

# Comparison Assessment of Pier Dimension Measurement with Different Terrestrial Laser Scanner (TLS) Setup Location

Wan Mohamed Syafuan<sup>1\*</sup>, Neza Ismail<sup>1</sup>, Daniel Efandi<sup>1</sup>,

<sup>1</sup>Department of Civil Engineering, National Defense University of Malaysia, Kuala Lumpur, Malaysia.

\*wmsyafuan@upnm.edu.my

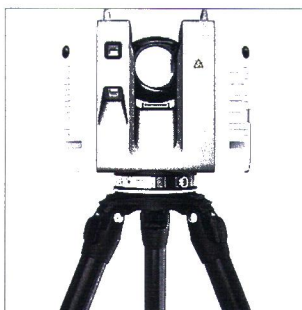
**Abstract.** A bridge is a structure that joins two highways and has four distinct parts: the deck, abutment, pier, and joist. For safety reasons, this structure required routine inspections by a qualified inspector. Suggesting a new approach that uses non-contact testing technologies (NCT) will resolve all the difficulties related to the inspector's current conventional method's increased time, expense, and labor intensity. Compared to traditional approaches using visual inspection, NCT technologies are prospective instruments for assessing the state of bridges since they allow for quick and simple measurement with little disruption to traffic. Terrestrial Laser Scanner (TLS) is now taught in surveying courses to help surveyors perform their jobs more efficiently. The goal of this study was to make technology use better because it requires less human interaction with quality results. TLS contains a points cloud consisting of x, y, and z coordinates; hence it can produce 3-dimensional (3D) model output. The main objective of this study is to produce the 3D model from point cloud data, followed by the second objective, which is to compare measurement of pier dimension with various distance of TLS setup distance location. To achieve this objective, configuration of TLS with Zig Zag setup location to cover all of bridge structure to produce a 3D model and configure three various distance TLS setup location to measure the accuracy of pier dimension. The control actual data was done by measuring using Total Station and measuring tape. The output of point cloud data from TLS using Cyclone Register360 was compared with actual data. The results shown point cloud data from TLS can produced 3D model with accurate dimension measurement. Setup the TLS location depends on the suitability of the work to increase the quality of data.

## 1. Introduction

Civil infrastructure, including bridges, buildings, roads, dams, and pipelines, determines the degree of urban development, economic standing, and industrial prosperity. Despite this, structural degradation and failure remain significant problems. The primary goal of bridge condition monitoring is to measure in-service effectiveness and identify material degradation to determine the structure's reliability and life span. Structure age, traffic congestion, vehicle overloading, frequent wind loads, environmental devastation, and climatic disasters have all contributed to the destruction of urban bridges in recent years, which can eventually result in a reduction in their load-carrying capacity, or even catastrophic collapse, regardless of whether they are adequately retained [1]. Bridges are among the most vulnerable and critical components of the road network system and must be thoroughly inspected and maintained [2]. There were 8,205 bridges in service across Peninsular Malaysia in 2010. All these bridges were still in a condition monitoring conduction. Visual examination, which comprises continuous monitoring to check

bridge structural integrity, has conventionally been used to analyze the condition. Traditional periodical inspection and condition assessment methods based on on-site physical inspectors are time-consuming, expensive, and potentially dangerous. Although most inspection guidelines recognize the skills and experience of people performing bridge inspections, the quality and consistency of visual inspection results are highly dependent on the motivation and equipment of those conducting such inspections [3].

During the operation of any structure, deterioration is a significant issue. It happens because of ageing, heavy use, environmental influences, and other causes. A terrestrial laser scanner (TLS) as shown in Figure 1, is a type of surveying instrument that uses laser technology to capture highly accurate three-dimensional (3D) data of a physical environment or object. TLS is commonly used in fields such as architecture, engineering, construction, and archaeology to create accurate 3D models of buildings, landscapes, and cultural heritage sites [4]. Emerging technologies are changing many industries by focusing on improving product quality, increasing production rates, and lowering long-term costs. The construction industry is rapidly integrating new construction techniques and technology to increase productivity and efficiency in construction operations [5].



**Figure 1.** Leica RTC360 Terrestrial Laser Scanner.

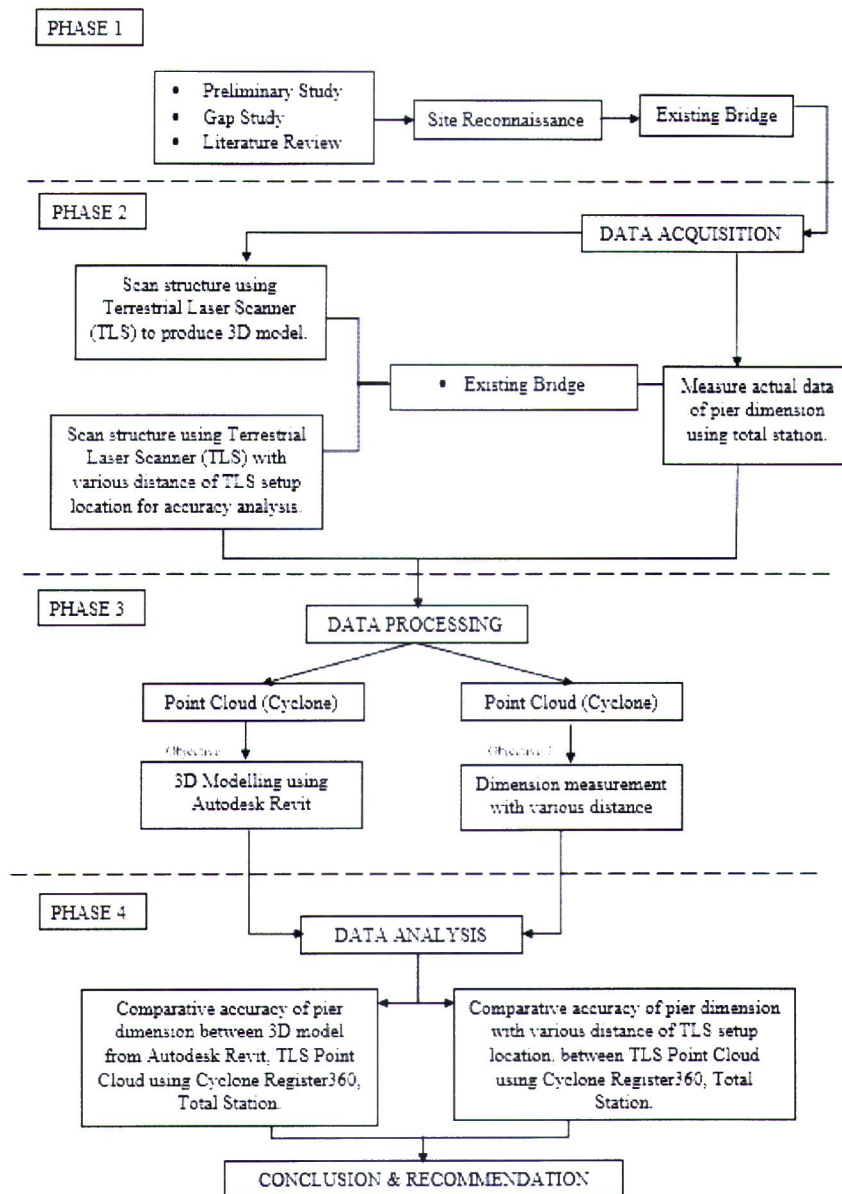
Current inspection and data management procedures, both visual and paper-based, have several flaws. First, when doing the inspection and evaluation, inspectors may be exposed to safety risks, particularly when attempting to reach regions with limited accessibility. Second, inspection equipment, like elevating platforms and scaffolding, is costly and may cause traffic congestion by requiring lane closures [6]. TLS collects the range (x, y, z) and intensity data of objects in a scene using either time-of-flight (TOF) or phase-based technologies. Both approaches calculate the range differently, but they acquire each range point in the equipment's spherical coordinate frame by putting a laser on a pan-and-tilt mechanism that supplies the point's spherical angular coordinates. With only a few scans, laser scanning technology can capture extensive and highly accurate 3D data for an entire construction area [7]. A laser scanner's data is presented in point clouds, with color and intensity data frequently connected with each point inside the cloud. Point cloud data can be processed using computer vision algorithms to locate cracks for the condition assessment of reinforced concrete structures [8]. Laser scanning, among other 3D sensing technologies, is the best-suited technique for correctly and efficiently recording the 3D state of construction projects and infrastructure conditions [9].

TLS accuracy is affected by the angle of sight and distance from the object to be scanned. As a result, each method has advantages and disadvantages in terms of accuracy, time consumption, effort, and expenditures [10]. This study aims to produce a 3D model from the Terrestrial Laser Scanner (TLS) point cloud data and compare the dimension measurement with various distance TLS setup between point cloud derived by TLS, measurement using Total Station, and measuring tape.

## **2. Methodology**

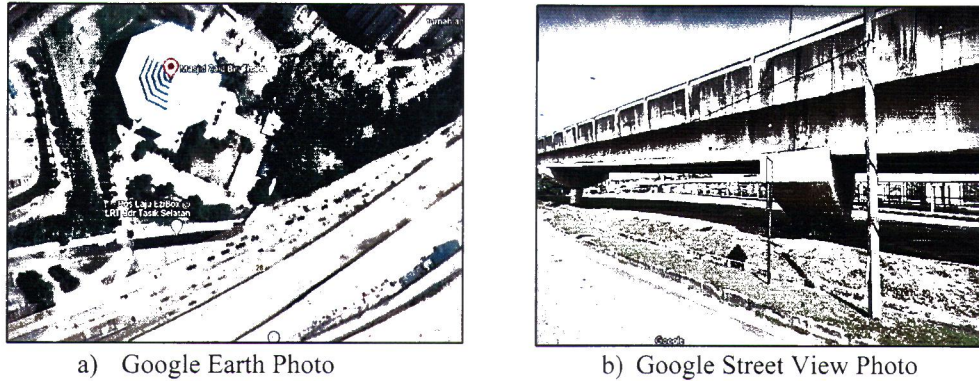
As shown in Figure 2, this study was divided into four main phases. Phase 1 involves the gap study and reviews, preliminary study, and site reconnaissance for the existing bridge. In Phase 2, data acquisition by scanning the existing bridge using TLS and measuring the actual data using Total Station and

measuring tape. To achieve the objectives, two types of TLS setup configuration were conducted. The first TLS data collection is scanning the bridge structure with Zig Zag setup location, and second configuration is various distance setup location of TLS. Phase 3 revolves within data processing using Cyclone Register360. In this phase, Cyclone Register360 was used to process the point cloud data, whereas Autodesk Revit was employed to generate a 3D model for the bridge. In the last phase (Phase 4), data analyses were conducted the comparison of pier dimensions between 3D model derived by Autodesk Revit, point cloud data derived by TLS using Cyclone Register360, Total Station, and measuring tape. Another analysis is comparison of pier dimensions with different TLS setup location between point cloud data derived by TLS using Cyclone Register360, Total Station, and measuring tape.



**Figure 2.** Methodology of the study.

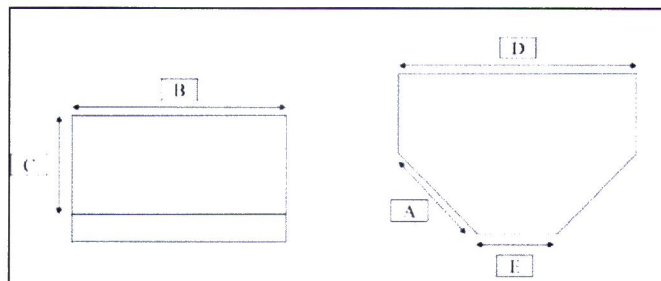
## 2.1 Study Area



**Figure 3.** Study Area.

The study was conducted at the overpass bridge in front Masjid Zaid bin Thabit near LRT Bandar Tasik Selatan, Kuala Lumpur. Figure 3(a) shows the satellite imagery obtained from Google Earth whereas Figure 3(b) shows the Google Street View Photo of the same site. The selected of elevated bridge having variation of pier height which is vital to this study.

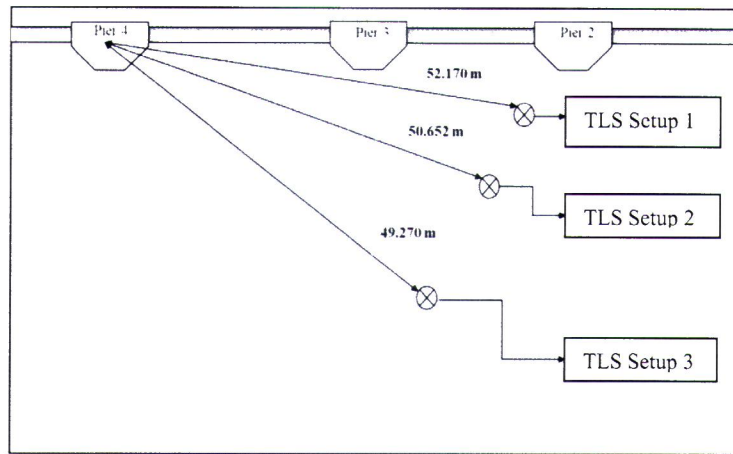
The study began with the proper installation of the TLS at several pre-determined locations around the field area. As shown in Figure 4, five parts of the bridge's piers were appointed to be measured using Total Station and the measuring tape, acting as actual data measurement.



**Figure 4.** Bridge's pier illustration from overpass bridge Bandar Tasik Selatan

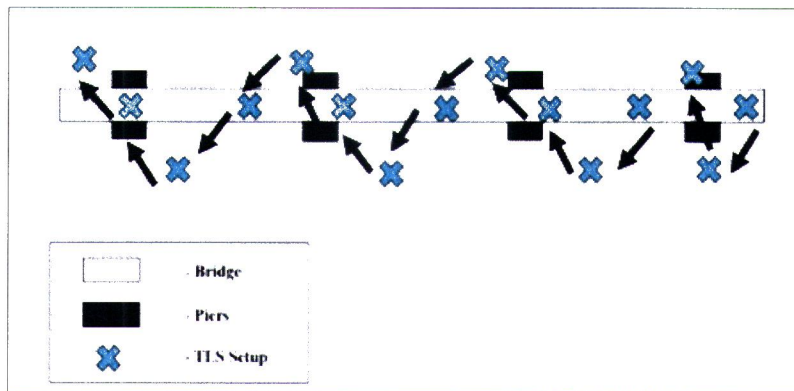
## 2.2 Data Collection

There software needed to be utilized in TLS data collection is Cyclone Field360. In Figure 5, TLS was set up with various distances from the bridge's pier, 52.170m, 50.652m, and 49.270m. All the data will be collected using the TLS with Cyclone Field360 mobile apps. The next step was collecting the data using Total Station and measuring tape.



**Figure 5.** TLS configuration for accuracy analysis

Next, for 3D modelling, fifteen (15) TLS setups were envisioned in Figure 6. The scanner operation took 2 minutes and 40 seconds for each setup point with configuration high resolution and single scan. The configuration was not meant to be horizontally parallel to the bridge since the scanner's ability to cover the radius of the bridge component was limited.



**Figure 6.** TLS configuration for 3D modelling

### 2.3 Data processing

Next, all the data from TLS will be processed using Cyclone Register360 as shown in Figure 7. The first step starts with importing the raw data. Using a Cyclone Register360, the connection between the points of the equipment layout was made. After export raw data, the reference point was not correctly aligned. To make sure that the reference point was connected to the correct orientation, this software was used to register the point cloud using Cloud to Cloud method. To create a link for each reference point, the first link must be connected. Each point in the TLS setup had its unique numbering depending on how the equipment was configured during the data collection. After connecting to another link, examine each connection's strength and overlap value to determine whether the reference point is correctly aligned. The identical method is repeated until all 15 reference points have been created. The required percentage for the overlap is 40%, and the required percentage for the strength of point connecting condition is 30%.



**Figure 7.** Data processing using Cyclone Register360

#### 2.4 Three-dimensional (3D) modelling

Figure 8 shows the step of 3D modelling using Autodesk Revit. To begin a 3D modelling project, launch Autodesk Revit and select a new project. Choose the modelling template file. Next, select both Project Base Point and Survey Point in the boxes under the tab for visibility and graphic view. Select point clouds under the insert tab. Add the RCP-formatted bridge point cloud data from Cyclone Register360. To properly visualize the point cloud image and handle the 3D modelling, the point cloud image must first be rotated. The second is to select any elevation from the project browser and click it to align the level with the point cloud image. Initially, only two lines from the level were offered for alignment. The structure tab can be used to add a level. Level 0.000 must be parallel to the point cloud image's ground level throughout this stage. To make it simpler to draw, move the second line of the level parallel to the level of the pier.



**Figure 8.** 3D modelling using Autodesk Revit

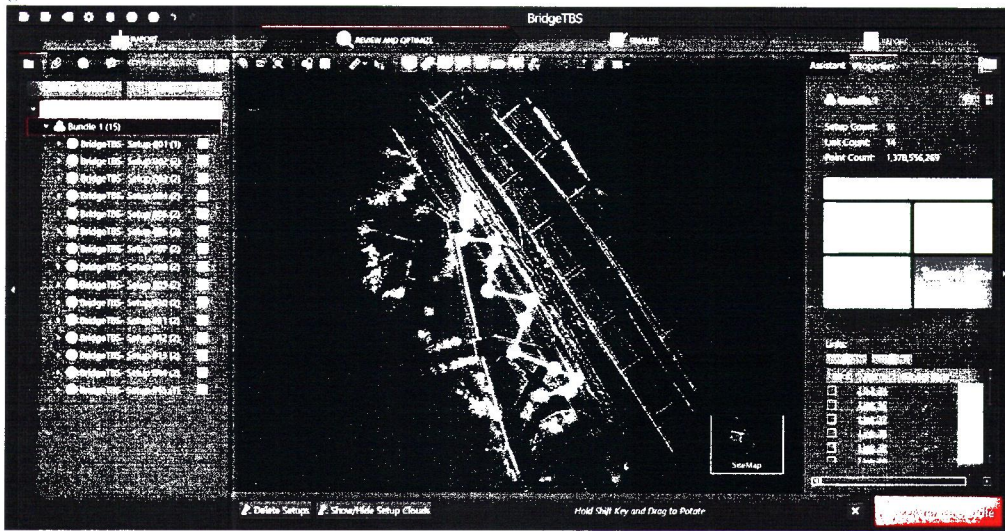
After setting the alignment of the point cloud data, proceed to the next step, pre-modelling the bridge. First, go to the Manage tab to hide the point cloud. This step avoids the distraction of focus and the laptop system from lag. Secondly, click the tab Massing and Site and select Conceptual Mass. In the Conceptual Mass ribbon, choose In-Place Mass. Then move to create a reference line for the bridge's pier. Once the primary bridge's pier is complete, copy the drawing, pick the Aligned tab to Same Place ribbon during pasting, and then click the tab. This step, known as point clouds alignment, makes sure that every pier is in the appropriate place. Continue from the point cloud alignment step until generate the reference grid for the roadway. To construct land for the model, select topo surface under the Massing and Site Tab. Create the 3D model's land. Lastly, create dimensions to measure the model.

### 3. Results and Discussion

The results and discussion were conducted in two different ways which is output quality report TLS configuration for 3D modelling, and TLS configuration with various distance setup for accuracy analysis.

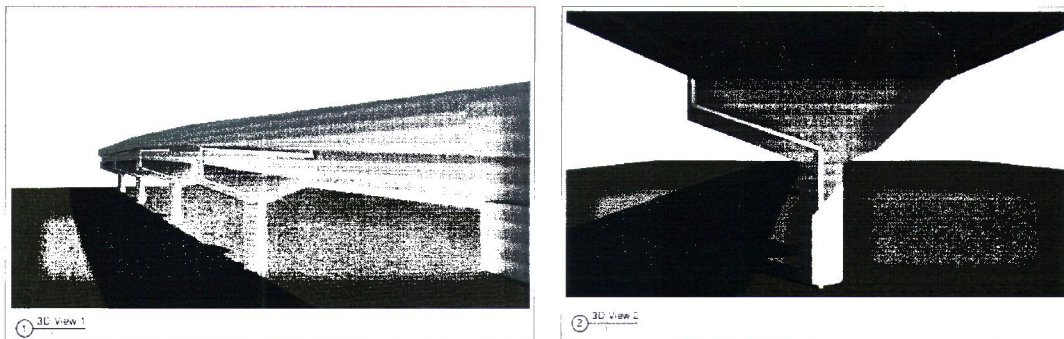
#### 3.1 Outputs quality report TLS configuration for 3D modelling

Figure 9 shows the result or output of the quality report processed by Cyclone Register360 for 3D Modelling setup configuration. The total of point cloud with 15 setup count is 1,378,556,269. The Bundle Error after process with visual alignment is 0.001m. The overlap of point cloud is 51% and the strength is 39%.



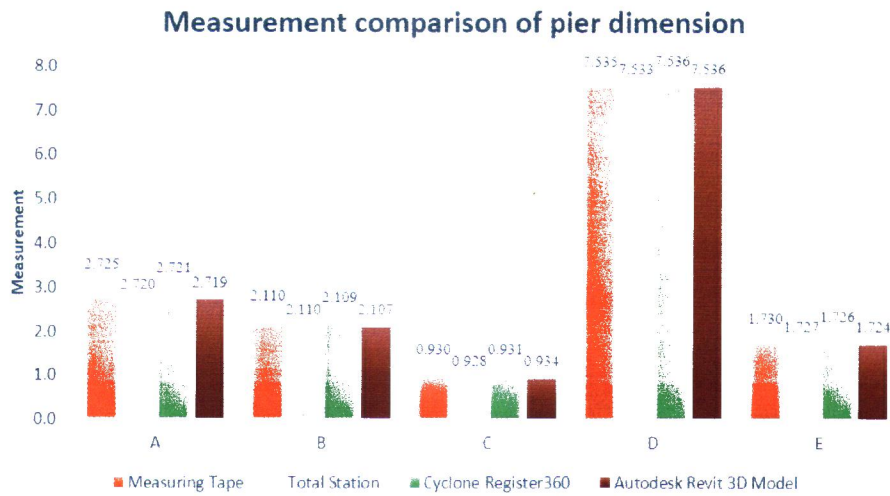
**Figure 9.** Quality report processed by Cyclone Register360 for 3D modelling.

Figure 10 shows the output of the 3D model from Autodesk Revit Software. The 3D model attracted people's attention compared to the 2D model. It is because it provides the viewer with a lot more information compared to the 2D model. For example, in 2D can obtain width and length. However, in 3D acquired height, width, and length, adding more information to the viewer. Next is a comparison of measurement to analyze whether the measurement of 3D point cloud data from both Cyclone Register360 and 3D modelling using Autodesk Revit.



**Figure 10.** 3D result of bridge's pier

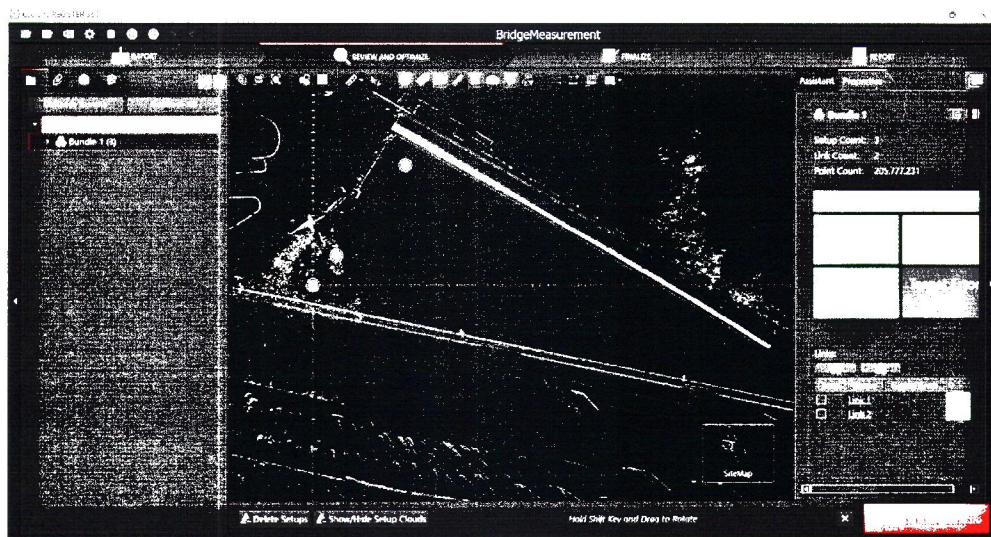
Based on Figure 11, there are not many differences in the comparisons for the various measurement tools. Due to the human error, the precise point cloud data dragged from Cyclone Register360 to Autodesk Revit was identical, the modelling phase that redraws the model using the point cloud will result in an error since it requires the right and ideal point cloud to be moved.



**Figure 11.** Measurement comparison of pier dimension

### 3.2 Outputs quality report TLS configuration with various distance setup for accuracy analysis.

Figure 12 shows the result or output of the quality report processed by Cyclone Register360 setup configuration with various distance. The total of point cloud with 3 setup count is 205,777,231. The Bundle Error after process with visual alignment is 0.001m. The overlap of point cloud is 71% and the strength is 29%.



**Figure 12.** Quality report processed by Cyclone Register360 setup configuration with various distance.

Table 1 shows total numbers of point cloud for each setup location. By comparing the number of point clouds on each TLS setup, TLS on Setup 3, which is the nearest distance provides the highest number of point clouds collected while Setup 1, which is the longest distance, collects the lowest number of point clouds.

**Table 1.** Total numbers of point cloud for each setup location

Setup	Distance (m)	Point cloud
1	52.170	61,840,617
2	50.625	65,688,004
3	49.270	78,248,610
Total		205,777,231

For accuracy assessment, the equation of RMSE formula used to measure comparison of actual measurement with the acquired data measurement by TLS. RMSE is indicated in Equation 1. Thus, the lower the value, the higher the accuracy.

$$RMSE = \sqrt{\frac{\sum_{i=1}^N (P_i - O_i)^2}{n}} \quad (1)$$

Note that from the equation (1) Where;  $P_i$  = the predicted value for the  $i$ th observation in the dataset;  $O_i$  = the observed value for the  $i$ th; observation in the dataset;  $n$  = the sample size

Table 2 shown the measurement comparison of Setup 1 with distance location of TLS is 52.170m from piers. These configurations offer methods for determining whether the TLS's distance affects accuracy. The lowest difference between TLS Point Cloud Cyclone Register360 and Total Station was bridge part D with 0.003m, but the lowest difference between TLS Point Cloud Cyclone Register360 and measuring tape was bridge part D with 0.005m. While the highest was bridge part A for comparison between TLS Point Cloud and Total Station with 0.020m, and TLS Point Cloud and measuring tape is 0.025m. The value of RMSE for Setup 1 is 0.014 between TLS Point Cloud and Total Station, and 0.017 between TLS Point Cloud and measuring tape.

**Table 2.** Measurement comparison of Setup 1 (52.170m).

Bridge Part	TLS Point Cloud (m)	Total Station (m)	Different (m)	TLS Point Cloud (m)	Measuring tape (m)	Different (m)
A	2.700	2.720	-0.020	2.700	2.725	-0.025
B	2.098	2.110	-0.012	2.098	2.110	-0.012
C	0.910	0.928	-0.018	0.910	0.930	-0.020
D	7.530	7.533	-0.003	7.530	7.535	-0.005
E	1.715	1.727	-0.012	1.715	1.730	-0.015
<b>RMSE</b>			<b>0.014</b>			<b>0.017</b>

While from TLS setup location on Setup 2 with distance location 50.625m, the lowest difference measure comparison as shown on Table 3 between TLS Point Cloud and Total Station was bridge part B and part C with 0.004, but between TLS Point Cloud and measuring tape was only bridge part B with 0.005m. While the highest between TLS Point Cloud and Total Station was bridge part D with 0.008, but between TLS Point Cloud and measuring tape was bridge part A, D, and E with 0.010m. For Setup 2, the value of RMSE between TLS Point Cloud and Total Station is 0.006, and between TLS Point Cloud and measuring tape is 0.008m.

**Table 3.** Measurement comparison of Setup 2 (50.625m).

Bridge Part	TLS Point Cloud (m)	Total Station (m)	Different (m)	TLS Point Cloud (m)	Measuring tape (m)	Different (m)
A	2.715	2.720	-0.005	2.715	2.725	-0.010
B	2.105	2.110	-0.004	2.105	2.110	-0.005
C	0.924	0.928	-0.004	0.924	0.930	-0.006
D	7.525	7.533	-0.008	7.525	7.535	-0.010
E	1.720	1.727	-0.007	1.720	1.730	-0.010
<b>RMSE</b>			<b>0.006</b>			<b>0.008</b>

By referring Table 4 is comparison of TLS Setup 3 with distance 49.270m, the highest difference between TLS Point Cloud and Total Station was 0.003m on bridge part E, and between TLS Point Cloud and measuring tape is bridge part A with 0.007m. While the lowest difference between TLS Point Cloud and Total Station is bridge part B, C, and D with 0.001m, and between TLS Point Cloud and measuring tape is bridge part C and D only with 0.001m. The RMSE between TLS Point Cloud and Total Station is 0.001m, and between TLS Point Cloud and measuring tape is 0.004m.

**Table 4.** Measurement comparison of Setup 3 (49.270m).

Bridge Part	TLS Point Cloud (m)	Total Station (m)	Different (m)	TLS Point Cloud (m)	Measuring tape (m)	Different (m)
A	2.718	2.720	-0.002	2.718	2.725	-0.007
B	2.108	2.110	-0.001	2.108	2.110	-0.002
C	0.929	0.928	0.001	0.929	0.930	-0.001
D	7.534	7.533	0.001	7.534	7.535	-0.001
E	1.724	1.727	-0.003	1.724	1.730	-0.006
<b>RMSE</b>			<b>0.001</b>			<b>0.004</b>

## 5. Conclusion

Based on this study, Terrestrial Laser Scanning (TLS) technology is a powerful tool for collecting accurate and detailed data on bridge conditions. This technology uses a laser scanner to generate a three-dimensional point cloud of the bridge structure, which can then be analyzed to assess the condition of the bridge. TLS is a less hazardous process and environment. It only involves semi-contact than the visual inspection method, which might be problematic for the inspector because it requires using scaffolding or conducting an inspection on a busy road. The TLS accuracy shows that this technology can be used to monitor the status of bridges. But, to setup the TLS location depends on the suitability of the work to increase the quality of data. The point cloud data from TLS create a model full of information and is helpful for various applications. Both the Cyclone Register360 measurement and the 3D model produced by Autodesk Revit were still within the surveying tolerance value, as seen by the comparison of RMSE. Due to the TLS's ability to offer the 3D model utilizing Cyclone Register360, this technology also improved how simple it is to send the as-built data. By importing modelling into the Autodesk Revit, it may be provided appropriately.

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