EVALUATING TERRESTRIAL LASER SCANNING (TLS) FOR HARD AND SOFT LANDSCAPE MAPPING

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KEY WORDS: Terrestrial Laser Scanning, Landscape Mapping, Hardscape, Softscape, Three-Dimensional point cloud.

ABSTRACT:

Landscape mapping is concerned with space planning whereby it emphasized space use in terms of function, mobility space, social space, and also ecological space. To plan this space design to reflect its purpose, initial data collection is critically needed. Depending on the site's characteristics such as hard and soft landscape features, collecting all of this data will be tedious and time-consuming. This research aims to employ Terrestrial Laser Scanning to iteratively approach landscape mapping and provide a landscape map architectural standard. In this research, by adapting Terrestrial Laser Scanning, a geomatic instrument that enables surveyors to immediately deliver accurate terrain relief mapping, technical structural assessments will be utilized to scan a diverse terrain, with a particular emphasis on hard and soft landscapes. The method of data acquisition for Terrestrial Laser Scanning was the traverse method, with that location-specific data will then be processed to generate a 3D point cloud model with georeferenced and transform it into 2D hard and soft landscape mapping. Then, a comparison will be made between the landscape map created from this research and the conventional landscape architecture approach. As a result of the data validation, it shows that Terrestrial Laser Scanning can provide high accuracy data in terms of northing, easting, and heights. Moreover, it can be concluded that there are numerous advantages to providing efficient information and an accurate representation of the site in a 3D model/point cloud, which enables landscape designers or architects to design a landscape map to their fullest potential in terms of creativity, landscape placement strategies, and as-built survey for maintenance updates. In addition, promote the development of more efficient landscape mapping techniques.

1. INTRODUCTION

Landscape mapping has numerous definitions. It can also be viewed as a tool for visualizing enterprise designs in 2D (Van der Torre *et al*.,2006). This research describes landscape maps that help designers, property owners, and architects make landscape planning decisions. These study elements are in two groups: Softscape, including trees, brush, grass, etc, and hardscape displays human-made items like furniture, chairs, rocks, etc. Softscape and hardscape are crucial for landscape design balance (Shahli *et al*.,2014). Obtaining the best landscape mapping data during fieldwork can be time-consuming and difficult. A 3D laser scanner able to scan objects and surfaces quickly. Terrain laser scanning makes it easier to acquire complex 3D point clouds (Yang *et al*, 2014). Terrestrial laser scanning is excellent for obtaining exact 3D dense point cloud data in geomatics, where each point provides coordinates, elevation, and RGB. Terrestrial laser scanning has improved the Geomatics technique and result quality (Abbas *et al*.,2014). This research will focus on laser scanning in producing and evaluating hard and soft landscape maps using point clouds data. This study compares laser scanning to traditional methods for mapping hard and soft landscapes. Total station and GPS topography data aren't as detailed as terrestrial laser scanning. Terrestrial laser scanning produces a 3D model. Visualizations help to communicate the design principles (Hassan, 2014). 3D laser scanning can be used in architecture, archaeology, construction, etc. Architects and landscape designers generate landscape maps for restorations and building projects. Architects need current, precise, and detailed information to create designs and drawings (Klimoski, 2006). This research will transform 3D laser scanning data into 2D landscape mapping. 2D drawings can be made from 3D models (Deruyter *et al*., 2009).

1.1 Terrestrial Laser Scanning (TLS)

TLS has helped surveyors collect data where it can generate a 3D model in addition to measuring tons of points in a scan that includes a high density of 3D data. According to Abbas *et al* (2014), the laser scanner is a hybrid of photogrammetry and total station measurement. Terrestrial Laser Scanning doesn't require a lot of manpower to complete a project or hold the prism for data collection. Instead, Terrestrial Laser Scanning is installed on a scan station and registers the instrument's position, elevation, and height. According to Calin *et al*., (2015), Terrestrial Laser Scanning allows for the measurement of a vast number of points on the monitored object or site without requiring them to be accessible, but merely visible. One of the most fundamental characteristics of a Terrestrial Laser Scanning concept is utilized to determine the distance between the scanner and the target. Time of flight and phase shift measurement. Additionally, there are many advantages to using a Terrestrial Laser Scanning as shown in Table 1.1 Terrestrial laser scanning creates 3D models faster and more accurately than other methods.

Table 1.1 The advantages of using Terrestrial Laser Scanning

No.	Advantages of using Terrestrial Laser Scanning
1.	Able to provide data rapidly
2.	Data collected consists of high-density 3D data
3.	Save time and men power to carry out a project
4.	Do not require making contact for measurement, because Terrestrial Laser Scanning is based on a remote sensing technique
5.	Due to the reason stated on No 4, Terrestrial Laser Scanning able to access the inaccessible area, corners, edges, and so on

6.	It captures super high detail including capturing images which able to produce color point cloud data.

1.2 Landscape Mapping

The ecosystem is incomplete without landscape. Landscape mapping is the main focus of this research which is important in serving as an aid in the decision-making process of landscape planning for landscape designers, property owners, and architecture. The landscape is typically designed by an architect or landscape designer to provide an environment that is of great use to the people. In order to construct the plans and designs for the job at hand, architects and landscape designers require current, precise, and complete information. With 3D model of the landscape or site, in the case of renovation or study condition of site, is quite beneficial. Landscape information is necessary to carry out design and planning in order to create a landscape map for maintenance or renovation purposes. The current landscape map it is limited due to 2D representation of plan/map for planning and design. The most fundamental way of designing is by using sketches through site visit or create based map based from google map. The conventional method mentioned has their own limitations and is inconvenient to acquire the data from site such as numerous visits for site data collection, time-consuming during site inventory, and inaccurate representation of site. Hence 3D model is a great solution to eliminate the problem face from using conventional method. This is because with a preserved 3D model, architect or landscape design can always refer to the 3D model for references instead of travel back and forth to the same site which is time consuming and waste of effort. Visualizations play a critical role in creating and communicating design concepts (Hassan, 2014). According to Klimoski (2006), a 3D model is a great tool for an architectural project, whether for public presentations and for usage among project designers.

1.3 Hard and soft landscapes

A landscape map is a visual depiction of a place that is often utilized to plan the layout of an outdoor space which generally consists of different elements in the landscape. Hard landscape, also known as hardscape, with features such as human build components like furniture, chair, rock, etc. The soft landscape, also known as a softscape, with features such as trees, scrub, grass, etc. According to Shahli *et al*., 2014, to create balance in landscape designs, softscape and hardscape are critical. The elements utilized in the landscape design are usually diverse depending on culture and society's life. When it comes to a site or landscape that required renovation, the existing condition is required, it is even better to have a preserved 3D model as a reference for visualization. With modern technology such as Terrestrial Laser Scanning, it is capable of collecting data in high-density 3D data of the landscape to produce the existing condition of the site in a 3D model. Hence hard and soft landscape maps are able to be produced via Terrestrial Laser Scanning.

1.4 Three-Dimensional (3D) Model

According to Klimoski (2006), a 3D model is a great tool for an architectural project, whether for public presentations or for usage among project designers. It is a useful tool for visualization for both design and planning. The point cloud models are converted to 3D models through a modelling procedure that may be done with 3D modelling software like Magnet Collage and Cloud Compare. Although terrestrial laser scanning provides data in a 3D model, the 3D model will be converted to 2D landscape mapping for this research. The 3D model may be utilized to create 2D drawings (Deruyter *et al*., 2009).

2. METHODOLOGY

The methodology of this research can be divided into several phases, namely: Phase 1: Research site identification and planning, Phase 2: Data Acquisition, Phase 3: Data Processing, and Phase 4: Result & Data Analysis. The following section will specifically discuss each phase. A methodology flowchart is shown in Figure 2.1.

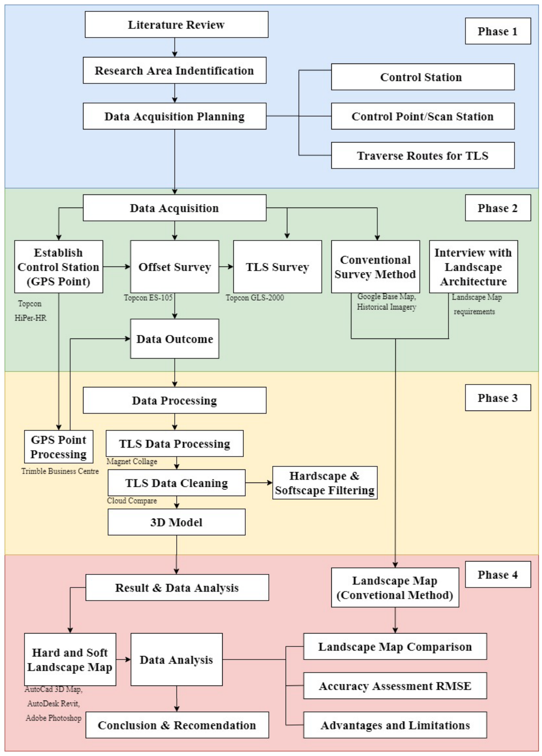

Figure 2.1 Methodology flowchart in this study

2.1 Phase 1: Research site identification and planning

As the purpose of this research is to map hard and soft landscapes using Terrestrial Laser Scanning, an area next to Block C02, FABU, UTM Skudai, Johor Bahru with an appropriate proportion of hard and soft landscapes was chosen as the research site.

2.2 Phase 2: Data Acquisition

There are three different types of instruments used for data acquisition in this section, all of which contributed to the overall results of the research. Table 2.1 will elaborate on each type of instrument used in data acquisition in detail.

Table 2.1 The types of instruments used in data acquisition for this research

No	Equipment	Method	Results
1	Global Positioning	A control station (GPS point) was established, and a	Two stations

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	System (Topcon Hiper-HR GNSS receiver)	rapid static survey was conducted to get known coordinates for both GPS points. At least two control stations were established and observed by setting GNSS receiver for rapid static survey for the purpose of georeferencing (Malaysia RSO geocentric).	consist of true coordinates established near the research site. (GPS 1 & GPS 2)
2	Total Station (Topcon ES-105)	In order to obtain the true coordinates of each control point for the scan station, an offset survey was used. Total Station were set on the established GPS point (GPS1) with backsight of GPS 2 then observed the bearing and distance of every control point (CP). Coordinate of the control point will then be computed. This is to ensure all stations will acquire a true coordinate in order to carry out traverse via Terrestrial Laser Scanning for direct georeferencing.	All four checkpoints consist of true coordinates (CP1, CP2, CP3 & CP4)
3	Terrestrial Laser Scanning (GLS-2000)	The traverse method was used with the establishment of control points and checkpoints were used as scan stations to cover the research site. The Terrestrial Laser Scanning is then initialized by entering the coordinates of the Terrestrial Laser Scanning occupation point and the backsight and foresight prism to register the coordinate reference system. The error can be checked by comparison between measurement from the Terrestrial Laser Scanning and control points coordinates. After finishing a scan in a station, next the Topcon GLS-2000 scanner moved next station with a set of backsight and foresight prism. Repeat the same step as described above to carry out the remaining scan station until the research site is fully scanned.	Raw data of the research site which can be processed into a 3D point cloud and 3D model.

The existing landscape map of the research site is unavailable due to a shortage of documentation from the Real Estate Office, Landscape Department, Universiti Teknologi Malaysia. The landscape map of the research site was created using the landscape architecture approach and a base map taken from Google Maps.

Figure 2.2 Proposed control station (GPS point) and checkpoints (CP)

2.3 Phase 3: Data processing

The raw data were further processed via, georeferenced, and data cleaned to remove unnecessary to obtain a 3D model via Magnet Collage. After 3D model process, Autodesk Revit was used to convert the 3D model to rich chart builder project format (.RCP). It was then loaded into Autodesk AutoCAD 3D for digitizing using the rich chart builder project file. The hard and soft landscape maps were created using the 3D model as a base map. After digitizing the base map, the hard and soft landscape maps were created and designed in Photoshop.

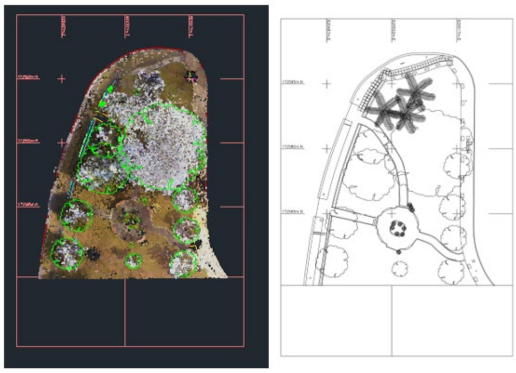

Figure 2.3 Side-by-side aerial view of 3D point cloud and digitized based map and been converted into a portable document format

3. RESULT AND DISCUSSION

This section discusses the anticipated outcomes of this study. The final product was produced based on the methodology section mentioned before. The result of this research is a 3D point cloud, 2D hard and soft landscape map, evaluating in terms of potential and accuracy assessment of the hard and soft landscape map. Also, this section explores the benefits and limitations of adapting Terrestrial Laser Scanning in landscape mapping.

3.1 Terrestrial Laser Scanning Data Validation

This section consists of data comparison and accuracy assessment. Before producing a landscape map, the accuracy of the 3D point cloud model was determined based on the tolerance of data from the Terrestrial Laser Scanning traverse survey by determining the differences in the backsight error value. Table 3.1 shows the backsight error from the Terrestrial Laser Scanning observation.

Table 3.1 Terrestrial Laser Scanning backsight error

No.	Backsight Station	Offset Survey (Total Station)			Distance (m)
		Easting (X)	Northing (Y)	Height (Z)	
1	GPS 1	0.0001	0.0032	0.0077	0.0032
2	GPS 2	-	-	-	-
3	CP 1	0.0020	-0.0007	0.0006	0.0021
4	CP 2	-0.0008	-0.0007	-0.0004	0.0011
5	CP 3	-0.0013	-0.0012	-0.0426	0.0018
6	CP 4	-0.0007	0.0031	0.0000	0.0000

As mentioned in the previous section, checkpoints were calculated via an offset survey because rapid-static surveying beneath tall buildings and trees was not recommended due to the risk of multipath inaccuracy. As a result, data comparison between Terrestrial Laser Scanning coordinates and offset survey coordinates can be used to do another accuracy assessment. It should be noted that by transferring height from GPS points (GPS 1), the height of checkpoints was entirely calculated based on the observation of Terrestrial Laser Scanning.

Table 3.2 Result of GPS points and checkpoints

Station	Terrestrial Laser Scanning			Offset Survey (Total Station)		
	Easting	Northing	Height	Easting	Northing	Height
GPS 1	626517.4550	172595.2780	28.1403	626517.455	172595.278	28.140
GPS 2	-	-	-	626533.766	172626.833	26.898
CP 1	626518.4740	172556.0440	30.0600	626518.474	172556.044	-
CP 2	626494.7270	172553.7690	29.4280	626494.727	172553.769	-
CP 3	626503.3920	172561.5590	30.2520	626503.392	172561.559	-
CP 4	626501.5950	172569.9320	29.3990	626501.595	172569.932	-

Based from Table 3.1 and Table 3.2, the results of Terrestrial Laser Scanning were captured up to the sub-millimeter level, much beyond the standard of a typical geomatic survey (millimeter level). In terms of the landscape architecture need, the adjustive elements require approximate accuracy, not precise accuracy, whether analyzing existing features such as hard and soft landscapes or designing a landscape map. As a result, accuracy was assured by incorporating Terrestrial Laser Scanning into landscape architectural mapping.

Table 3.3 Data validation of Terrestrial Laser Scanning and Offset Survey

Station	Difference (Offset Survey – Terrestrial Laser Scanning)		Difference square
	Easting	Northing	
GPS 1	0.000	0.000	0.000
GPS 2	-	-	-
CP 1	0.000	0.000	0.000
CP 2	0.000	0.000	0.000
CP 3	0.000	0.000	0.000
CP 4	0.000	0.000	0.000
		Average	0.000
		RMSE	0.000

The disparities between Terrestrial Laser Scanning and offset results may be observed in Table 3.3 with flawless precision even for the backsight error, which comprises of sub-millimeter error. However, if the usual geomatic survey standard is followed, where millimeter level accuracy is acceptable, Terrestrial Laser Scanning is indeed capable of achieving high-level accuracy.

3.2 Advantages and Limitations of Producing Landscape Map with Terrestrial Laser Scanning

Terrestrial Laser Scanning is an ideal tool to deliver information in a form of a 3D model that contains information that could exceed expectations for architecture, it can present architecture with the greatest visualization when building their landscape map. Not to mention the true colour of the site is also provided as the output of scanning.

In terms of geomatic surveys, Terrestrial Laser Scanning may supply real-time or the newest information related to the site. Additionally, a visual representation of a landscape map can be realistic with the aid of a geodetic laser scanner that could direct georeferenced the site with a true coordinate system or preferred coordinate system depending on the area. In landscape mapping softscape diameter spread of a tree and the height of a tree is crucial. This is because the diameter spread of trees or shrubs plays a vital part in the prevention of overpopulation, interference with overhead utility wires, automobile and pedestrian traffic obstruction, and other concerns. With that, an actual representation of the site is guaranteed by using Terrestrial Laser Scanning as shown in

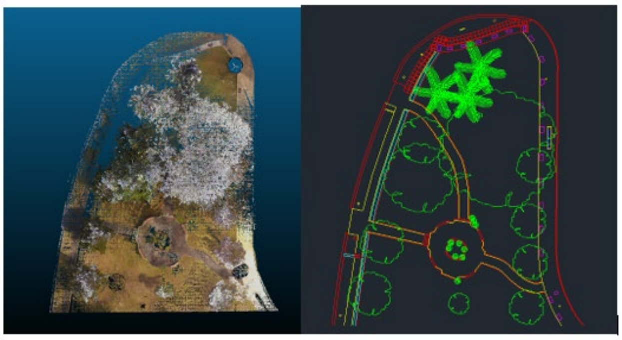

Figure 3.1 Actual representative of site, 3D point cloud from CloudCompare (left) and digitized 2D based map (right)

Site inventory was completely dependent on prediction and expertise. During an interview with Dzulzazreen Bin Mohd Zubir, an assistant landscape architect at Universiti Teknologi Malaysia, he stated that since the existence of Wi-Fi, landscape designers have had to ensure that the tree is not higher than a neighboring building because it would interfere with the Wi-Fi signal. As according to Lacan *et al*. (2009), urban trees can hinder Wi-Fi transmissions, and radio frequency engineers are aware of the possibility of trees interfering with microwave communications. As a result, Terrestrial Laser Scanning could aid in determining the true height of an existing softscape in terms of 3D model, position, and height. This could potentially aid in landscape upkeep.

3.3 Landscape maintenance update

It is also a fantastic tool for site maintenance and updating when Terrestrial Laser Scanning is used. Users can get real-time information about the current hardscape and softscape using the 3D model or 3D point cloud produced by Terrestrial Laser Scanning. This could ensure that quality control is done and that the database is even more accurate. Table 3.4 shows the comparison between two landscape maps produces in this research for quantitative checking.

Table 3.4 Comparison of landscape maps 2022 vs 2018 for quantitative checking

Type of hard and soft landscape	Landscape map (Terrestrial Laser Scanning on 2022)	Landscape map (Historical Imagery 2018)
	Hardscape features	
Flat Stone	67	unknown
Broken Flat Stone	9	unknown
Drainage steel cover	18	18
Cement stair steps	4	4
Red Brick Strecher	6	0
	Softscape features	
Coconut Tree	3	3
Elm Tree	10	7
Fern Tree	0	2
Bush	10	0

As can be seen from Table 3.4 above, flat stone hardscape is shown to be unknown for Landscape map 2018 which is produced via architecture conventional method while the landscape map produce via Terrestrial Laser Scanning shows 67 pieces of flat stone. This is one of the cases mentioned above where it will cause confusion or error when comparing with both real site and landscape map. With the capability of Terrestrial Laser Scanning, it could provide high accuracy detail of site in a form of a 3D model and 3D point cloud. Figure 3.2 and Figure 3.3 show the output of Flat Stone.

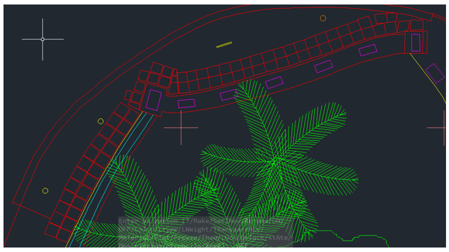

Figure 3.2 Flat stone digitized from 3D point cloud model

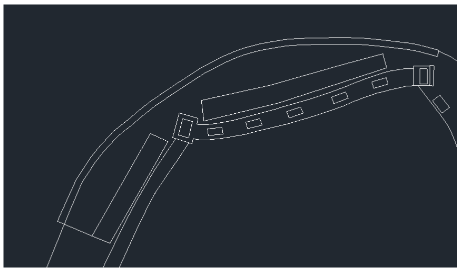

Figure 3.3 Flat stone digitized from historical google based map

3.4 Landscape Map Comparison

This section will be a comparison between hard and soft landscape maps produced with the adaption of Terrestrial Laser Scanning and Landscape map produced by the conventional method of architecture. Table 3.5 will show the comparison between the landscape map produced with the adaptation of Terrestrial Laser Scanning and the landscape map produced with the architecture conventional method in a simple form.

Table 3.5 Comparison between landscape (TLS) and Landscape (Conventional method/Interviewed with Landscape Architecture)

	Landscape Map (Terrestrial Laser Scanning)	Landscape Map (Conventional method/Interviewed with Landscape Architecture)
Time taken for data acquisition	- Each station scans 5-20minutes (depending on the resolution, higher resolution takes longer time scan) for a whole site roughly 5 hours.	- 3 days to one month for site inventory. - Months through meetings and discussion with client. - GIS software or google map, instant.
Coordinate system	- True coordinate system or desired coordinate system. - Optional for direct georeferenced or indirect georeferenced.	-Depending on client -Google map only in WGS84. - Complicated procedure to change desired coordinate system using GIS software.
Position	- Provide height of existing landscape features	- Prediction and assuming
Data collected	- 3D point cloud - RGB, realistic representation of site	- 2D sketch/ Pictures - Site documentation
Men power	- 1-2 persons	- 1-2 persons
Data processing for a base map	- 2 days for point cloud processing. - 1 day for digitizing base map.	- 1 day for base map, sketch based on google ruler measurement. - Instantly, when client provides blueprint of site.
Extra	- Provide 3D model or 3D point cloud for better visualization. - Able to refer back digitally with 3D representation of site.	- Solely based on the memory of the designer. - Tons of documentation to refer. - Site sketch as references

3.5 Final Result of hard and soft landscape mapping

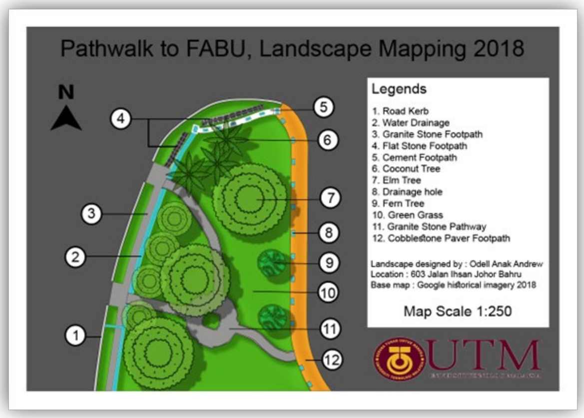

Figure 3.4 Pathwalk to FABU, Landscape Mapping 2018 produced based from the architecture conventional method via google based map

Figure 3.5 The Pathwalk of Mastery FABU, Hard and Soft Landscape Mapping produced via adaption of TLS

4. CONCLUSION

The objective of this research was to determine the ideal implementation of Terrestrial Laser Scanning in Landscape Mapping. On the basis of the analysis presented, it can be concluded that there are numerous advantages to providing efficient information and an accurate representation of the site in a 3D model/point cloud, which enables landscape designers or architects to design a landscape map to their fullest potential in terms of creativity, landscape placement strategies, and as-built survey for maintenance updates. The exceptional precision demonstrated by the above data validation proves that the proposed approach is compatible with existing landscape architecture map standards. Due to the importance of visualization in landscape architecture, the potential of a 3D model or 3D point cloud can be enhanced in future research to further improve the use of Terrestrial Laser Scanning in landscape mapping. With more study, this could be resolved in the future.

ACKNOWLEDGMENTS

I want to thank Dr. Suzanna Binti Noor Azmy who directed, supported, and advised me at every level. I also want to thank Prof. Dr. Zulkepli Bin Majid for his ideas and suggestions for this research study. I also want to express my gratitude to Universiti Teknologi Malaysia for providing the necessary instruments and softwares. In light of this, I would like to express my gratitude to Sir Mohd Faizi bin Mohd Salleh and Sir Anuar Bin Aspuri for mentoring me in terms of technical and processing skills. Finally, I would want to express my appreciation and gratitude to Dr. Muhamad Solehin Fitry bin Rosley for his guidance and constructive criticism about landscape architecture.

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