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The Pavement Condition Index (PCI) Method for Evaluating Pavement Distresses of The Roads in Iraq- A Case Study in Al- Nasiriyah City

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ABSTRACT : The pavement condition index (PCI) method provides a simple way for determining maintenance and repair (M-R) needs and priorities. The PCI procedure was developed by the U.S. Army Corps of Engineers in 1997. In this study, an attempt was made to adopt the PCI method to evaluate the pavement state and suggest suitable maintenance and repair (M-and-R) works for the 13 damaged roads. The area of the study is roads net damaged with raveling distress in Al-Hadharat Quarter in the city of Nasiriyah which located in the south of Iraq. The pavement had divided into branches which sub-divided into sections. The type and severity of pavement distress were assessed by visual inspection. The distress data used to calculate the PCI for each sample unit. Then the PCI of the whole pavement section is determined. The calculated PCI was assessed with the pavement condition rating. The results show that the PCI Rating evaluation was ranging from fair to poor roads, very poor and one case of serious, but never reached to fail case in any of the studied roads. The study shows that the (PCI) method provides a suitable measure of the present condition of the pavement. The main conclusion of the study is the ability to conduct the PCI method to diagnose pavement distresses and evaluate pavement condition in the studied area. The use of (PCI) method is efficient in the prior evaluation of road condition in order to implement suitable maintenance to the distressed pavement.

KEYWORDS:
Pavement Condition Index (PCI), Pavement Distress, Raveling Distress, Distress Severity, Inspection data sheet

1. INTRODUCTION..

Road networks are an essential part of the development of a country; therefore, they must be maintained in functional condition. Maintenance of the road involves prior evaluation of road condition in order to implement suitable maintenance so accurate evaluation of road condition should be done before the application of maintenance process.

As the road pavement is one of the basic parts of the road infrastructure, continuous maintenance and rehabilitation (M-and-R) works should be conducted periodically to prevent deterioration caused by repetitive traffic loading and environmental factors.

The pavement condition index (PCI) method is a numerical indicator that provides a measure of the present condition of the pavement based on the distress observed on the surface of the pavement. It provides a simple way for determining maintenance and repair (M-R) [5] needs and priorities. The ASTM covers standard practice for this procedure under the designation: D 6433 – 09.

2. HISTORICAL BACKGROUND

The PCI procedure was developed by the U.S. Army Corps of Engineers in 1997 [1]. In 2003 Galehouse et al list some of the benefits of PCI Which include the identification of the need for immediate M-and-R of roads; development of a road network, preventive maintenance strategies and budgets; and evaluation of pavement materials and designs [2] while in 2011 Hajj, et al clarify that Although the PCI rating of a roadway which is based on the observed surface distresses is not a direct measure of structural capacity, skid resistance or road roughness; but, it is an objective tool for assessing the M-and- R needs of a roadway section with respect to an entire pavement system [3]. In 2014 a case study was conducted in Hilla city by Jassim A. Alwan to prepare a site & laboratory studying to define the distresses and the pavement condition for one of the main roads by defining pavement distresses and their arising causes by standard American Pavement Condition Index (PCI) method and compare pavement condition definition with the familiar classical method [4].

As the PCI procedure deals with the subject of pavement distress identification most comprehensively and is based on a sound statistical technique of pavement sampling; Prof. Dr Fareed M.A. Karim et al used the PCI procedure to evaluate the pavement condition in terms of the surface distresses in Yemen in 2016 [5].

In 2017 Mohd. Shoyeb Ansari and A. R. Kambekar demonstrate a methodology for evaluating the condition of the road. The proposed study assumes that the condition of road follows a probabilistic behavior ranging from the best condition to worst and attempt to evaluate the condition of the road using surface distress survey. The probabilistic pavement condition index (PCI) is then evaluated. The study concluded that the proposed method can be used where limited fund and less time are available for inspection and maintenance of roads [6]. In the same year Ewadh et. al submitted a paper to develop a pavement condition index model using PAVER 6.5.7 for a flexible pavement urban road in the Kerbala city center. Data collected for pavement distress (type, dimension, and severity) were used to find PCI. The result of the prediction model of PCI shows that it is valid to be used in

the prediction of the condition of pavement for the same famil[illegible]. [7]

3. I[illegible]CRIPTION OF STUDY AREA

The area of the study is a roads net in Al-Hadharat Quarter in the city of Nasiriyah which located in the south of Iraq as shown in Figure 1.

Figure 1. Location of the Study Area (Al-Hadharat Quarter)

The total area of the quarter is 130,000 m^2 and contain 725 home with other service construction. There are 13 roads in the quarter having a total length of 1,308.69 m and total area equal to 1, 1819.61 m^2 show different level of raveling distress (Fig.2). In this study, an attempt was made to adopt the PCI method to evaluate the pavement state and suggest suitable maintenance and repair (M-and-R) works for the 13 damaged roads.

Figure 2. The Distressed roads in the Quarter

4.METHODOLOGY

The Pavement Condition Index (PCI) method is adopted in this study. The pavement is separated into branches that are detached into sections. Each section is divided into sample units. The type and severity of pavement distress is assessed by visual inspection of the pavement sample units. The distress data are used to calculate the PCI for each sample unit. Then the PCI of the whole pavement section is determined [(1)]. The calculated PCI will be assessed with the pavement condition rating—a verbal description of pavement condition as a function of the PCI value that varies from "failed" to "good" as shown in Fig.3 to identify the level and severity of the distresses in order to select the suitable remedies.

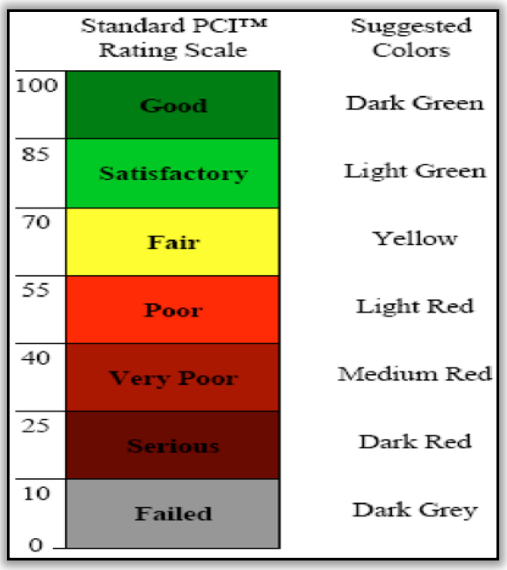


Figure 3. Pavement Condition Index (PCI) Rating Scale [(1)]

Raveling is one from 19 distresses which are included in the PCI method with three levels of distresses severity (low, medium and high) are classified for each distress type. These three severity levels of raveling distress according to the PCI method are shown in the Figure 4.

Fig(4A) High–Severity severity *Fig (4B) Medium –Severity* *Fig(4C)High*

Figure 4. Raveling Distresses Severity

5. THE FIELD STUDY

Several site investigations were carried out to Al-Hadharat Quarter in the city of Nasiriyah to collect the required data about raveling distresses. The studied area was divided into sections that have certain consistent characteristics throughout their area.

The total number of deteriorated roads were 13. A visual inspection of the pavement surface with field measurements provided valuable information which are used to evaluate the current pavement condition. The collected information was summarized in the Table 1.

Table 1. ASPHALT PAVEMENT SURVEYED ROADS DETAILS

Road No.	*Road Map Code*	*Road Width (m)*	*Road Length (m)*	*No. of Samples*	*Sample Dimension (m*m)*
1	*(B - 20)*	*9*	*84.6*	*9*	*9 * 10*
2	*(C - 46)*	*7*	*77.33*	*8*	*7 * 10*
3	*(C - 45)*	*7*	*120.41*	*6*	*7 * 20*
4	*(B - 13)*	*9*	*143.33*	*8*	*9 * 20*
5	*(B - 14)*	*9*	*136.67*	*10*	*9 * 15*
6	*(B - 15)*	*9*	*130.44*	*7*	*9 * 20*
7	*(D - 04)*	*12*	*229.72*	*12*	*12 * 20*
8	*(C - 48)*	*7*	*63.07*	*5*	*7 * 15*
9	*(C - 33)*	*7*	*63.07*	*5*	*7 * 15*
10	*(B - 32)*	*9*	*69.74*	*4*	*9 * 20*
11	*(B - 31)*	*9*	*76.68*	*4*	*9 * 20*
12	*(B - 30)*	*9*	*83.63*	*5*	*9 * 20*
13	*(B - 47)*	*9*	*30*	*3*	*9 * 10*

During a PCI survey, visible signs of deterioration were recorded and analyzed to determine the distress density which was calculated as follows:

Distress Density = (Distress amount in m^2 (ft^2)/ Sample unit area in m^2 (ft^2)) *100%

For each density the deduct value is calculated from Figure 5 which is presented by PCI method. [1]

The total deducts values (TDV) and maximum corrected deduct values (CDV) were obtained in order to estimate the PCI value as recommended by PCI method [1].

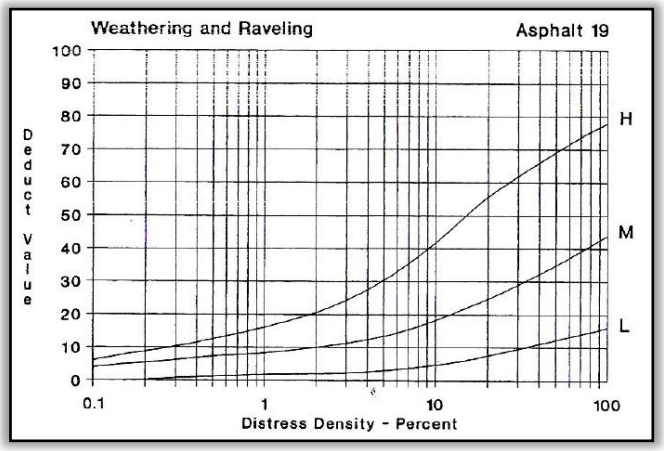


Figure 5. Deduct Value % of Weathering & Raveling Distress [1]

All the collected data, field measurements, estimated PCI index and PCI Rating Evaluation were summarized in tables as shown in Table 2 which represents the inspection data sheet for the studied roads. The diagnosed raveling distresses were classified according to their severity to (low, medium and high).

Table 2. Asphalt Pavement Inspection Data Sheet

6. DATA ANALYSIS AND ASSESSMENT

Throughout the site surveys and the collected data which were analyzed according to the PCI method, the results show that the PCI Rating evaluation was ranging from fair in two roads (no.9 & no.13), to poor in three roads (no.3, no.5 & no.10), very poor in seven roads (no.1, no.2, no.4, no.6, no.7, no.11 and no.12) and one case of serious in road no.8, but never reached to fail case in any of the studied roads .The fair state is clarified through road number (9) as shown in Figure 6& Table 3.

A- Low - Severity Raveling | B- Medium - Severity Raveling | C- High - Severity Raveling

Figure 6. Raveling Distress severity Road No. (9) (Fair condition)

Table 3. Asphalt Pavement Inspection Data Sheet of Road No. (9) (Fair Condition)

The Road Map Code No.			Road No.9 - (C - 33)				
The Describe			Width (m)	Length (m)	Total Area (m^2)		
The Data of the Total Road Section			7	63	441		
The Sample Unit Size			7	15	105		
Distress Survey Type			Raveling			Density %	Deduct Value %
No	Sta.	Area No.	Severity Status	Width m	Length m	Severity Area m^2	
1	0+0 to 0+15	I # 1	Low	6	8	48	10.9	5
		I # 2	Med.	3	5	15	3.4	11.5
		I # 3	High	3	5	15	3.4	25
2	0+15 to 0+30	I # 1	Low	6	12	72	16.3	6.5
3	0+30 to 0+45	I # 1	Low	5.66	10	56.6	12.8	5.5
		I # 2	Med.	6	5	30	6.8	15
4	0+45 to 0+60	I # 1	Low	7	15	105	23.8	11
5	0+60 to 0+63	I # 1	Med.	12	3	36	8.2	16.5
Total Values						**377.6**	**85.6**	**96**
Describe	Severity Level	Density Ratio	Highest Deduct Value			HDV	25

The Road Map Code No.					
The Describe			Width (m)	Length (m)	Total Area (m2)
The Data of the Total Road Section					
The Sample Unit Size					
Distress Survey Type			Raveling			Density %	Deduct Value %
No	Sta	Area No.	Severity Status	Width m	Length m	Severity Area m^2	
		# 1	Low					
		# 2	Medium					
		# 3	High					
Total Values								

Describe	Severity Level	Density	Highest Deduct Value	HDV	
			Max. Allow. No. of Deducts	m	
Low Ratio %			Number of Deduct Value	nD	
Medium Ratio %			Number of Deduct Value >2	q	
High Ratio %			Max. Correct Deduct Value	CDV	
Total Ratio %			Pavement Condition Index	PCI	
Pavement Evaluation			**Result**		

			Max. Allow. No. of Deducts	m	7.89
Low Ratio %	74.3	63.8	Number of Deduct Value	nD	9
Medium Ratio %	21.7	18.4	Number of Deduct Value > 2	q	9
High Ratio %	4	3.4	Max. Correct Deduct Value	CDV	44
Total Ratio %	100	85.6	Pavement Condition Index	PCI	56
Pavement Evaluation			**Result**		**Fair**

The poor state is explained through road number (3) as explained in Figure 7 and Table 4.

A- Low - Severity Raveling | B- Medium - Severity Raveling | C- High - Severity Raveling

Figure 7. Raveling Distress severity Road No. (3) (Poor condition)

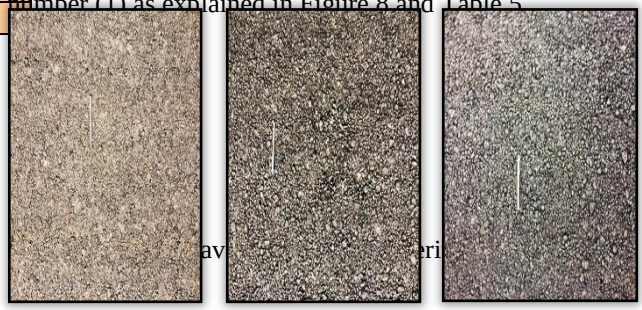
Table 4. Asphalt Pavement Inspection Data Sheet of Road No. (3) (Poor condition)

The Road Map Code No.	Road No.(3) (C - 45)		
The Describe	Width m	Length m	Total Area m
The Data of the Total Road Section	7	120.4	842.87
The Sample Unit Size	7	20	140

Distress Survey Type				Raveling			Density %	Deduct Value %
No	Station	Area No.	Severity Status	Width m	Length m	Severity Area m^2		
1	0+00 to 0+20	C#1	Low	1	10	10	1.186	1.8
		C# 2	Medium	0.5	10	5	0.593	8
		C# 3	High	5.7	6.5	37	4.396	29
2	0+20 to 0+40	C# 1	Low	0.5	10	5	0.593	1.5
		C# 2	Medium	2	10	20	2.373	10
		C# 3	High	1.5	10	15	1.78	20
3	0+40 to 0+60	C# 1	Low	0.5	10	5	0.593	1.5
		C# 2	Medium	3.5	10	35	4.152	13
		C# 3	High	1.5	10	15	1.78	20
4	0+60	C# 1	Low	1.5	8	12	1.424	2
	to 0+80	C# 2	Medium	0.5	1.5	0.75	0.089	4
5	0+80 to 1+00	C# 1	Low	1	10	10	1.186	1.8
6	1+00 to 1+20	C# 1	Medium	2	14	28	3.322	2.5
		C# 2	High	3	10	30	3.559	3
Total Values						227.8	27.02	118.1

Describe	Severity Level	Density		
			Highest Deduct Value	HDV 29
			Max. Allow. No. of Deducts	m 7.52
Low Ratio %	43.9	5	Number of Deduct Value	nD 14
Medium Ratio%	26.7	10.5	Number of Deduct Value > 2	q 9
High Ratio %	29.4	11.5	Max. Correct Deduct Value	CDV 52
Total Ratio %	100	27	Pavement Condition Index	PCI 48
Pavement Evaluation			Result	Poor

While the very poor state is explained through road number (1) as explained in Figure 8 and Table 5.



A- Low - Severity Raveling B- Medium - Severity Raveling C- High - Severity Raveling

Road No. (1) (very poor)

And serious condition is represented by road no. (8) as illustrated in Figure 9 and Table 6.

A- Low - Severity Raveling B- Medium - Severity Raveling C- High - Severity Raveling

Figure 9. Raveling Distress severity Road No. (8) (Serious condition)

The Road Map Code No.	Road No.(1)- (B - 20)		
The Describe	Width (m)	Length (m)	Total Area (m^2)
The Data of the Total Road Section	9	84.6	761.40
The Sample Unit Size	9	10	90

Distress Survey Type				Raveling			Density %	Deduct Value %
No	Sample Station	Area No.	Severity Status	Width m	Length m	Severity Area m^2		
1	0+00 to 0+10	A1	Low	0.6	10	6	5.38	5
		A2		2.5	2	5		
		A3		3	10	30		
2	0+10 to 0+20	A1	Low	2	7.05	14.1	5.79	4.5
		A2		1.6	10	16		
		A3		1.4	10	14		
3	0+20 to 0+30	A1	Low	1.7	10	17	6.17 3	4
		A2		1.5	10	15		
		A3		1.5	10	15		
4	0+30 to 0+40	A1	Low	1.4	10	14	5.25	3
		A2		1.6	10	16		
		A 3		1	10	10		
5	0+40 to 0+50	A1	Low	1.1	10	11	2.89	2.5
		A2		1.1	10	11		
6	0+50 to 0+60	A 1	Low	1	10	10	1.31	1.8
		A 2	Med.	1.3	5	6.5	0.85	8.5
7	0+60 to 0+70	A 1	Low	1.1	10	11	3.41	3
		A 2	Med.	1.7	10	17	2.23	10
		A 3	Low	1.5	10	15	---	---
8	0+70 to 0+80	A 1	Low	1	3	3	0.39	1
		A 2	Med.	0.5	3	1.5	0.19	5.5
		A 3	High	9	10	90	11.8	43.5
9	0+80 to 0+90	A 1	Low	1.2	10	12	1.58	2
		A 2	High	8.3	7	58.1	7.63	37
Total Values						418.2	54.9	131.3

Describe	Severity Level	Density		
			Highest Deduct Value	HDV 43.5
			Max. Allow. No. of Deducts	m 6.19
Low Ratio %	58.6	32.167	Number of Deduct Value	nD 14
Medium Ratio %	6	3.284	Number of Deduct Value > 2	q 11
High Ratio %	35.4	19.451	Max. Correct Deduct Value	CDV 65
Total Ratio %	100	54.9	Pavement Condition Index	PCI 35
Pavement Evaluation			Result	Very Poor

Table 6. Asphalt Pavement Inspection Data Sheet of Road No. (8) (Serious condition)

The main causes of raveling distress may be belonging to:

1- Lack of binding due to use inappropriate binder or less than required.
2- The use of dirty and or fragile aggregate.
3- Weakness in the asphalt layer as a result of improper compaction and delay in laying time after mixing.

Road No.	Road Map Code	Distress Density (%)	PCI Index	PCI Rating Evaluation	Suggested Pavement Treatment
1	B-20	54.925	35	Very Poor	Slurry Seal
2	C-46	49.877	39	Very Poor	Slurry Seal
3	C-45	27.026	48	Poor	Fog Seal
4	B-13	51.593	37	Very Poor	Slurry Seal
5	B-14	66.451	54	Poor	Fog Seal
6	B-15	76.152	36	Very Poor	Slurry Seal
7	D-04	85.592	27	Very Poor	Slurry Seal
8	C-48	76.331	21	Serious	Slurry Seal
9	C-33	84.712	56	Fair	Not Need
10	B-32	82.050	44	Poor	Fog Seal
11	B-31	88.245	29.5	Very Poor	Slurry Seal
12	B-30	66.428	27	Very Poor	Slurry Seal
13	B-47	88.888	68	Fair	Not Need

4- Improper heating and mixing of asphalt mixture.

Table (7) below, shows all roads evaluation according to PCI method.

Table 7. Served Roads Evaluation Pavement Condition Index (PCI)

No	Road Map Code	Road Width (m)	Road Length (m)	Road Area (m^2)	Distress Density (%)	PCI INDEX	PCI RATING Evaluation
1	B-20	9	84.6	761.4	54.93	35	Very Poor
2	C–46	7	77.33	541.3	49.88	39	Very Poor
3	C-45	7	120.4	842.8	27.02	48	Poor
4	B- 13	9	143.3	1,290	51.59	37	Very Poor
5	B- 14	9	136.6	1,230	66.45	54	Poor
6	B-15	9	130.4	1,174	76.15	36	Very Poor
7	D-04	12	229.7	2,757	85.59	27	Very Poor
8	C- 48	7	63.07	441.5	76.33	21	Serious
9	C- 33	7	63.07	441.5	84.71	56	Fair
10	B- 32	9	69.74	627.7	82.05	44	Poor
11	B-31	9	76.68	690.1	88.24	29.5	Very Poor
12	B-30	9	83.63	752.7	66.43	27	Very Poor
13	B- 47	9	30	270.0	88.88	68	Fair

The possible remedies for each road are depending upon the distress severity therefore the suggested treatment can be listed in Table 8.

The Road Map Code No.				Road No. 8 - (C - 48)				
The Describe				Width (m)	Length (m)	Total Area (m^2)		
The Data of the Total Road Section				7	63.07	441.49		
The Sample Unit Size				7	15	105		
Distress Survey Type				Raveling				
No	Sta.	Area No.	Severity Status	Width m	Length m	Severity Area m^2	Density %	Deduct Value %
1	0+0 to 0+15	H# 1	Low	3	6	18	4.077	3
		H# 2	Med.	3	6	18	4.077	12.5
		H# 3	High	5	7	35	7.928	37.5
2	0+15 to 0+30	H# 1	Med.	6	12	72	16.31	22.5
3	0+30 to 0+45	H# 1	Med.	6	12	72	16.31	22.5
4	0+45 to 0+60	H# 1	Med.	6	12	72	16.31	22.5
		H# 2	High	5	7	35	7.928	37.5
5`	0+60 to 0+63	H# 1	High	5	3	15	3.4	6.5
Total Area Values						337	76.33	164.5

Describe	Severity Level	Density			
			Highest Deduct Value	HDV	44
			Max. Allow. No. of Deducts	m	6.14
Low Ratio %	5.3	4.077	Number of Deduct Value	nD	7
Medium Ratio %	69.4	53	Number of Deduct Value > 2	q	7
High Ratio %	25.2	19.2	Max. Correct Deduct Value	CDV	79
Total Ratio %	100	76.3	Pavement Condition Index	PCI	21
Pavement Evaluation			Result		Serious

Table 8. Served Roads Evaluation Pavement Condition Index (PCI)

No.	Road Condition	Treatment
1	Fair	----
2	Poor	Fog Seal
3	Very Poor	Slurry Seal
4	Serious	Slurry Seal

The roads with fair condition didn't need for instantaneous treatment while emulsified asphalts (fog seal) may be used to repair the poor condition roads. The fog seal increases adhesion between mixture components. The suitable deal with serious deteriorated roads is the use of slurry seal consists of slow setting emulsion with well graded small gravel and filler. The slurry seal (3-6 mm

thickness) is used to fill cracks and holes and outlaw disintegration of mixture fragments.

Table (9) shows final summery for all 13 considered roads in the study.

Table 9. The Served Roads Summary

7. CONCLUSION

In this study, an attempt was made to adopt the PCI method to evaluate the pavement state and suggest suitable maintenance and repair for the 13 damaged roads. The results show that the PCI Rating evaluation was ranging from fair to poor roads, very poor and one case of serious, but never reached to fail case in any of the studied roads.

The study shows that the (PCI) method provides a suitable measure of the present condition of the pavement based on the distress observed on the surface of the pavement. The main conclusion of the study is the ability to conduct the PCI method to diagnose pavement distresses and evaluate pavement condition in the studied area. The use of (PCI) method is efficient in the prior evaluation of road condition in order to implement suitable maintenance to the distressed pavement.

8. RECOMMENDATIONS

Throughout site investigation, distresses diagnosis and pavement assessment according to PCI: Pavement Condition Index method the main recommendations can be listed below:

1- Treat raveling distress in all the studied roads according to the suggested treatments.

2- It is necessary to clean the deteriorated sections with suitable manner such as pumped air and remove all disintegrated materials before starting treatment.

3- It is required to conform all requirements and technical specifications for laying and compaction according to Iraqi specifications (R8 & R9).

4- More studies about the use of PCI method in Iraq should be conducted.

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