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# Roof Inspection Using Drone at Melaka Islamic Museum

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**Abstract**

Abandonment of heritage buildings is not a new phenomenon. Heritage building structures usually have structural weaknesses because of being exposed to the weather over a long period of time. Infrequent maintenance can increase the risk of material failure at any time. Building inspection is done to assess the condition of a structure, especially the roof. The method of manual roof inspection is an approach that has been done for a long time to ensure that a building can still be used to this day. With some constraints in manual roof inspection, drone inspection is a new method and can reduce safety risks for inspectors. The current study used UAV technology in roof inspections at the Melaka Islamic Museum. The study was conducted by recording images through Pix4Dmapper. The orthomosaic images were taken to be analyzed through Global Mapper software. All defects were successfully recorded using UAV inspection technology and a defect scale according to the Condition Survey Protocol 1 (CSP1) Matrix reference was successfully produced. In addition, all the defects recorded can help the museum maintenance team with conservation and maintenance work.

## 1. Introduction

Development is crucial for a country's economic, social, and administrative growth. To ensure stable, secure, and aesthetically pleasing structures, maintaining essential qualities, including the roof, is essential. A roof inspection is a way to protect and prevent the roof from experiencing leaks, damage, cracks, and dirt. A roof inspection is a method of identifying problems that need to be fixed and objects that are out of position. Roof inspections should be done at least once a year to avoid problems. The inspection of the roof on the building is to ensure it is in its original form and when it is noticed that there is a leak coming from the ceiling, the building suffered damage because of storms and heavy rains [1]. There are several ways to do a roof inspection such as manual inspection and digital by using a drone.

A roof inspection examines every component of a roof, including its structural support, the stability of the roofing material, and if there are any signs of damage throughout the ceiling and walls. There are a few signs of a roof that may be sagging which are cracked, splintered, sagging ceilings, missing collar ties or rafter ties, and exterior walls that are tilting or leaning [1]. Roofs located in windy areas are subject to upward pressure that blows the roof edges and causes the membrane or roof system to detach. According to the InterNACHI

Residential Standards of Practice, the inspector shall check from ground levels or eaves such as the roof covering, flashings, skylights, chimney, and other roof penetrations, and the general structure of the roof [2].

There are a few benefits of using drone technology such as a brief review and assessment of the situation when using a drone to do an inspection. By employing a drone, a clear and detailed snapshot of the defect has been recorded from the camera attached to the drone itself, and it may cut the time it takes to inspect a building and the degree of safety is high since it is safe. Furthermore, it can provide access to difficult-to-reach regions, as well as avoid maintenance planning and maximize output [3]. This study is focused on how efficient work using unmanned aerial vehicles can reduce the high risk while doing the inspection. Recent technological advances have enabled the construction of a wide range of modern unmanned aerial vehicles for a variety of applications. Unmanned aerial vehicles (UAVs) are aircraft that do not have a human pilot on board. Recent technological advances have enabled the construction of a wide range of modern unmanned aerial vehicles for a variety of applications [4]. UAV is an alternative way to replace the conventional application method of high-rise building maintenance work that exceeds 7 floors.

Roof construction is crucial for a building's stability, strength, durability, weather resistance, fire resistance, thermal insulation, and aesthetics. Regular maintenance is essential for maintaining a roof. The Melaka Islamic Museum, a historical building, requires UAV inspections due to its historical status. The Malacca Islamic Museum aims to study Islam's arrival in Melaka, and its growth, and showcase Islamic-related documents while maintaining Malacca's historic role as a center for spreading Islam and developing Islam in Malaysia. Conventional inspections are risky for historic buildings, as they lack structural strength. UAV technology can help detect defects in swampy, forest, and tall buildings. Understanding common roof defects and their areas can aid in detecting and fixing problems.

## 2. Materials And Methods

Roof inspection at Malacca Islamic Museum involved advanced aviation technology, UAV, and Pix4DMapper software, identifying damage and enhancing safety. A detailed explanation of the methodology in the current work was discussed in the next subsection.

### 2.1 Drone

Before taking off, ensure the area is clear of people and objects, ensure the drone's battery is fully charged, and have all necessary accessories. Maintain a good view of the sky to avoid potential hazards. Familiarize yourself with drone flying to perform basic maneuvers and avoid crashes [5]. Set off and land drones far from people, buildings, or power lines. Use empty sports complexes at midday. Maintain constant speed and altitude, gradually increasing throttle. Ensure flat surfaces and consider getting a landing pad. Check local laws and keep an eye on public property [5] Drones should hover safely for 20-30 seconds to save time for returning home if needed during flight [5].

### 2.2 Assessment Scale

Table 1 shows the CSP1 Matrix scale used by surveyors to assess building flaws and their severity. It involves condition and priority assessment, with each defect assigned a condition and priority grade. The overall score for each flaw is calculated by multiplying each rating by the number of defects. To avoid incorrect interpretations, maintenance standards on defect definitions must be allocated carefully for each grade. Addressing red-coded deficiencies is crucial, as they can impact the entire roof structure and expose building users to risk. The CSP1 Matrix concept was applied for this inspection to generate an accurate and exact result [6]. Table 2 shows the matrix assessment used for this study case.

**Table 1** *Condition assessment protocol 1 and priority assessment [6]*

| Condition Assessment Protocol 1 | | |
|---|---|---|
| Condition | Scale value | Description |
| 1 | Good | Minor servicing |
| 2 | Fair | Minor repair |
| 3 | Poor | Major repair/Replacement |
| 4 | Very Poor | Malfunction |
| 5 | Dilapidated | Damage/Replacement of Missing Parts |
| Priority assessment | | |
| Priority | Scale value | Description |
| 1 | Normal | Functional; cosmetic defect only |
| 2 | Routine | Minor defect, but could become serious if left unattended |
| 3 | Urgent | The serious defect does not function at an acceptable standard |
| 4 | Emergency | Element/ structure does not function at all; or presents risks that could lead to fatality and/ or minor injury. |

**Table 2** *Matrix assessment [6]*

| Scale | | Priority assessment | | | |
|---|---|---|---|---|---|
| | | E 4 | U 3 | R 2 | N 1 |
| Condition assessment | 5 | 20 | 15 | 10 | 5 |
| | 4 | 16 | 12 | 8 | 4 |
| | 3 | 12 | 9 | 6 | 3 |
| | 2 | 8 | 6 | 4 | 2 |
| | 1 | 4 | 3 | 2 | 1 |

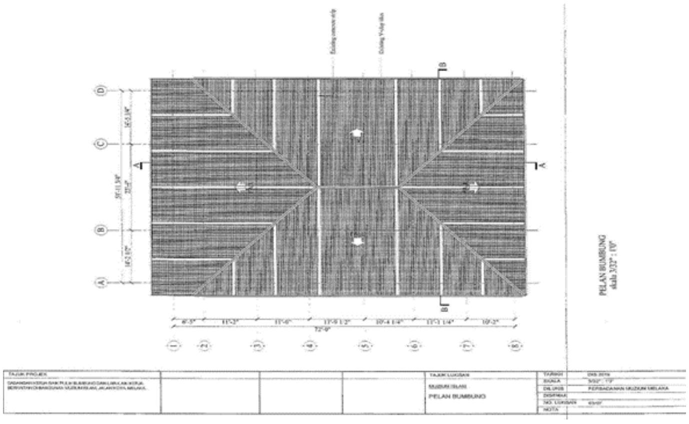
## 2.3 Data Collection

DJI Phantom 4 Pro was being calibrated using the DJI Go software to make sure it was stable and accurate before launch. Then link the UAV with Pix4DCapture and state the area that needs to be inspected, which is the roof of the Melaka Islamic Museum as shown in Fig. 1. The images that have been captured from the drone are combined into full images of a roof and converted into a drawing using AutoCAD software. Every image was processed and analyzed using sections divided into grids as shown in Fig. 1(b). To gain a clearer image of any damage occurring, a more extensive study is undertaken at any defective or defective spot.

Data Image Processing is done after the image on the roof is taken and recorded using the Phantom 4 Pro UAV drone. The images that were taken during the UAV flight were transferred from the drone into the computer and then processed using photogrammetry methods that have a lower cost than image capture using a tool from an airplane. A complete image covering the entire roof plan of the Melaka Islamic Museum Building can be obtained using the Photogrammetry software method which is Pix4DMapper. Pix4DMapper has a function that automatically shows the center of the image on Google Maps. The image needs to be uploaded to Pix4DMapper and the location of the center of the image by GPS provides information about the area involved in the image processing of the roof section to produce a quality and clearer image [7].


(a)


(b)



(c)

**Fig. 1** *(a) Area taken from the roof (b) Drone's route on the roof (c) Roof plan*

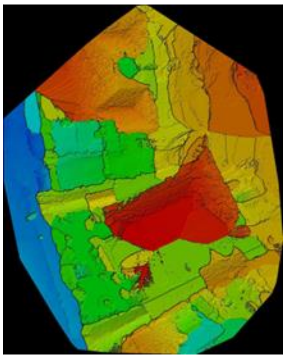
## 3. Results and Discussion

This chapter presents and analyzes research results on producing an orthophoto image using the UAV method for roof conditional assessment at the Melaka Islamic Museum. The study aims to identify defects and classify them using the Condition Survey Protocol 1 (CSP1) Matrix. The results provide a clear comparison between UAV and manual inspection methods.

### 3.1 Image Processing

The site shot must be converted into an image version through a further step to effectively portray the roof construction fault. The first step in this procedure is to upload the photos as a single image to Pix4DMapper, where it can be viewed for defect identification. The image needed to be zoomed in to show the defect, and the brightness and contrast were adjusted to improve the image's outcome. The time to fly the UAV at Islamic Museum Melaka is 3 minutes while the altitude to fly the UAV for the museum is 30 meters. Fig. 2 shows the result of the roof image processing using the Pix4DMapper application of Orthomosaic and the corresponding sparse Digital Surface Model (DSM) before densification.

**(a)**



**(b)**

**Fig. 2** *(a) Orthomosaic and (b) the corresponding sparse Digital Surface Model (DSM) before the densification*

## 3.2 Condition Assessment

The inspection form includes roof components requiring examination at condition and priority levels 1-5. Condition and priority assessments are also included, ensuring accurate calculations on the CSP1 Matrix. These evaluations are crucial for determining the roof's damage types. Table 3 is an inspection form on the roof that has been modified in accordance with the CSP1 Matrix. After analysis, most of the components on the roof of the Malacca Islamic Museum are at levels 1 and 2 for both severity of damage and priority assessment.

**Table 3** *Example of presenting data using a table*

| Severity of damage assessment for roof | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: 22/2/2023 | | | | | | | | Time: 5.20 p.m. | | | |
| Type of roof | Component | Severity of damage | | | | | Priority Assessment | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Hip roof | Roof structure | / | | | | | / | | | | |
| | Finishing | | / | | | | | / | | | |
| | Insulation | / | | | | | / | | | | |
| | Flashing | / | | | | | / | | | | |
| | Gutter | / | | | | | | / | | | |
| | Rainwater-channel | / | | | | | | / | | | |
| | Gable | / | | | | | / | | | | |
| | Ridge | / | | | | | / | | | | |

Following the scoring of each flaw, the total roof rating is computed, which summarizes the roof's condition. The whole roof rating is calculated by multiplying the scores of each defect. The CSP1 Matrix includes an image box, an imperfect plan tag, and an executive summary for reporting purposes as shown in Table 4. According to the results, most of the damage is minor flaws or small defects, and all the Matrix results are green, indicating little damage and not serious. Considering the museum is currently undergoing maintenance, there is no damage that poses a threat to the building's occupants. Furthermore, most of the minor damage was noticed in specific spots such as under trees, rainwater drainage, and towards the end of the roof where there is minimal space for plants and moss to grow.

**Table 4** *Defect analysis*

| Defect | Location |
|---|---|

| Condition | Priority | Matrix | Color |
|---|---|---|---|
| 2 | 1 | 2 | |

Element/ components: Roof pieces

Defect details: Displacement

Required action: Put the roof pieces back in place

| Condition | Priority | Matrix | Color |
|---|---|---|---|
| 2 | 2 | 4 | |

Element/ components: Roof pieces

Defect details: Humidity

Required action: Replace the new roof tiles

| Condition | Priority | Matrix | Color |
|---|---|---|---|
| 1 | 2 | 2 | |

Element/ components: Roof

Defect details: Plant growth and moss

Required action: Uproot the plant

| Condition | Priority | Matrix | Color |
|---|---|---|---|
| 1 | 2 | 2 | |

Element/ components: Gutter

Defect details: Clogged drainage by wood and dried leaves

Required action: cleaning works according to schedule

## 3.3 Comparison Between UAV Technology with Conventional Inspection

Aerial surveys provide precise site data, while drones automate inspections, making them more efficient for architectural and engineering design experts. Table 5 is a brief comparison of fundamental differences between drone inspections and physical inspections.

**Table 5** *Comparison between UAV and conventional inspection*

| Aspects | UAV | Conventional [8] |
|---|---|---|
| Safety | Fly drones from an appropriate distance and acquire live visual evidence of the area | higher risk of climbing to the roof area to find out the defects |
| Time | Allow to observe big areas with a few capture | A long time is required in preparation for climbing work |
| Cost | Requires a relatively expensive initial cost but can run a long time | Auxiliary equipment, such as gondolas & cranes |
| Quality | The images can be uploaded to photogrammetry applications and used to create attractive motion, realistic maps, and 3D model | The quality of the image improved because closer distance with the defect area |

## 4. Conclusion

The research utilized UAV images to create an orthophoto image for a roof condition assessment at Melaka Islamic Museum, achieving the study's objectives. This research compared conventional and UAV roof inspections, focusing on defect rates and overall safety. UAVs offer advantages such as reducing physical inspections, preventing damage, and providing a detailed log of images captured during the flight. This study highlights the potential benefits of UAVs in roofing system assessment. This study utilizes drone technology, software for image analysis, and Condition Survey Protocol 1 (CSP1) Matrix to expedite roof inspections. Pix4Dcapture captures images from various heights, enabling better roof condition visualization. Data is analyzed, producing a general map of the building site. A modified inspection form and CSP1 Matrix are used for a reasonable property assessment. The UAV swarm method offers safety, time, energy, and cost savings for building inspections. However, it faces challenges like limited battery capacity and the presence of heterogeneous types with different flying capabilities and energy efficiency [8].

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