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DEVELOPMENT OF A COMPOSITE PAVEMENT PERFORMANCE INDEX TO MONITOR THE PAVEMENT CONDITION IN NDUM

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ABSTRACT

Road surface condition of a pavement is one of the most important pavements features as it affects the dynamic load of vehicles travelling on it, the quality of travel and the vehicle operating cost. It is important to maintain a good road surface condition to promote safety and to reduce traffic accidents and injuries. The Composite Pavement Performance Index (CPPI) is one of the important tools to measure the performance or condition of a pavement. By conducting pavement evaluation using the CPPI, civil engineers could prioritize the maintenance and rehabilitation which usually incurred a huge cost. In National Defence University of Malaysia (NDUM), there is no proper maintenance and rehabilitation scheduled for the roads as there is no performance evaluation tool available to measure the pavement performance or condition. Thus, the objective of this study is to develop a Composite Pavement Performance Index (CPPI) to monitor the pavement condition and to rank the roads in NDUM. To develop the CPPI, road defects data were collected from 6 internal roads in NDUM. From the data collected, four (4) major types of distresses: rutting, pothole, crocodile cracking and longitudinal cracking are more likely to occur on the pavements in NDUM. By measuring the growth of the distresses over a period of six (6) months, the CPPI was developed to rank the roads in NDUM. Using the CPPI, this study demonstrated that the road connecting to the library building experienced the worst pavement deterioration in NDUM with a value of CPPI of 24. The condition of the pavement was classified as poor. Thus, it is recommended that the road connecting to the library building should be reconstructed to increase the safety for road users.

1.0 INTRODUCTION

Road surface condition or the pavement condition, is one of the most important pavements features as it effects the dynamic load of vehicles travelling on it, the quality of travel and the vehicle operating costs. Dynamic load of vehicle travelling on pavement surface will accumulate when it is open to traffic. It is essential to consider the pavement defects under different vehicle loading and weather conditions. Road damage also can happen due to compressive strength loss attributed to poor compaction process during the construction phase. Pavement distresses are classified into two different categories. The first category is known as functional failure. In this case, the pavement does not carry out its intended function without either causing discomfort to passengers or high stresses to vehicles. The second category, known as structural failure, includes a collapse of pavement structure or the breakdown of one or more components of the pavement with such magnitude that the pavement becomes incapable of sustaining the loads imposed upon its surface [1].

Functional failure of pavements depends primarily on the degree of surface roughness while structural failure in pavement may be attributed because of fatigue, consolidation or shear developing in the

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subgrade, sub-base, base course or surface [2]. Road pavements require continuous maintenance, and rehabilitation works to prevent defects and deterioration caused by repetitive traffic loadings and environmental factors such as weathering. However, with the limited fund allocated for pavement works, there is a need to use the available funds as effectively as possible in pavement preservations. To accomplish this, a systematic procedure for scheduling maintenance and rehabilitation works to optimize the benefits to road users and to minimize the costs to the agency responsible for pavement management is recognized as a useful measure. Known as the Pavement Management System (PMS), such a system would allow administrators and engineers to allocate funds, personnel, resources etc. most effectively [3]. The Composite Pavement Performance Index (CPPI) is one of the useful tools under the PMS where it is normally conducted annually to evaluate the changes that occurred in the road network system especially measuring the pavement performance, for example, the distresses develop in the pavements, pavement's defects and deteriorations. The CPPI is a method of evaluation based on inspections and observations.

In National Defence University of Malaysia (NDUM), there is no PMS or the use of CPPI to monitor the pavements' condition. A general search on the records of maintenance and rehabilitation for roads in NDUM revealed that there is no scheduled routine maintenance or periodic maintenance works conducted for the roads. However, most of the maintenance and rehabilitation works were carried out due to events (such as the convocations) or after receiving emergency and complaints from the top management. A reconnaissance survey around NDUM was conducted in early September 2018 and it was observed that most of the roads, especially those minor roads with less traffic volumes in NDUM has minor to major distresses, defects and deteriorations. Thus, it was then suggested that the development of a CPPI would be useful to help the NDUM's Development and Maintenance Department to carry out the assessment for the roads annually to schedule a routine or periodic maintenance for the pavements. This is very important to preserve the serviceability of the pavement and to ensure the pavement would last until the end of its service life. Due to limited funding is available for pavement maintenance and rehabilitation, prioritizing the roads would help the NDUM's Development and Maintenance Department to plan and to schedule a routine or periodic maintenance for the pavements.

2.0 METHODOLOGY

Several stages must be accomplished to achieve the objectives of this study. Figure 1 shows the flow chart of the research methodology employed for this study. These include literature review, site reconnaissance survey, data collection and analysis, development of CPPI, verification and validation of CPPI and finally pavement ranking using the developed CPPI. A literature review provides useful information on the methodology adopted in previous studies to develop a CPPI. After literature review, a site reconnaissance survey was conducted to identify the type of pavement distresses that commonly occur in pavements in NDUM. Next, a schedule was planned to measure the growth of the distresses over time. The pavement distresses were marked, measured and recorded at a weekly or bi-weekly basis from October 2018 to March 2019 for a period of six (6) months.

The data obtained from measuring the growth of the pavement's distresses were then used to model the growth of the distresses. The odds ratio measuring the growths of the pavement distresses were computed and were used to calculate the weightage for each type of distresses before they were used to develop the CPPI. The CPPI was developed based on the type of common pavement distresses in NDUM. The developed CPPI was verified and validated before it is used to rank the pavement quality in NDUM. Finally, using the CPPI developed, the pavement performance or conditions of the pavements in NDUM were evaluated.

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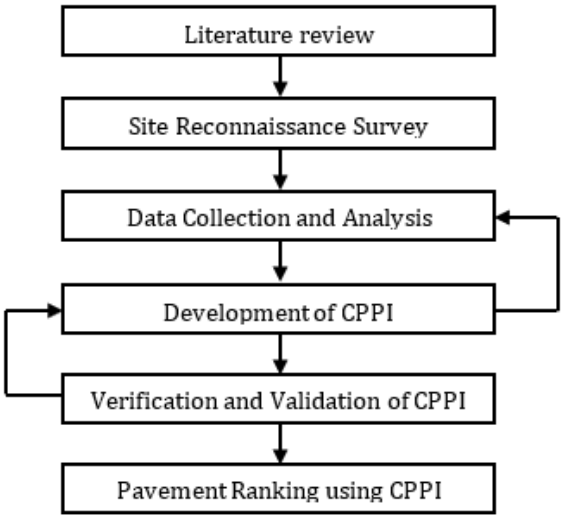

Figure 1. Flowchart of research methodology

2.1 Site Reconnaissance Survey and Data Collection

During the site reconnaissance survey, six (6) roads in NDUM that satisfied the site selection criteria were included in the study. The pavement distresses with low, medium and high severity were found for these roads. Table 1 shows the detail of the roads while Figure 1 shows the layout plan of the study location.

Table 1. Study location

No.	Road's Name	Length (m)	Width (m)	Area (m^2)
1	Main Road	330.00	8.00	2640.00
2	Lembah	157.70	9.00	1419.30
3	Wisma Pegawai Kadet	112.60	5.70	641.80
4	Marine Centre	360.00	4.60	1656.00
5	Library	179.90	7.20	1295.28
6	Officer's House	406.00	3.60	1461.60

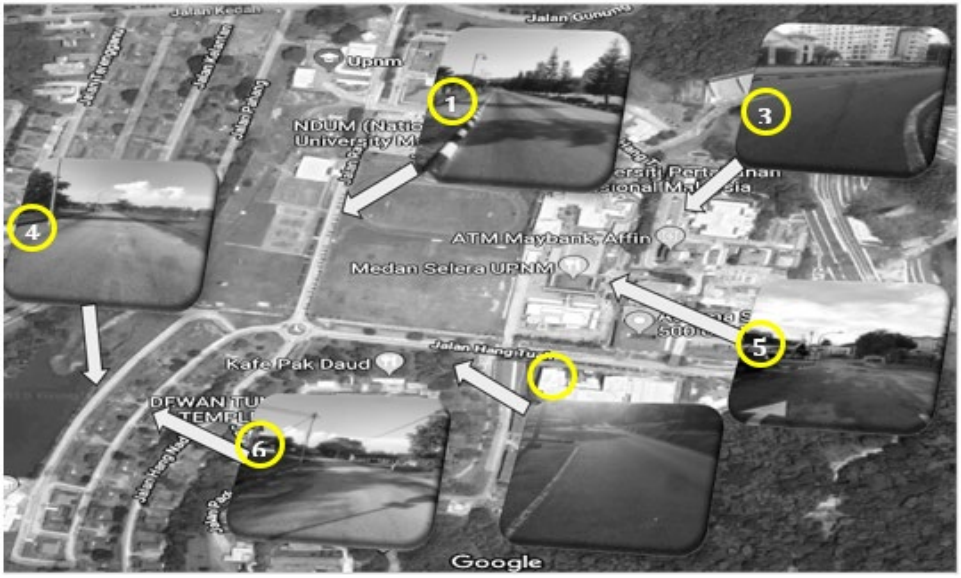

Figure 2. Layout plan of the study location

The common pavement distresses at these roads are longitudinal cracking, crocodile cracking, pothole and ravelling. The measurement of pavement distress is conducted by measuring the size of the distress (length, width and depth) using ruler and measuring tape. Some distress such as pothole was also marked

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with the spray paint. The growth of the distresses was measure weekly and bi-weekly depending on the rate of defects. Table 2 shows the defects rating criteria adopted from Mustafa (1992) [4].

Table 2. Pavement distress rating criteria [4]

Rating Criteria	Severity of Distress		
	Low	Moderate	High
Longitudinal cracking (m)	< 3.0	3.0 - 15.0	> 15.0
Crocodile Cracking (m^2)	< 1.0	1.0 - 0 3	>3.0
Ravelling (m^2)	< 1.0	1.0 - 3.0	>3.0
Pothole (m^2)	< 0.3	0.3 - 0.9	> 0.9

The severity level of various pavement distresses was important when interpreting the condition of the roads as different severity of distress may require different rehabilitation and maintenance method and incurred different costs.

2.2 The CPPI Score Rating

The CPPI score rating varies from 0 to 100, with a higher score showing that the pavement is in an excellent condition while a lower score representing that the pavement is requiring maintenance and rehabilitation as the pavement condition is below expectation [5]. Table 3 shows the CPPI rating adopted from Shahin (1997) [5].

Table 3. CPPI Score Rating

Score	Remarks	Colour Indication
0.0 - 10.0	Failed	
11.0 - 25.0	Serious	
26. 0- 40.0	Very Poor	
41.0 - 55.0	Poor	
56.0 - 70.0	Fair	
71.0 - 85.0	Satisfactory	
86.0 - 100.0	Good	

The pavement performance rating is determined from a correlation that presents pavement condition rating as a function of the PPI value. Table 3 shows the PPI ratings. When interpreting the collected visual condition data, three different aspects of the collected data are of interest: the composite index, the type of distress present and the rate of deterioration. The PPI value itself provides a general idea of the pavement condition and the magnitude of work that will be required to rehabilitate the pavement. Pavements at the upper end of the scale are more likely to be candidates for maintenance and minor rehabilitation, while those in the lower ranges are more likely to require structural rehabilitation or reconstruction.

3.0 RESULTS AND DISCUSSIONS

The actual survey of the section was carried out on 14 April 2019. A few depressions of medium and high severity level, a few longitudinal cracks of low severity, some of the medium and high severity of pothole and ravelling was found by using visual inspection of each section. The survey and distress identification procedures were carried out as per the reference mentioned for the six (6) roads section. Figure 3 shows the condition survey data sheet for Library Road, which shows that the sample has PPI = 24 and a rating of 'poor'. Each type of distress has a separate figure to find the deduct value for that section and the type of distress. Figure 3 shows the flexible pavement's deduct values for distress 43, while Figure 4 shows the flexible pavements deduct for distress 42. The total deduction value (TDV) of each survey unit is defined by having to add all the deduction values of each distress condition for each section. The corrected deduction value (CDV) will be defined using Figure 5. All types of distress from each section will be collected and placed on the data sheet. The PPI is compute using the relation PPI = 100 – CDV.

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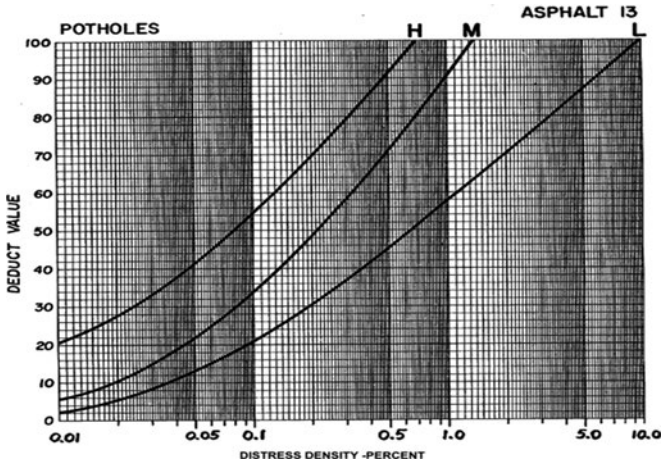

Figure 3. Flexible Pavement's deduct value, distress 43, pothole

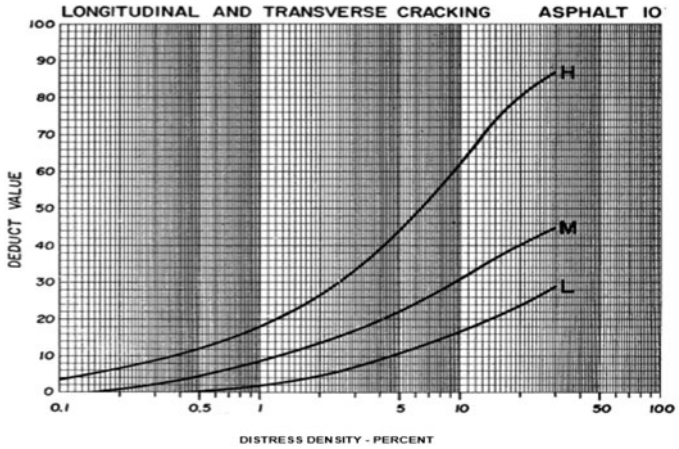

Figure 4. Flexible Pavement's deduct value, distress 42, longitudinal cracking

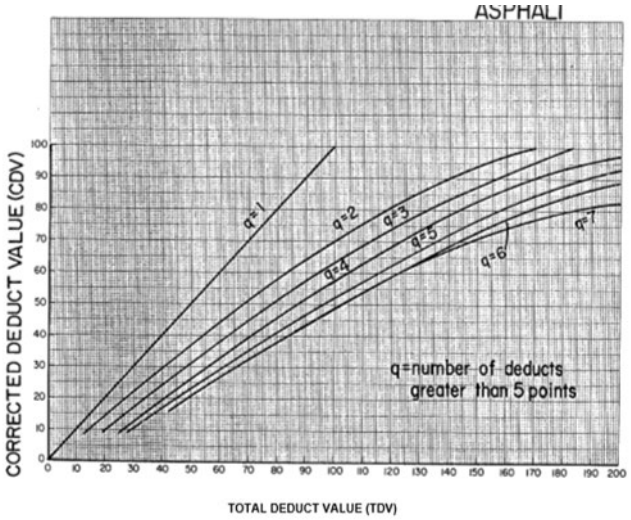

Figure 5. Corrected deduct value

The pavement deterioration data is obtained directly from the road location for each sample unit on each road section. The results of the survey results were then measured to gain the PPI value of each pavement segment. The total value of a survey in a single road segment PPI unit is the value of PPI in the road section being reviewed. The PPI value of each section is the estimated value for each sample unit. Assessment of the condition of each section based on the PPI value obtained by reference to the assessment scale shown in Table 4.

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Table 4: The PPI value and the level of Pavement Condition

Rs No.	Name of the road	PPI value	Pavement Condition	Priority Ranking
1	Main Road	78.0	satisfactory	5
2	Jalan Lembah	76.0	satisfactory	3
3	Wisma Pegawai Kadet	79.0	satisfactory	6
4	Marine Centre	77.0	satisfactory	4
5	Library	24.0	poor	1
6	Officer's House	67.0	fair	2

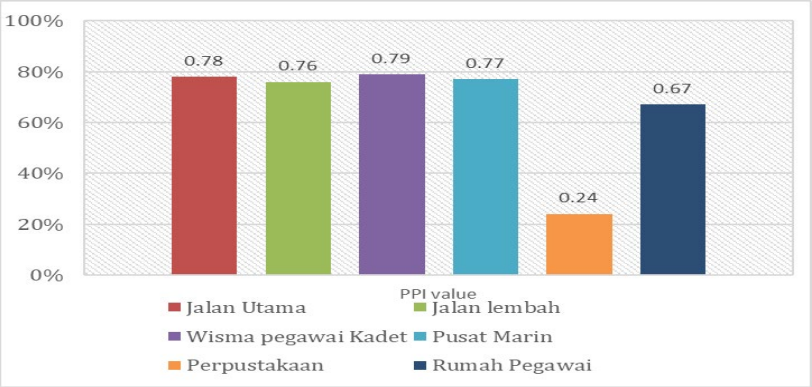

Figure 6. Percent of each section road in NDUM

4.0 CONCLUSION

Based on Table 4 and Figure 6, there are one section of the road that experienced the worst condition, namely the Library road with a value equal to 24 PPI (poor). Based on the decision matrix PPI issued by Ontario Good Roads Association in 2009, this section is recommended for reconstruction, while the section Main Road, Jalan Lembah, Wisma Pegawai Kadet, Marine Centre and Officer's house Maintenance activities such as preventive maintenance must be carried out to prevent damage and effective treatment. From this result also we can see the priority ranking of road for maintenance. The table 4 shows that the Library is the first priority for maintenance followed by Officer's House, Jalan Lembah, Marine Centre, Main road and lastly Wisma Pegawai Kadet. It has also been found from this project that the NDUM pavement segment rating is "fair" with the average Pavement Performance Index = 66.7, with several section rates as "poor". An experiment was conducted to decide if current NDUM pavement section is strong enough to support moving traffic loads as it is important to determine the asphalt's load density. The analysis shows that the pavement section is operationally strong to carry the load forced. The recommended repairs for the road sections are a continuation of the existing maintenance policy based on the established rating. Table 4 presents a feasible method of maintenance at the given level of severity for each type of distress.

5.0 ACKNOWLEDGEMENTS

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