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Visual Inspection of Heritage Mosques Using Unmanned Aerial Vehicle (UAV) and Condition Survey Protocol (CSP) 1 Matrix: A Case Study of Tengkera Mosque and Kampung Kling Mosque, Melaka

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Visual Inspection of Heritage Mosques Using Unmanned Aerial Vehicle (UAV) and Condition Survey Protocol (CSP) 1 Matrix: A Case Study of Tengkera Mosque and Kampung Kling Mosque, Melaka

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Abstract. Heritage buildings have unique architectures. According to the National Heritage Department, the concept of conservation of the heritage accepted and practiced universal is 'Authenticity in Heritage Conservation'. The dilapidated study is the practice of identifying and recording building defects by means of photographic and digital documentation prior to conservation work. The objectives of this study is to identify the roof and mosque tower conservation methods and to visually record and analyze information in order to know the type of defect or damage that occurs in the heritage mosque structure. The use of Unmanned Aerial Vehicle (UAV) was used for roof and tower inspection at Tengkera Mosque and Kampung Kling Mosque which later the images were generated using Pix4D Mapper. The CSP1 Matrix Assessment Protocol is used as a rating tool because it is ideal for a variety of structures to classify data based on the circumstances and the assessment of its harm. There are 13 defects area at Kampung Kling Mosque and 11 defects at Tengkera Mosque consisting paint faded, vegetation growth, and crack. From results obtained in this study, a thorough maintenance can be done.

1. Introduction

The heritage mosque here is a mosque built before the arrival of foreign invaders to Malaysia while the vernacular architecture is related to the availability of materials, craftsmen and technology that existed before the colonial era [1]. The Kampung Kling Mosque and the Tengkera Mosque, Melaka are among the historical mosque found in Malaysia [2]. In the context of conservation of heritage buildings, the most important aspect is ethics rather than aesthetics. Consequently, in conservation, beauty is not a measure but how to return a building as it was originally [3]. Building inspection is a process for identifying and recording the situation or building defect levels. Survey of building conditions and damages experienced known as the dilapidated study. The dilapidated study is the practice of identifying and record building defects by means of photographic and digital documentation before work conservation [4]. In order to identify defects and damages, visual inspection is required to determine the condition of the building, disability and cause [5]. The work of conservation of historical buildings should be carried out carefully to minimize disturbance to the structure and fabric of the building. Large trucks, special elevating platforms or scaffolding on buildings cause high logistical efforts and costs as well as high personnel costs for the specially trained

machine operators [6]. Therefore, during dilapidation survey, the used of UAV can be considered as an alternative tool in visual inspection. Visual inspection is one of the process of dilapidation survey in obtaining information about the defects and damages of the building [7]. Normally, the tools used during the visual inspection of the building by using binoculars and camera [8]. Previously, the inspection is usually done from very limited naked eye observation. UAV has being used as alternative way for collecting data visually for the exterior structure [9].

Photogrammetry UAV is one of the alternative technologies that introduce real-time application, more detailed and low-cost data [10]. The study focuses on the structure of mosque roof and tower using the DJI Phantom 4 micro UAV aircraft at Kampung Kling Mosque and Tengkera, Melaka. UAV Photogrammetry opens a wide range of new applications within various close domains, incorporating aerial and land photogrammetry. After recording each defect, the assessment of the building condition is made using the CSP1 Matrix Assessment Protocol as a rating tool because it very suitable for a variety of structures to classify data based on the seriousness and assessments of its defects [11]. The system gathers two sets of data which is, building conditions and the seriousness of building defects, which can be analyzed to provide ratings the overall state of the building. The CSP1 matrix has also been developed to shorten the process of interpreting data which will then help shorten the checking time in place. Although the breakdown of the elements of each building may vary from building to building, this does not prevent the matrix format from being able to cope with any working conditions of the survey [12]. Therefore, the aim of this study is to identify the conservation methods done at the roof and mosque tower later to record and analyze information visually using micro UAV aircraft to know the type of defect or damage that occurs in the structure of the mosque. By achieving this study objectives, conservation for a heritage mosque can be made to ensure this mosque can be preserved from being swallowed by a time that we did not realize this legacy building can contribute to national development.

2. Materials and Method

There are two main stages in the evaluation of the conditions of the building. The first stage is a visual inspection using UAV, while the second stage is a state evaluation using CSP1 Matrix. UAVs for visual inspection at Tengkera Mosque and Kampung Kling Mosque were carried out in three phases: planning, data observation, and image processing.

2.1. Data Capture

The flight direction planning must first be determined to simplify the process of data collection and to avoid unforeseen events. The direction of flight is horizontally on the mosque's roof, while the vertical direction for the mosque tower [13]. The flight method uses the concept grid as a reference to identify damage and defects. In this study, Pix4D Capture is used to record the images and identify the defects for the mosque roof and DJI Go is used to record the images for the mosque tower closely. The time to fly the UAV at Kampung Kling Mosque is 3 minutes and Tengkera Mosque is 4 minutes while the altitude to fly the UAV for both mosques is 30 meters. Figure 1 and Figure 2 show the flight direction using the grid as the reference position image at the Mosque Tengkera show the direction that use the grid as the reference position image in the Kampung Kling Mosque.
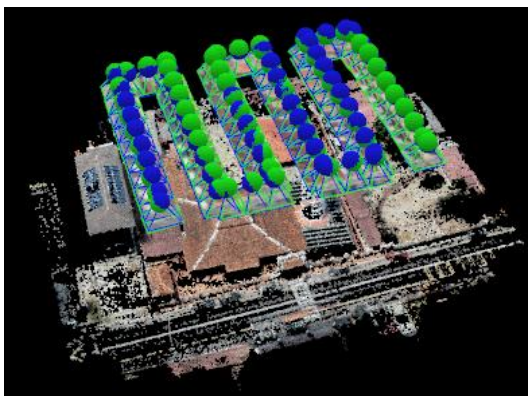
Figure 1. Tengkera Mosque
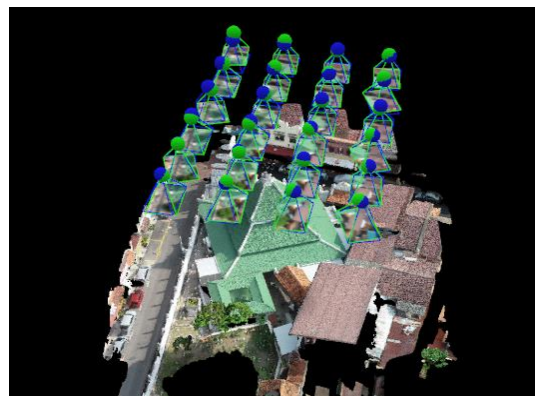

Figure 2. Kampung Kling Mosque

To conduct this study, one will remotely control UAV and two others will give instructions and notify the controller of the aircraft's position so that the controller can follow the observer's direction to the UAV controller. The UAV micro-aircraft operator should always communicate with the observer in order to maintain a distance of 2 meters from the roof and a clearer visual tower [14]. For Tengkera Mosque, there are 57 points and 21 points measured for roof and tower respectively whereas at Kampung Kling Mosque, 15 and 10 points were identified for roof and tower.

2.2. Images Processing
Once the image has been processed, the image is transferred to the Pix4D Mapper software for Tengkera Mosque and Kampung Kling Mosque to obtain the defects and damages coordinates. The Pix4D Mapper software tool is used to analyze similar image content structures, called matching points, in two or more images and link them together based on these points in order to create a map for the both moques, which in turn can produce 3D models. These stitching or mosaicking methods are based on pattern recognition techniques which analyze The panorama creation software [15] analyzes the input data under the assumption that images recorded are made only by pivoting without changing the camera's position. Figure 3 and Figure 4 show the images being processing using the Pix4D Mapper at Tengkera Mosque and Kampung Kling Mosque.
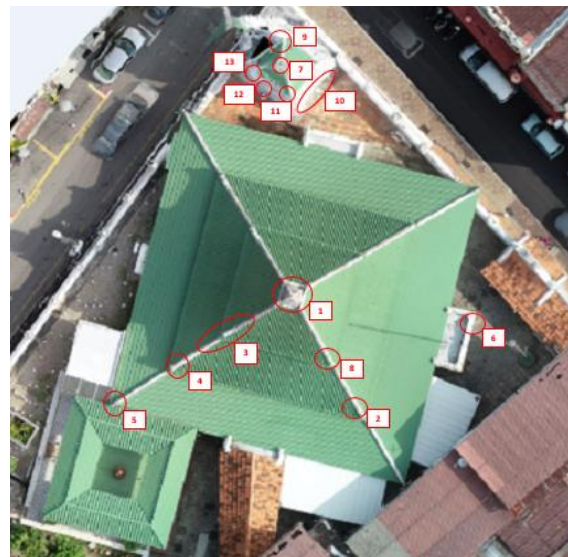

Figure 3. Tengkera Mosque

Figure 4. Kampung Kling Mosque
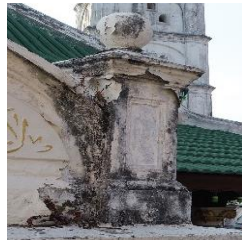
3. Result and Discussion
From image processing, the total number of defect can be identified. Figure 5 and Figure 6 show the location of the roof and tower defects of the Kampung Kling Mosque and Tengkera Mosque that has been marked. Therefore, defects will be easily identifiable and referenced.
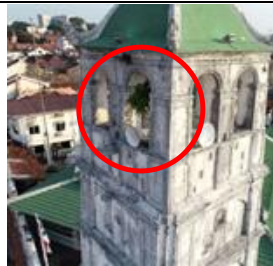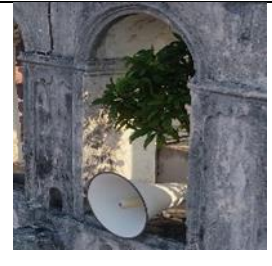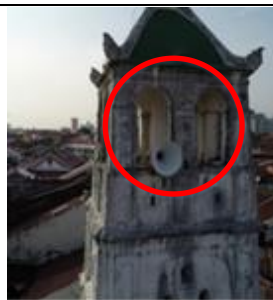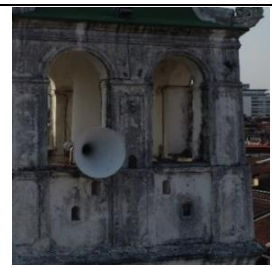
Figure 5. Kampung Kling Mosque

After each defect is recorded, an overall assessment of the condition of the building is made, which summarizes the condition of the building. The building will be evaluated on the basis of the overall average score. The full score is used to give the building an overall rating: Good, Fair or Dilapidated. Table 1 and Table 3 show four examples of analysis of defects.

Table 1. Example of analysis of defects at Kampung Kling Mosque

No of defect: 4		
<table><tr><td>Condition</td><td>Priority</td><td>Matrix</td><td>Colour</td></tr><tr><td>3</td><td>3</td><td>9</td><td></td></tr></table> Element / component : EL/CS 24 (Wall) Defect description: DS/CS 27 (Vegetation growth) Recommendation: Conduct periodic cleaning work Location : 193810.06, 243088.06, 9.84		
No of defect : 6		
<table><tr><td>Condition</td><td>Priority</td><td>Matrix</td><td>Colour</td></tr><tr><td>3</td><td>3</td><td>9</td><td></td></tr></table> Element / component : EL/CS 24 (Wall) Defect description : DS/CS 08 (Damage) Recommendation : Scrape and re-paint the wall Location : 193830.72, 243091.37, 7.34		

No of defect : 13

Condition	Priority	Matrix	Colour
3	3	9	🟨

Element / component : EL/A 14 (Roof)
Defect description : DS/CS 27 (Vegetation growth)
Recommendation: Conduct periodic cleaning work
Location : 193817.69, 243107.32, 19.40

No of defect: 10

Condition	Priority	Matrix	Colour
3	3	9	🟨

Element / component : EL/A 14 (Roof)
Defect description : DS/CS 13 (Corrosion)
Recommendation: Repaint the building
Location : 193820.22, 243108.85, 14.49

Overall, 13 damage images were detected. All of the information gathered for the CSP1 Matrix is recorded in Schedule of Building Condition form for reporting purposes, the CSP1 Matrix comprises an executive summary as shown in Table 2. The type of defect and the total defect can be recognized and categorized according to the section of the building. Wall damage, vegetation growth and corrosion are among the types of damage involved. It can conclude that Kampung Kling Mosque in a fair condition which is the building classification rating is 6.4 using d/e formula.

Table 2. Schedule of Building Condition form at Kampung Kling Mosque

No.	Component	Defect	Condition assessment (a)	Priority assessment (b)	Matrix analysis C= (axb)
1	Roof	Corrosion	3	2	6
2	Roof	Vegetation growth	3	2	6
3	Roof	Corrosion	2	2	4
4	Roof	Vegetation growth	3	3	9
5	Roof	Corrosion	2	1	2
6	Roof	Damage	3	3	9
7	Roof tower	Corrosion	2	1	2
8	Roof	Vegetation growth	2	3	6
9	Wall tower	Vegetation growth	2	3	6
10	Wall tower	Corrosion	3	3	9
11	Roof tower	Vegetation growth	3	3	9
12	Wall tower	Vegetation	2	3	6

| 13 | Tower | growth Vegetation growth | 3 | 3 | 9 |

Total, d = 83

Total matrix, d = 83

Total defect, e = 13

Building classification rating, d/e = 83/13 = 6.4
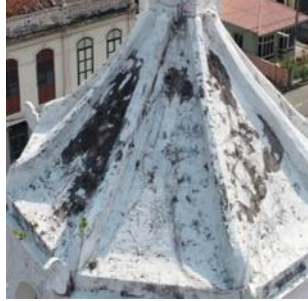
Building rating = Fair

Figure 6. Tengkera Mosque

Table 3. Example of analysis of defects at Tengkera Mosque

No of defect : 2		
<table><tr><th>Condition</th><th>Priority</th><th>Matrix</th><th>Colour</th></tr><tr><td>3</td><td>2</td><td>6</td><td></td></tr></table> Element / component : EL/A 04 (Decorative elements) Defect description: DS/A 05 (Cracks) Recommendation : Paste back using mortar cement Location : 192099.08, 243898.18, 40.18		
No of defect: 3		
<table><tr><th>Condition</th><th>Priority</th><th>Matrix</th><th>Colour</th></tr><tr><td>3</td><td>2</td><td>6</td><td></td></tr></table> Element / component : EL/A 04 (Decorative elements) Defect description: DS/A 05 (Cracks) Recommendation : Paste back using		

mortar cement Location : 192101.57, 243905.51, 40.28		
No of defect : 10 Element / component : EL/CS 24 (Wall) Defect description : DS/CS 27 (Vegetation growth) Recommendation : Conduct periodic cleaning work Location : 192114.63, 243898.84, 48.39		
No of defect: 11 Element / component : EL/A 04 Decorative elements Defect description : DS/A 19 Vegetation growth Recommendation : Conduct periodic cleaning work Location : 192113.68, 243897.53, 49.67		

For defect 10:

Condition	Priority	Matrix	Colour
2	2	4	(green)

For defect 11:

Condition	Priority	Matrix	Colour
2	2	4	(green)

Overall, 11 damage images were detected. Based on the building section, the type of defect and the total defect can be recognized from the table. Wall damage, vegetation growth and corrosion are among the types of damage involved. All the information collected for the CSP1 Matrix is recorded for reporting purposes in the Schedule of Building Condition form, the CSP1 Matrix comprises an executive summary as shown in Table 4. It can conclude that Kampung Kling Mosque in a good condition which is the building classification rating is 2.82 using d/e formula.

Table 4. Schedule of Building Condition form at Tengkera Mosque

No.	Component	Defect	Condition assessment (a)	Priority assessment (b)	Matrix analysis C= (axb)
1	Roof	Rust effect	1	1	1
2	Roof	Cracked	3	2	6
3	Roof	Cracked	3	2	6
4	Roof	Vegetation growth	1	2	2
5	Roof	Rust effect	1	1	1
6	Roof	Missing	1	2	2
7	Roof	Cracked	1	2	2
8	Towers	Others	1	1	1
9	Towers	Cracked	1	2	2
10	Towers	Vegetation growth	2	2	4
11	Towers	Vegetation growth	2	2	4

Total, d = 31

Total matrix, d = 31
Total defect, e = 11
Building classification rating, d/e = 31/11 = 2.82
Building rating = Good

4. Conclusion

In conclusion, maintenance works and preservation of heritage buildings in Malaysia are very important to ensure the value of national assets and the heritage mosque's architecture can be maintained in addition to provide a conducive and comfortable atmosphere for worship visitors and mosque users. Although there are defects and minor damage to the roof and mosque towers, the mosques of the heritage are still in good condition and function as desired. In this study, damage and defects to the roof and mosque tower are caused by various causes and worse damage is also caused by unstable preservation. Therefore, the responsible party should undertake periodic inspection and early prevention measures to minimize the risk of further damage or failure. In addition, civil engineering focuses more on inspections, repairs, restoration, and conversion of existing structures in the interests of the environment, the economy, and society. This study shows the importance of UAV applications for image production and information in more detail to support evaluation of the conditions of the building structure. The use of UAV should be encouraged, particularly in the scope of high structural inspection, and the use of Pix4D Capture, Global Mapper and DJI Go in civil engineering should be expanded as it help to minimize the cost of operation, reduce time and friendly user.

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