Inspection Analysis of Historic Buildings with Aid of "Unmanned Aerial Vehicle" (UAV)

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Abstract: A precise evaluation of buildings is a challenging task. Safety assessment based on qualitative and quantitative data is needed before any data can be interpreted. Quantitative data requires complex methods which enable professionals will make it time and money consuming. Therefore, it is very important to use simpler methods in order to evaluate the potential risk of buildings as a first step towards preservation. Building maintenance is very important in ensuring the condition of historical building is still in a good condition. The purpose of the maintenance is implemented at the Governor's Museum and Melaka Literature Museum which located in downtown Melaka. As such, the CSP1 Matrix or "Condition Survey Protocol 1" method is used to assess the external structure of the building. The structure of a building cannot be effectively identified if proper maintenance is not performed. This is also likely to result in future structural failure of the building which contributes to undesirable accident. Therefore, the use of UAV in building observation and CSP1 Matrix methods was successfully applied in classifying each available inspection analysis of historical building.

Index Terms: Unmanned Aerial Vehicle (UAV), CSP1 Matrix, Historical Assessment Building Survey (HABS), Building Defect

I. INTRODUCTION

This study detail of surveys and observations carried out on the outer space of the structure and the condition of a historic building. Therefore, this study is conducted in a museum, which holds a thousand unique treasures in the country for people's gaze[1]. The photos taken are to be investigated and determined the extent of the damage and the flaws through the photo documentation.

In addition, the damage in places that is difficult to approach at locations where such building defects occur further to the issue of unsatisfactory building damage.

For an example location where the accessibility is quite difficult to detect damage such as those on a roof. This require a special equipment to approach the affected area and also difficult to deal with in the early stages as it is not visible to the naked eye. For this study, two museums have been selected to be medium which were Governor's Museum (Figure 1) and Melaka Literature Museum (Figure 2)and both situated in Melaka.

Fig. 1 Governor's Museum

Fig. 2 Melaka Literature Museum

Condition Survey protocol (CSP1) is used as a rating apparatus as it is very suitable for various structures to classify the data based on its condition and harm evaluations. CSP1 Matrix has also been developed in order to shorten the process of interpreting data which would then help shortening on-site inspection time. It is then proven to be useful and reliable in carrying building inspections [2].

It is mentioned that maintaining architectures that has aged more than 50 years in good condition will create a better image for Malaysia and showing respect to its history [3]. This brings all the more reason for visual inspection to be carried out.

II. LITERATURE REVIEW

Building condition assessment (BCA) is a critical activity in Malaysia's Comprehensive Asset Management Model. It is closely related to building performance that impact user's life and decision making. Building condition is very important to supports a decision making and it is also critical to the management in achieving the service standard for maintenance. Furthermore, it was stated that a building may become worn-out and requires maintenance after 5 years as it expected to be long last for about 60 years [4]. Based on statement before, it is believed that many defects have been occurred on historical buildings and it is important to applied the building condition assessment on historical building in order to monitor the performance, the building condition and also to prevent any damage or defect of building.

No building is maintenance-free become adage nowadays. Maintenance is defined as the continuous care and protection involving minor repair works carried out to building elements in order to keep it in good order thereby prolonging the life of such element and the entire building for as long as possible and this will require considerable administrative and managerial expertise [5]. Therefore, every historical building requires care and protection to limit deterioration. According to Kayan [6], many problems in historic building conservation are related to poor knowledge of parties and organizations responsible to maintain and conserve historic buildings leading to premature loss of valuable historic fabric. Furthermore, the limited availability of resources and financial support, shortage of material and labor to reproduce materials and replicate crafts become the biggest challenge in building conservation.

Kerr [7] mentioned that "of all the processes of conserving heritage buildings, maintenance is the single most important process". Dann and Contell [8], also emphasized that regular maintenance is still considered as the most suitable way of preserving historical buildings nowadays.

In order to make a precise evaluation of buildings is a very challenging task. Safety assessment based on qualitative and quantitative data is needed before any data can be interpreted. Quantitative data requires complex methods which enable professionals will make it time and money consuming [9]. Therefore, it is very important to use simpler methods in order to evaluate the potential risk of buildings as a first step towards preservation. Last but not least, with the aim of contributing to the development of preservation of a building by using CSSP1 Matrix and also UAV, this research focuses on providing rating process that can be used to assess a building's defects.

The Unmanned Aerial Vehicle (UAV) is also known as the drone, an aircraft that does not require a pilot to handle it. The UAV has two variants which are whether operated by remote control, or freely flown based on aviation planes that have been initially programmed using a difficult dynamic automation system. The UAV is divided into two fixed-wing and rotary-wing. The fixed-wing UAV has the shape of an ordinary aircraft equipped with a wing system. This type requires an aerodynamic design on the wing. Next, the UAV rotary-wing is a type that has a spin to fly. Rotary-wing is divided into two types which are single-rotor and multi-rotor. The extensive use of drones in the study is due to the fact that the aircraft is equipped with a camera capable of taking the picture or video according to the drone operator [10]. Micro UAV able to fly less than 1 hour, limited load factor and optimum level of image quality that is useful between 800 feet to 1200 feet and an image resolution of 6cm to 15cm per pixel [11].

One of the methods for assessing building conditions is the Matrix of the Condition Review Protocol (CSP1 Matrix). This work requires information about each defect to be evaluated in terms of its state and priority. Defects recorded and recorded in place with evidence (images and plans). Scores obtained from the scoring system determine the level of disability or component such as in good condition, and obsolete. In addition, the sources of disabilities that may be identified are also known [12]

In CSP1 matrix, visual inspection is an important part of detecting on the surface of the building. The camera will be used as a recording device to capture the image. Protectors required to provide this information can be difficult when considering a simple tower structure or even multi-language building since the essential lifting equipment is required for inspection. The purpose of avoiding this effort is to use the unmanned aerial vehicle (UAV).

III. METHODOLOGY

This phase are the most crucial parts of all an consist of two phase which the first one is visual inspection and the other one will be assessment of condition evaluation by using CSP1 Matrix

A. Visual Inspection

On both museums, visual inspection was used to detect all of the defects occurred. The purposes of acquiring and analyzing data which then can be proceeded with quality control. The data gathered was carried out by an UAV for called Phantom 3 for defects above the first floor and a cameraman for defects that occurred on the ground floor or below. Furthermore, this UAV could fly for 23 minutes total and about 5km range radius flight with a live 720p HD view of what the camera sees [13]. This feature makes this UAV to reach on top of the buildings easily [14]. Figure 3 shows the calibration process of an UAV before take-off.

**Fig. 3 Calibration process of Phantom 3 before take-off**

B. Inspection and Evaluation

There are various ways that can be implemented to evaluate and inspect a building structure such as CSP1 Matrix and supervision of supervision according to the scope of the JKR's work. Both ways use the same concept of evaluating the performance of a building, but using a slightly different method. This assessment is carried out so that the upgrading and renovation works that will be implemented in a building are easier.

This inspection is important in ensuring Operational and Maintenance, Evaluation, Recovery, Renewal and Upgrading, and Building Disposal requirements can be implemented easily and effectively. Therefore, the guidelines for each of the methods will be used to facilitate the work of inspectors conducting the checks. The guidelines are complete on the building inspection method so that the building's rating is reviewed in line with the latest technological developments.

This assessment process and inspection take different time for the condition of a building. The wide area of the building also plays a major factor as well as the weather factor of the building's faucet is not supervised in its area but also outside it. The cost to be paid for this repair work depends on the rate of damage and the frequency of building materials during the assessment process. For more information on how CSP1 Matrix rating can refer to previous study by the author where using CSP1 matrix for building inspection at mosques in area of Pagoh – Muar, Johor [15].

In Malaysia, historical buildings are different from one another in terms of architectural style, function, structure and building defects which require a comprehensive approach to building conservation and systematic. [16] In order for this assessment to be easily analyze parts of the museum are being separated using grid line. Figure 4 shows an example of gridline at roof structure for Melaka Literature Museum. Each grid line can be referred after this inspection for further actions for the maintenance to take parts afterwards.
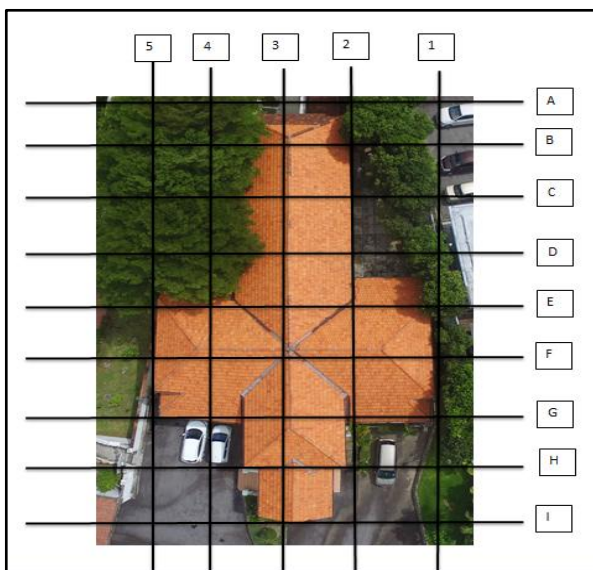
Fig. 4 Example of gridline at roof structure for Melaka Literature Museum

IV. RESULTS AND DISCUSSIONS

A total of 137 building defects was recorded on Governor's Museum and 50 defects for Melaka Literature Museum. The building defects and the building condition of both of the historical building were analyze and classified by using the Condition Survey Protocol (CSP)1 Matrix. For reporting purposes, every photo with complete analyze box which is the grid line, type of elements, type of defects and recommendation. (Figure 5).


Fig. 5 Example of data analysis using CSP1 Matrix

The defects can be various depends on what elements it occurred. From this research, defects that were recorded such as crack, mould growth, vegetation growth, broken, damage, corrosion and others. The possible explanation for this most likely due to the exposure of weather and aging process.

Figure 6 shows the percentages of building defects that detected occur on both museums. Mold growth (38%) of building defect leads the other types of building defect that occur on Governor's Museum followed by 20% cracking while for Melaka Literature Museum the highest percentage of defects was cracking (30%) followed by 24% of corrosion Another types of building defect occurred can be figured out based on data graph given in Figure 6 below. Before conducting any maintenance action to the buildings, it is more advisable to study in advance every possible causes of building defect and damage in order to avoid the same defects or damage from recurring.
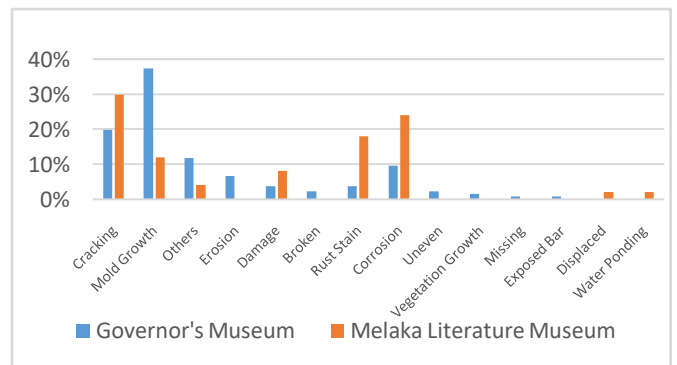
Fig. 6 Percentages of building defects that detected occur on both museums

Based on Figure 7, it shows that Melaka Literature Museum have a smaller rating compared to Governor's Museum. Although the Governor's Museum was built in 1996 but it has the highest rating compared to both museums. Despite all of that, gap of year between both museums are about 12 years different of years of built where Melaka Literature Museum was built around 1986 nevertheless with proper care it will be still in a good shape. The museums undergo an effective maintenance for their structures because both of it are still in good condition.
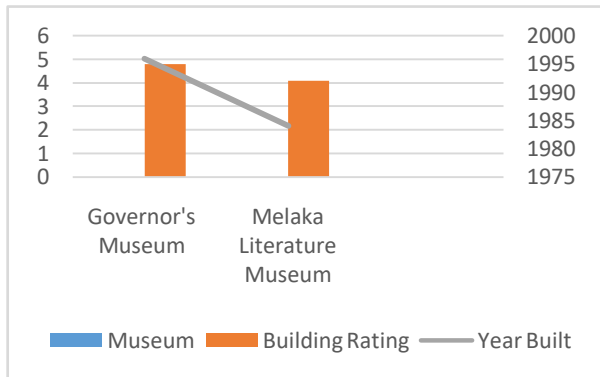

Fig. 7 Rating of museum vs year of built

Table. 1 Overall Building Rating [11]

No	Building Rating	Score
1	Good	1 to 4
2	Fair	5 to 12
3	Dilapidated	13 to 20

Table 1 shows overall building ratio as stated in CSP1 Matrix [17]. By referring to that table and Figure 7, it showed that both museums are in Good condition. This is because the rating are 4.8 for Governor's Museum and 4.1 for Melaka Literature Museum.

V. CONCLUSION

Visual inspection of a building by using an UAV is another technique to check the defect occur on the exterior building. Research has been proved by using the UAV's visual recording provide information for inspection of the building. Other than that, this operation by using UAV apparently will somehow minimize the cost of operation, reduce time and friendly user. By referring back to CSP1 Matrix, visual inspection is the important part to detects defects at the surface of the buildings. CSP1 Matrix also become more efficient due to the absence of UAV for obtaining photography data.

In conclusion, both museums are in good condition especially Melaka Literature Museum. Despite it's being built in 1986, due to proper maintenance made, it is still quite equivalent to Governor's Museum that were built around 1996. Therefore, it is recommended that periodical inspections be carried out on this building and that any actions recommended by this report are carried out to prevent further dilapidation to the buildings.

REFERENCES

1. Department of Museum Malaysia. 'Museum defination', available online at Department of Museum Malaysia Official Website, www.jmm.gov.my/en (assed on December 2018).
2. N.Hamzah, M.Mahli, A.I Che-Ani, M.M Tahir, N.A.G.Abdullah and N.M Tawil, "The Development of smart school condition assessment based on condition survey protocol (CSP) 1 matrix", in Engineering and Technology, 71, 2010.
3. A.Ghafar Ahmad, " Building Maintenance", Universiti Sains Malaysia, 1994.
4. A.Olanrewaju, "Behavioral issues in maintenance of university buildings", in Journal of Retail & Leisure Property, vol. 9, 5, Macmillan Publishers Ltd , 2011, pp. 415-428.
5. A.Idrus, F. Khamidi& M. Sodangi, "Maintenance management framework for conservation of heritage buildings in Malaysia,". in Modern Applied Science, 4(11), 2010.
6. Kayan, "Conservation of heritage buildings: maintaining old government buildings in Kuala Lumpur after gazetted period," in Prosiding Seminar Jangka Pendek. Kuala Lumpur: University of Malaya. 2003.
7. S. J. Kerr, "Conservation plan," 5th Ed., The National Trust of Australia, Sydney, pp.43, 2000.
8. N. Dann &T. Contell, "Maintenance in conservation in Forsyth," in Understanding Historic Building Conservation, Blackwell, Oxford, pp. 185-198, 2007.
9. H. Kim, S. H. Sim and S. Cho, " Unmanned Aerial Vehicle (UAV)-powered concrete crack detection based on digital image processing", Unversity of Illinois, Urbana-Campaign, United States, 2015.
10. DJI, Phantom 3 Advanced. Retrieved from: https://www.dji.com/phantom-3-adv, 2015.
11. I.Ibrahim, Penggunaan UAV bagi aplikasi awam, 2009.
12. Cobra,"The Construction,"in Building and Real Estate Research Conference of the Royal Instrituion of Chartered Surveyors, September 2010.
13. J. Unger, M. Reich & C. Heipke, "UAV-based photogrammetry: Monitoring of a building zone," in The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 40(5), 2014, pp. 601-606.
14. C. Eschmann, C.M. Kuo, and C. Boller, "Unmanned Aircraft Systems for remote building inspection and monitoring", in Proc. Of the 6th European workshop on structural health monitoring, DGZIP, Germany, 2012.
15. M. Mokhtar, M. Kaamin, N. Ngadiman, & N. B. Hamid,"The application of UAV and CSP1 matrix for building inspection at mosques in 1area of Pagoh – Muar, Johor," in AIP Conference Proceedings (Vol. 2016), 2018.
16. A.Ghafar Ahmad , "Understanding common buildings defects: dilapidation survey report," in Majalah Arkitek, 16(1), 2004, pp. 19-21,
17. A.I. Che Ani, A.S.M Tazilan, K.A. Kosman, "The Development of a Condition Survey Protocol Matrix", in Structural Survey. 29(1):35-45, 2011.