



## The Effect of Speed Humps on Highways Pavement Condition

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### ABSTRACT

Speed humps used as a tool of traffic calming technique that applied to force drivers to reduce their vehicle' speeds at some locations. For developed countries, the implementations of speed humps are often used within residential areas as well as at locations of schools crossing. For developing countries (e.g. Iraq), speed humps are used even at urban and urban highways. This paper investigates the effect of applying such speed humps on pavement condition index (PCI). For the purpose of this study, ten urban and rural highway sites that paved by asphalt concrete have been selected from Al-Diwaniyah city, Iraq. Each site has been divided to sections before and after the humps. Each section has been surveyed to record the distress types used in calculations the values of PCI. It has been noticed that the rutting distress is the dominant type for sections just before the humps. The PCI values were significantly lower at sections near the humps compared with the faraway sections. In addition, the effect of speed humps on the PCI values can be neglected at urban highways where minimal trucks used these highways. The results of the paper suggested that an attention should be provided to identify reasonable warrants for installing of speed humps on flexible highway pavements.

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## 1. INTRODUCTION

Speed humps used as a tool of traffic calming technique that applied to force drivers to reduce their vehicle' speeds at some locations. These humps are raised obstruction with a height 3 to 4 inches that fixed on road pavements to cause specific impeding for vehicle speeds and usually located across the whole width of the road. For developed countries, the speed humps are often used within residential areas as well as at locations of schools crossing. For developing countries (e.g. Iraq), speed humps are used even at urban and urban highways at locations usually near highways intersections, U-turn sites and even at high speed sites [1, 2]. Globally, the common shapes of speed hump are parabolic, circular, and sinusoidal. The common type of speed humps that used in Iraq is the parabolic one. A typical speed hump that used in Iraq is shown in Figure 1.

The main positive impact of speed hump is representing by significant improvement in traffic safety through reducing the number of killed and injured people

[3-5]. Another good effect for humps is the significant reduction of turning time at median U-turn sites which means improving the merging conditions [6].

However, there are many negative issues appeared as results of using such humps. It has been found that the humps have increased the fuel consumption as a result of stop-and-go condition of traffic. The traffic pollution has significantly increased and the probability of vehicle damage has also increased [7, 8].

There are many methods for evaluating the surface condition of the highway pavements such as present serviceability index (PSI), present serviceability rating (PSR) and pavement condition index (PCI). The PSR measurement is based on users' subjective opinions related to the riding quality and that would produce difficulties in producing accurate evaluation [9]. The PSI was developed later based on complicated measurements for surface distresses and linked with mathematical equations. The PCI method makes a scale for evaluation of pavements based on the quantity and severity of

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highway distresses. According to the US department of transport [9], the PCI is the most widely method that is successfully adopted for many highway agencies.

Setyawan et al. [10] based on data from five highway sections, derived a correlation between the PCI and the remaining life based on collected data. Elhadidy et al. [11] investigated the correlation between PCI and another evaluation method called international roughness index (IRI); they suggested a strong relationship. Many other research works addressed the evaluation of their local pavements using the PCI method [12, 13].

The investigations on the effect of speed humps on highway surfaces have been conducted by some research work. The PCI is the common index that used in the evaluation. In Egypt, Abdel-Wahed and Hashim [14] examined the effect of humps parameters (such as height and width) on PCI; they reported that the pavement surface is significantly influenced by such humps and their characteristics. Similar results were obtained by Bekheet [15] based on data from Alexandria highways (Egypt). The study concluded that raveling was the dominant distress near the humps.

Gedik et al. [16] concluded that the most affecting parameter is the height of the hump in considering drivers discomfort. Al-Obaedi [2] used radar speed gun device to examine the speeds at humps and found that drivers are forced to slow down with an average speed of about 20km/h.

So far, little attention has been paid in previous research work for the effect of humps on pavement surface and with the increasing of the use of speed humps in Iraq. An investigation on the effect of speed humps on pavement condition became necessary. This paper uses real observation data to examine the possible effect on highway pavements. The idea is to evaluate the pavement surface for some selected sites at sections faraway and near to the speed humps.

## 2. METHODOLOGY

The research methodology adopted here is representing by sites selection, data collection and analysing the data.



Figure 1. A typical speed hump used in Iraq

For sites selection, ten sites have been selected representing urban and rural highways within Al-Diwaniyah province (Iraq). Each site of these has one or more speed humps. For the purpose of data collection, each site has been divided to sections based on the distance with respect to speed humps.

While the evaluation methods such as PCI, PSR and PSI are commonly used for long highway sections; it is believed that such evaluation methods are still applicable even for relatively short sections (such as the sections used in this study). Numerical analysis is required to compare between section with and without speed humps. The PCI method has been selected in this study since it can be directly linked to the pavement distresses that can be accurately obtained from sites [15]. Therefore, the collected data from each site is represented by recording the distress types and severity of the distresses as required according the PCI method.

The PCI method makes a scale for evaluation of the highways based on the calculated PCI value that ranges from 0 to 100. Low values of PCI indicate the worst condition. Table 1 shows the PCI scale that ranges from failed (0 – 10) value to good (85 – 100) value.

The estimation of PCI value for a given roadway section is based on estimating the deduct value for each distress type and severity. According to the method, there are three severity types for each distress (low, medium and high). The severity of each distress depends on the technical evaluation. For example and for the rutting failure, the rutting is regarded as “low severity” if the rut depth is between (6-13) mm and regarded as “middle severity” if the rut depth is higher than 13mm and up 25mm. Values of rut depth that higher than 25mm is regarded as “high severity”. The estimation of deduct values are obtained from some figures based on the distress density calculated by Equation (1) and the severity type. For example, the Figure 2 shows a graph for estimating of deduct values for rutting distresses. The sum of the considered deduct values for the distress types should be corrected using specific procedure described in ASTM D6433 [17] to estimate the maximum corrected deduct value (MCDV). The procedure suggested to limit the maximum number of deduct values for each section based on Equation (2). The MCDV is then obtained based on some iterations using a correction graph. The PCI is estimated assuming that the pavement condition is at a perfect conditions (PCI =100) and subtracting MCDV as in Equation (3). For the details of the PCI method, please refer to ASTM D6433 [17].

$$\text{Distress density} = \frac{\text{Distress quantity}}{\text{Section area (m}^2\text{)}} * 100 \quad (1)$$

$$m = 1 + \frac{9}{98} (100 - HDV) \quad (2)$$

$$PCI = 100 - MCDV \quad (3)$$

where:

m: is the maximum taken deduct values

HDV: is the heighest individual deduct value

MCDV: is the maximum corrected deduct value

### 3. SITE SELECTION AND DESCRIPTION

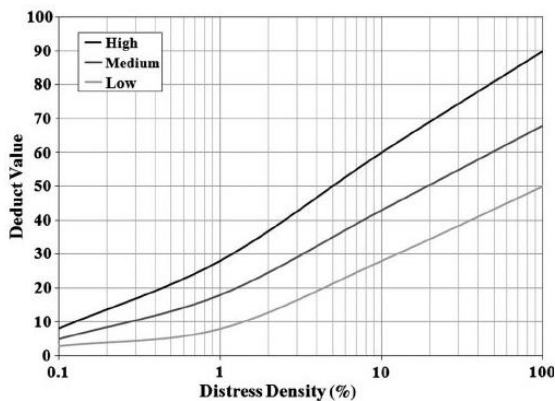
Ten sites have been selected in this study, within Al-Diwaniya city (Iraq), to investigate the effect of speed humps of the pavement condition. All the selected sites have speed humps and paved by asphalt concrete layers. Some of the selected sites are classified as rural multilane highways (connect between cities) where the traffic usually is mixed (i.e. trucks and small cars) and the others are urban multilane highways where most traffic is representing by small cars.

In order to examine the effect of speed humps on pavement condition properly, it is required that the traffic volume at the selected site would be the same at the whole length of the section. Therefore, all of the selected sites were chosen to be out of the influence of merging or diverging areas (i.e. no exit or entrance within the selected sites).

Each site has been divided into sections as recommended by (ASTM D6433) with a length of 50m.

**TABLE 1.** PCI values evaluation

PCI value	Evaluation
0 - 10	failed
10 - 25	serious
25 - 40	very poor
40 -55	poor
55 - 70	fair
70 -85	satisfactory
85 - 100	Good



**Figure 2.** An example of the figures used in PCI method (source: Shahin [18] based on ASTM D6433 [17])

Table 2 presents a summary of the selected sites with the number of sections and speed humps. In total 43 sections were independently surveyed associated with 14 speed humps.

### 4. SURVEYING RESULTS

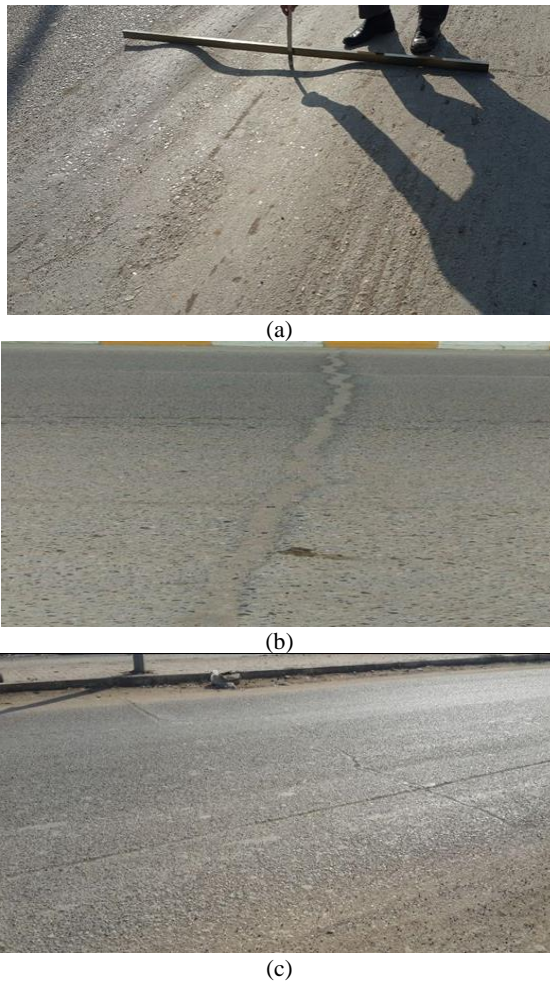
For each site and for each section with a length 50m, visual inspection is applied to survey and record the available distress types such as cracks, rutting, potholes, and others. Once a distress is noticed, measurements will be applied to estimate its dimensions and frequency. For rutting distress, a rigid and straight bar is used to estimate the rut depth and the tape is used to estimate its longitudinal length (see Figure 3a) based on such measurements, the severity and the deduct value will be obtained for each distress type.

Table 3 presents the recorded distress types, distress quantity, distress density, deduct values and the PCI for the sections of the site no. 1. Figure 4 shows a graph illustration of the sections used in site no. 1. The site represents a rural multilane highway that connects between Al-Diwaniya and Najaf provinces. The highway serves mixed traffic with about 15% trucks.

The surveying results in Table 3 suggest that longitudinal, traverse and block cracking were found in a pavement section no. 1, which is faraway from the influence of the speeds hump. In approaching toward the hump, rutting distress was created because of the reduction in traffic speeds approaching the hump. Fig. 3 shows some distress types taken from site 1.

**TABLE 2.** Summary of the selected sites

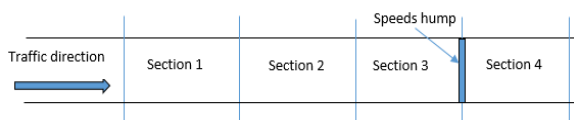
Site No.	Location	Number of Speed humps	Number of sections	Type of the road	
1	Diwaniyah-Najaf	1	4	Rural multilane	
2	Diwaniyah-Dagara	1	3		
3	Diwaniyah – Hamza	1	3		
4	Diwaniya- Hilla	3	9		
5	Hilla-Diwaniyah	3	9		
6	The university ring road 1	1	3		
7	The university ring road 2	1	3		
8	College of engineering road	1	3		
9	Um Al-Khail road	1	3		Urban multilane
10	Al-Jazair entrance road	1	3		



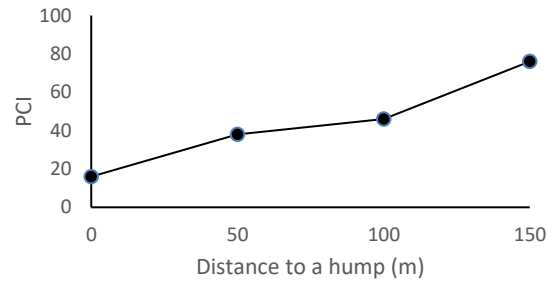
**Figure 3.** Typical distresses taken from site 1: (a) rutting distree, (b) transverse cracking, and (c) longitudinal and transverse cracking

The PCI values in Table 3 suggest that the most affecting type of distresses is the rutting since it causes the highest deduct values. Figure 5 shows the variation in PCI values with the distance to a hump for site no.1 and suggests that the PCI values were significantly decreasing in approaching to the speeds hump.

The results for the site no. 2 that connects between Al- Diwaiyah and Al-Daghara cities are shown in Table 4. The highway represents rural multilane highway with



**Figure 4.** A graph illustrates the sections of site no. 1



**Figure 5.** PCI values with a distance to the hump in site no. 1

two lanes at each direction. With a similar trend to those results for site no. 1, the PCI value for a section close to the speeds hump was much lower than PCI value for a section faraway of the speeds hump.

The results of the PCI values for the other sites (sites 3 to 10) are shown in Table 5. It shows the results for the PCI values for sections faraway on the speeds hump, just before the hump, and just after the hump. The data taken from sites 3 and 4 are for three humps at each site while the other sites has only one hump each.

The results for sites 3 to 7 suggest that the PCI values were significantly reduced at sections close to speed humps. For example, the PCI value for site 3 at a section faraway from the hump is 91.5 while the PCI values for the sections just before and after the hump were 14.5 and 57.5,- respectively. This is could be related to the presence of high proportion of trucks that used these rural roads since these trucks are forced to reduce their speeds at the sections before the humps. The section just after the hump is also influenced because trucks have limited acceleration abilities. It is well known that the movement of traffic with low speeds would increase the time that the pavement is exposed to traffic loading and that inversely affect the pavement condition.

For sites 8 to 10, which classified as urban roads, the results suggested that the PCI values are not greatly influenced by the proximity to the humps. This is due to a fact that these urban roads do not accommodate high proportion of heavy trucks and that produces minimal effect on pavement condition.

From the above results, it can be concluded that the presence of speed humps on urban asphalt concrete pavements, with mixed traffic (i.e. passenger cars and trucks), would significantly reduce the pavement serviceability. However, further research is needed to cover other humps with different longitudinal sections and pavement types.

**TABLE 3.** The surveying and PCI results for site 1

Section No.	Station	Distress type	Distress quantity	Distress density	Severity	Deduct value	MCDV	PCI
1	100-150 before a hump	Longitudinal cracking	22 m	5.5	Low	4	24	76 Satisfactory
		Longitudinal cracking	6 m	1.5	Medium	3		
		Block cracking	120 m <sup>2</sup>	30	Low	16		
		Transverse cracking	8 m	2	Medium	5		
		Transverse cracking	1.5 m	0.375	High	4		
2	50-100 before a hump	Block cracking	73 m <sup>2</sup>	18.25	Low	12	54	46 Poor
		Alligator cracking	20 m <sup>2</sup>	5	Medium	26		
		Transverse cracking	1 m	0.25	High	3		
		Longitudinal cracking	10 m	2.5	Low	1		
		Rutting	40 m <sup>2</sup>	10	Medium	44		
3	0-50 before a hump	Transverse cracking	3.5 m	0.875	High	7	62	38 Very poor
		Longitudinal cracking	38 m	9.5	Medium	17		
		Block cracking	88 m <sup>2</sup>	22	Low	9		
		Rutting	120 m <sup>2</sup>	30	Medium	58		
4	0-50 After a hump	Transverse cracking	2 m	0.5	High	5	84	16 Serious
		Rutting	152 m <sup>2</sup>	38	High	82		
		Longitudinal cracking	40 m	10	Low	8		
		Rutting	48 m <sup>2</sup>	12	Low	28		

**TABLE 4.** The surveying and PCI results for site 2

Section No.	Station	Distress type	Distress quantity	Distress density	Severity	Deduct value	MCDV	PCI
1	100-150 before a hump	Alligator cracking	2 m <sup>2</sup>	0.56	Medium	27	29	71 Satisfactory
		Transverse cracking	4 m	1.11	Medium	2.7		
2	0-50 before a hump	Rutting	1.65 m	0.459	Medium	12	78	22 Serious
		Transverse cracking	6.5 m	1.795	Medium	3.5		
		Potholes	1	0.278	Low	7		
		Alligator cracking	30 m <sup>2</sup>	13.88	Medium	67		
		Depression	17.5 m <sup>2</sup>	4.885	High	43		
3	0-50 after a hump	Rutting	33 m <sup>2</sup>	9.17	Medium	43	78	22 Serious
		Transverse cracking	10.2 m <sup>2</sup>	2.83	Medium	7.5		
		Alligator cracking	20 m <sup>2</sup>	5.5	High	55		
		Potholes	1 count	0.278	High	30		

**TABLE 5.** Summary of the PCI results for sites 3 -10

Site No.	No. of humps	Location of a section with respect to the hump			Road type
		Faraway	50 m before	50 m after	
3	1	91.5	48	57	Rural multilane roads
	1	86	32	50	
4	2	86	6	28	
	3	86	74	86	
5	1	86	30	50	
	2	84	46	43.5	
6	3	84	42	67.5	
	1	95	34	57	
7	1	89	88	85	
8	1	88.5	74	94	
9	1	84	90	74	
10	1	95	94	94	

## 5. CONCLUSIONS

This paper addressed the effect of using speed humps on the condition of the highway pavements. PCI method is adopted to evaluate the surface condition of the highway pavements. Ten urban and rural highways sites that paved by asphalt concrete have been chosen from Al-Diwaniyah city (Iraq). Each site has been divided into sections faraway, just before and just after the humps. Each section has been surveyed to record the distress types used in calculations the values of PCI. The results showed that the rutting distress is the dominant and the most effective type for sections just before the humps. The PCI values were significantly lower at sections near the humps compared with faraway sections. In addition, the effect of speed humps on the PCI values can be neglected at urban highways where minimal trucks used these highways. The findings of the research suggested that an attention should be given to adopt reasonable warrants for fixing of speed humps on flexible highway pavements.

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**Persian Abstract**

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**چکیده**

سرعت گیر به عنوان ابزاری از تکنیک آرام سازی ترافیک استفاده می شود که رانندگان مجبور می شوند سرعت خودروهایی خود را در بعضی از نقاط کاهش دهند. برای کشورهای توسعه یافته، پیاده سازی تپه های سرعت گیر اغلب در مناطق مسکونی و همچنین در مکان های عبور از مدارس استفاده می شود. برای کشورهای در حال توسعه (به عنوان مثال عراق)، تپه های سرعت گیر حتی در بزرگراه های شهری و داخل شهر استفاده می شوند. در این مقاله به بررسی تأثیر استفاده از چنین تپه های سرعت گیر بر حسب شاخص وضعیت روسازی (PCI) می پردازیم. به منظور انجام این مطالعه، ده سایت بزرگراه شهری و روستایی که با بتن آسفالت آسفالت شده اند، از شهر الدیوانیه عراق انتخاب شده اند. هر سایت به بخش هایی قبل و بعد از برآمدگی تقسیم شده است. در هر بخش برای ثبت انواع استرس مورد استفاده در محاسبه مقادیر PCI بررسی شده است. مشاهدات نشان می دهد که استرس روتینگ نوع غالب برای بخش هایی است که درست قبل از تپه ها وجود دارد. مقادیر PCI در مقاطع نزدیکی به سرعت گیر در مقایسه با بخش های دور افتاده به طور قابل توجهی پایین بود. علاوه بر این، تأثیر تپه سرعت گیر در مقادیر PCI را می توان در بزرگراه های شهری که حداقل کامیون ها از این بزرگراه ها استفاده می کردند، اغماض کرد. نتایج حاصل از این مقاله نشان می دهد که برای شناسایی حکم های مناسب برای نصب تپه های سرعت گیر در پیاده روه های بزرگراه انعطاف پذیر باید توجه شود.

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