METODE ZA PROCJENU STANJA KOLOVOZNE KONSTRUKCIJE SA PRIMJEROM OCJENE NA ULICAMA U NOVOM SADU

Milan Marinković
[1] *Fakultet tehničkih nauka Novi Sad, Departman za građevinarstvo i geodeziju, milan.marinkovic@uns.ac.rs*

Rezime: *U ovom radu su prikazane metode za procjenu stanja fleksibilnih kolovoznih konstrukcija. Tokom vremena dolazi do oštećenja kolovozne konstrukcije usljed saobraćajnog opterećenja, klimatskih faktora, redovnosti održavanja i kvaliteta materijala. Da bi mogli procjeniti postojeće stanje kolovozne konstrukcije potrebno je da izvršimo snimanja ili odgovarajuća mjerenja. Postoje nedestruktivne i destruktivne metode za određivanje stanja kolovoza. U ovom radu su prikazane 4 metodologije prikupljanja podataka vizuelnim pregledom i način obrade dobijenih rezultata. Navedene metodologije su: Pavement Condition Index (PCI), Strategic Highway Research Program (SHRP), Pavement Condition Rating (PCR), Present Serviceability Rating (PSR). Za svaku od metodologija su navedene skale ocjena i šta koja ocjena predstavlja.Takođe, prikazani su tipovi oštećenja za svaku od metodologija. Pored toga prikazan je i jedan primjer procjene stanja ulica u Novom Sadu prema Pavement Condition Index metodologiji.*

Ključne reči: *vizuelna procjena stanja, metodologije, kolovozne konstrukcije, oštećenja, nivoi oštećenosti, održavanje puteva.*

METHODS FOR ASSESSING THE CONDITIONS OF PAVEMENT WITH AN EXAMPLE OF ASSESSMENT IN NOVI SAD

Milan Marinković
[1] *Faculty of Technical Sciences of Novi Sad, Department of Civil Engineering and Geodesy*

Abstract: *This paper presents methods for assessing the condition of flexible pavement structures. Over time, pavement structures are damaged due to traffic loads, climatic factors, maintenance frequency and material quality. In order to assess the current condition of a pavement structure, it is necessary to perform surveys or appropriate measurements. There are non-destructive and destructive methods for determining the condition of pavements. This paper presents 4 methodologies for collecting data by visual inspection and the method of processing the obtained results. The mentioned methodologies are: Pavement Condition Index (PCI), Strategic Highway Research Program (SHRP), Pavement Condition Rating (PCR), Present Serviceability Rating (PSR). For each of the methodologies, rating scales are listed and what each rating represents. Also, the types of distresses for each methodology are shown. In addition, an example of assessing the condition of pavements in Novi Sad according to the Pavement Condition Index methodology is shown.*

Keywords: *visual assessment of condition, methodologies, pavement structures, distress, distress levels, road maintenance.*

1. INTRODUCTION

The pavement structure is a multi-layered system that serves to accept and transfer the load from the vehicle to the layers below it. The basic types of pavement structures are: flexible, semi-rigid and rigid pavement structures. Over time, the pavement deteriorates due to several factors. The main factors that contribute to the deterioration of the condition of pavement structures are: traffic load, quality of materials, climatic influences and the method and history of maintenance. Due to the deteriorating condition, it is necessary to carry out maintenance on the road in order to improve the condition [1]. Before the maintenance are carried out, it is necessary to determine the existing condition of the pavement. There are non-destructive and destructive methods for assessing the condition of the pavement structure. Non-destructive methods, as their name suggests, do not require damage to the existing pavement in order to determine the condition, while destructive methods damage the existing pavement structure. Within non-destructive methods, there are those that serve to assess the state of the structure and thickness of the pavement, such as Falling Weight Deflectometer (FWD) [2], Benkelman beam [3], Ground Penetrating Radar (GPR) [4], and there are also non-destructive methods that serve to visually assess distress to the surface of the pavement structure. This paper will present several methods for visual assessment of the condition of the road and will present an example of assessing the condition of the road surface for several streets in Novi Sad according to the PCI methodology.

2. METHODOLOGIES FOR VISUAL ASSESSMENT PAVEMENT STRUCTURE

Today, there are several ways to collect data on the condition of the road:
1. Visual field assessment of road conditions
2. Determining the condition based on video recordings and photographs manually or via software
3. Vehicles for recording road conditions

All of the above methods must be based on some procedure or method. Methods for assessing the condition of the pavement express the condition of the pavement through an appropriate numerical value. There are various methods and in this paper a few will be listed: Pavement Condition Index (PCI), Strategic Highway Research Program (SHRP), Pavement Condition Rating (PCR), Present Serviceability Rating (PSR).

2.1. Pavement Condition Index (PCI)

This methodology is defined by the ASTM D6344 - 24 – (Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys) [5]. According to this methodology, a pavement surface can be rated on a scale of 0 to 100, with 0 being the worst and 100 being the best condition. Pavement conditions are grouped into one of seven groups (Figure 1.).

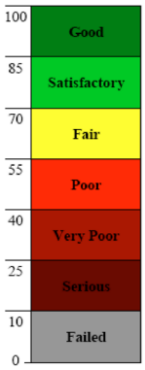

Figure 1. *Rating ranges and conditions according to PCI methodology* [5]
Source: (ASTM D6433-24-Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys)

To assess the condition, it is necessary to select a road section that has the same purpose, the same pavement structure, the same maintenance history and the same traffic load. The section is then divided into sub-sections whose area must be in the range of 225 ±90 m^2. After that, the minimum number of sub-sections for inspection is determined. This number is determined by the equation 1:

$$n = \frac{N*s^2}{\frac{e^2}{4}*(N-1)+s^2} \qquad (1)$$

where:
N-total number of sub-sections
e- acceptable error in estimating PCI values on a section. For the first calculation ± 5 points
s- standard deviation of PCI values on sub-sections within a section. When performing initial recording, s =± 10 points is recommended.

The resulting number n is rounded up to a higher value. The review interval is then determined using the equation 2:

$$i = \frac{N}{n} \qquad (2)$$

The PCI value calculation procedure consists of the following steps:

1. Distress surveys
2. Density of individual distress
3. Determining of deduct value
4. Determining the allowable number of deducts (m)
5. Total deduct values

6. Determining the corrected deduct values
7. PCI calculation

2.1.1. Distress surveys

According to this methodology, there are 19 (20) types of distress, which are listed in the Table 1. All distress, except for polished aggregate, has three levels of intensity: low (L), medium (M) and high (H). The causes of all distress are also shown in the Table 1.

Table 1. *Types of distress according to PCI methodology [5]*

Distress code	Distress	Cause of distress	Distress level
1	Alligator cracking	Traffic load	L, M, H
2	Bleeding	Other	L, M, H
3	Block cracking	Climate	L, M, H
4	Bumps and Sags	Other	L, M, H
5	Corrugation	Other	L, M, H
6	Depression	Other	L, M, H
7	Edge cracking	Traffic load	L, M, H
8	Joint reflection cracking	Climate	L, M, H
9	Lane/ shoulder drop off	Other	L, M, H
10	Longitudinal and transverse cracking	Climate	L, M, H
11	Patching and utility cut patching	Other	L, M, H
12	Polished aggregate	Other	-
13	Potholes	Traffic load	L, M, H
14	Railroad crossing	Other	L, M, H
15	Rutting	Traffic load	L, M, H
16	Shoving	Traffic load	L, M, H
17	Slippage cracking	Other	L, M, H
18	Swell	Other	L, M, H
19	Weathering/ raveling	Climate	L, M, H

During the survey of the condition of the pavement, all observed distress is recorded in the form shown below (Figure 2).

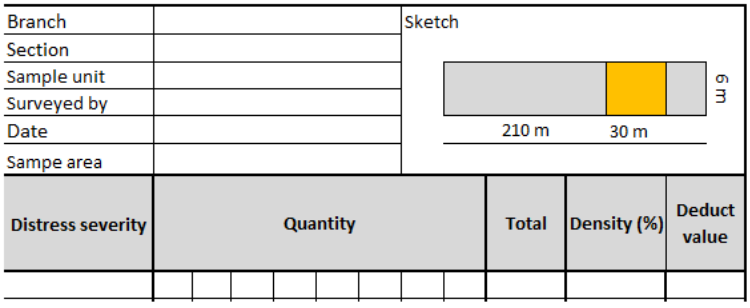

Figure 2. *Condition survey data sheet for sample unit* [5]
(Source: ASTM D6433-24-Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys)

The standard provides photographs with examples of what each type of distress looks like, which is an aid to the inspection staff if there are any doubts when classifying individual distresses.

2.1.2. Density of individual distress

The distress density is calculated according to the following equation 3:

$$Distress\ density = \frac{Distress\ area}{Sample\ unit\ area} \quad (3)$$

2.1.3. Determining of deduct value

Based on the density and type of distress and its intensity, deduct values are determined from the diagrams given in the standard. Figure 3 shows a diagram for determining the deduct value for alligator cracking.

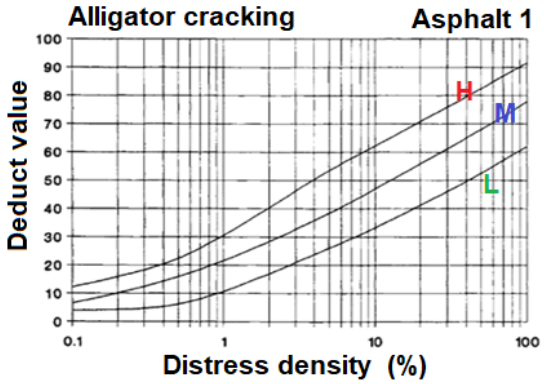

Figure 3. *Diagram for determining deduct value* [5]
Source: (ASTM D6433-24-Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys)

2.1.4. Determining the allowable number of deducts (m)

When all distresses and deduct values are registered on a sub-section, the deduct values are arranged in descending order from highest to lowest, and then the number m is calculated based on the equation 4:

$$m_i = 1 + \frac{9}{98} * (100 - \max CV) \qquad (4)$$

2.1.5. Total deduct value

After determining how many deduct values points are taken into account based on the parameter m, then we add all the deduct values and get the total deduct values.

2.1.6. Determining the corrected deduct values

Based on the total deduct values and number of deduct values greater than two (q), the values of the corrected sums of deduct values are determined.

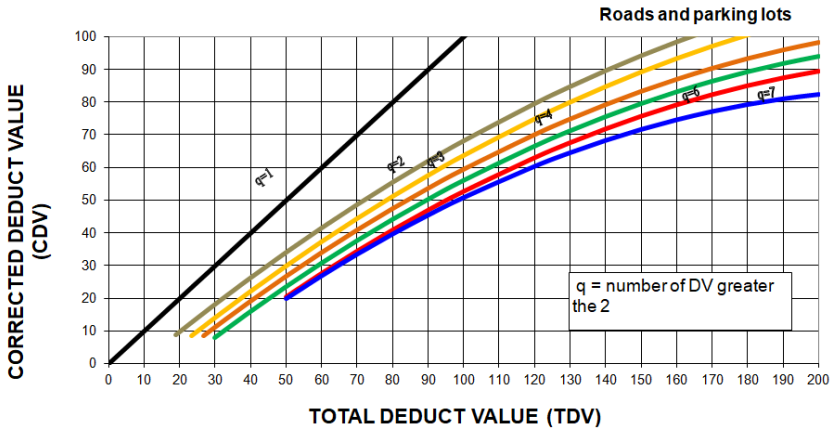

Figure 4. *Diagram for determining corrected deduct values* [5]
Source: (ASTM D6433-24-Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys)

2.1.7. PCI calculation

The last step is to determine the PCI for each individual sub-section based on the maximum value of corrected deduct values according to the equation:

$$PCI = 100 - \max CDV \qquad (5)$$

This is how the PCI values for individual subsections were determined, and for the PCI of the entire section, two cases are possible.

If the areas of the subsections are equal, then we use equation 6:

$$PCI = \frac{\sum_{i=1}^{n} PCI_i}{n} \quad (6)$$

If the areas of the subsections are not equal, then we use equation 7:

$$PCI = \frac{\sum_{i}^{n} PCI_i * A_i}{\sum_{i}^{n} * A_i} \quad (7)$$

2.2. Strategic Highway Research Program (SHRP)

As part of the SHRP program, a Distress Identification Manual [6] has been developed. According to the Manual, there are 15 types of asphalt pavement distress, grouped into five categories:

1. Cracking
2. Patches and potholes
3. Surface deformations
4. Surface defects
5. Miscellaneous distresses

Distresses are classified according to the degree of intensity (low, moderate, high).

Table 2. *Types of distresses according to SHRP methodology* [6]

Distress group (A, B,C, D, or E) and distress type (1,2,3,…..15)	Distress group (A, B,C, D, or E) and distress type (1,2,3,…..15)
A. Cracking	C. Surface deformation
1. Fatigue cracking	9. Rutting
2. Block cracking	10. Shoving
3. Edge cracking	D. Surface defects
4a. Wheel path longitudinal cracking	11. Bleeding
4b. Non-wheel path longitudinal cracking	12. Polished aggregate
5a. Reflection cracking at joints	13. Raveling
5b. Transverse reflection cracking	E. Miscellaneous distresses
5c. Longitudinal reflection cracking	14. Lane/shoulder drop-off
6. Transverse cracking	15. Water bleeding and pumping
B. Patching and potholes	
7. Patch/Patch deterioration	
8. Potholes	

The manual defines sections of 1km and subsections of 30.5m. Distresses is drawn in the prescribed form, the level of intensity is recorded and photographs are taken, which will later be attached to the report. What is special about this methodology is that there are no numerical values or indices expressing the condition of the pavement, but only a summary overview of the percentage of damage to the pavement is provided. The SHRP-LTPP methodology is intended primarily for monitoring the condition of the sections included in the LTPP experiment and is not intended for direct application to record the condition of other roads.

2.3. Pavement Condition Rating (PCR)

The Pavement Condition Rating (PCR) [7] was developed by the Ohio Department of Transportation to provide a procedure for identifying and describing the severity and extent of pavement distress. The PCR index expresses the impact of different types of distresses, their intensity, and extent on the overall condition of the pavement. The PCR index is calculated by subtracting deduct values for each type of distress observed, according to the following equation 8:

$$PCR = 100 - \sum Deduct \quad (8)$$

The PCR scale ranges from 0 to 100, where a value of 100 represents a pavement in perfect condition, with no visible distresses, and a value of 0 represents a pavement with all distresses of maximum intensity and extent. The Pavement Condition Rating distinguishes 13 types (Table 3) of distress to asphalt pavements. According to the intensity, the distresses are classified into three levels:

1. Low
2. Medium
3. High

According to the extent, or frequency of occurrence, the distress can be:

1. Occasional
2. Frequent
3. Extensive

Table 3. *Distress types and distress weights according to PCR methodology* [7]

Distress weight	Distress	Distress weight	Distress
10	1. Raveling	5	8. Corrugations
5	2. Bleeding	15	9. Wheel Track Cracking
5	3. Patching	10	10. Block and Transverse Cracking
5	4. Potholes/Debonding	5	11. Longitudinal Cracking
5	5. Crack Sealing Deficiency	5	12. Edge Cracking
10	6. Rutting	5	13. Random Cracking
0	7. Settlement		

According to PCR, the assessment of the road condition is carried out on the entire road. The road is divided into sections of 3-5 km in length, with lanes for different directions being observed as different roadways.

2.4. Present Serviceability Rating (PSR)

Present Serviceability Rating (PSR) [8,9] is defined by the Association of State Highway and Transportation Officials (AASHTO) based on a series of experiments conducted between 1956 and 1961. The PSR scale ranges from 5 to 0, i.e., it varies from excellent to practically impassable pavement.

Table 4. *Distress types and distress weights according to PCR methodology*[8,9]

PSR score	Description	Verbal score
4,0 -5,0	Only new or nearly new pavement.	Very good
3,0 -4,0	Visible signs of surface deterioration, beginning to show evidence of rutting and fine random cracks.	Good
2,0 -3,0	Surface defects may include rutting, map cracking and extensive patching.	Fair
1,0 -2,0	Distress affect the speed of free-flow traffic. Pavement may have large potholes and deep cracks. Distress includes raveling, cracking, rutting, and occurs over 50 %, or more, of the surface.	Poor
0 – 0,9	Pavement in extremely deteriorated condition. The facility is passable only at reduced speeds. Large potholes and deep cracks exist. Distress occurs over 75 % or more of the surface.	Very poor

Since the Present Serviceability Rating is a subjective rating system (Table 4), which requires a team of experts to drive along roadway and assess its condition descriptively based on a defined scale. This method was not practical for assessing the condition of long sections and that is why it was improved so that it does not require the presence of highly specialized personnel. The Present Serviceability Index was created for this purpose.

$$\log PSI = 5{,}03 - 1{,}91 * \log(1 + SV) - 0{,}01 * \sqrt{C + P} - 0{,}2139 * RD^2 \quad (9)$$

where is:
SV - slope variance
C, P - cracks/patches – (m² / 1000m²)
RD – rutting depth - (cm)

3. EXAMPLE OF ASSESSMENT OF THE CONDITION OF STREETS IN NOVI SAD ACCORDING TO PCI METHODOLOGY

In this paper, the PCI methodology was applied to several streets in Novi Sad in order to determine the condition of these roads. The condition of the following streets was assessed:

1. Vojvode Knićanina street
2. Miše Dimitrijevića street
3. Kolo srpskih sestara street

The survey of the condition was carried out at the beginning of 2023. The most common distresses observed during survey:

1. Vojvode Knićanina street - patching, longitudinal and transverse cracking, polished aggregate
2. Miše Dimitrijevića street - alligator cracking, patching (Figure 5)
3. Kolo srpskih sestara street- patching, longitudinal and transverse cracking

Figure 5. *Dominant distresses in Miše Dimitrijevića street (left- alligator crackings, right- patchings)*

According to methodology the following PCI values for the streets was calculated:

1. Vojvode Knićanina street 65.13
2. Miše Dimitrijevića street 61.8
3. Kolo srpskih sestara street 84.25

After the survey, distress maps were drawn and then a QGIS database was created. The Figure 6 shows a graphical representation of the roads with condition colors according to the PCI methodology.

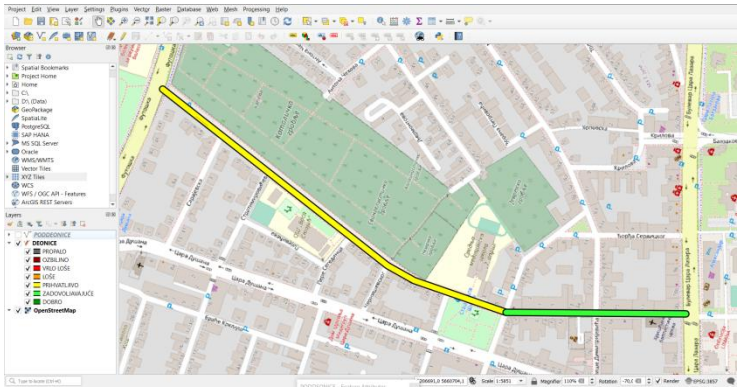

Figure 6. *Display of streets in QGIS based on their condition (yellow color - Vojvode Knićanina street, green color - Kolo srpskih sestara street)*

4. CONCLUSION

Regular and timely maintenance of pavement structures is very important. In order to do this in an acceptable manner, it is necessary to regularly assess the condition of the pavement. There are non-destructive and destructive methods for determining the condition. This paper presents methods based on visual inspection of the pavement. The following methods for assessing the condition are described: Pavement Condition Index (PCI), Pavement Condition Index (PCI), Strategic Highway Research Program (SHRP), Pavement Condition Rating (PCR), Present Serviceability Rating (PSR). For each methodology, the

distress and the assessment process are listed. Finally, an example of assessing three streets in Novi Sad using the PCI methodology is presented.

ACKNOWLEDGMENTS

This research has been supported by the Ministry of Science, Technological Development and Innovation (Contract No. 451-03-34/2026-03/200156) and the Faculty of Technical Sciences, University of Novi Sad through project “Scientific and Artistic Research Work of Researchers in Teaching and Associate Positions at the Faculty of Technical Sciences, University of Novi Sad 2026” (No. 01-3609/1).

REFERENCES

[1] Schattler, K., Rietgraf, A., Wolters, A., Zimmerman, K. (2011). Implementing Pavement Management Systems for Local Agencies –State-of-the-Art/State-of-the-Practice Synthesis, Report No. FHWA-ICT-11-094, Illinois Center for Transportation Department of Civil and Environmental Engineering

[2] Schmalzer Peter, N. (2006). LTPP Manual for Falling Weight Deflectometer Measurements, Version 4.1, Report No. FHWA-HRT-06-132, Federal Highway Administration. (on-line) available at: https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/06132/06132.pdf (20.03.2026)

[3] Linda M. Pierce, L. M., Bruinsma, J.E., Smith, K.D., Wade,M.J., Chatti, K., and Vandenbossche, J.M. (2017). Using Falling Weight Deflectometer Data with Mechanistic Empirical Design and Analysis, Volume III: Guidelines for Deflection Testing, Analysis, and Interpretation Report No. FHWA-HRT-16-011, Federal Highway Administration. (on-line) available at: https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/16011/16011.pdf (20.03.2026)

[4] United States Environmental Protecting Agency (2026). Ground Penetrating Radar (GPR). (on-line) available at: https://www.epa.gov/environmental-geophysics/ground-penetrating-radar-gpr (30.03.2026)

[5] Advancing Standards Transforming Markets (2024). ASTM D6433-24-Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys

[6] Strategic Highway Research Program (2014). Distress Identification Manual for the Long-Term Pavement Performance Project, Report No. FHWA-HRT-13-092,(on-line) available at: https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/13092/13092.pdf

[7] Saraf, L.C. (1998). Review of PCR Methodology. Report No. FHWA/OH-99/001. Ohio Department of Transportation, (on-line) available at: https://pages.mtu.edu/~balkire/CE5403/Lec12.pdf

[8] Michigan Technological University. Pavement Condition Indices, module 6, (on-line) available at: https://rosap.ntl.bts.gov/view/dot/17906

[9] Aderinlewo, O. (2016). Comparative Assessment of Road Rating Systems, Journal of Engineering Studies and Research – Vol. 22 (2): 7-14, (on-line) available at: https://jesr.ub.ro/journal/article/view/107