total station (TS). The initial stage in assessing accuracy involves establishing control sites within the designated research area. The traversal data was utilized to compute the control points, while the TLS data was used to reference the coordinates of these points. Subsequently, Cloudcompare processes and analyzes TLS data. The software generates a point cloud, a three-dimensional representation of the study area.

Additionally, it streamlines the process of eliminating edges, faces, and points. Following the generation of the point cloud, the subsequent stage involves comparing the coordinates of individual points to those present in the cloud. The comparison above is employed to compute absolute and relative mistakes in TLS data. The absolute error refers to the numerical discrepancy between the coordinates of the control points and the point cloud coordinates. The observed difference represents an absolute inaccuracy. The relative error can be calculated by dividing the absolute error by the distance of the control point. The ratio above serves as a measure of relative inaccuracy. Subsequently, the conclusions of the accuracy evaluation are examined, and their significance is assessed. According to the Malaysian Department of Survey and Mapping (DSMM) (2009), there are prescribed tolerances for permissible inaccuracies. As per the provisions of this legislation, it is acceptable to utilize TLS data to conduct area-measuring analysis.

3.0 Finding and Analysis

Based on the study project's findings, as depicted in Table 2, it has been determined that the TLS approach produces coordinate values comparable to those provided by the Total Station (TS) method. On average, the discrepancy in northing coordinates is 0.004 metres, whereas the disparity in easting coordinates is 0.002 metres. The Malaysian Department of Survey and Mapping (DSMM) permits a tolerance of 0.05 metres in the coordinate system's precision. Concerning this matter, the observed area exhibits a percentage variation of 1.37 per cent. A minimum threshold of 5% is established for the permissible discrepancy in the measured area.

Table 2. Differences in Cassini-Soldner Coordinate.

	Total Station		**Terrestrial Laser Scan**		**Difference**	
Point	**Northing (m)**	**Easting (m)**	**Northing (m)**	**Easting (m)**	**Northing (m)**	**Easting (m)**
1	-53399.922	8547.070	-53399.924	8547.070	0.002	0
2	-53387.461	8518.295	-53387.466	8518.298	0.005	0.003
3	-53374.521	8530.446	-53374.517	8530.445	0.004	0.001
4	-53385.830	8552.905	-53385.836	8552.909	0.006	0.004
5	-53396.846	8578.136	-53396.844	8578.138	0.002	0.002
6	-53412.158	8574.924	-53412.160	8574.927	0.002	0.003

Upon conducting segmentation, it was determined that a point cloud generated using the TLS exhibited an intensity measurement of 34010465 units. The finding above was made after the completion of the segmentation procedure. The present study involved a specific geographic area spanning 895.677 square units. The density of the point cloud played a crucial role in the subsequent analysis and interpretation. Diab et al. (2022) propose that a higher intensity value corresponds to a more significant reflection or response from the targeted surface. The adaptability of this attribute allows for differentiation among various sorts of materials or objects within the scanned region. The utilization of this data has the potential to streamline and enhance the process of segmenting and categorizing the attributes of point clouds, leading to increased simplicity and accuracy.

Point cloud intensity is crucial in developing highly accurate and complete three-dimensional models. Post-processing techniques, such as texture mapping and material classification, have effectively enhanced textures' visual fidelity and realism. Using intensity values simplifies the categorization, segmentation, and visualization of objects. Consequently, the understanding of scanned areas is improved. One can enhance their understanding by leveraging the relationship between intensity and analysis, leading to improved decision-making and a more profound comprehension of the observed environment (Hassan & Rahman, 2021). The fundamental principle underlying the formula is the concept that the area of a polygon can be determined by summing the areas of its signed triangles. The concept being referred to is commonly recognized as the calculation of the area of a triangle with signed values.

The formula is derived from the theoretical concept that the area of a polygon can be determined by summing the signed areas of its constituent triangles. The formula is formally expressed as:

$$\text{Area} = [(x1y2 + x2y3 + ...+ xn\text{-}1yn + xny1) - (y1x2 + y2x3 + ...+ yn\text{-}1xn + ynx1)]/ 2 \quad \text{Eq. [1]}$$

Where (x1, y1), (x2, y2), ..., (xn, yn) are the boundary points coordinates.

The area of a polygon can be efficiently calculated by utilizing the coordinates of its boundary points and employing the Shoelace area formula. This approach offers a time- and resource-efficient method for computing the polygon's area. Terrestrial laser scanning is a recently developed methodology employed for spatial measurement (Kerekes & Schwieger, 2020).

Table 3. Differences area in percentages.

Area m^2	
Total Station	**Terrestrial Laser Scan**
895.677	895.800
Δ = 1.37%	

Based on the results as depicted in Table 3, the discrepancy observed amounts to around 1.37 per cent, and it can be observed that the estimation of value derived from the coordinates acquired using TLS closely approximates the value obtained through the utilization of the Total Station. In 2009, the Malaysian Department of Survey and Mapping (DSMM) determined, as depicted in Figure 13, that the acceptable limit for deviation in a measured area compared to the authorized area set by the State Authority (PBN) should not surpass 5% for land parcels smaller than 40 hectares in size. The result above was derived from the data collected by the DSMM over the preceding year. Furthermore, concerning the coordinate system, the permissible limit for displacing border vectors in urban and town areas and newly constructed projects is 0.050 metres. This pertains to both established and prospective communities.

On the other hand, the permissible limit for vector displacement in specific alternative sites is 0.10 metres. TLS, a widely recognized technique in cadastral surveying, has been firmly established as a precise and dependable means of measuring areas. As mentioned earlier, the result was derived by examining evidence that adhered to acceptable standards. This discovery demonstrates a significant concurrence between the two methodologies, implying that TLS can provide accurate and reliable area measurements. TLS is a viable alternative to the cadastral approach because of its minimal coordinate adjustments, ensuring precise and consistent outcomes.

4.13 Perbezaan Keluasan

4.13.1 Had penerimaan perbezaan keluasan yang diukur berbanding keluasan yang diluluskan oleh Pihak Berkuasa Negeri (PBN) adalah seperti berikut:

i. tidak melebihi 5 % bagi luas di bawah 40 hektar;

ii. tidak melebihi 2 hektar bagi luas antara 40 hektar dan 200 hektar; dan

iii. tidak melebihi 1 % bagi luas melebihi 200 hektar.

4.14 Had Anjakan Koordinat

4.14.1 Had anjakan vektor tanda sempadan yang dibenarkan adalah 0.050 meter bagi kawasan bandar/pekan serta pembangunan baru manakala bagi kawasan lain had anjakan vektor adalah 0.10 meter.

4.14.2 Had anjakan tiga (3) tanda lama bagi tujuan tanam pastian hendaklah separuh (1/2) daripada had maksima anjakan vektor tanda sempadan yang dibenarkan.

Figure 13. Rule and Regulations by Malaysian Department of Survey and Mapping (DSMM), 2009.

The measurements of TLS or cadastral regions may be subject to potential influences arising from several factors, such as the quality of the scanner utilized, the configuration parameters employed, and the occurrence of human error. Cadastral measurements encompass ascertaining borders, which may be susceptible to human error. However, it is crucial to emphasize the importance of precision and calibration in TLS devices. According to Zharova et al. (2021), various measures are recommended to address the issues at hand. These measures include properly calibrating and maintaining TLS equipment, establishing well-defined boundaries, implementing quality control procedures, and validating results through comparisons with alternative approaches or cross-referencing pre-existing datasets. By adopting these measures, the aim is to either prevent or mitigate the impact of these problems.

The results of this study indicate that incorporating TLS into cadastral surveys can yield several advantageous effects of the surveying procedure. TLS is a widely used protocol designed for secure data transmission, enabling the capture and examination of data at a satisfactory level of detail. The data’s capacity to capture diverse geometric features makes it particularly valuable for accurately determining boundaries and measurements. The inherent potential of data facilitates this phenomenon. The comprehensive coverage offered by this method allows for a reduction in the number of field visits needed to gather the essential data, hence enhancing the efficiency of the data collection process. TLS is a technologically advanced solution that provides several benefits over previous methodologies, particularly in expedited time management and economical resource allocation. The point cloud data that has been gathered can be observed visually and subjected to analysis in a three-dimensional structure. This can facilitate the detection of anomalies and the verification of boundaries. This phenomenon is made feasible due to the capacity to analyze the data within a three-dimensional framework. TLS also offers reliable and verifiable records that can serve as valuable evidence in legal disputes and documentation. In a broad sense, using TLS technology enhances cadastral and management processes' accuracy, effectiveness, and reliability.

4.0 Conclusion

This paper presents a comparative analysis of TLS and the TS method in the context of measuring regions, offering valuable insights. When comparing TLS to traditional cadastral surveying, it becomes evident that TLS provides a dependable and efficient approach for obtaining precise measurements. The analysis and interpretation of TLS point clouds primarily depend on utilizing intensity data, as it plays a crucial role in differentiating various materials and objects within the scanned surroundings. A laser scans the Earth's surface, generating three-dimensional images using TLS technology. The usage of TLS might be considered a viable choice because of its little discrepancy in coordinate values when compared to traditional cadastral techniques. This implies that TLS can perform land mapping.

5.0 Recommendations

The recommendations include the establishment of well-defined boundaries, the careful calibration and maintenance of TLS equipment, and the implementation of rigorous quality control measures. Furthermore, a study on the reliability of Terrestrial Laser Scanning (TLS) is required in various geographical places. Considering the conflicting findings of previous studies, it is recommended that future studies on the accuracy of TLS adopt a traversal strategy in data collection to enhance the quality of data. This improves the accuracy level due to the limited availability of equipment that may be easily obtained from the market. These principles aid stakeholders in optimizing the benefits of TLS and enhancing decision-making processes and land management practices.

Acknowledgement

The authors highly acknowledge the Ministry of Higher Education Malaysia (MOHE) for funding this work under the Fundamental Research Grant Scheme (FRGS), Registration Proposal FRGS/1/2021/WAB09/UTM/02/1. Not to mention the UTM Encouragement Research Grant (under research votes PY/2022/04229) for providing funding, instruments and an experimental site. Special thanks to the UTM-PDRM Geospatial Forensics Satellite Laboratory, UTM's Geospatial Imaging & Information Research Group (GI2RG), Geomatic Innovation Group Research Group (GnG), Royal Malaysia Police (PDRM) and Geodelta Sdn. Bhd., specifically Mr. Mohamad Ikhwan and Mr. Danish Aiman Aqmal, for their dedicated contributions to this project.

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