

TECHNICAL REPORT

**CONSERVATION WORKS ON
HERITAGE BUILDING**

**Generating as Built Drawing by UAV Application and 3D
Laser Scanner for Facilities Maintenance**

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The project, which began on 1st February 2018 and was scheduled to end on 31st August 2019, was extended to 15th October 2019 due to unforeseen circumstances. The generous grant from IP Fokus Sdn. Bhd. allowed us to conduct our research with the highest level of professionalism and to achieve our goals effectively.

This project has contributed to the advancement of knowledge in the field of unmanned aerial systems and has facilitated the development of novel applications and techniques for enhancing the capabilities of these systems, ultimately benefiting the wider community.

Once again, thank you IP Fokus Sdn. Bhd. for their generous support, and we look forward to the opportunity to collaborate with them again in the future.

PREFACE

This technical report presents the outcomes of a research project entitled "Conservation Works on Heritage Building: Generating As Built Drawing by UAV Application and 3D Laser Scanner for Facilities Maintenance". The project was initiated and funded by IP Fokus Sdn. Bhd. and was conducted by the Centre of Excellence for Unmanned Aerial Systems (COE-UAS), UniMAP.

The aim of this project was to explore the use of unmanned aerial vehicles (UAVs) and 3D laser scanners in generating as-built drawings for the maintenance of heritage buildings. The project sought to address the challenge of accurately documenting and maintaining heritage buildings, which are often complex structures with intricate designs and historical significance.

The research project commenced on 1st February 2018 and was initially scheduled to end on 31st August 2019. However, due to unforeseen circumstances, the project was extended to 15th October 2019. Throughout the duration of the project, the research team worked diligently to achieve the objectives of the project.

This technical report provides a comprehensive overview of the project, including the background and rationale, methodology, data collection, and analysis, and the key findings and recommendations. It also includes a detailed description of the UAV and 3D laser scanning technologies used in the project, as well as the software used for data processing and analysis.

We would like to express our gratitude to IP Fokus Sdn. Bhd. for providing the research grant that made this project possible. We would also like to thank the research team for their dedication and hard work throughout the project. It is our hope that the findings and recommendations of this project will contribute to the advancement of the use of UAVs and 3D laser scanners for the maintenance of heritage buildings.

1. INTRODUCTION

Heritage buildings are an important part of a country's cultural identity as they represent the grandeur and dignity of a nation's history. These buildings are also the beginning of a race, religion, and country and state in the era of circulation. Therefore, it is crucial to restore and preserve heritage buildings for future generations to emphasize the importance of documentation.

With the advancement of technology, new tools such as computers and digital media have given new opportunities in the conservation of heritage buildings. This has led to the development of various technologies like remote sensing, photogrammetry, geographic information system (GIS), and 3D laser scanning, each with its own advantages and disadvantages.

This report investigates the use of 3D laser scanning, UAV photogrammetry, and Building Information Modelling (BIM) software to reconstruct and develop a new as-built drawing of a heritage building. This approach aims to provide an accurate and detailed representation of the building, which can be used for restoration and preservation purposes.

1.1 Problem Statement

The lack of proper as-built drawings for most of the heritage buildings in Malaysia, especially those aged 50 years and above, is causing improper maintenance and inadequate preservation of these structures. Masjid Alwi in Perlis is one such heritage building that requires an as-built drawing to facilitate its preservation and maintenance. The absence of documentation also hinders future research and reference on heritage building preservation. Recording and archiving of heritage structures are vital to preserving and acknowledging their historical and socio-cultural significance. Neglect and inadequate restoration and maintenance of cultural properties due to timelines and insufficient resources pose a threat to their survival. Heritage buildings can serve as significant resources in preserving a nation's culture and customs. Conventional surveying techniques have been employed over the past two decades to inventory and estimate the value of legacy structures.

1.2 Aim and Objectives

The aim of this research is to create a new as-built drawing of the heritage building by utilizing data analyzed from 3D laser scanning, UAV photogrammetry, and Building Information Modelling (BIM) software.

The research objectives are as follows:

- To create a comprehensive 3D model of the heritage building by utilizing data obtained from the UAV photogrammetry and 3D laser scanning techniques.
- To produce accurate and detailed as-built drawings of the heritage building using Building Information Modeling (BIM) software.

1.3 Research Scope

The scope of this research project is focused on the Alwi Mosque located in Perlis, Malaysia. The data used for analysis in this project includes data collected using UAVs and Terrestrial Laser Scanners.

1.3.1 Site of Investigation

The research area selected is located in Perlis, a state in the north of Peninsular Malaysia, with geographic coordinates at latitude 6° 26' 36.9204" N and longitude 100° 12' 56.7564" E. Perlis is an area that is growing in higher education. The focus of the research is on the heritage buildings in Perlis, particularly the Alwi Kangar Mosque, which was built in 1931 and completed in 1933. The mosque is known for its unique construction method, which utilizes a mixture of white egg and sand, resulting in the beauty of Mogul art. The mosque is gazetted as a National Heritage Site and can accommodate up to 500 pilgrims at one time. Due to the use of large eggs in the construction, it took almost three years to complete.



Figure 1.1. Alwi Mosque, Kangar.

1.4 Research Approach

A proper research approach is essential to achieve the research objectives. This study adopted a three-phase approach, which was designed to fulfil the objectives of this research. The first phase involved "Planning and Preparation," which included selecting the research area, equipment, software, and data acquisition sources. The second phase focused on "Data Processing," which describes how the data from UAV, 3D laser scanner, and Building Information Modelling (BIM) software were processed. The third and final phase focused on

"Result and Analysis," which involved analyzing the data to reconstruct and develop as-built drawings for Masjid Alwi, Kangar, Perlis. A general overview of the research approach is shown in Figure 1.2.

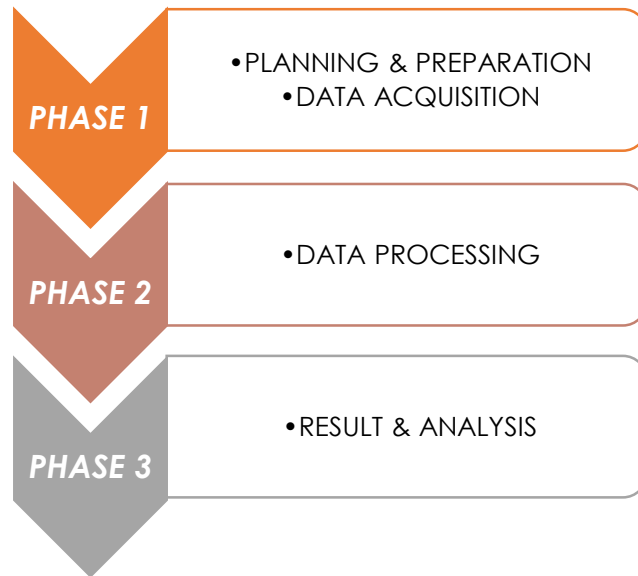


Figure 1.2. Research approach for generating As-Built drawings of heritage buildings using 3D laser scanning, UAV photogrammetry, and BIM software.

2. RELATED WORKS AND STUDIES

2.1 Heritage Building

A heritage building is a structure that possesses significant architectural, aesthetic, cultural, or historical value, which has been recognized as such by the Planning Authority/Heritage Conservation Committee or any other relevant governing body within the jurisdiction of the building. These buildings are representative of a community's tangible cultural heritage, which constitutes the practices and objects passed down from previous generations. However, many heritage buildings have been neglected over time. As an object of built heritage, a building represents the historical evidence and values of the local community (Said, Aksah, & Ismail, 2013). Malaysia has numerous heritage buildings in state capitals that serve as sources of livelihood and prestige for the owners and the nation.

2.1.1 Conservation of Heritage Building in Malaysia

The protection of heritage buildings in Malaysia is a joint effort between the government and the private sector. The establishment of the National Heritage Department in 2006 reflects the government's commitment to preserving Malaysia's heritage buildings. Preservation guidelines emphasize maintaining the original building and structure as much as possible. However, preserving the authentic value of national heritage presents a significant challenge, particularly in making decisions about preservation. The Burra Charter defines preservation as a process that aims to maintain the social significance of a place, which involves a range of cultural and social values that give each place its unique identity and meaning to society. Preserving cultural significance is not just about architectural considerations, but also involves economic and social issues, including the sustainable management of changes. It is essential to protect various values of built cultural heritage in the most cost-effective way.



Figure 2.1. Kampung Kuala Dal Old Mosque, Kuala Kangsar before and after conservation in 2009. (Harun, 2011)

2.1.2 Facilities Management on Heritage Building

Facilities management is of utmost importance when it comes to the preservation and conservation of heritage buildings, particularly as the original blueprints may be missing or in poor condition. The Cultural Heritage Act in Malaysia categorizes heritage into tangible and intangible forms, including buildings, monuments, regions, languages, performances, dances,

and martial arts. All potential cultural heritage can be listed and claimed as national heritage assets. In accordance with Section 67 (Harun, 2011), nine criteria should be considered for potential heritage buildings when declaring them as national heritage properties. These criteria include historical significance or association with Malaysian history, the best design or aesthetic features, scientific or technical innovations or achievements, social or cultural associations, the potential for education and scientific investigation of Malaysian cultural heritage, importance in displaying a richness or range of features, rarity or distinctiveness of the natural or cultural heritage, representative nature of a site or object, and any other relevant matter related to cultural heritage significance.

Outdated drawing sets can cause significant problems in the construction industry. They can lead to errors and inconsistencies in the construction process, which can result in costly rework and delays. This is why it's essential to have effective document management processes in place, to ensure that all the necessary information is available at the right time and in the right place. In recent years, digital solutions have emerged that can help address some of these issues, by providing real-time as-built documentation that accurately reflects the current state of the construction project. However, there are still challenges to be overcome, such as the need to convert paper documents to digital format, and the difficulty of ensuring that all team members have access to the latest version of the documentation.

On the contrary, real-time as-built drawings are the result of an iterative process of data sharing, which includes associated element callouts, requests for information (RFIs), punch items, and markups. This approach allows for drawings to accurately reflect the project's current status as it changes over time, providing owners with precise as-built drawings upon completion. In the past, all information was tracked and captured using paper documents. In the pre-digital era, the construction industry established complex systems to organize and track printed materials. Strict rules governed every aspect of construction documents, from the timing of printing to assembly requirements. Nevertheless, maintaining effective communication among team members and keeping documents up-to-date was almost impossible.

Digital documents are increasingly replacing paperwork, not only for original construction documents but also for contractually designated record drawings (typically requested in PDF or CAD format). However, in the field, it is still common for markups to be done on paper. Despite this, for an industrial construction project, the number of documents required can be in the thousands. Transferring accurate information from one set of documents to another presents a significant challenge (Josh Newland, 2015).

2.2 Unmanned Aerial Vehicle (UAV)

Unmanned aerial vehicles (UAVs), commonly known as drones, are aircraft that do not require a human pilot on board. They are part of an unmanned aircraft system (UAS) that consists of the UAV itself, a ground-based controller, and a communication system between the two components. The UAVs can operate with varying levels of autonomy, either under the remote control of a human operator or autonomously through on-board computer systems (ICAO, 2011).

UAVs were initially designed for missions that were considered too tedious, risky, or unclear for human pilots, in contrast to manned aircraft. While their early applications were primarily in military contexts, their usage has grown considerably in recent years, extending to a broad range of commercial, scientific, recreational, agricultural, and other areas, as noted by Franke

(2015). These applications include but are not limited to policing and surveillance, product deliveries, aerial photography, and drone racing.

2.2.1 Aerial Photogrammetry Using UAV

The UAV system is a cost-effective and flexible solution for photogrammetry and remote sensing, making it a revolutionary technology in this field. Compared to other mobile mapping systems, the UAV is a more suitable option due to its low cost. The basic principle of the UAV is based on photogrammetry, using a camera mounted on the UAV, flight planning, and maps and analysis similar to photogrammetry but at a lower altitude. This low-cost and low-altitude aerial vehicle can quickly provide data and update it in real-time, without the need for long-term waiting like satellite images. (Samad, 2013; Everaerts, 2008)

An unmanned aerial vehicle (UAV) is an aircraft that can fly without a pilot on board and can operate autonomously using an airframe and an on-board computer system that includes sensors, a Global Positioning System (GPS), and CPUs. These aircraft are capable of flying a wide range of missions and can be controlled remotely from a ground-based station. UAVs are often used in emergencies and other situations where human pilots cannot safely or effectively operate aircraft. The following figure, Figure 2.2, depicts the capture of an aerial perspective of Masjid Alwi during the data acquisition process.



Figure 2.2. An aerial perspective of Alwi Mosque was captured during the data acquisition process.

2.2.2 Building Mapping with UAV

Micro Aerial Vehicles (MAVs), commonly known as flying drones, have emerged as an indispensable tool in various fields, including architecture, engineering, and construction (AEC). As the cost of this technology continues to plummet at an accelerated pace, companies are increasingly leveraging the versatility and efficiency of drones. This is particularly true in the case of construction teams worldwide, who are employing these flying machines as imaging systems to streamline the inherently complex and often laborious building process. Equipped with a simple yet effective passive digital camera, these drones can effortlessly navigate through existing structures, gathering and returning rich, multi-layered data on building details. This data is then used to develop accurate 3D digital models of exterior facades, facilitate renovation plans through virtual 3D simulation, and even automatically generate 3D printable prefabricated structures (Daftry, Hoppe, & Bischof, 2015).

SfM, short for Structure from Motion, is a well-explored subject with various techniques emerging in recent years. These techniques have been designed to effectively process numerous highlighted images from photograph network collections and automatically construct a 3D model. Some of the techniques include those proposed by Daftry et al. (2015), Vu et al. (2012), Skarlatos and Kiparissi (2012), Roca et al. (2013), and Snavely et al. (2008). They claim to have improved robustness, resulting in high quality and accuracy similar to laser range sensor systems at a fraction of the cost. These implicit advantages have not only gained recognition among researchers but have also attracted an ever-increasing number of end-users, who are not experts in computer vision, for applications such as architectural reconstruction and scene documentation.

The SfM procedure requires certain prerequisites to obtain a precise and comprehensive 3-D model, such as a moderate viewing angle between images to facilitate feature matching, overlapping view cones, and textured images with non-repetitive patterns and minimal lighting changes. It is impossible for a user to determine whether the acquired images fulfil all the requirements, and the completeness of the scene, i.e., the coverage of the scene, is also a challenging issue. Any parts of the scene that are not captured with sufficient image overlap cannot be reconstructed. Determining the level of completeness depends on the desired reconstruction resolution and the surface itself, and it is not possible to assess the degree of completeness without prior knowledge. However, humans can quickly answer this question by comparing a 3D model to the real world (Daftry et al., 2015).

2.3 Terrestrial Laser Scanner (TLS)

Terrestrial laser scanning is a ground-based alternative to airborne LIDAR used for mapping terrain and landscapes with high resolution. Although originally intended for as-built modeling of architecture and engineering structures, these scanners can also be used for high-resolution mapping of terrain, vegetation, and other landscape features over shorter distances, ranging from 50-300 meters. These scanners operate similarly to airborne LIDAR, utilizing laser signals to calculate distances based on the time delay of the returned laser pulses. They capture a dense array of distance return values that can be assembled into highly detailed digital 3-D landscape models, which can be transformed into GIS DEMs. Additionally, many of these terrestrial scanners capture digital photos of the scanned areas and attach RGB color values from the photos to each laser distance return, resulting in highly photorealistic 3-D landscape models.

2.3.1 *TLS Enhancing the Building High-Density 3D Data*

The total station has evolved significantly since its early days as a theodolite, and today's models are equipped with advanced electronic distance measurement units and sensors that enable high precision and accuracy in measurements. Robotic and motorized total stations have become increasingly popular, allowing for automatic recognition and tracking of reflector prisms, as well as remote steering by the user. These multi-sensor systems provide a range of functionalities that make them an essential tool for land surveyors, engineers, and researchers alike. With the continued advancement of technology, it is likely that total stations will continue to evolve and offer even more sophisticated features and capabilities in the future.

In addition to the technological advancements in surveying equipment, there have also been significant developments in software and data processing techniques. The use of Geographic Information Systems (GIS) has become a fundamental tool for data management, visualization, and analysis. Survey data can be integrated with other types of geospatial data, such as satellite imagery or topographic maps, to provide a more complete picture of the study area.

Furthermore, the use of machine learning and artificial intelligence techniques is becoming increasingly common in the analysis of survey data. These techniques can be used for feature extraction, classification, and prediction, among other applications. For example, machine learning algorithms can be used to identify changes in the surveyed area over time or to classify different types of land cover.

Geodetic measurements using Global Navigation Satellite Systems (GNSS), total stations, and Terrestrial Laser Scanners (TLS) are commonly used for surveying. While GNSS and total stations require the user to manually select points of interest for direct measurements, TLS provides dense point clouds that represent the 3D geometry of a scene surface. The 3D coordinates of the points of interest can then be obtained through point cloud processing. In addition to TLS, photogrammetry methods also create dense point clouds thanks to the development of powerful stereo-matching algorithms. These surveying methods are often used by specialists from various research communities, for tasks ranging from detection of changes to structural monitoring, depending on the scale of the area surveyed and the type of data required for analysis.

2.4 Building Information Modelling (BIM)

BIM is a software-enabled process that facilitates document management, coordination, and simulation across the entire lifecycle of a project, from planning and design to construction, operation, and maintenance. It is widely used in the design and documentation of building and infrastructure projects, wherein every detail of the project is modelled in a 3D intelligent model. The model is useful for the analysis and exploration of design options, as well as for creating visualizations that allow stakeholders to visualize the project before it is built. Ultimately, the model is used to generate design documentation for the construction process (Autodesk, 2018).

The global architecture, engineering, and construction (AEC) industry has the crucial responsibility of providing social and economic spaces for the world's growing population, as well as maintaining and restoring existing buildings and infrastructure. As such, the industry must seek smarter and more efficient ways to design and build, not just to keep up with the increasing global demand but also to create more intelligent and resilient spaces.

BIM not only enables design and construction teams to work more efficiently but also allows them to capture valuable data generated during the process, which can benefit operations and maintenance activities. Additionally, BIM data can inform planning and resource allocation at the project, city, or country level. Consequently, BIM mandates are being increasingly implemented worldwide (Bortoluzzi, Efremov, Medina, Sobieraj, & McArthur, 2019).

2.4.1 BIM as Information Analyzer for Generating As-Built Drawing

In the management of construction projects, the significance of accurate information cannot be overstated. A successful construction project involves the use of available data and knowledge to make informed decisions across various disciplines including architecture, engineering, construction, and operation (AECO) (Ke Chen et al., 2015). In current practice, Building Information Modeling (BIM) is typically isolated from the actual physical building processes throughout its lifecycle. Even though an architectural or structural model may be highly detailed and precise, it remains static if its contents cannot be synchronized with the ongoing building process.

Therefore, a BIM is often limited in its ability to respond to ongoing AECO processes, whereas an ‘as-built’ model is better positioned to support information exchange and decision-making throughout the project lifecycle (Zhong et al., 2017; He et al., 2017). A conceptual framework that emphasizes the theoretical perspective of bridging BIM and building (BBB) can be utilized to connect the information contained in BIM with the physical building processes to make BIM more reflective of real-life situations. Such a framework can help to consolidate research work in BBB, which has so far evolved in a fragmented manner. Additionally, it can enable the building to be theorized as a cluster of data. Currently accomplished through various Information and Communication Technologies (ICTs), BBB has become a critical research question in information management (IM) for decision-making in contemporary project management. An integrated conceptual framework can help to structure strategic development directions in this area, facilitating future research on bridging BIM and building to proceed on a more stable footing (He et al., 2017).

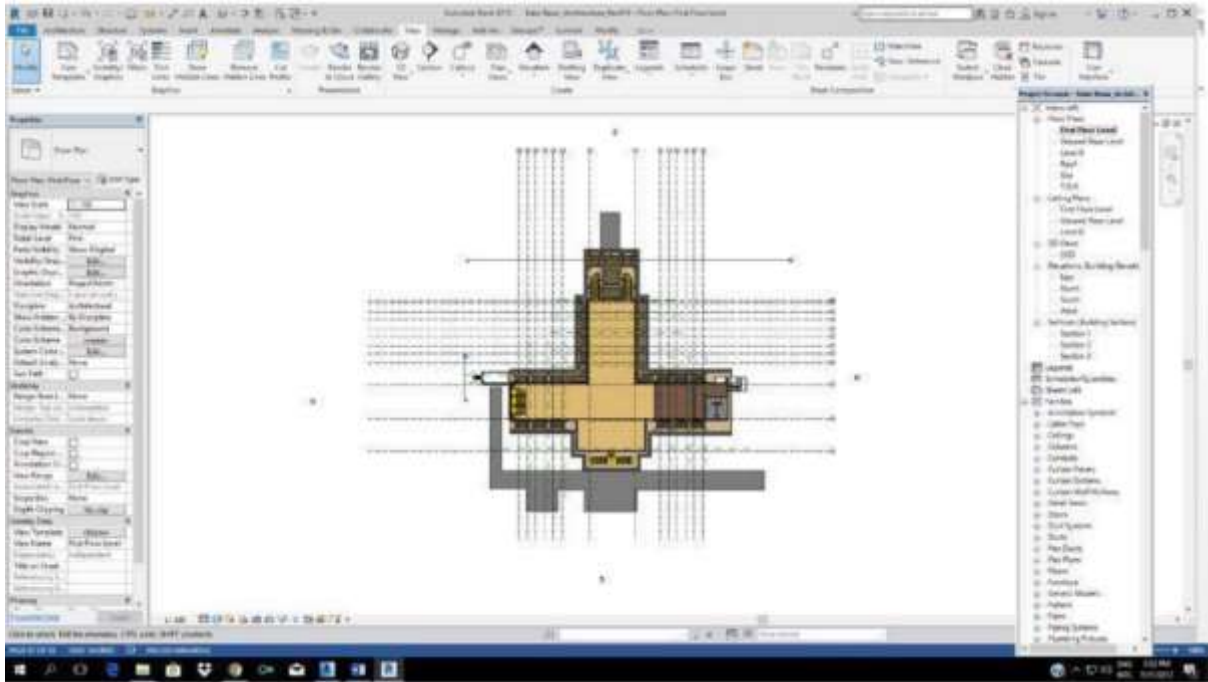


Figure 2.3. Extracting data and information from As-Built drawings for BIM Model. (Ali, Ismail, Hashim, Suhaimi, & Mustafa, 2018)

3. DATA COLLECTION AND ANALYSIS

The methodology employed in this research was designed based on three stages. The first stage involved data collection, which was categorized into two types, namely aerial photographs and land survey data obtained from 3D laser scanning. For the aerial photos, a DJI Inspire 2 with IMU data was used to capture images that provided geometrical positioning with centimetre-level accuracy. PIX4D Mapper software was utilized for data analysis, which proved to be the most effective tool for the job. The IMU data helped determine the orientation of the photograph, thus allowing for accurate identification of surface roughness and evenness. In contrast, land survey data was collected through the use of Terrestrial Laser Scanning (TLS) or a Trimble 3D laser scanner.

The second stage of the research involved data processing, which was further subdivided into two types. The first type focused on 3D modelling, which was performed using PIX4D Mapper software. The 3D modelling process was broken down into three primary stages: "Initial Processing," "Point Cloud and Mesh," and "DSM, Orthomosaic." While 3D laser scanning could also produce 3D modelling outputs, PIX4D Mapper software was found to be the most effective method for facilities management. The 3D laser scanning data was processed using Building Information Modelling (BIM) software to verify the as-built drawing.

The final stage of this methodology involved the results and analysis of the processed data, as shown in Figure 3.1. This stage revealed the outcomes of the data processing, which ultimately led to the final output of the research. Figure 3.1 outlines the proposed methods for reconstructing and developing a new as-built drawing of a heritage building by utilizing data analyzed from a Trimble 3D laser scanner, UAV photogrammetry, and Building Information Modelling (BIM) software.

3.1 Planning and Preparation

Prior to data collection, planning, and preparation are necessary. This involves determining the scope of work, including the survey area and the instruments and software required for the project. Effective planning and preparation can ensure the efficiency and high quality of data collection in the study. Additionally, proper planning and preparation can help save time and cost, as increasing time leads to increased costs. The figure below illustrates the general planning and preparation for UAV and TLS.

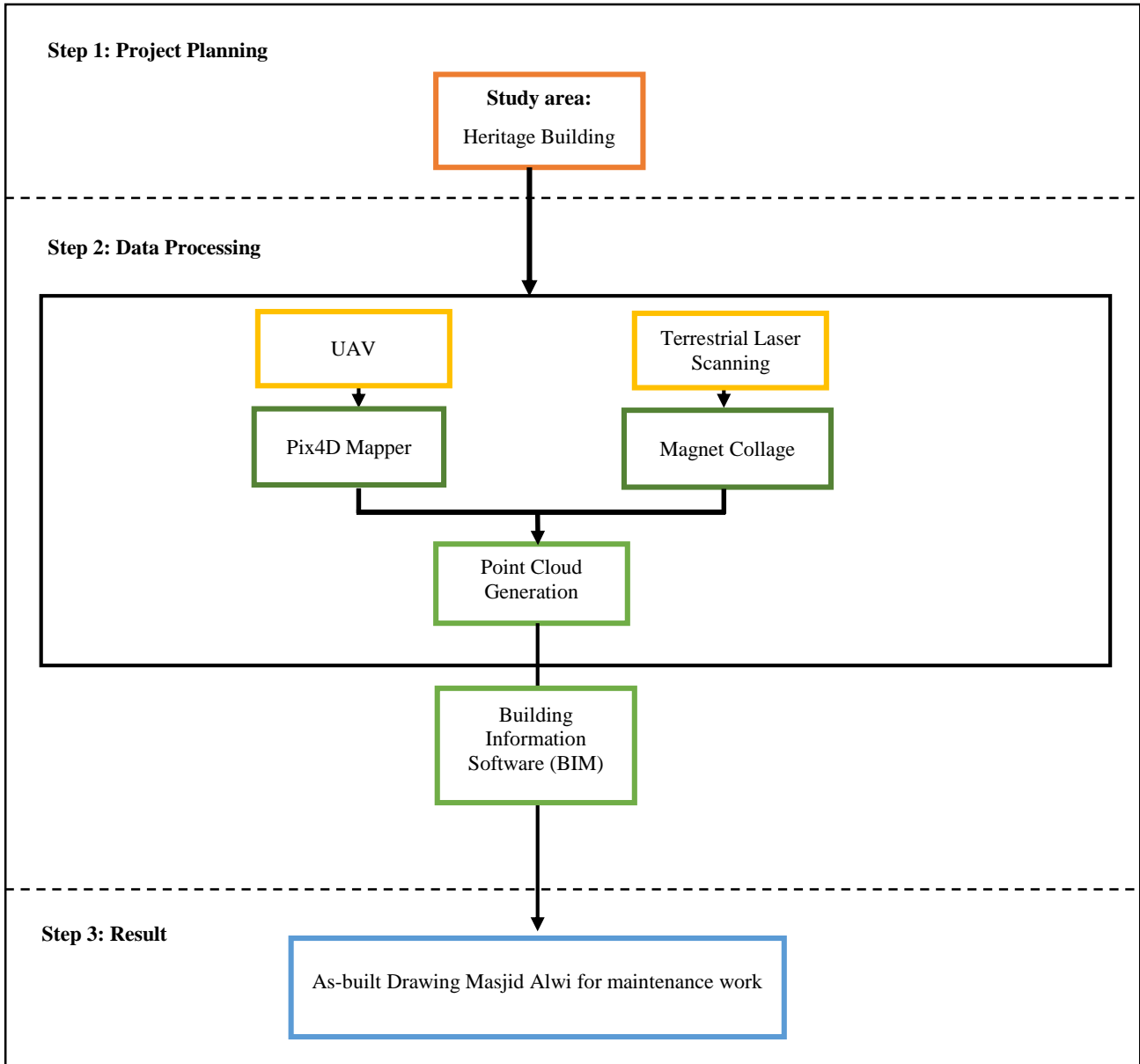


Figure 3.1. Data collection and analysis.





3.1.1 Research Site

This research is focused on the Alwi Mosque in Kangar, Perlis. The study area encompasses a perimeter of 350 meters. Adequate planning and preparation are crucial for this study, including defining the study area's scope, developing a flight plan to obtain necessary data, and ensuring the safety of the study area during data collection.

3.1.2 Instrument Used

The research was carried out using a DJI Inspire 2 for aerial and external data acquisitions, while for land survey and internal data acquisitions, we used a Trimble M3 Total Station and Topcon GLS 2000. The following table provides a list of the instruments used in the data collection process along with the corresponding quantities.

Table 3.1 List of instruments used for internal and external data collections

Instrument	Description	Quantity
	Tripod	3
	Total Station	1
	Terrestrial Laser Scanner	1
	2.5" Prism	2

3.1.2.1 DJI Inspire 2

In this project, the DJI Inspire 2 was utilized to gather aerial data on Masjid Alwi. The following are the particulars of the DJI Inspire 2 specifications.

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Table 3.2 DJI Inspire 2 specifications

AIRCRAFT		
No.	Descriptions	Remarks
1.	Model	T650A
2.	Weight	7.58 lbs (3440 g, including propellers and two batteries, without gimbal and camera)
3.	Max Takeoff Weight	9.37lbs (4250 g)
4.	GPS Hovering Accuracy	Vertical: ± 1.64 feet (0.5 m) or ± 0.33 feet (0.1 m, Downward Vision System enabled) Horizontal: ± 4.92 feet (1.5 m) or ± 0.98 feet (0.3 m, Downward Vision System enabled)
5.	Max Angular Velocity	Pitch: 300°/s Yaw: 150°/s
6.	Max Tilt Angle	P-mode: 35° (Forward Vision System enabled: 25°) A-mode: 35° S-mode: 40°
7.	Max Ascent Speed	P-mode/A-mode: 16.4 ft/s (5 m/s) S-mode: 19.7 ft/s (6 m/s)
8.	Max Descent Speed	Vertical: 13.1 ft/s (4 m/s) Tilt: 13.1-29.5 ft/s (4-9 m/s)
9.	Max Takeoff Sea Level	1.55 mi (2500 m) 3.1 mi (5000 m with specially-designed propeller)
10.	Max Wind Speed Resistance	10 m/s
11.	Max Flight Time	Approx. 27min (with Zenmuse X4S) Approx. 23min (with Zenmuse X7) (Hovering at sea level with no wind.)
12.	Motor Model	DJI 3512
13.	Propeller Model	DJI 1550T
14.	Indoor Hovering	Enabled by default
15.	Operating Temperature	-4° to 104° F (-20° to 40° C)
16.	Diagonal Distance (propeller excluded)	23.8 inch (605 mm, Landing Mode)
17.	Max Speed	58 mph or 94 kph(Sport mode)

REMOTE CONTROLLER		
No.	Descriptions	Remarks
1.	Model	GL6D10A
2.	Operating Frequency	2.400-2.483 GHz 5.725-5.850 GHz
3.	Max Transmitting Distance(unobstructed, free of interference)	2.4 GHz: FCC: 4.3 miles (7 km); CE: 2.2 miles (3.5 km); SRRC: 2.5 miles (4 km); MIC: 2.5 miles (4 km); 5.8 GHz: FCC: 4.3 miles (7 km); CE: 1.2 miles (2 km); SRRC: 3.1 miles (5 km); MIC: - ;
4.	EIRP	2.4 GHz: FCC: 26 dBm; CE: 17 dBm; SRRC: 20 dBm; MIC: 17dBm; 5.8 GHz: FCC: 28 dBm; CE:14 dBm; SRRC: 20 dBm; MIC: - ;
5.	Video Output Ports	USB, HDMI
6.	Power Supply	Built-in battery
7.	Charging	DJI charger
8.	Dual User Capability	Host-and-Slave connection
9.	Mobile Device Holder	Tablet or Smart Phone
10.	Max Mobile Device Width	170 mm
11.	Output Power	9 W (Without supplying power to smart device)
12.	Operating Temperature	-4° to 104° F (-20° to 40° C)
13.	Storage Temperature	Less than 3 months: -4° to 113° F (-20° to 45° C) More than 3 months: 72° to 82° F (22° to 28° C)
14.	Charging Temperature	32° to 104° F (0° to 40° C)
15.	Battery	6000mAh 2S LiPo
16.	USB Supply Power	iOS: 1 A @ 5.2 V (Max); Android: 1.5 A @ 5.2 V (Max)



Figure 3.2. DJI Inspire 2.

3.1.2.2 Trimble M3 Total Station

The Trimble M3 Total Station is equipped with a compact, lightweight, and sturdy system design. It is furnished with dependable and trustworthy mechanical technology, which serves to enhance any land surveying project. The latest Trimble Access field software, coupled with the optional streamlined workflow modules on-board, has proven to be advantageous and offers additional features to support surveyors in their work. Another notable addition to its new system features is the bright and vibrant touchscreen QVGA display. Additionally, the instrument is available with the option of an optical or laser plummet, giving surveyors a range of choices.

Table 3.3 Total station specifications

Easy to learn and to operate	The Trimble M3 boasts the Trimble Access™ field software, which integrates trusted mechanical total station dependability with the potent, functional, and adaptable software that contemporary users require.
Design to keep you moving	Thanks to its compact and lightweight design, the Trimble M3 can be moved around the job site with great ease and efficiency. The instrument comes equipped with two hot-swappable, long-life batteries that are capable of powering it for up to 26 hours of uninterrupted operation.
Trimble M3 DR 5" W	The Trimble M3 DR 5" Winterized version is specifically engineered to cater to users who work in cold temperatures. This version is designed to be utilized in low-temperature conditions, and when operating in extremely cold environments, the rear display heater will automatically switch on at temperatures approximately around -15°C to ensure uninterrupted functionality.

3.1.2.3 Topcon GLS 2000 Laser Scanner

The GLS-2000 is an industry-leading laser scanner that every serious practitioner should have in their toolkit. This laser scanner can be effectively utilized at any job site to capture existing as-built conditions. The instrument boasts a scan range of over 350m, making it a versatile tool that incorporates valuable point cloud data into a wide range of project applications. The GLS-2000 offers a quick, simple, and efficient method for capturing high-speed 3D point cloud data without compromising the precision demanded by today's demanding professionals.

Table 3.4 Terrestrial Laser Scanner specifications

Full Dome Field-of-View (FOV)	The GLS-2000 instrument offers a 3600 (H) and 2700 (V) FOV, allowing for the capture of point cloud data in enclosed areas such as building interiors, mechanical rooms, under bridge spans, pipe racks, and other challenging spaces.
Long-range Scanning up to 350 m	The distance measuring range of the GLS-2000 is user-selectable, making it suitable for a wide range of applications. The instrument can be used for short distance measuring in applications where precision is critical, as well as for long-distance measuring in projects that involve large structures and material stockpiles.
Selectable Laser (3R/1M) Class	To address eye-safety concerns in populated areas, the GLS-2000 features different measurement modes (with varying laser output) that can be switched between Class 3R and Class 1M depending on the job site requirements. This ensures that the instrument can be safely used in a variety of settings.
Direct HI Measurement	With its exclusive laser plummet function, the GLS-2000 accurately measures instrument height with a one-touch operation, enabling faster set-up times in traversing operations. This feature enhances the instrument's efficiency and productivity, making it a valuable tool in a wide range of applications.

3.1.3 Software Used

The study's planning and preparation involved the use of Pix4D Mapper and Civil Design Software. Third-party software, such as ArcMap and AutoCAD 2014 software, were also employed to aid in data analysis and processing.

3.1.3.1 Pix4D Mapper



Figure 3.3. Pix4D Mapper Pro.

Pix4D Mapper Pro is a highly accurate mapping software that enables the capture of 3D textured models, digital surface models, and NDVI maps more accurately than any other software available on the market. Its fully automatic workflow saves time and effort when it comes to exporting and acting on recorded data.

Compared to its competitors, Pix4D Mapper Pro is more intuitive for less technically-minded users and offers excellent customer support based in Switzerland. The company provides workshops, direct support, and a "Knowledge Base" for users to self-train and troubleshoot any issues encountered while using Pix4D for surveying needs.

This software has proven useful in various industries, including estimating rockfall danger after landslides, inspecting the UK's tallest tower, and assisting with large-scale industrial surveying, among other applications. Pix4D Mapper Pro allows organizations to perform these tasks precisely without putting workers at risk, which could have significant implications for the future of work.

3.1.3.2 ArcMAP



Figure 3.4. ArcMap 10.2.

In this section, we will introduce and provide an overview of ArcMap, the central application used in ArcGIS. ArcMap is an essential tool for displaying and exploring GIS datasets related to your study area. It enables you to assign symbols, create map layouts for printing or publication, and even create and edit datasets.

ArcMap employs a layer-based approach to representing geographic information, where each layer represents a different aspect of the data. In addition to layers, ArcMap includes other map elements, such as a data frame that contains map layers for a given extent, a scale bar, a north arrow, a title, descriptive text, and a symbol legend. These features make ArcMap a powerful and versatile tool for displaying, analyzing, and managing geospatial data.

3.1.3.3 AutoCAD 2014

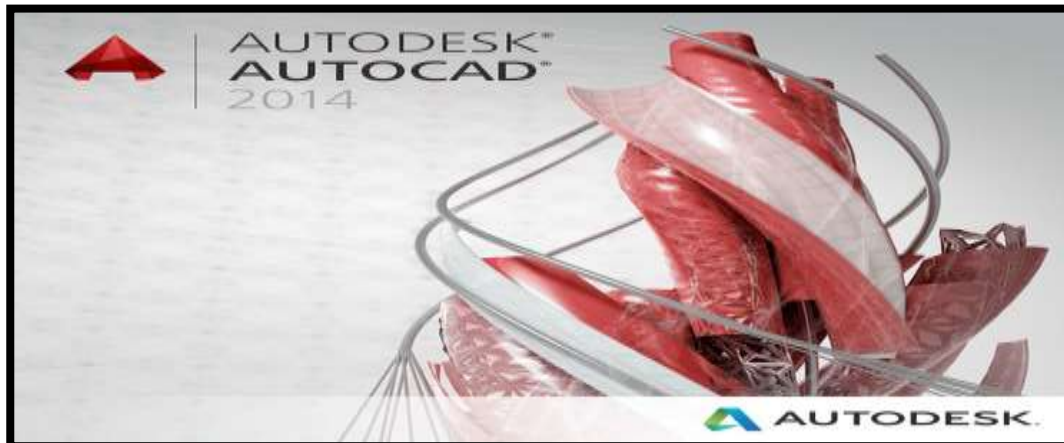


Figure 3.5. AutoCAD 2014.

Autodesk AutoCAD 2014 software revolutionizes design workflow by connecting and streamlining it in unprecedented ways. Its new design feed social collaboration tools to drive greater project stakeholder involvement, making it easier for team members to share their ideas and feedback. Time-saving enhancements speed up everyday workflow, allowing designers to complete projects more efficiently. Additionally, AutoCAD 2014 features live maps and powerful new reality capture capabilities, enabling designers to connect their designs to the real world around them.

3.1.3.4 Autodesk Recap Pro



Figure 3.6. Autodesk Recap.

Autodesk ReCap is an essential tool for professionals in architecture, engineering, and construction industries who work with laser scans and point cloud data. The software allows for a smooth and efficient workflow, from importing and managing large datasets to cleaning up and editing point clouds. ReCap also provides a range of advanced features, such as automatic registration and alignment of point clouds, and the ability to create 3D models and animations from scan data. With ReCap, users can quickly and easily convert raw point cloud data into high-quality, accurate models that can be used for a wide range of design and analysis tasks.

3.1.3.5 Autodesk Revit 2017 (BIM Software)



Figure 3.7. Autodesk Revit 2017.

Revit is widely used in the construction industry for its ability to create a virtual model of a building or structure, allowing for accurate planning, coordination, and communication between all parties involved in a construction project. The software offers features such as parametric modeling, where changes made to one part of the model will automatically update all other related parts, and the ability to generate construction documents directly from the model. This improves accuracy and efficiency, reduces errors, and ultimately saves time and money during the construction process. Additionally, Revit's database can be used to store and manage important building information, such as materials, equipment, and maintenance schedules, which can be accessed throughout the building's lifecycle.

3.2 Data Collection

The conventional method of data collection using a total station involves the use of an electronic/optical instrument to measure angles and distances between points. This method requires the placement of reflectors or prisms at specific locations, which can then be measured by the total station. The collected data can be used to create 2D and 3D models of the surveyed area.

On the other hand, the use of Unmanned Aerial Vehicles (UAVs), also known as drones, has become increasingly popular in recent years for surveying and mapping. UAVs equipped with cameras and sensors can capture high-resolution images and generate accurate 3D models of the surveyed area. This method offers a faster and more cost-effective way of collecting data

compared to conventional methods. By using both conventional and new methods of data collection, this study can benefit from the advantages of each method and achieve more accurate and comprehensive results.

3.2.1 Utilizing UAV to Acquired Aerial Data

Using a DJI Inspire 2 drone for UAV data collection is a great choice as it is a popular drone model for surveying and mapping due to its high-resolution camera and stable flight performance. The DJI Ground Station App is a useful tool for planning and executing automated flights and ensuring that the drone flies the designated path and altitude for optimal data collection.

The decision to set the side lap and overlap at 80% and 70%, respectively, is a common industry standard for generating accurate 3D models and maps. The altitude of 100 meters above MSL is also a good choice, as it provides a good balance between ground resolution and image coverage area.

Taking multiple flights to ensure adequate image overlap is important to ensure that the images can be stitched together accurately and generate a high-quality 3D model or map. Using Pix4D software will also help with this process as it can automatically process the acquired images and generate a range of outputs such as 3D models, orthomosaics, and point clouds.

3.2.2 Utilising TLS to Acquired Ground Data

The traversing method is a technique used in surveying to mark and measure points accurately. It involves setting up a baseline, which is a straight line connecting two points of known coordinates, and then measuring the distances and angles from the baseline to other points. This allows for the creation of a network of points with accurate coordinates. In this case, the traversing method was used to mark the coordinates for the laser scanner to ensure accurate data collection.

It's important to note that scanning during clear weather is ideal because it allows for better-quality images due to the absence of shadows and other weather-related factors. Additionally, conducting the internal scanning process during night time after Isya's prayer time is a thoughtful consideration to avoid disturbing people who are there to pray.

Overall, the use of a laser scanner and traversing method for data collection can result in highly accurate and detailed 3D models of the mosque's internal and external areas, which can be useful for various purposes such as documentation, analysis, and restoration.

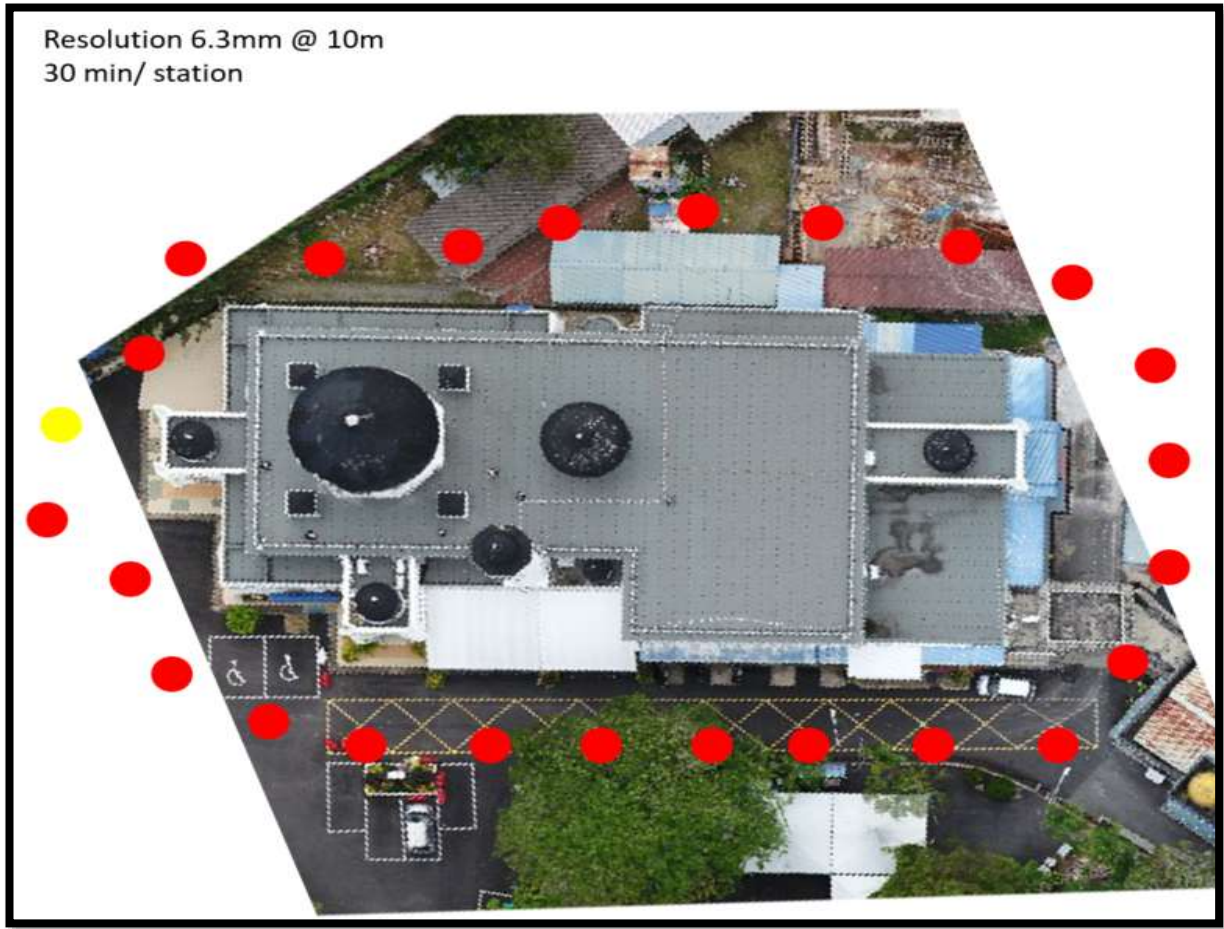


Figure 3.8. Plan position for TLS Scanner for external scanning.

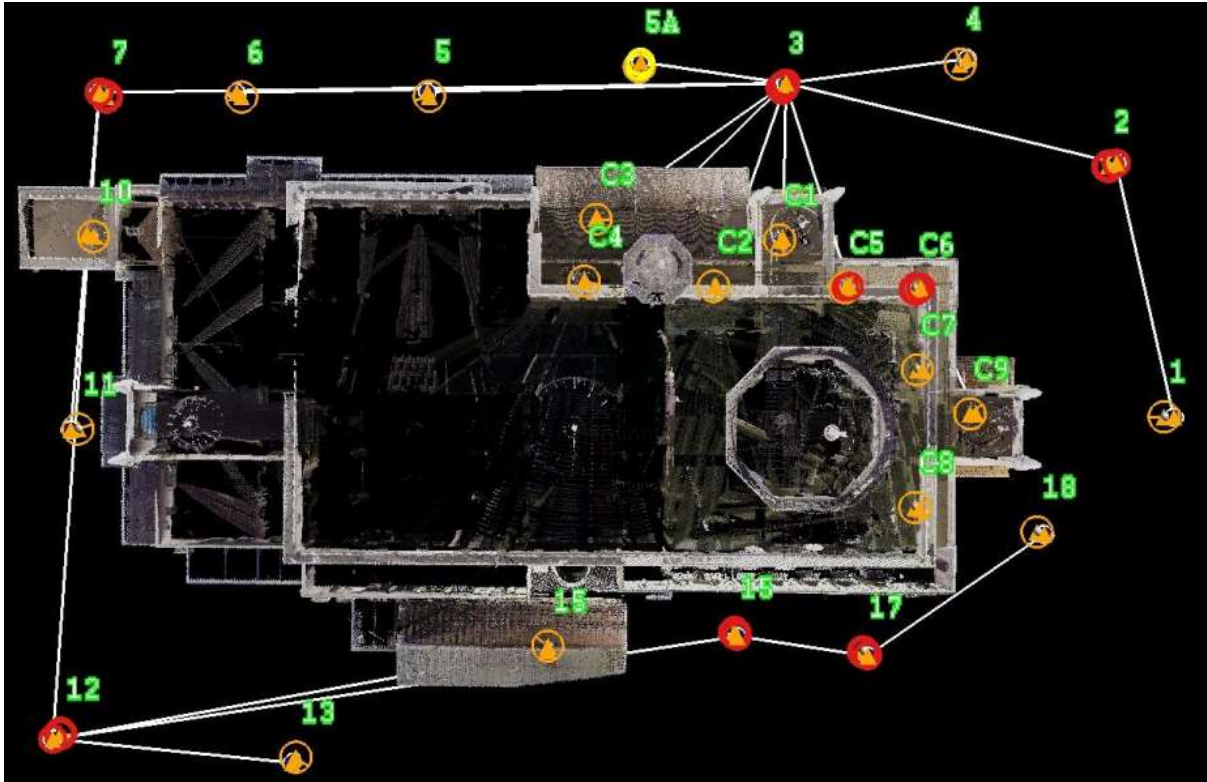


Figure 3.9. TLS actual position during external scanning.

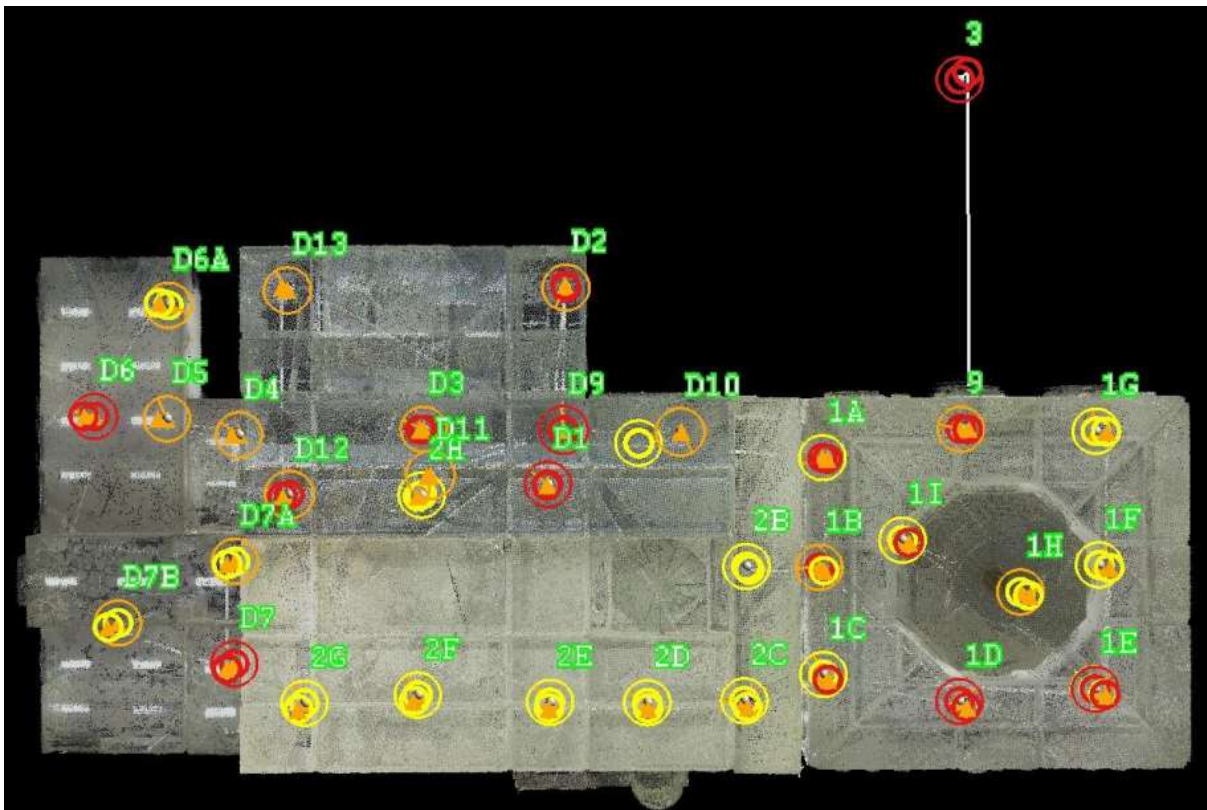


Figure 3.10. TLS Scanner Positions During Internal Scanning.

3.3 Data Processing

In this study, data were collected through two distinct methods: aerial collection via unmanned aerial vehicles (UAVs) and ground collection via terrestrial laser scanning (TLS). In addition, the study utilized a UAV equipped with Pix4D Mapper software for data processing. Both data collection methods employed AutoCAD for data analysis.

It is worth emphasizing that the data processing techniques employed in a study can significantly impact the accuracy and reliability of the research findings. Therefore, it is crucial to ensure that the data processing methods used are appropriate for the research objectives and yield high-quality results.

3.3.1 Processing Aerial Data Acquired by UAV

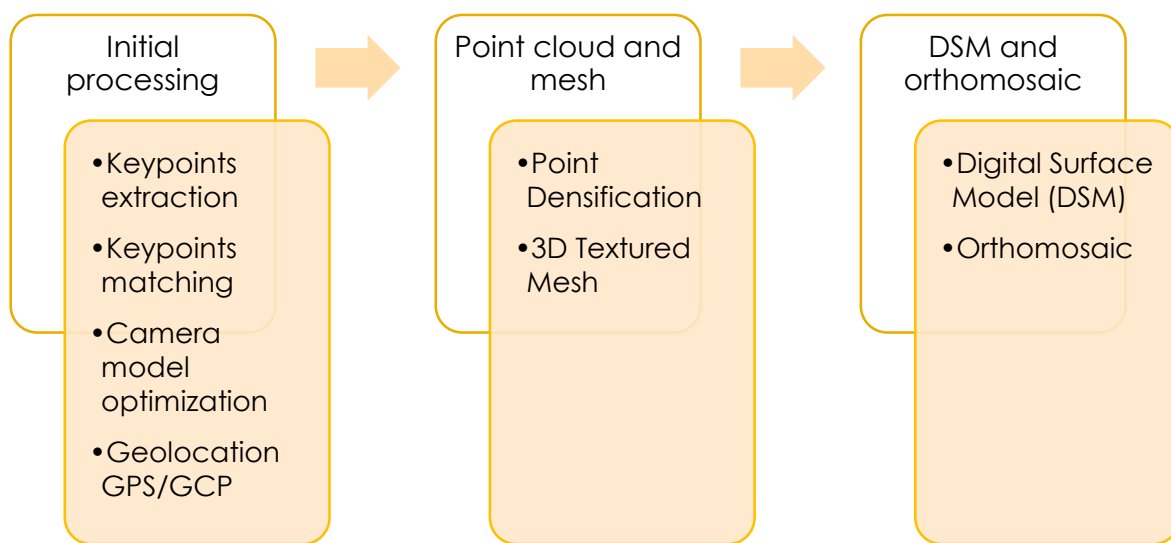


Figure 3.11. Pix4D Mapper Pro processing.

3.3.1.1 Initial Processing

When commencing the initial data processing, Pix4D Mapper software calculates key points on the input images. These key points are then used to identify correspondences between the images. Using the initial correspondences, the software performs an Automatic Aerial Triangulation (AAT) and Bundle Block Adjustment (BBA).

If the initial processing has already been executed and needs to be restarted, the software will utilize the existing key points and image matches to begin the AAT and BBA. However, if the project type has been altered between processing iterations, additional image matches may be computed. This is due to the fact that the matching procedure differs depending on the project type.

3.3.1.2 Point Cloud and Mesh

The number of points generated during the Point Cloud and Mesh creation process in Step 2 can vary depending on multiple factors, including image size, image content, and processing options. As a result, it is difficult to provide an accurate estimate of the exact number of points generated. However, statistical information on the number of points in the Point Cloud can be

gathered and analyzed to provide insight into the overall volume of data generated by this process.

- i. It is challenging to estimate the number of points generated during the Point Cloud and Mesh creation process in Step 2 accurately. However, based on projects that used 15 MP images, it can be inferred that the number of points observed is likely to be considerable.
- ii. To provide more insight into the Point Cloud and Mesh creation process, the following options were utilized during the process:
 - a) Image Scale was set to 1/2, which reduced the size of the image to half its original size.
 - b) Point Density was set to Optimal, which maximizes the number of points generated while maintaining quality.
 - c) The number of matches used was 250 per image, resulting in the creation of 20-50 million points.

The Point Cloud serves as the foundation for generating the 3D Textured Mesh, which consists of a surface constructed using triangles. In the process of generating the 3D Textured Mesh, the vertices of the triangles are strategically placed to minimize the distance between certain points on the Point Cloud and the surface. Additionally, any Processing Area and/or Image Annotation that may have been defined will also be incorporated into the generation of the 3D Textured Mesh.

3.3.1.3 DSM and Orthomosaic

By default, the software selects one Ground Sampling Distance (GSD) automatically. However, users have the flexibility to adjust the resolution to multiples of the GSD as needed.

Noise filtering is used during the Point Cloud generation process to address any noisy or erroneous points. The algorithm corrects the altitude of these points by using the median altitude of the neighbouring points.

The software generates the Digital Surface Model (DSM) in GeoTIFF format by default. For larger projects, the DSM is typically split into multiple tiles, and a separate GeoTIFF file is produced for each tile. The method used for DSM generation can impact the processing time and quality of the results.

The Orthomosaic is also saved in GeoTIFF format by default, and for larger projects, the Orthomosaic is split into multiple tiles, with one GeoTIFF file generated per tile. Users can choose to activate the Merge Tiles option to produce a single Orthomosaic GeoTIFF file by merging the individual tiles. If this option is not activated, the merged Orthomosaic file will not be generated.

3.3.2 Processing Ground Data Acquired by TLS

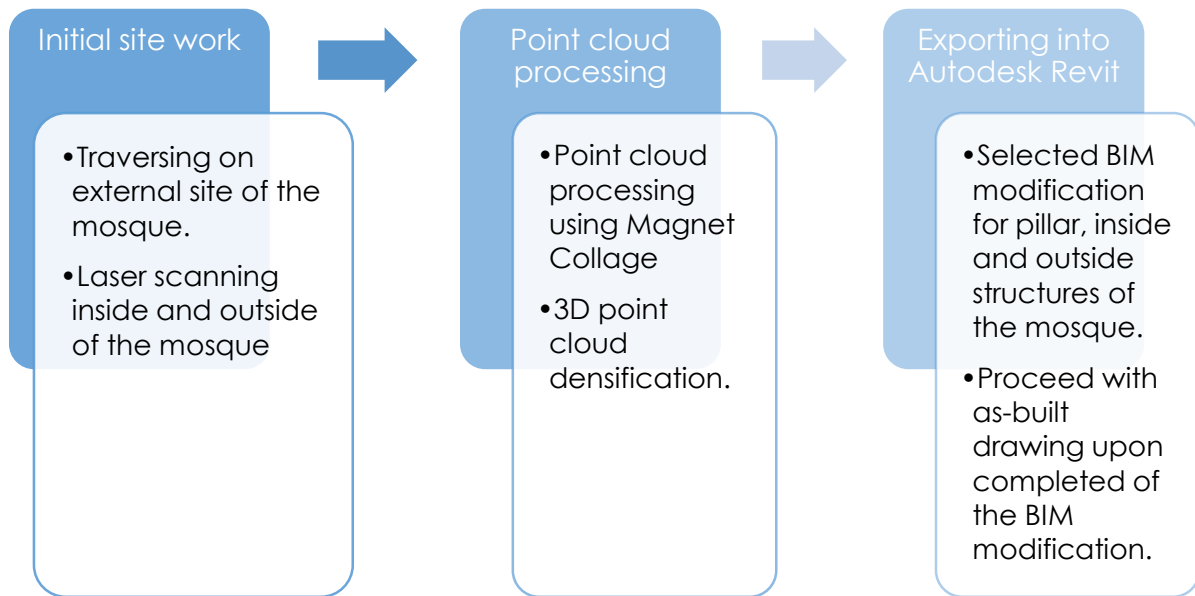


Figure 3.12. Terrestrial Laser Scanning process work flow.

3.3.2.1 Initial Site Work

Before conducting a TLS (Terrestrial Laser Scanning) survey of Alwi Mosque, a traversing process is necessary to establish the coordinate and station points for the scanner. A total of 28 points have been marked for the external site of the mosque, while 32 points have been marked for the internal site. These marking points indicate the locations where the scanner will be positioned during the scanning process.

3.3.2.2 Point Cloud Processing

The Topcon GLS 2000 scanner is equipped with the latest point cloud processing software, called Magnet Collage. All the point cloud data captured during the scanning process has been imported into the software. The data has been categorized into three distinct sites: internal scanning, external scanning, and a combination of both internal and external scans.

3.3.2.3 Exporting Into Autodesk Revit

The combination of internal and external scanning data using TLS has resulted in an impressive 3D mesh model of Masjid Alwi. However, some modifications are required to accurately depict the pillars, windows, doors, and internal structures of the mosque. To accomplish this, the point cloud data has been exported into Autodesk Revit for BIM (Building Information Modeling) modifications. Revit provides advanced tools for creating and refining the 3D model of Masjid Alwi. Once the modifications are complete, an as-built drawing layout plan can be produced, providing detailed dimensions of Masjid Alwi.

3.4 Output

The ultimate result of this project is the integration of both UAV and TLS data of Alwi Mosque into a 3D point cloud format. Additionally, an as-built drawing of Alwi Mosque has been generated to fulfil the research objectives.

4. RESULTS AND DISCUSSIONS

This chapter presents the outcomes of the analysis conducted in this research using Pix4D and Revit software. The research objectives have been successfully achieved, and the results demonstrate the creation of a 3D model of a heritage building using data from UAV photogrammetry and 3D laser scanning through the use of Revit software. In addition, an as-built drawing of the heritage building has been generated using Building Information modelling (BIM) software. Further details regarding the analysis process will be described to produce the final product.

4.1 3D Model of Alwi Mosque, Kangar



Figure 4.1. Data point cloud Alwi Mosque, Kangar.

Figure 4.1 displays the point cloud data obtained from both UAV photogrammetry and 3D laser scanning, which serve as crucial data for generating the as-built drawing of heritage buildings using BIM software. This point cloud data provides detailed measurements of wall thickness, column height, doors, and walls, which can supplement conventionally measured building surveys and hand-measured components. With this data, BIM development can be expedited and become more comprehensive in terms of architecture and structure. Figure 4.2 depicts the 3D model of the exterior of Alwi Mosque, which was generated using this point cloud data.

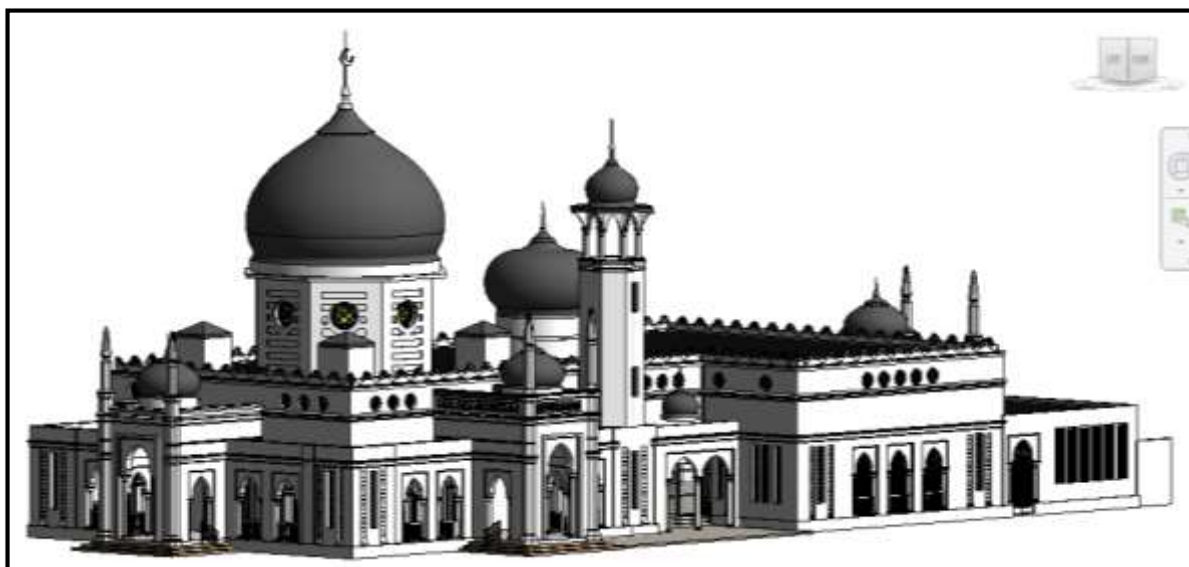


Figure 4.2. 3D model of the exterior for Alwi Mosque, Kangar.

4.2 Building Information Architecture

The Alwi Mosque was constructed in 1931 with a wall thickness of 37.50 centimetres. The building was later expanded to the right of the mosque, with the new walls having thicknesses of 25.00 and 30.00 centimetres. The thickness of the mosque walls can be clearly observed in Figure 4.3, where the red colour indicates a wall thickness of 37.50 centimetres, yellow represents 30.00 centimetres, and green represents 25.00 centimetres.

Alwi Mosque, comprises 33 concrete columns, including 16 round columns with a diameter of 32 cm, and 17 rectangular columns, with 8 columns measuring 30 x 30 cm, 3 columns measuring 50 x 50 cm, 3 columns measuring 50 x 37 cm, 2 columns measuring 15 x 25 cm, and 1 column measuring 15 x 15 cm. Additionally, 117 Roman pillars are utilized for the entrance and corridor. The thickness of the mosque's walls varies, with a red colour indicating a thickness of 37.50 cm, yellow indicating 30.00 cm, and green indicating 25.00 cm. The information obtained from the point cloud data has facilitated the development of a detailed as-built drawing of the mosque, including wall thickness and the height of columns, doors, and walls. In addition, the 3D model generated using the UAV photogrammetry and 3D laser scanner data in Revit software has allowed for modifications to the structure of the mosque, resulting in a comprehensive and accurate representation of the building.

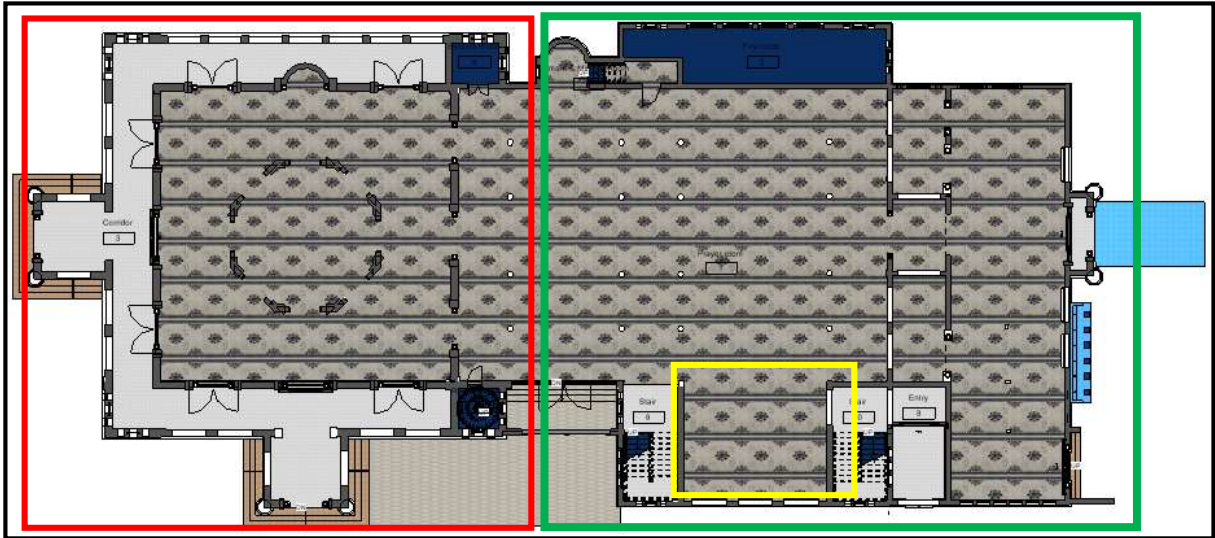


Figure 4.3. The thickness wall for red is 37.50 cm, a yellow are 30.00 cm and a green are 25.00 cm.

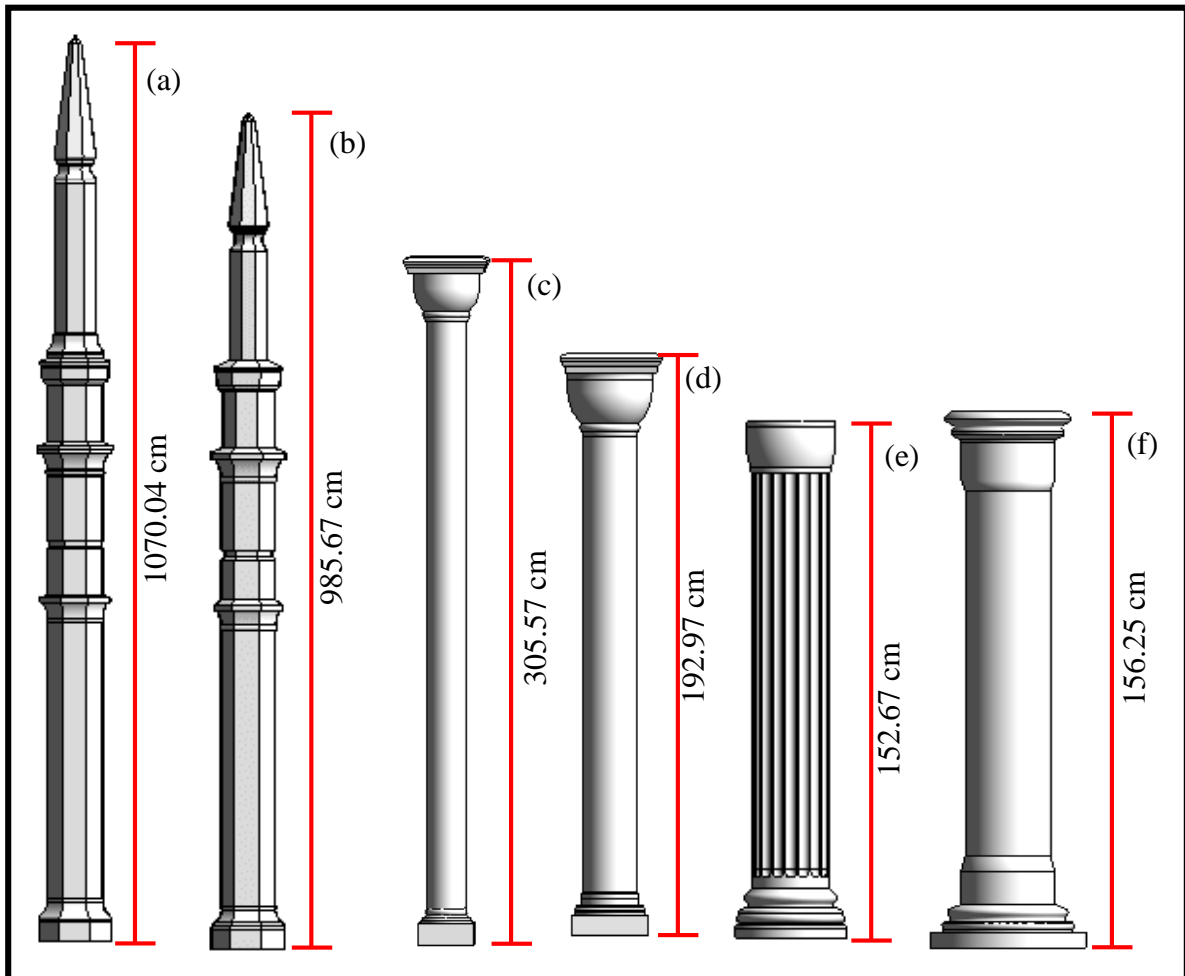


Figure 4.4. Type roman pillars that use for Alwi Mosque and height for each pillar.

The Alwi mosque is further equipped with 12 entrances, 115 windows, and 2 stairs leading to the second floor. Among the windows, 84 are of classic style, 15 are colonial and 16 are fixed windows. A depiction of the various types of windows used in the mosque is illustrated in Figure 4.5. The prayer room covers a floor area of 987 square meters, comprising 811 square meters on the ground floor and 176 square meters on the second floor. Additionally, the corridor spans an area of 158 square meters. The entrance to the mosque predominantly comprises glass doors, with 3 wooden doors interlinking rooms 1, and 2 and the door tower and 1 aluminium door located at the rooftop. Further details of the architectural aspects at Alwi mosque are presented in Table 4.1.

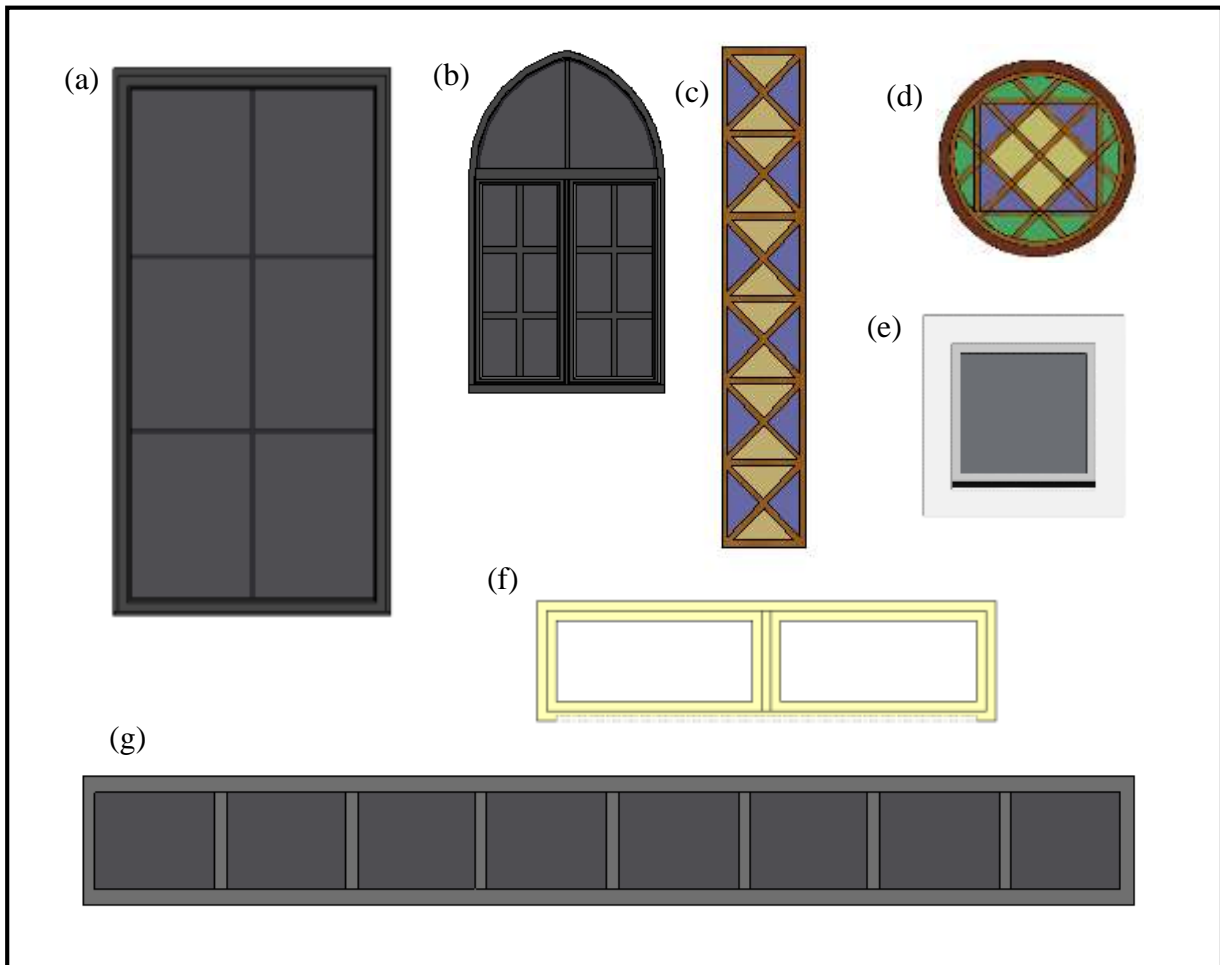


Figure 4.5. The types of windows in the Alwi Mosque.

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Table 4.1 Lists of the architectural information available at Alwi Mosque

No.	Architecture	Total	Size
1	Wall (thickness) <ul style="list-style-type: none"> • 37.50 cm • 25.00 cm • 30.00 cm 		
2	Columns <ul style="list-style-type: none"> • Concrete <ul style="list-style-type: none"> (a) Round <ul style="list-style-type: none"> ➤ 32.00 cm diameter (b) Rectangular <ul style="list-style-type: none"> ➤ (a) ➤ (b) ➤ (c) ➤ (d) ➤ (e) • Roman <ul style="list-style-type: none"> ➤ (a) (<i>refer Figure 4.4</i>) ➤ (b) (<i>refer Figure 4.4</i>) ➤ (c) (<i>refer Figure 4.4</i>) ➤ (d) (<i>refer Figure 4.4</i>) ➤ (e) (<i>refer Figure 4.4</i>) ➤ (f) (<i>refer Figure 4.4</i>) 	16 8 3 3 2 1 2 4 15 88 6 2	30 X 30 cm 50 X 50 cm 50 X 37 cm 15 X 25 cm 15 X15 cm 1070.04 cm 985.67 cm 365.57 cm 192.97 cm 152.67 cm 156.25 cm
3	Door <ul style="list-style-type: none"> • Glass <ul style="list-style-type: none"> ➤ Main Door ➤ Sliding ➤ Double • Wooden <ul style="list-style-type: none"> ➤ Single <ul style="list-style-type: none"> ▪ Door tower ▪ Door room ➤ Double • Aluminum 	1 5 6 1 1 1	248 X 536 cm 209.00 X 177.50 cm 200.00 X 250.00 cm 203 X 76 cm 200 X 93 cm 215 X 110 cm 200 X 80 cm
4	Window <ul style="list-style-type: none"> • Colonial window <ul style="list-style-type: none"> ➤ (a) (<i>refer Figure 4.5</i>) ➤ (b) (<i>refer Figure 4.5</i>) • Classic <ul style="list-style-type: none"> ➤ (c) (<i>refer Figure 4.5</i>) ➤ (d) (<i>refer Figure 4.5</i>) • Fixed <ul style="list-style-type: none"> ➤ (e) Single glass (<i>refer Figure 4.5</i>) ➤ (f) Double glasses (<i>refer Figure 4.5</i>) ➤ (g) Eight glasses (<i>refer Figure 4.5</i>) 	7 8 20 5 51 8 4 1 3 6 1 1	176.22 X 324.27 cm 209.61 X 120.00 cm 265.89 X 44.31 cm 135.50 X 44.31 cm 75 cm in diameter 130 cm in diameter 50 X 50 cm 205 X 62 cm 290 X 283 cm 200 X 250 cm 160 X 283 cm 65 X 535 cm

4.3 As-Built Drawing of Heritage Buildings

Figure 4.6 (a) & (b) displays the plan of Alwi Mosque generated using Revit software. The plan exhibits the building's sides and floor plans, including the 3D shape of the mosque. The plan provides detailed information about the mosque's height and width. The individual side and floor plans are available in the appendix. The plan can aid various stakeholders, including the Fire Department, construction companies, and surveyors.

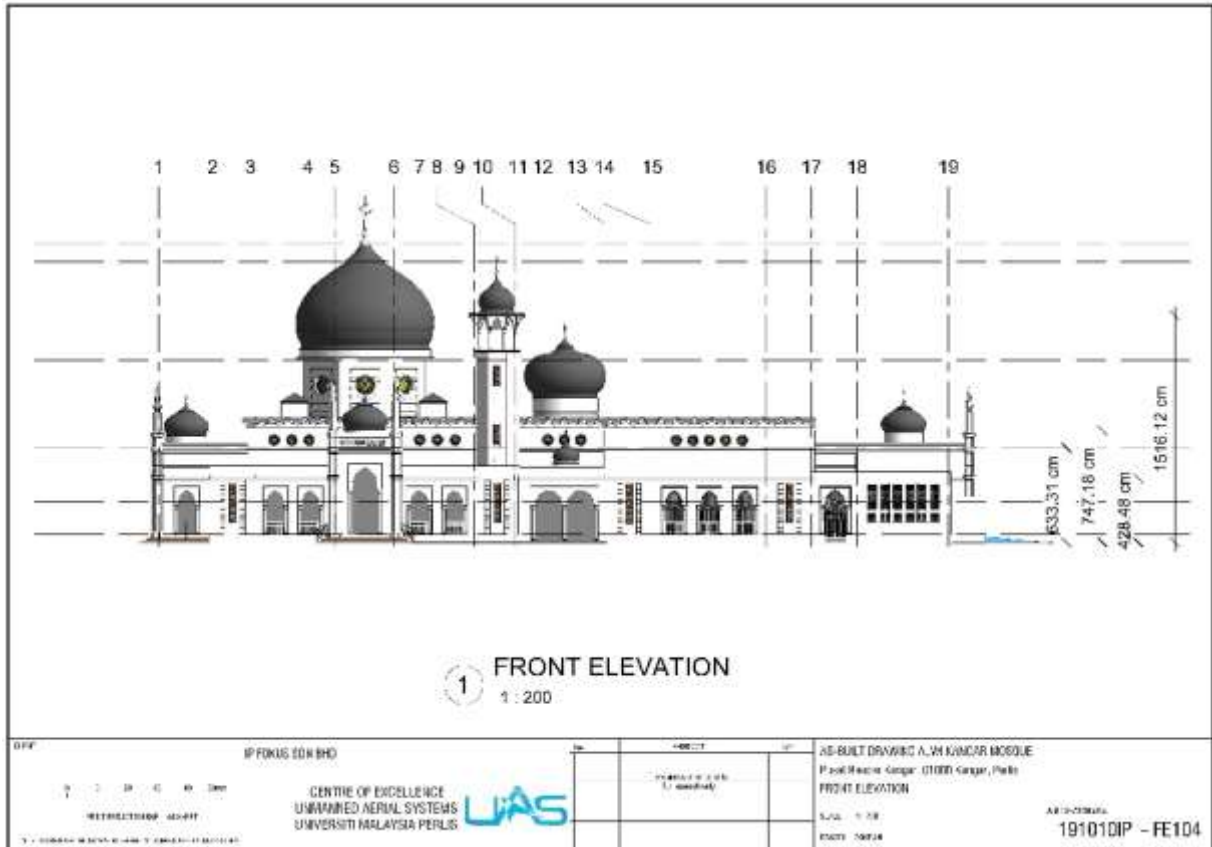


Figure 4.6 (a). Plan processed using Revit software.

TECHNICAL REPORT

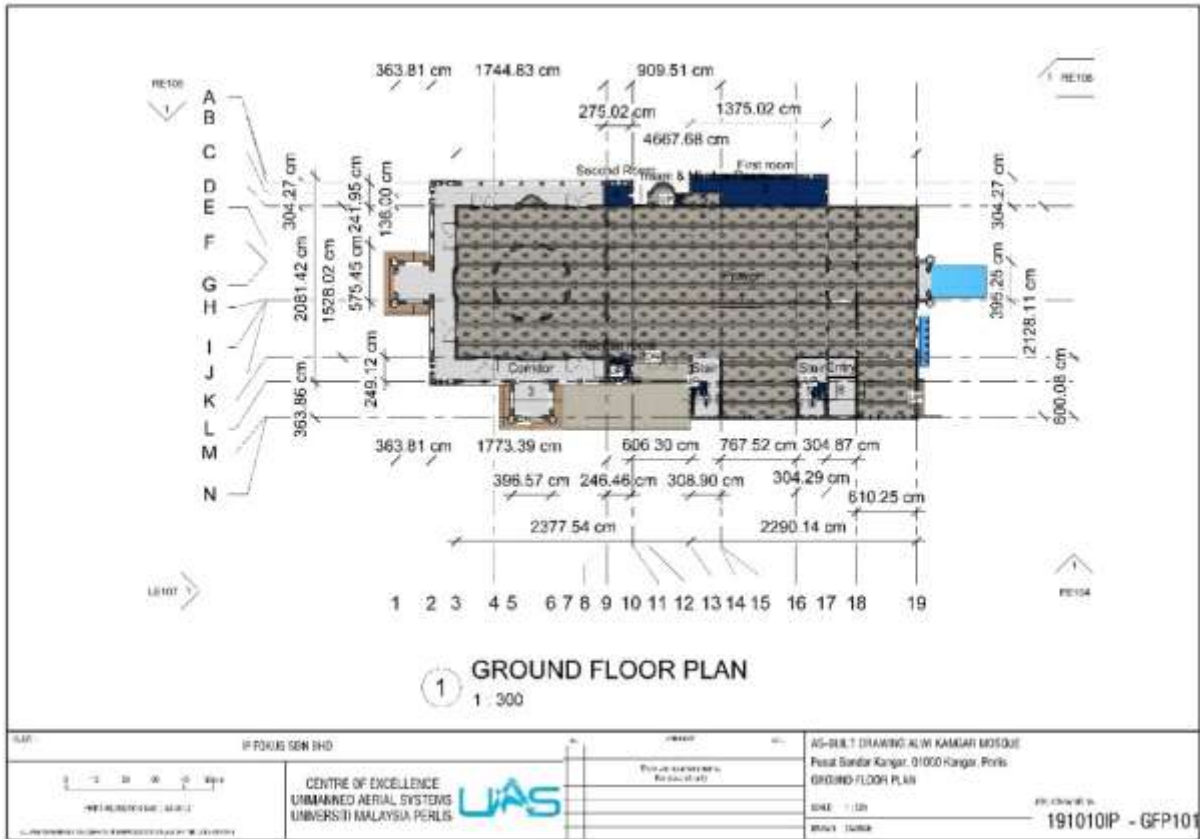


Figure 4.6 (b). Plan processed using Revit software.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In conclusion, this research successfully achieved its main objective of generating a new as-built drawing of a heritage building using modern technologies such as 3D laser scanning, UAV photogrammetry, and BIM software. The 3D model generated from the data collected by UAV photogrammetry and 3D laser scanning was combined using GCP, resulting in comprehensive point cloud data that helped develop the BIM model. The BIM model was used to extract 2D information for drawing sheets, plans, and sections that were supplemented with high-level detailing. The model also contained metadata that facilitated basic scheduling activities for walls, windows, doors, and floor areas.

The analysis in this research was focused on the Alwi Mosque's prayer area, which helped determine wall thickness, window and door sizes, area, total column, and design differences. The research concludes that the 3D model can help in maintaining the survey brief as it continuously evolves and provide insight, understanding, and meaningful information related to heritage buildings. The research findings can also help planners and engineers with restoration and refurbishment purposes.

Based on the success of this research, it is recommended that future studies explore the application of these modern technologies and BIM workflows in other heritage buildings. Moreover, it is crucial for consultants involved in the project chain to have relevant experience in BIM to ensure the success of the project. The as-built drawing layout plan can be used by various parties such as the Fire Department, Construction, and surveyors for their respective purposes.

5.2 Recommendations

Based on the findings of this research, there are several recommendations that could be useful for future studies:

1. This research provides support for departments or agencies involved in the management, maintenance, and research of cultural heritage, such as archaeologists, conservators, and other cultural heritage professionals.
2. For future studies, the use of computer-aided design (CAD) drawings could assist architects in identifying the significance of a building.
3. The results of this research provide valuable information for architects to quantify conservation efforts, and repeating surveys could assist conservators in determining appropriate protection measures.
4. It is recommended to incorporate more advanced technology, such as virtual reality, into the BIM workflow to enhance the visualization and understanding of the heritage building.
5. Further research can explore the possibility of using machine learning and artificial intelligence algorithms to automate the process of data analysis and modelling.

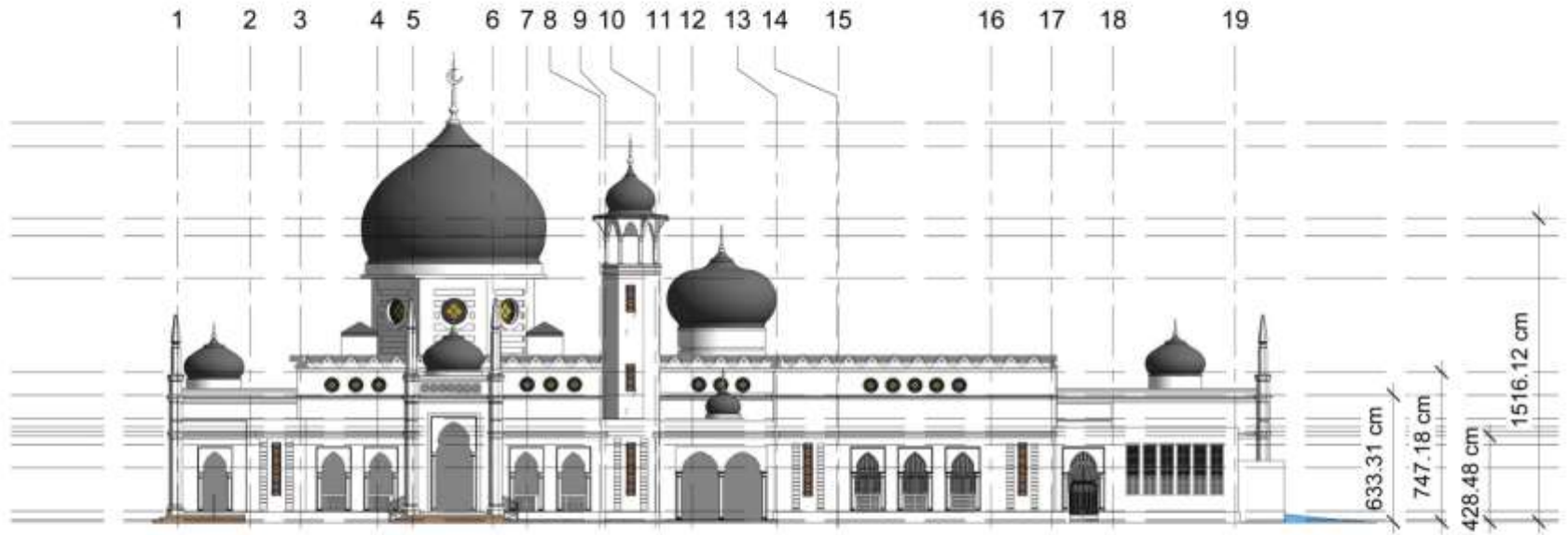
6. It is suggested to conduct comparative studies with other heritage buildings to determine the effectiveness and efficiency of the BIM workflow in heritage building documentation and management.
7. The BIM model generated in this research can be used as a baseline for future maintenance and renovation projects. It is recommended to update the model regularly to reflect any changes made to the building over time.
8. The use of Ground Control Points (GCPs) should be further explored to improve the accuracy of the 3D models generated from UAV photogrammetry and 3D laser scanning.
9. Collaboration with local communities and stakeholders should be encouraged to gather additional information and insights about the heritage building.
10. It is recommended to adopt an interdisciplinary approach involving experts from different fields, such as architecture, engineering, archaeology, and cultural heritage, to ensure a holistic and comprehensive understanding of the heritage building.

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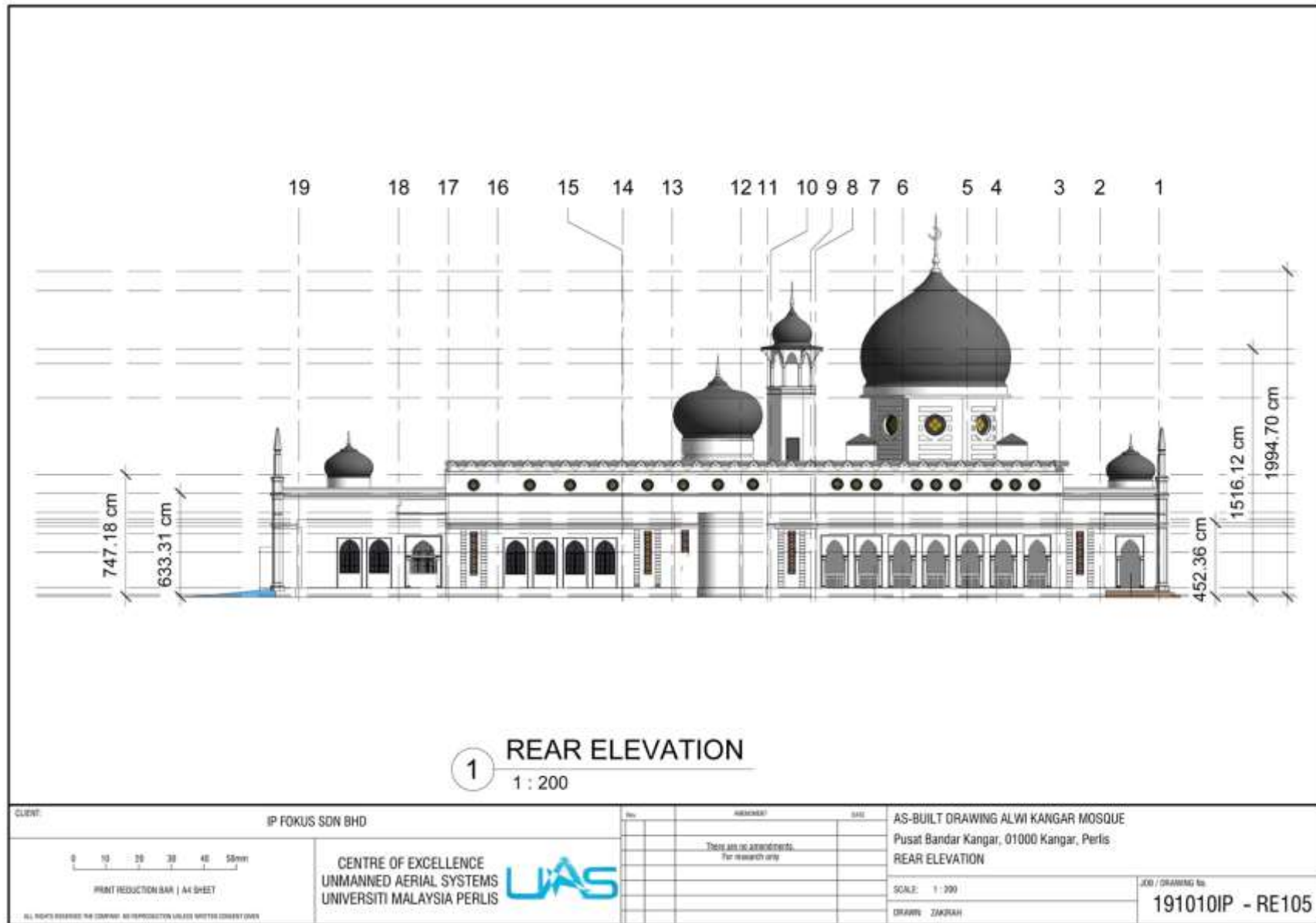
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APPENDIX

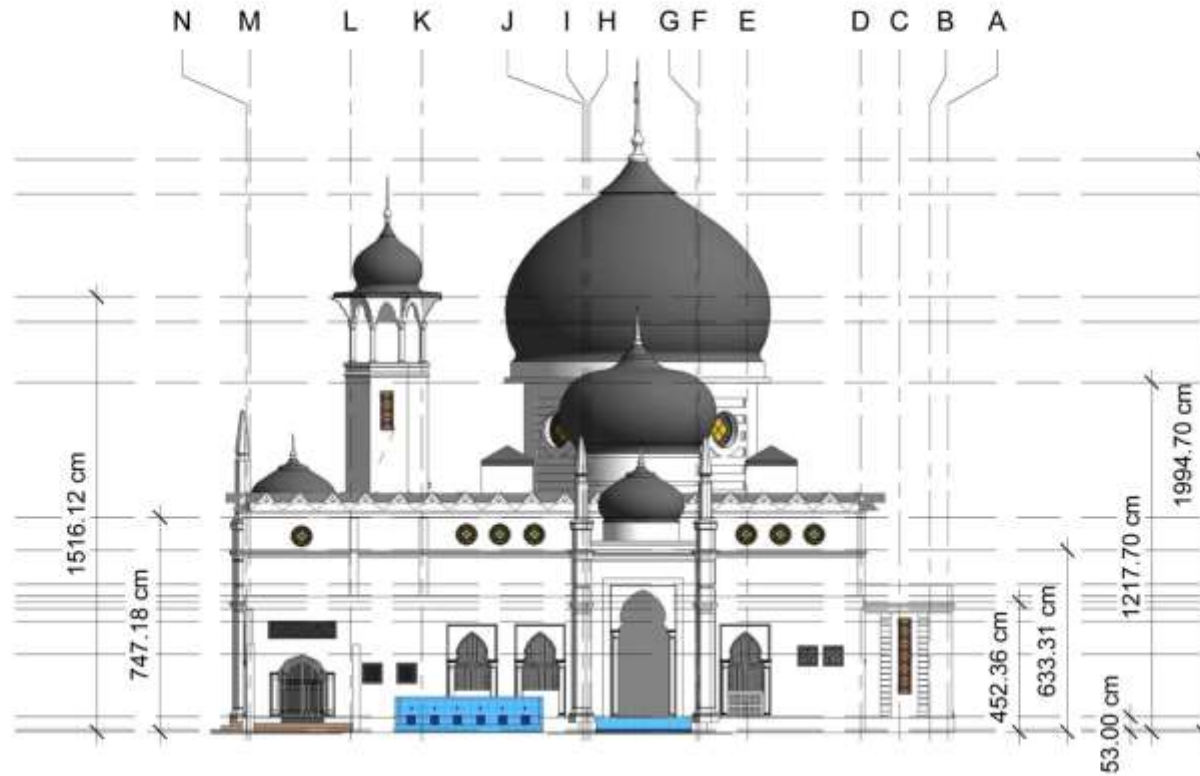


1 FRONT ELEVATION
1 : 200

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		<p>THIS IS A UNCLASSIFIED DOCUMENT For research only</p>			Pusat Bandar Kangar, 01000 Kangar, Perlis	191010IP - FE104
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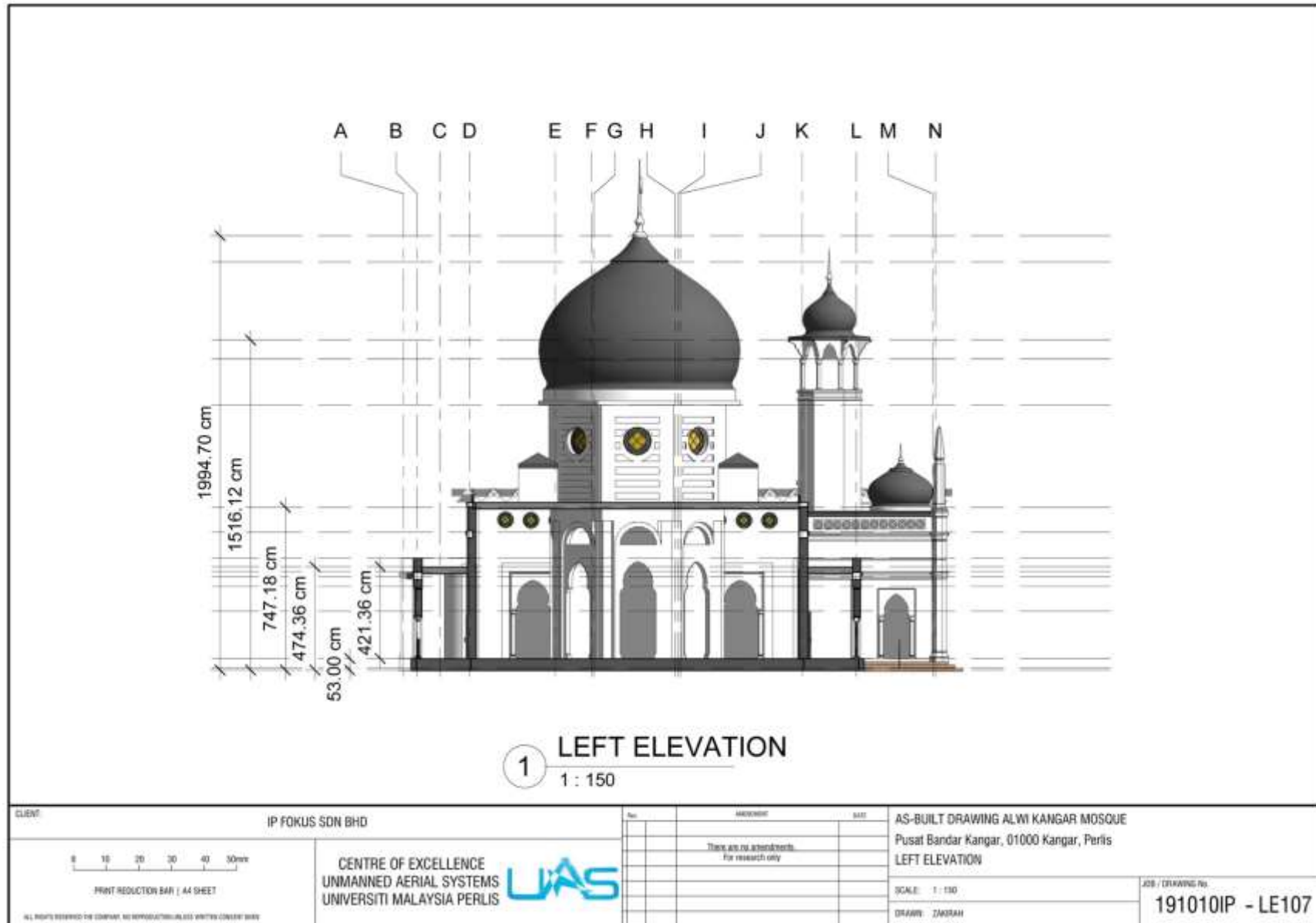


TECHNICAL REPORT

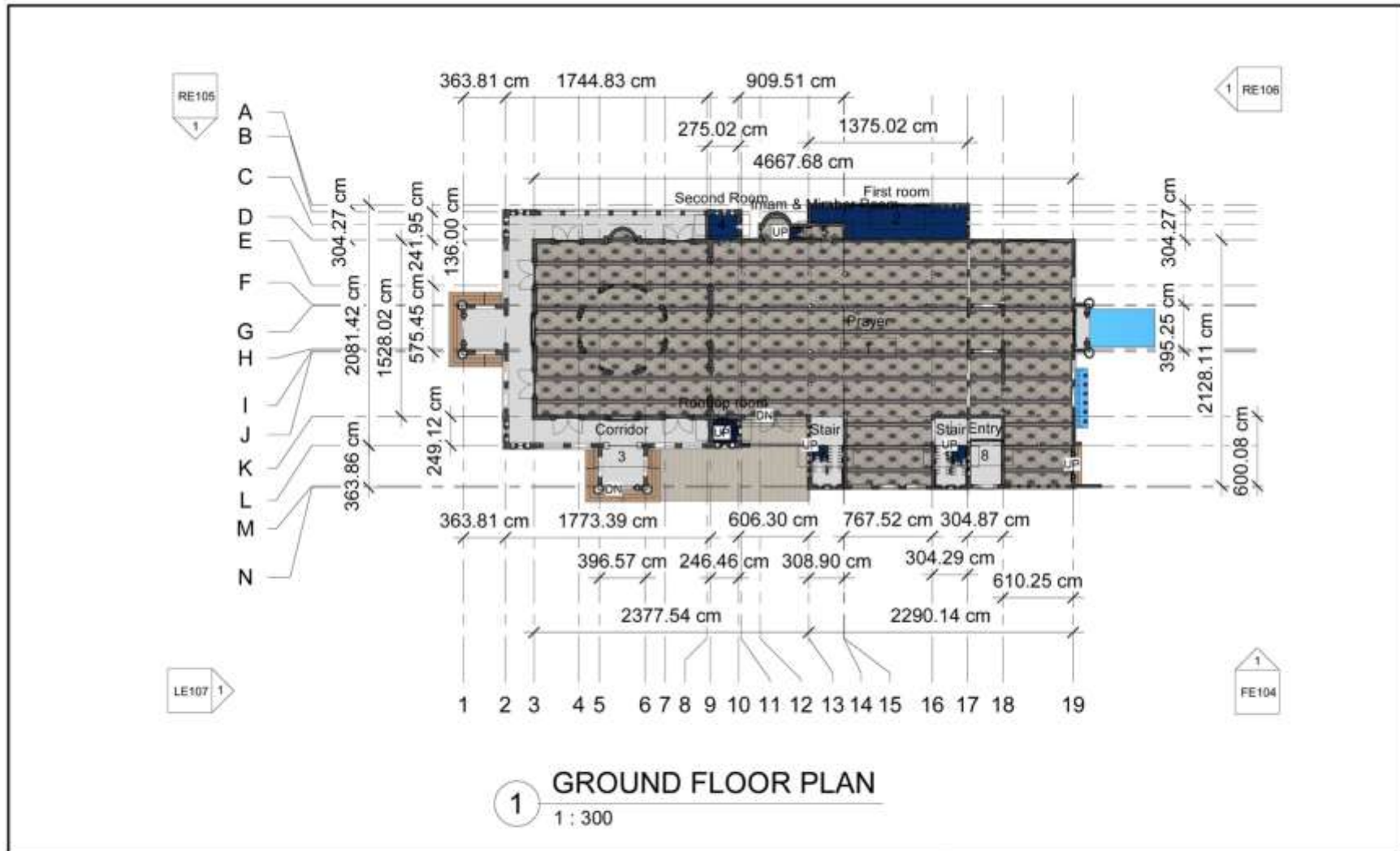


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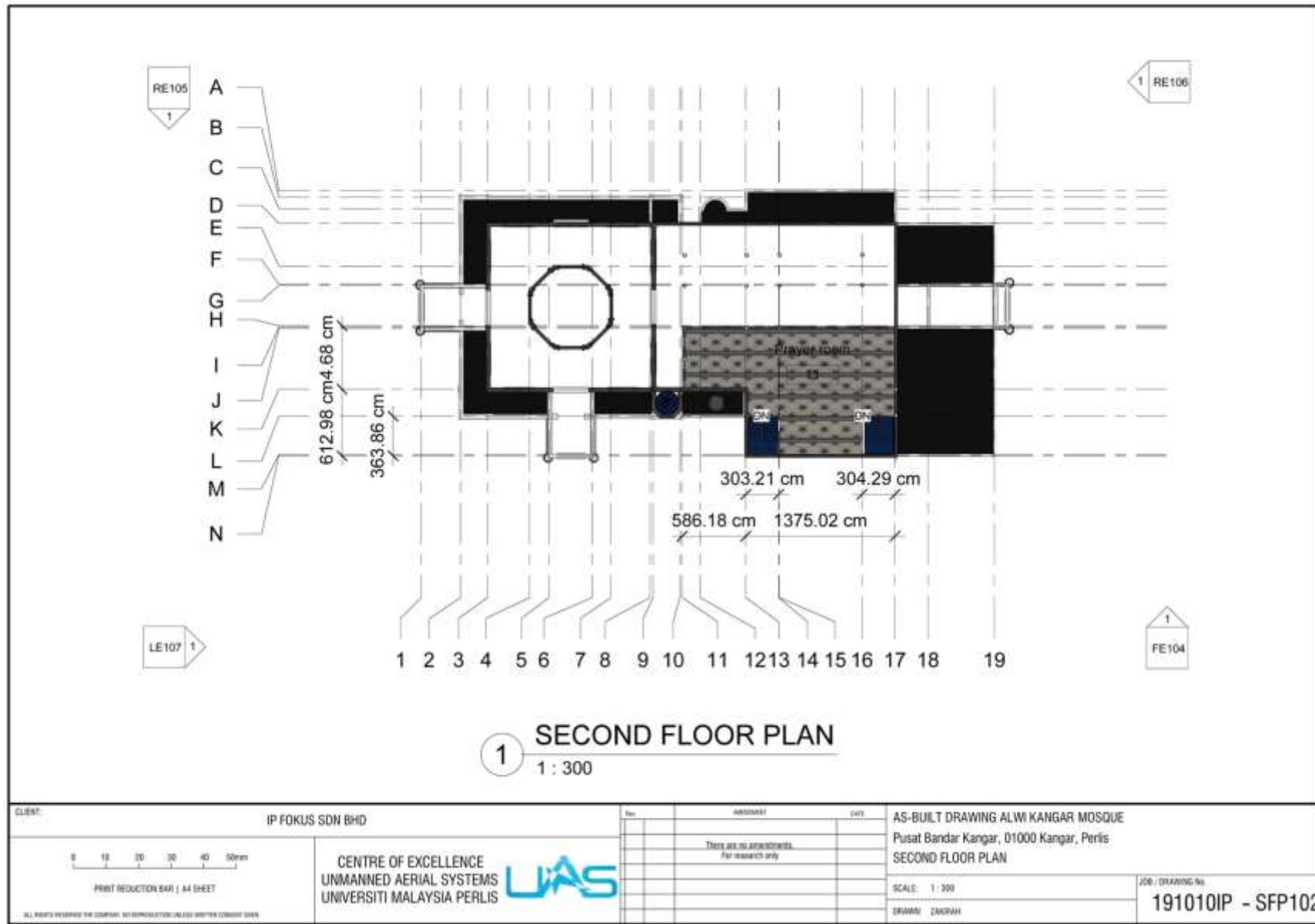
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						RIGHT ELEVATION	
<p>CENTRE OF EXCELLENCE UNMANNED AERIAL SYSTEMS UNIVERSITI MALAYSIA PERLIS</p>						SCALE: 1 : 150	
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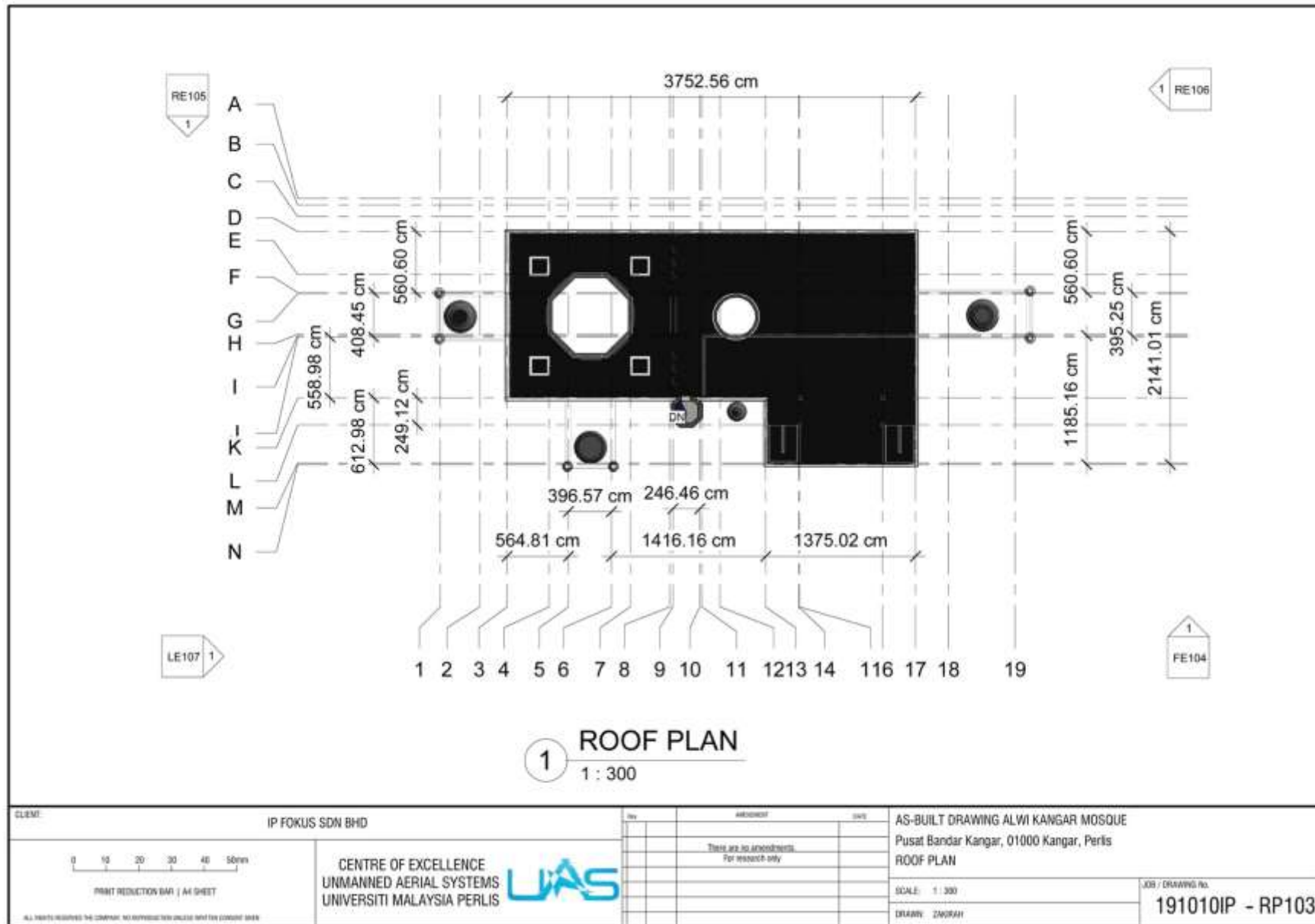
TECHNICAL REPORT



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SCALE: 1 : 300				JOB / DRAWING No.: 191010IP - GFP101	
DRAWN: ZAKRIAH					



TECHNICAL REPORT



1 ROOF PLAN
1 : 300

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Scene at the Site Area

Rejukan : TUSB/Projek/2017(4)(2)

Tarikh : 30 April 2018

Prof Dr Hazry Bin Desa

Fakulti Teknologi Kejuruteraan,

Universiti Malaysia Perlis (UniMAP), Aras 1, Blok S2,

Kampus UniCITI Alam, Sungai Chuchuh,

Padang Besar 02100 Perlis

Tuan,

PERLANTIKAN SEBAGAI PEGAWAI PENYELIDIK BAGI PROJEK 'SPONSORED RESEARCH TUSB'

Dengan segala hormatnya, saya merujuk kepada perkara di atas.

2. Adalah dimaklumkan bahawa, pihak TUSB ingin melantik tuan sebagai pegawai penyelidik kepada projek "The Development of 3D Laser Scanner And UAV Imaging Data Processing Method For Geospatial Database And Conservation of Heritage Building in Malaysia", yang telah dianugerahkan kepada TUSB oleh IP Fokus Sdn Bhd.

3. Maklumat perlantikan Kontrak Penyelidikan adalah seperti berikut:

Skop	: Melakukan aktiviti berkaitan penyelidikan bagi pihak TUSB
Jumlah Peruntukan	: RM 110,500.00
Tarikh Lantikan	: 12 April 2018
No Projek	: 2018/04/0010

4. Pihak TUSB mengucapkan tahniah dan berharap pihak Tuan dapat melaksanakan dan menyiapkan projek di atas dalam tempoh masa yang ditetapkan.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"

"Saya Berubah, Kita Mengubah"

Yang benar,


Dr. Zunkid Ibrahim
Ketua Pegawai Operasi
Technopreneur At UniMAP Sdn. Bhd.

TECHNOPRENEUR@UniMAP

Appointment Letter