Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 1 (2022) 001-011

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

Unmanned Aerial Vehicle (UAV) Technology Use in Visual Road Inspection at Ft005, Johor Bahru-Melaka (Pengkalan Raja, Pontian)

Nor Athirah Basri[1], Saiful Azhar Ahmad Tajudin[1,2*], Masiri Kaamin[3]

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Johor, MALAYSIA

[2]Department of Civil Engineering, Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Johor, MALAYSIA

[3]Department of Civil Engineering, Center for Diploma Studies,
Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rtcebe.2022.03.01.001
Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: Visual road inspection is one of the key phases of road maintenance, whose function is to examine and describe the condition of road infrastructure. Local authority still uses conventional road inspection method. However, this method has its drawbacks. In this study, Unmanned Aerial Vehicle (UAV) was used to help in the road infrastructure information search and determining the severity level of road in visual road inspection. The objectives of this study are; to capture road images at study locations using UAV technology, to produce a data for pavement distress using UAV photogrammetry method, and to analysis level of pavement distress using the Pavement Condition Index (PCI) method. Results from this study showed that UAVs are suitable for aerial mapping with condition that it is operated by a professional operator during data acquisition and the use of UAVs as a verification medium is clearly more efficient than the conventional method because it measures every end and vertex of the road using a digitising method, whereas the conventional method measures from vertex to vertex of the road using a theodolite. By using this technology, the PCI results shown that 206 locations with 11 different types of pavement distress have been identified. Overall, the pavement distress of this road from section 1 to 4 is at a serious level and necessitates reconstruction.

Keywords: Visual Road Inspection, Uav Technology, Photogrammetry Method, Pavement Condition Index.

Corresponding author: saifulaz@uthm.edu.my

1. Introduction

Malaysia is moving to become a developed country. Roads play an important role in helping the growth of the economy and society in Malaysia. Presently, roads in Malaysia including Sabah and Sarawak are classified into three primary classes that has more than 17,830 (km) federal roads, state roads 61,100 (km) and toll expressway 1,700 (km) [8]. In Malaysia, the Public Works Department of Malaysia (JKR) was given responsibility for routine, periodic, and urgent maintenance. Road maintenance work needs to be undertaken to ensure safety and comfort for users and to make traffic more effective as well. Maintenance management requires an assessment of the condition of the pavement to be carried out periodically to ensure the traffic is still smooth without disruption on the surface of the pavement. Road maintenance includes two phases, known as maintenance and rehabilitation (M&R). Before maintenance work is carried out, visual road inspection is the first work to be undertaken to evaluate the structural condition of pavement distress [5].

Road maintenance includes two phases, known as maintenance and rehabilitation (M&R). Before maintenance work is carried out, visual road inspection is the first work to be undertaken to evaluate the structural condition of pavement distress [5]. The local authority in Malaysia still used a manual walking survey to collect data. Traditionally, pavement distress surveys have been carried out manually through human observation, interpretation, and effort. The manual walking survey method was used to inspect the road pavement while walking and collecting data on a data sheet. Visual surveys are a common method used by most engineers; however, they have significant drawbacks such as being slow in progress because they can only collect a small amount of data per day, expensive because more workers are required to conduct these surveys, and the data collected through manual walking surveys tend to be more subjective and less accurate because it is influenced by evaluators' experience [2]. It also has high repeatability because the assessment of a given pavement section may differ from one survey to the next, posing a serious safety hazard to surveyors due to high speed and volume traffic.

A new technology which is UAV technology is used in this study to determine quality and performance compare to the manual walking survey to detect damage in road surface. UAV is a new technology that promises rapid data acquisition for analysis, especially for small aerial mapping with high resolution imagery. High resolution images captured by the UAV platform are capable of extracting metric information from the Earth's surface [10]. UAV are technologies that can be used in various fields such as for agriculture, surveillance, geographic mapping, road maintenance and disaster management [6]. In this study, UAV technology is used as an alternative in visual road inspection work. The objectives of this study are; (i) to capture road images at study locations using UAV technology, (ii) to produce a data for pavement distress using UAV photogrammetry method, and (iii) to analysis level of pavement distress using the PCI method. The study area will be focused on the road Sections 43.7 & 44, FT005 Pengkalan Raja, Pontian.

2. Literature Review

Roads are one of the largest public assets in many countries. Road improvements deliver great and sometimes dramatic benefits to road users through improving accessibility from one location to another, improving comfort, speed and safety, and reduced vehicle operating costs. In order to sustain these beneficial effects, a well-planned maintenance program must be followed by road improvement. Road inspections should be carried out to identify the type of maintenance to be conducted [5].

Visual road inspections are important for the management of roads and are crucial for the maintenance and rehabilitation of roads. Visual road inspections are conducted to collect and evaluate data four types of pavement health condition, namely roughness, distress, bearing capacity and skid resistance. The timely identification and correction of road distress is an important part of road condition surveys because conventional road inspections are time-consuming and needs a lot of workers [11].

In obtaining the data, the UAV technology used is DJI Phantom 4Pro v2.0. UAV used to identify the problems on the flexible pavement. The advantage of the UAV is that it is capable of being used to keep track of areas where human beings cannot go physically and it can send out live video or images of those places, without going to those places physically [10]. This application saves the time and labor. Saving time means being able to reduce job costs, a vital factor to consider in budget constrained government work. UAVs are becoming increasingly used because the ultra-light cameras and it provide great resolution images for low- altitude photogrammetric work.

In this study, the pavement condition index (PCI) method used to identify various pavement distress factors on the flexible pavement, defines their level of severity, recommends the fixing of methods for these problems, and identifies possible reasons. PCI is identified by pavement distress data. For this reason, distress data is very important in the projection of road service life.

3. Methodology

The methodology consists of four fundamental stages which is flight planning, data collection, images processing and analysis data.

3.1 Data Collection

Grid mission is used as a pattern in this study to capture the image for road. The mission is carried out with the help of Pix4Dcapture, which must be installed on a smartphone. This application will aid in the smooth operation of flights. Only one person can operate the UAVs remote control to collect data. Figure 1 shown the flight pattern grid. Before beginning the flight mission, the flight height must be determined.

The UAV was flown from a height of 30 metres above ground level. The road grid size is set to 46mx359m. Using this application, the UAV will fly at a medium speed for this mission. The Pix4dcapture application was used to control the UAV as a whole. The most important thing to do during the flight mission is to ensure that the UAV's Global Positioning System (GPS) is connected to the smartphone via the Pix4dcapture application.

Figure 1: Images of Road with Grid Mission Flight using Pix4Dcapture

3.2 Images Processing

Image of road taken via UAV by using the Pix4Dcapture application installed in the smartphone will be processed using the Pix4Dmapper software to produce orthomosaic Photo and Digital Surface Model (DSM). Pix4Dmapper will combine all the photo taken by UAV. There are 728 images of road.

Pix4DMapper generates orthomasaic images and Digital Surface Model (DSM) from UAVs. The data that has been transferred to the computer is entered into Pix4DMapper for processing. The data are then processed in three stages by Pix4DMapper, namely Level 1: Initial Processing, Level 2: Cloud and Mesh Points, and Level 3: Digital Surface Model (DSM), Orthomosaic and Index [11]. Prior to generating the orthomosaic Pix4D generates a 3D point cloud. The point cloud generated by the 728 images. The point cloud can be edited to remove any spurious points. The point cloud looks quite pixelated, so there is an option in Pix4D to view a 3D mesh instead. The 3D mesh is a 3D model where all the dots of the point cloud are connected in order to create a surface. This can be seen in Figure 2.

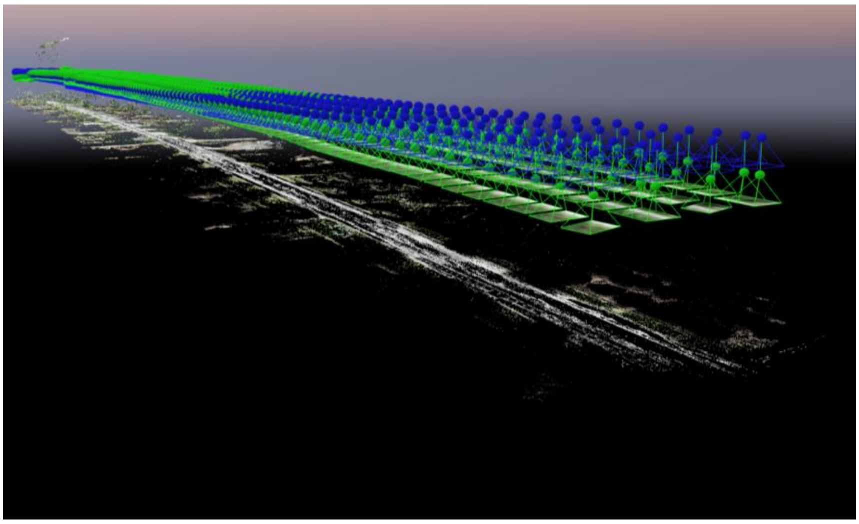

Figure 2: The Mesh Stage During the Image Processing

As a result of these three processes, an orthomosaic image, as shown in Figure 3, is produced. The zoom in image is a UAV image that can be seen clearly by using the orthomosaic image.

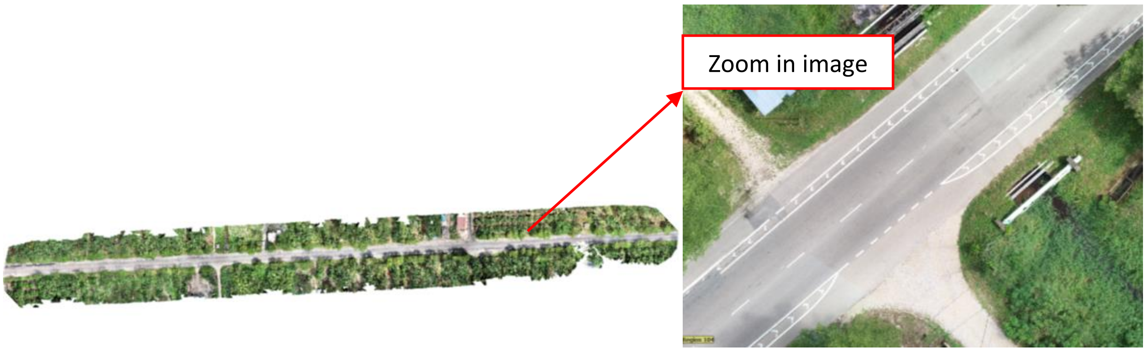

Figure 3: Orthomosaic Images Produced using Pix4DMapper

3.3 Develop Pavement Distress Data

Using the software Global Mapper, the user can perform, a identify pavement distress on orthomosaic images and DSM to find the information needed. In order to make it easier and to know the exact position of each pavement distress, the study area was divided into 5 sections at a distance of 200m for each section.

The following information is required to determine pavement distress: width, length, area, depth, location, severity level and types of pavement distress based on orthomosaic and DSM image. For all sections, the same method was used to determine the distress pavement. Figure 4 shown information to determine the pavement distress.

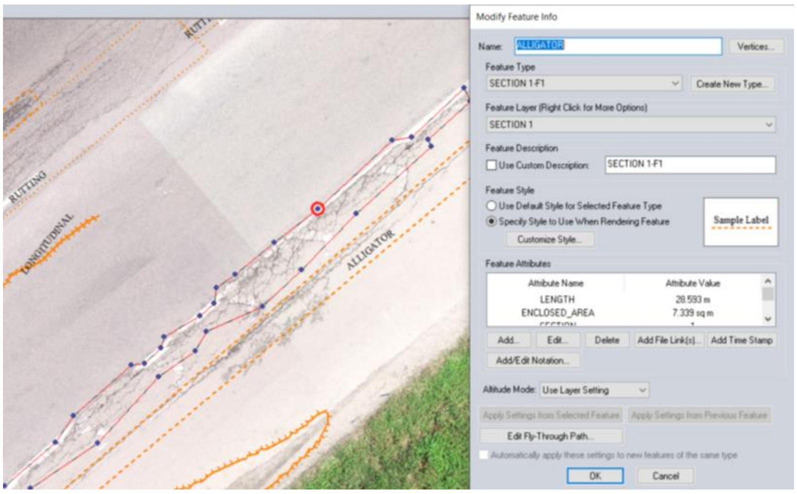

Figure 4: Determine the Pavement Distress Data

4. Results and Discussion

The following are findings that have been focused in this study. The first (1) is a query for pavement distress and the second (2) is the severity level of pavement distress using PCI method.

4.1 Query Analysis for Pavement Distress

Query pavement distress is a question addressed if an authority or anyone, wanted to obtain information for pavement distresses, attribute data can be used to obtain the information. This is because the data is automatically saved in the Global Mapper software. If anyone want to determine the location of pavement distress, just select the data and the location will be display as shown in Figure 5. Depending on the situation, the same method is used to obtain query analysis.

Figure 5 shown example of query to determine the location of the high severity level pavement distress in section 1. The severity level of pavement distress is divided into three categories: low (L), medium (M), and high (H). Section 1 will provide an example of a high severity level for this query. An example of query is:

"How to obtain pavement distress data in section 1, at a high (H) severity level?".

Figure 5: Steps to Determine the Location of Pavement Distresses

The data obtained from figure 5 represents the location of all types of pavement distresses that are at a high level of severity in section one.

4.2 Summary Types of Pavement Distress in Each Section

The obtained attributes data are exported to Excel in order to generate graphs and which will be used when analyzing pavement distress using PCI method. Figure 6 shown one of the exported data attributes to Excel.

	A	B	C	D	E	F	G	H	I	J	K
1	<Feature N	<Feature Ty	LENGTH	BEARING	WIDTH	SECTION	DISTRESS C	DISTRESS S	ENCLOSED_	DEPTH	<Descriptio
2	ALLIGATOR	SECTION 3-	41.165 m			3	1	01 H	8.749 sq m		SECTION 3-
3	ALLIGATOR	SECTION 3-	22.836 m			3	1	01 H	8.969 sq m		SECTION 3-
4	ALLIGATOR	SECTION 3-	36.461 m			3	1	01 H	7.164 sq m		SECTION 3-
5	ALLIGATOR	SECTION 3-	26.212 m			3	1	01 H	6.543 sq m		SECTION 3-
6	ALLIGATOR	SECTION 3-	31.072 m			3	1	01 H	8.291 sq m		SECTION 3-
7	ALLIGATOR	SECTION 3-	19.211 m			3	1	01 H	3.537 sq m		SECTION 3-
8	ALLIGATOR	SECTION 3F	35.843 m			3	1	01 H	14.135 sq m		SECTION 3F
9	ALLIGATOR	SECTION 3-	31.8 m			3	1	01 H	10.838 sq m		SECTION 3-
10	ALLIGATOR	SECTION 3-	23.275 m			3	1	01 H	6.783 sq m		SECTION 3-
11	ALLIGATOR	SECTION 3-	13.715 m			3	1	01 H	2.203 sq m		SECTION 3-
12	BLEEDING	SECTION 3-	13.817 m			3	2	02 H	3.265 sq m		SECTION 3-
13	BLEEDING	SECTION 3-	4.496 m			3	2	02 L	0.954 sq m		SECTION 3-
14	BLEEDING	SECTION 3-	5.174 m			3	2	02 M	1.224 sq m		SECTION 3-
15	BLEEDING	SECTION 3-	18.4 m			3	2	02 M	8.069 sq m		SECTION 3-
16	BLEEDING	SECTION 3-	10.205 m			3	2	02 H	3.43 sq m		SECTION 3-
17	EDGE	SECTION 3-	12.216 m	50− 20' 17.5"		3	7	07 H			SECTION 3-
18	EDGE	SECTION 3-	4.606 m	51− 09' 19.4"		3	7	07 M			SECTION 3-
19	LONGITUDI	SECTION 3-	3.566 m	50− 36' 42.	0.021m	3	10a	10a H			SECTION 3-
20	LONGITUDI	SECTION 3-	2.169 m	47− 45' 28.	0.0072m	3	10a	10a M			SECTION 3-
21	LONGITUDI	SECTION 3-	20.876 m	51− 09' 36.	0.067m	3	10a	10a M			SECTION 3-
22	LONGITUDI	SECTION 3-	4.456 m	230− 14' 1:	0.0193m	3	10a	10a H			SECTION 3-
23	LONGITUDI	SECTION 3-	15.609 m	229− 58' 1:	0.068m	3	10a	10a M			SECTION 3-
24	LONGITUDI	SECTION 3-	5.775 m	49− 24' 22.	0.019m	3	10a	10a H			SECTION 3-

Figure 6: Attribute Data in Excel Form

The graph was created using type of pavement distress data and total pavement distress. The term "type of pavement distress" refers to each type of pavement distress, whiles "total pavement distress" refers to the sum of all types of pavement distress that occur in that section.

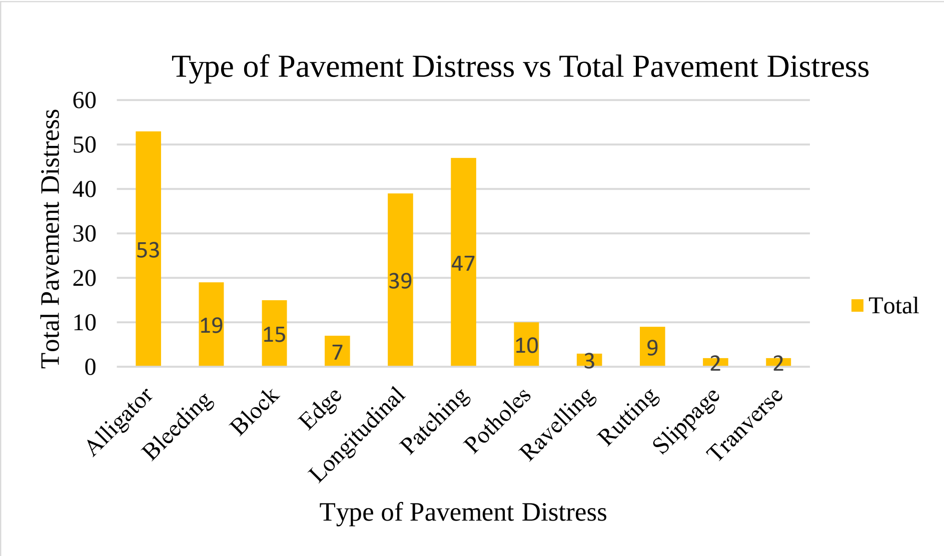

Figure 7: Graph for All Section

Figure 7 shown the total distress survey for all section. The data shows that 11 of the 19 distress types encountered on the subject road. The quantities of distress areas are listed according to the type of distress and also indicate the total pavement distress. Among all the distresses, alligator cracking and patching contribute the highest number of occurrences, which are 53 and 47 respectively. This is due to the road is the main federal road connecting the people of Pontian and nearby areas to Johor Bahru and Singapore. The area has long been a hot topic of discussion in newspapers and on social media, due to the cracking problem at this road [4]. According to the Figure 7, cracking is the highest cause for this road. This is due to the fact that cracking is the most common and serious type of distress that affects all asphalt pavements [9].

This road constructed on soft soil. Various types of maintenance, such as regulate, resurfacing, CIPR, and others, are performed on that road each year. However, it did not solve the problem. This is because, the maintenance performed are only temporary, as they are only performed on the road's pavement surface. Those maintenance also result in additional loads on the road base surface. The crack will become wider as the load increases. Furthermore, during peak hours, this road sees a significant increase in traffic, which is one of the causes of cracking [4]. Therefore, The PCI method is used to determine the level of pavement distresses in this study area, which is then followed by appropriate maintenance recommendations based on the road's level of service.

4.3 Severity Level of Pavement Distress using PCI Method

Pavement Condition Index (PCI) is used to evaluate the condition of the pavement based on a simultaneous assessment of the type of distress, density and severity. The pavement condition index (PCI) is a numerical index ranging from 0 to 100 that indicates the overall condition of the pavement, 0 for failed pavements and 100 for new pavement conditions [12]. It is widely used in civil engineering. Figure 8 shown the index's ratings.

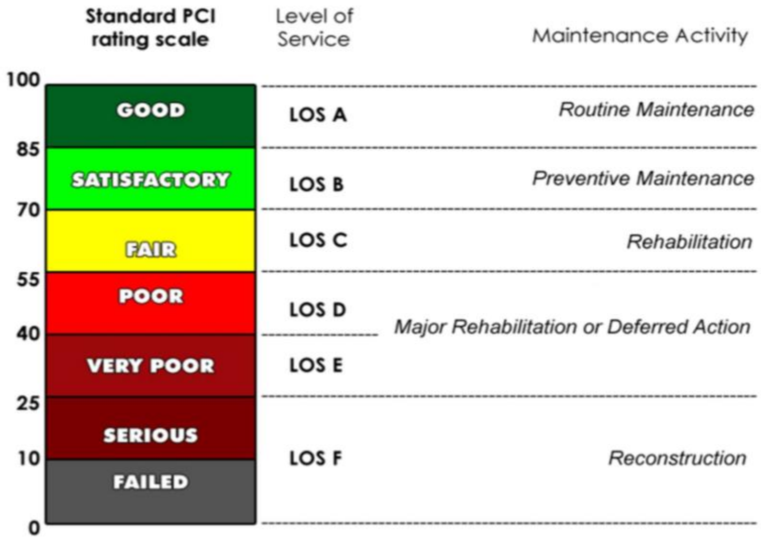

Figure 8: Pavement Condition Index (PCI) Rating Scale

The following are the steps for entering pavement distress data obtained from attribute data [12]:

1. Inspect the sample unit, assess the type of distress and the level of severity and then measure density,
2. Deduct values for each category of distress and severity are determined from the deduct value curves,
3. The total deduct value (TDV) is determined by summing up all individual deduct values,
4. The corrected deduct value (CDV) can be calculated from the correction curves once the TDV is computed,
5. The PCI is calculated using the relationship PCI = 100 – Max.CDV for each sample unit inspected

Example of a PCI calculation for section 1 that makes use of the obtained attribute data will be shown. Table 1 contains the data that was analysed for Section 1 to aid in the calculation of PCI. Following is a step for calculating the pavement condition index for pavement distress in Section 1.

Table1: Calculation Sheet for Section 1

LOCATION: FT005, JOHOR BAHRU-MELAKA
SECTION: 1
ROAD WIDTH (m): 15 × 200 = 3000

DISTRESS SURVEY	QUANTITY															TOTAL	DENSITY %	DEDUCT VALUE
01M	1.54	2.42	16.3	13.49	2.14											35.89	1.1963333	22
01H	5.47	9.62	24.06	33.34	7.34	19.47	6.85	28.23	6.61	12.58	2.27	16.87	1.31	5.42	1.16	180.6		
01H	3.41	6.05	9.41	2.89	4.92	7.34										34.02	7.154	58
02L	1.07	1.1														2.17	0.0723333	0
02M	6.1	5.77														11.87	0.3956667	2
02H	31.39	13.17														44.56	1.4853333	5
03M	12.94	12.13	10.16	21.45												56.68	1.8893333	6
03H	60.02	44.97	9.15													114.14	3.8046667	18
10a L	0.0046	0.006														0.0106	0.0053	0
10a M	0.0074	0.0063	0.006													0.0197	0.00985	0
10a H	0.023															0.023	0.0115	5
11L	20.24	0.937	15.96	6.02	75.7	5.04										123.897	4.1299	7
11M	4.34	1.48	10.66	4.12	5.56											26.16	0.872	8
15L	20.33	37.53	3.83	31.47												93.16	3.1053333	17
15M	2.61	32.7	19.94	11.12												66.37	2.2123333	26
15H	11.46	29.69														41.15	1.3716667	29
19M	0.11	0.14														0.25	0.0083333	5
19H	0.25															0.25	0.0083333	7

Maximum allowable number of deduct, m

- Highest deduct value, HDV = 58
  m = 1 + (9/98)(100 - HDV)

  m = 1 + (9/98)(100 - 58)

  = 4.9

- Deduct values in descending order: 58, 29, 26, 22, 18, 17, 8, 7, 7, 6, 5,5,2
- Number of deduct values = 8

Maximum corrected deduct value, CDV

- Number of value greater than 2, q = 12
- Total deduct value =58+29+26+22+18+17+8+7+7+6+5+5= 208

CDV =

No.	Deduct values												Total	q	CDV
1	58	29	26	22	18	17	8	7	7	6	5	5	208	12	0
2	58	29	26	22	18	17	8	7	7	6	5	2	205	11	0
3	58	29	26	22	18	17	8	7	7	6	2	2	202	10	0
4	58	29	26	22	18	17	8	7	7	2	2	2	198	9	0
5	58	29	26	22	18	17	8	7	2	2	2	2	193	8	0
6	58	29	26	22	18	17	8	2	2	2	2	2	188	7	81
7	58	29	26	22	18	17	2	2	2	2	2	2	182	6	86
8	58	29	26	22	18	2	2	2	2	2	2	2	167	5	84
9	58	29	26	22	2	2	2	2	2	2	2	2	151	4	83
10	58	29	26	2	2	2	2	2	2	2	2	2	131	3	80
11	58	29	2	2	2	2	2	2	2	2	2	2	107	2	75
12	58	2	2	2	2	2	2	2	2	2	2	2	80	1	80

Maximum CDV =86

Determine the Pavement Condition Index

PCI = 100 - CDVmax

= 100 - 86

= 14

Based on the rating for PCI value of 14, this section of pavement is in serious condition.

The same procedure is followed for the other sections. The results for the five sections are shown in Table 2.

Table 2: Summary of Severity Level

	Section 1	**Section 2**	**Section 3**	**Section 4**	**Section 5**
Pavement Condition Index (PCI)	14	11	20	11	100
Level of Service (LOS)	LOS F	LOS F	LOS F	LOS F	LOS A
Maintenance Activity	Reconstruction	Reconstruction	Reconstruction	Reconstruction	Routine maintenance

The research work yielded a satisfactory result in that the desired objectives were completely met. The condition survey was completed successfully, and the PCI value and pavement distress quantities were calculated. Table 4.4 shows the results of the pavement condition index PCI for each section. The PCI pavement condition index for Sections 1 is 14 and section 3 is 20, and the PCI pavement condition index for Sections 2 and 4 is 11. These four sections necessitate reconstruction work. Section 5 has a PCI pavement condition index is 100, indicating that routine maintenance is required. Finally, a reconstruction work policy is recommended for section 1 to 4 because the PCI value of the road is below than 40, with a LOS F.

5. Conclusion

As a conclusion, it was discovered that UAVs are suitable for aerial mapping with condition that it is operated by a professional operator during data acquisition [3]. Figure 9 shown a comparison of images captured in the study area with cameras and drones. The image captured by the drone and the image captured by the camera are similar. This demonstrates that the drone is capable of producing high-quality images. It makes determining the pavement distress easier. In this study, UAV is used for data acquisition in pavement distress detection was developed. This study has a low-cost, flexible system that is simple to use and can capture fully automatic road visuals. The use of UAVs as a verification medium is clearly more efficient than the conventional method. It is advantageous because it saves money, and it can produce more accurate results because it measures every end and vertex of the road using a digitizing method, whereas the conventional method measures from vertex to vertex of the road using a theodolite [1]. Next, analysis was made in this study to evaluate pavement pressure using PCI. Appropriate sample sizes were chosen for visual inspection and evaluation. This road was discovered need to do reconstruction. An inspection was made to determine whether the existing pavement was strong enough to support the movement of moving traffic, as it was necessary to carry the imposed load. The analysis reveals that the pavement section is structurally weak due to the soft soil used on the sub-grade layer.

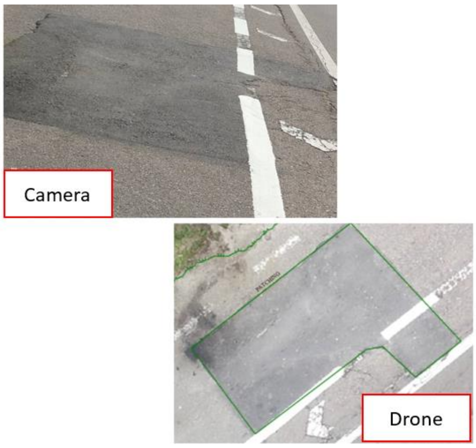

Figure 9: Comparison Images Capture with Drone and Camera

Acknowledgement

The authors would like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for give opportunity to write this thesis.

References

[1] A. N. Mohd Safie, K. N. Abdul Maulud, and O. Jaafar, “Auditing Road Maintenance Work Using Unmanned Aerial Vehicle,” *Jurnal Kejuruteraan SI 1(5) 2018: 23-27*, 2018.

[2] G. Rusbintardjo, C. M. Jiun, A. N. Ibrahim, P. Babashamsi, N. I. Md. Yusoff, and M. R. Hainin, “A Comparative Study of Monitoring Methods in Sustainable Pavement System Development,” *Jurnal Teknologi*, vol. 81, no. 5, 2019.

[3] K. N. Tahar, A. Ahmad, W. A. A. Wan Mohd Akib, and W. S. Udin, “Unmanned aerial vehicle technology for large scale mapping,” *nternational Symposium & Exhibition on Geoinformation (ISG)*, Sep. 2011.

[4] Makmal Penyelidikan Geoteknik, Create, “Kerja Pemendapan Jalan di FT005, Jalan Johor Bahru-Melaka (Pengkalan Raja, Pontian),” *Buletin CREaTE*, vol. 9, pp. 13–16, Nov. 2019.

[5] M. A. Shahid, “Maintenance management of pavements for expressways in Malaysia,” *IOP Conference Series: Materials Science and Engineering*, vol. 512, p. 012043, 2019.

[6] M. C. -, “What are popular uses of drones?,” *Geospatial World*, 08-Aug-2019. [Online]. Available: https://www.geospatialworld.net/article/what-are-popular-uses-of-drones/. [Accessed: 10-Nov-2020].

[7] M. S. Zafar, S. N. Raza Shah, M. J. Memon, T. Ali Rind, and M. A. Soomro, “Condition Survey for Evaluation of Pavement Condition Index of a Highway,” *Civil Engineering Journal*, vol. 5, no. 6, pp. 1367–1383, 2019.

[8] N. Ali Khalifa and A. Zulkiple, “A Simple Method on Measuring Road Pavement Damage For Access Road The Possibilities Pavement Design and Its Maintenance-an Overview View project Klang Commuter Station Project View project to Residential Estates. ,” *International Journal of Engineering Research 2(9):510-514*, vol. 2, no. 9, Sep. 2013.

[9] Pavement Research Center, “Pavement Condition Index (PCI),” *City and County Pavement Improvement Center*. [Online]. Available: http://www.ucprc.ucdavis.edu/ccpic/pdf/PCI 4-Pager final v2.pdf. [Accessed: 26-May-2021].

[10] Syed Furqan Rafique, Muhammad Saleem, and Syed Muhammad Aun, *Unmanned Aerial Vehicle*. LAP LAMBERT Academic, 2016.

[11] Y. Tan and Y. Li, "UAV Photogrammetry-Based 3D Road Distress Detection," *ISPRS International Journal of Geo-Information*, vol. 8, no. 9, p. 409, 2019.

[12] "ASTM D6433-11," *ASTM International - Standards Worldwide*. [Online]. Available: https://www.astm.org/DATABASE.CART/HISTORICAL/D6433-11.htm. [Accessed: 26-May-2020].