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Analysis of the correlation between the condition of urban pavements and elements of the drainage system

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ABSTRACT

The research in question aimed to analyze the correlation between the pavement condition index and the condition of two surface drainage elements: culverts and gutters. The study was carried out from the analysis of 19 stretches, distributed by the neighborhood of Tambaú, in João Pessoa-PB. The calculation for the condition of the pavements was carried out using the PCI method and the condition of the drainage elements was verified through subjective analysis. The research results showed when the elements fit or not in the ideal conditions, and although the drainage elements are considered in the performance of the pavements, the statistical evaluation showed a weak correlation between the condition of the pavements and the evaluated drainage elements.
Keywords: infrastructure systems; statistic; urban roads.

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In this work, author 1 contributed with the activity of literature review, data collection, writing of the work, discussion of results and conclusions, corresponding to 60% of the work, author 2 contributed with the activity of the original idea, review of the work final, opinions in the discussions, corresponding to 40%.

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Análise da correlação entre a condição de pavimentsos urbanos e elementos do sistema de drenagem

RESUMO

A pesquisa em questão objetivou analisar a correlação entre o índice de condição dos pavimentos e a condição de dois elementos de drenagem superficial: bocas de lobo e sarjetas. O estudo foi realizado a partir da análise de 19 trechos, distribuídos pelo bairro de Tambaú, em João Pessoa-PB. O cálculo para a condição dos pavimentos foi realizado pelo método do PCI e a condição dos elementos de drenagem foi verificada por meio de análise subjetiva. Os resultados da pesquisa mostraram quando os elementos se enquadravam ou não nas condições ideais, e embora os elementos de drenagem sejam considerados no desempenho dos pavimentos, a avaliação estatística apresentou uma correlação fraca entre a condição dos pavimentos e os elementos de drenagem avaliados.

Palavras-chave: sistemas de infraestrutura; estatística; vias urbanas.

Análisis de la correlación entre el estado de los pavimentos urbanos y los elementos del sistema de drenaje

RESUMEN

La investigación en cuestión tuvo como objetivo analizar la correlación entre el índice de condición del pavimento y la condición de dos elementos de drenaje superficial: desagües pluviales y cunetas. El estudio fue realizado a partir del análisis de 19 tramos, distribuidos por el barrio de Tambaú, en João Pessoa-PB. El cálculo del estado de los pavimentos se realizó por el método PCI y el estado de los elementos de drenaje se verificó mediante análisis subjetivo. Los resultados de la investigación mostraron cuando los elementos encajan o no en las condiciones ideales, y aunque los elementos de drenaje son considerados en el desempeño del pavimento, la evaluación estadística mostró una débil correlación entre la condición del pavimento y los elementos de drenaje evaluados.

Palabras clave: sistemas de infraestructura; estadística; caminos urbanos.

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1. INTRODUCTION

Considered as the main mode of transport, highways are of great importance in the development of the country (PIRES E MENDES, 2021), and for roads to fulfill their function properly, they must have an appropriate state of conservation.
A pavement with a structure that does not perform adequately can lead to undesired consequences. In this perspective, the drainage of a road helps in its conservation, in addition to preventing accidents on the roads. Therefore, one of the main objectives of draining highways is to protect the infrastructure from the negative action of water, such as reducing the floor structure and breaking up embankments (LIMA et al., 2022).
According to Pinheiro, Coutinho and Ferreira (2021), the drainage system is an essential element with regard to the performance of most of the elements that make up an urban road. Still according to the author, the correct conduction of water is the main function of the drainage system, being able to preserve the characteristics of the pavement design layers, such as the base, sub-base and subgrade, in addition to ensuring greater durability of the pavement, in addition to preventing the accumulation of water on the surface.
One way to make sure that the drainage system works correctly is by checking the good condition of the elements that compose it. In addition to the structure, cleaning and maintenance of the elements are also essential for the system to fulfill its design functions.
Therefore, the work in question proposed to evaluate the correlation between the condition of the selected pavements and the condition of two surface drainage elements of the stretches: culverts and gutters. From the correlation, it is intended to ascertain to what extent there is influence of the state of conservation of the drainage elements on the condition of the pavements. Finally, those responsible for managing the infrastructure systems can use the metrics presented as an aid for the maintenance and recovery of the evaluated structures.

2. LITERATURE REVISION

2.1 Pavementss

Road pavements are of great importance with regard to the development of a country in helping to carry out basic services, such as the transport of goods and the movement of the population. In view of their importance, it is necessary that the roads are in a good state of conservation so that they can offer their services in an adequate and safe way for users (LIMA et al., 2022).
One way to check whether pavements are in an acceptable state of repair is to calculate their condition index. One of these evaluations can be done from Pavement Condition Index (PCI), developed by the United States Army Corps of Engineers (USACE) in 1976. Initially developed only for the evaluation of airport pavements, and later in 1979 adapted to a specific version for the evaluation of road and urban pavements.
According to ASTM D6433-2018 - Standard Practice for Roads and Parking Lots pavement Condition Index Surveys, it is necessary to select a sample of size 225 m² ± 90m². The evaluation consists of carrying out the survey of defects, in addition to the quantity and severity of each one of them. Table 1 presents types of defects that must be identified during the application of the method.

Table 1. Asphalt pavement defects and measurement unit for the PCI Method

Defect	Measuring Form	Defect	Measuring Form
Fatigue Cracking	Area	Patches	Area
Bleeding	Area	Polished Aggregate	Area
Block Cracking	Area	Potholes	Unit
Elevations/settlements	Meter	Rail crossing	Area
Corrugation	Area	Rutting	Area
Localized sinking	Area	Shoving	Area
Edge crack	Meter	Cracks due to sliding masses	Area
Reflection Cracking at Joints	Meter	Swelling	Area
Gap between Pavement and shoulder	Meter	Raveling	Area
Longitudinal and transverse cracking	Meter	-	-

Source: ASTM (2018) – Adapted

To calculate the pavement condition index, it is necessary to obtain the Deduction Values (DV) according to the type, severity and extent of the defect, which represents the influence it has on the pavement condition, ranging from 0 and 100, where 0 means the defect does not impact the condition of the pavement and 100 means the defect has the maximum harmful interference. DV values are obtained with the aid of abacuses available in ASTM D6433-2018. By adding up the DVs, it is possible to obtain the Total Deduction Value (VTD) for the pavementss analyzed with the help of equation 1.

$$\mathrm{VTD} = \sum_{i=1}^{p}\sum_{j=1}^{mi} a(Tj, Si, Dij)xF(t, q) \qquad (1)$$

Where:
a(Tj,Si ,Dij): capacity loss function to serve traffic, whose independent variables are the type of:
Tj: types of defects;
Si: severity levels;
Dij: defect densities;
i: counter of types of defects;
j: severity levels counter;
p: total number of defect types;
mi: severity level number for the nth defect type;
F(t, q): adjustment factor to reduce the effect of excess types of defects. (t) depends on the number of functions (a), and (q) is the number of numerical values of functions (a) greater than 5.

In possession of the VTD, it is necessary to correct it depending on the number of defects present in each section, according to abacus 20 of the same standard. Therefore, it is possible to find the Corrected Deduction Amount (VDC) and, therefore, the PCI value resulting from Equation 2.

$$PCI = 100 - VDC \quad (2)$$

From the value obtained for the PCI in the section analyzed, the pavement is classified according to Table 2, varying its value from 0 (poor condition) to 100 (excellent condition).

Table 2. PCI Classification

Classification	PCI value
Great	86 – 100
Very Good	71 -85
Good	56 – 70
Average	41 – 55
Bad	26 – 40
Very Bad	11 - 25
Terrible	0 - 10

Source: Shahin (2005)

2.2 Drainage of Urban Pavements

According to Corrêa and Dutra (2018), the drainage system can be understood as the set of elements that aim to guarantee the integrity of the roads and their surroundings, in addition to promoting safety for users. Such devices direct the water to a suitable location, being properly planned during the construction or restoration of a road (REIS, 2016).

When referring to the urban drainage system, it is necessary to understand its subdivision into macro drainage and micro drainage (RESPLANDES et al., 2021). According to the Department of Sanitary Engineering at the University of São Paulo (2015), macro drainage can be defined as a cursor that directs a high volume of water, such as rivers and streams. In the case of micro drainage, it can be considered as the part of the system responsible for directing rainwater to the macro system. This is composed of elements such as gutters, manholes, manholes, manholes and galleries.

In the case of urban pavements on a road, the existence of a micro-drainage system for directing rainwater is essential, since it is necessary to maintain such essential infrastructure in ideal operating conditions (SOUZA, 2012).

With regard to the accumulation of water, whether surface or groundwater, it can be a harmful factor for highways. According to Lima et al. (2022), the accumulation of water on the roadway can severely impair the conditions of adhesion of the roadway, and may cause accidents.

In the case of floods, it is also possible to observe significant damage to the pavements and, consequently, to the population. In addition to the change in traffic with the visible reduction in safety, water is capable of infiltrating the layers of the pavement, reducing its useful life. The water that remains contained in the layers, in addition to that coming from the water table, can cause damage such as a reduction in the support capacity of the subgrade layer, in addition to sinking and even rupture (REIS, 2016).

3. METHODOLOGY

To fulfill the objective proposed by the research, the following sequence of activities was developed:

i) delimitation of the study area;
ii) preparation of forms for data collection;
iii) survey of data on the condition of the pavements;
iv) survey of data on the condition of drainage elements;
v) analysis of the correlation between the results found.

The evaluated excerpts are the subject of study by undergraduate and graduate students at the Federal University of Paraíba – UFPB. Due to the availability of a database on the stretches in question (item 3.1) and because it is considered a tourist district in the city where the quality of the roads needs to be presented in ideal conditions, it was decided to evaluate the correlation between the information.

Regarding the pavements, the survey of defects was carried out by analyzing images available in the database used, using the form available in NBR 006/2003 – PRO. To help the defects quantification step, concomitantly with the measurement, a photographic record was made for each defect so that their severity could be assessed, helping in the subsequent use of the abacuses of appendix X3 of Standard ASTM D6433 − 18, during the step of qualification.

To obtain data regarding the surface urban drainage system, a survey was carried out of the elements that made up the network, adapted from the study by Novaes et. al. (2019), based on filling in the forms prepared to quantify the existence of storm drains and gutters, as well as the qualification of their respective conservation conditions, which can be good, regular or terrible.

3.1 Characterization of the Excerpts

The evaluated stretches were distributed throughout the neighborhood of Tambaú, in the city of João Pessoa - PB. Roads that simultaneously had flexible paving and a surface drainage system were chosen. The location of the sections is shown in Figure 1.

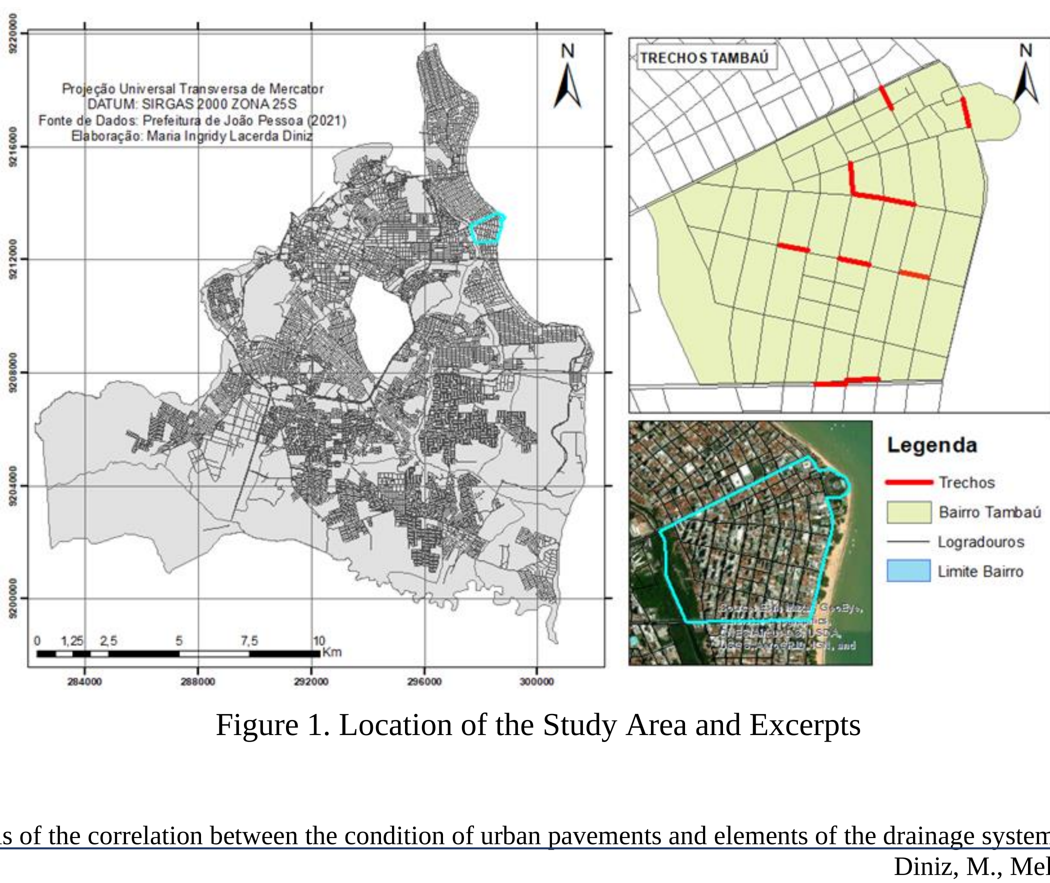

Figure 1. Location of the Study Area and Excerpts

The information detailed information about the locations of each section can be found at Table 3. To maintain the proportionality of the samples, all had the same length of 80 meters.

Table 3. Information about the Sections

Section	Range	Streat	Sense	Limits		Length (m)
				Start	Final	
1	Left	Road Our Mrs dos Navegantes	Tambaú - Manaíra	Space of being	Handicraft Market – Av. Ruy Carneiro	80
2	Right	Senhora dos Navegantes Road	Tambaú - Manaíra	Space of being	Handicraft Market - Ruy Carneiro Ave.	
3	Left	Nego Ave.	Beach	Infante Dom Henrique St.	Prof. Maria Sales Ave.	
4	Right	Nego Ave.	Beach	Infante Dom Henrique St.	Prof. Maria Sales Ave.	
5	Left	Nego Ave.	Beach	Av. Prof. Maria Sales	N. Sra dos Navegantes St.	
6	Right	Nego Ave.	Beach	Ave. Prof. Maria Sales	N. Sra dos Navegantes St.	
7	Left	Infante Dom Henrique St.	Tambaú - Manaíra	Nego Ave.	Av. Olinda	
8	Right	Infante Dom Henrique St.	Tambaú - Manaíra	Nego Ave.	Av. Olinda	
9	Left	Helena Meira Lima Street	Center	Prof. Maria Sales Ave.	Infante Dom Henrique St.	
10	Right	Helena Meira Lima Street	Center	Av. Prof. Maria Sales	Infante Dom Henrique St.	
11	Left	Helena Meira Lima Street	Center	Streat Monteiro Lobato	Streat Silvino Lopes	
12	Right	Helena Meira Lima Street	Center	Monteiro Lobato St.	Before the crosswalk with Silvino Lopes St._	
13	Left	Helena Meira Lima Street	Center	Antonio Lira Ave	Senhora dos Navegantes Road	
14	Right	Helena Meira Lima Street	Center	Antonio Lira Ave.	Senhora dos Navegantes Road	
15	Left	Pres. Epitácio Pessoa St.	Bessa	Road Senhora dos Navegantes	Prof. Maria Sales Ave.	
16	Right	Pres. Epitácio Pessoa St.	Bessa	Road Senhora dos Navegantes	Prof. Maria Sales Ave.	
17	Left	Pres. Epitácio Pessoa St.	Bessa	Manoel Cavalcante de Sousa Ave.	Prof. Maria Sales Ave.	
18	Right	Pres. Epitácio Pessoa St.	Bessa	Manoel Cavalcante de Sousa Ave.	Prof. Maria Sales Ave.	
19	Right	Adm. Tamandare Ave.	Bessa	Olinda Ave.	Sto. Antonio Square	

3.2 Statistic Analysis

It is possible to verify the existence of the relationship, as well as the intensity, existing between two variables from the analysis of your correlation. For this, the Pearson Correlation coefficient (r) presented by equation 3 (MERGH, 2019; OLIVEIRA *et al.*, 2022) was used.

$$r = \frac{\sum_{i=l}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{[\sum_{i=l}^{n}(X_i - \bar{X})^2][\sum_{i=l}^{n}(Y_i - \bar{Y})^2]}} \quad (3)$$

Where:
n: number of pairs of observations;
Xi: observation i of variable X;
Yi: observation i of variable Y;
$\bar{X}$: average of X values;
$\bar{Y}$: average of Y values.
In agreement with Francisco & Dantas Neto (2021), it is possible take intervals to help with interpretation of the results of r, as presented at table 4.

Table 4. Interpretation of Correlation Coefficient Values (r)

Correlation Coefficients (r)	**Types of Correlations**
r=1	Perfect Positive
0.8 ≤ r < 1	Strong Positive
0.5 ≤ r < 0.8	Moderate Positive
0.1 ≤ r < 0.5	Weak Positive
0 < r < 0.1	Intimate Positive
0	Null
0.1< r < 0	Intimate Negative
-0.5 < r ≤ -0.1	Weak Negative
-0.8 < r ≤ - 0.5	Moderate Negative
-1< r ≤ - 0.8	Strong Negative
r = -1	Perfect Negative

Source: Francisco & Dantas Neto (2021) Adapted

For the analysis in question, the PCI value, due to its calculation methodology present bigger accuracy of the real quantification of the state of condition of the evaluated element (pavements), will be considered with independent variable (X). The dependent variables will therefore be the manholes (Y_1) and the gutters (Y_2).
To assist in analysis statistics, the hypothesis statistical test was performed to ascertain the difference between the averages obtained. In this case, the following will be determined hypotheses:

$$H_0: \mu_1 - \mu_2 = 0 \quad (4)$$

$$H_A: \mu_1 - \mu_2 \neq 0 \quad (5)$$

Where:
H_0: Null hypothesis;
H_A: Alternative hypothesis;
μ_1 and μ_2: Averages of populations 1 and 2, respectively (Being the population related to the pavements and the population 2 each of the drainage elements at a time).

In that study, the case considered was that of data not paired, with population standard deviations _ known, resulting in two mean comparisons. The procedure consists of testing the mean differences between the populations, adopting the order of 0.5 based on the study by Medeiros et al. (2017). Then, the analysis verifies the following hypothesis:

$$H_0: \mu_d = 0,5 \quad (6)$$

$$H_A: \mu_d > 0,5 \quad (7)$$

Where:
μ_d: Difference of means between populations.

4. RESULTS AND DISCUSSION

4.1 Pavements Condition

The survey of the defects found in the pavements is shown in Table 5. The defects of block cracking, elevation and settlement, corrugation, joint reflection cracking, pavement/side slope unevenness, railway crossing, mass slippage, cracking due to slipping and swelling were not found during the survey, and due to this, there is no quantification of the aforementioned defects in Table 5.

Table 5. Quantification of Pavement Defects

Sec.	TF	E	AL	TB	TLV	R	AP	P	TR	D
	Area [m²]	Area [m²]	Area [m²]	Meter	Meter	Area [m²]	Area [m²]	Items.	Area [m²]	Area [m²]
1	-	-	-	12	143	5	-	-	-	50
2	88	-	-	-	90	2	-	-	15	200
3	59	-	0.5	42	46		-	1	-	210
4	79	-		38.7	42	11.25	-	-	-	220
5	-	-	-	-	43	4.25	-	-	-	38
6	-	-	-	-	21		-	1	-	26
7	-	-	-	-	-	-	-	-	-	5
8	-	-	-	-	35	-	-	-	-	13
9	-	0.1	-	-	-	-	-	-	-	46
10	-	-	-	-	-	4.5	-	-	-	61
11	-	-	-	-	-	2	-	-	-	9
12	-	0.5	-	-	-	-	-	-	-	19
13	-	-	-	-	-	1	6	-	-	-
14	-	-	-	-	-	-	-	-	-	36
15	-	-	-	-	49	-	-	-	-	73
16	32	-	-	-	-	-	2	-	-	54
17	-	-	-	-	6	-	-	-	-	80
18	-	-	-	-	-	-	-	-	-	32
19	-	-	-	-	-	-	-	-	-	15

Caption: TLV: Longitudinal and Transverse Crack, TF: Settlements, E: Bleeding, AL: Localized Sinking, TB: Block Crack, R: Patch, AP: Polished Aggregate, P: Potholes, TR: Rutting, D: Raveling.

From the evaluation of the survey of defects of the sections, it was it is possible to point out that the defect with wear and tear was the greatest record, appearing in almost all evaluated locations, with exception of Section 13.
A large number of the cracks presented may have been caused by reflection of the cracks at the base of parallelepipeds. It is important to highlight that no he was possible to acquire the information with City Hall about which flexible pavements evaluated had or no this type of base in parallel. the observation this factor was only possible when the base was exposed due to some pavements defect.
in agreement with Bernucci *et al.* (2008), these cracks also can be caused by too much, such as the action of repetitive traffic loads, climate action (thermal gradients), the possible binder aging and loss of flexibility, inefficient compaction of the coating, deficiency in asphalt binder content, undersizing, differential settlements, among others.
After weighting the affected area as determined by ASTM D6433/2018, it was possible to calculate the condition of the pavements from the PCI. The index values for each stretch, as well as the respective classification, are found in Table 6.

Table 6. Pavement Condition Classification by the PCI method

Section	PCI	Classification
1	56	Good
2	20	Too bad
3	37	Bad
4	50	Average
5	81	Very Bad
6	74	Very Good
7	98	Great
8	88	Great
9	92	Great
10	89	Great
11	94	Great
12	95	Great
13	99	Great
14	94	Great
15	62	Good
16	64	Good
17	83	Very Good
18	80	Very Good
19	85	Very Good

4.2 Condition of Drainage Elements
Existence and conditions of the drainage elements (mouths and gutters) were observed in the evaluated stretches. Information about the elements can be found at Table 7. The absence of both elements was found in excerpts 15 and 17. concomitant presence of the elements in the most of the sections evaluated, with exception of section 4, which does not featured wolf's mouths on the your extension, however counted with the presence of gutter.

Table 7. Quantification and Qualification of Drainage Elements

Section	Quantification of Elements		Qualification of Elements					
			Wolf mouth			Gutter		
	Wolf mouth	Gutter	Good	Regular	Terrible	Good	Regular	Terrible
1	3	Yes	x	-	-	-	-	x
2	two	Yes	-	x	-	-	x	-
3	1	Yes	x	-	-	-	x	-
4	0	Yes	-	-	-	-	x	-
5	1	Yes	x	-	-	-	x	-
6	1	Yes	x	-	-	-	x	-
7	2	Yes	-	-	x	-	x	-
8	2	Yes	--	x	-	-	x	-
9	1	Yes	x	-	-	x	-	-
10	1	Yes	x	-	-	x	-	-
11	1	Yes	x	-	-	x	-	-
12	1	Yes	x	-	-	x	-	-
13	1	Yes	-	x	-	x	-	-
14	1	Yes	x	-	-	x	-	-
15	0	No	-	-	-	-	-	-
16	1	Yes	x	-	-	-	x	-
17	0	No	-	-	-	-	-	-
18	1	Yes	-	-	x	-	x	-
19	1	Yes	x	-	-	-	x	-

in agreement with table 7, sections 1, 2, 7 and 8 presented more than one manhole to be evaluated. In this case, only one marking he was done in the element qualification column, since all the culverts of the same stretch had the same condition, such as stretches 2 and 8, which had two manholes each, and both pieces were in fair condition.

He was possible to verify that most of the culverts of the stretches, adding a total of 57.9%, fit at good condition category.

Regarding the condition of the gutters, only stretch 1 presented the Bad conditions. Then, even if the section has presented 3 culverts, the condition of the gutter possibly prevents the directing of water to them, which interferes with the functioning of the system. The other stretches had the gutters in regular (52.6%) or good (31.6%) conditions.

4.3 Correlation between Pavement Condition and Drainage Elements

Table 8 presents the comparison between the indices found for the condition of each evaluated element. To allow comparison between the data, adapted from Silva, Diniz and Melo (2020), the PCI values were divided by 25 (twenty-five) and converted to the same scale as the condition of the gutters and culverts, or that is, values between 0 and 4.

Table 8. Comparison between condition indices of evaluated elements

Section	Values			Condition Classification		
	PCI (Pavements)	Wolf's mouths	Gutter	PCI (Pavements)	Wolf's mouths	Gutter
1	2.24	3	1	Good	Good	Terrible
2	0.8	2	2	Very Bad	Regular	Regular
3	1.48	3	2	Bad	Good	Regular
4	2	0	2	Average	Does not exist	Regular
5	3.24	3	2	Very Bad	Good	Regular
6	2.96	3	2	Very Good	Good	Regular
7	3.92	1	2	Great	Terrible	Regular
8	3.52	2	2	Great	Regular	Regular
9	3.68	3	3	Great	Good	Good
10	3.56	3	3	Great	Good	Good
11	3.76	3	3	Great	Good	Good
12	3.8	3	3	Great	Good	Good
13	3.96	2	3	Great	Regular	Good
14	3.76	3	3	Great	Good	Good
15	2.48	0	0	Good	Does not exist	Does not exist
16	2.56	3	2	Good	Good	Regular
17	3.32	0	0	Very Good	Does not exist	Does not exist
18	3.2	1	2	Very Good	Terrible	Regular
19	3.4	3	2	Very Good	Good	Regular

From table 5, it is observed that in 5 sections (9, 10, 11, 12 and 14) the condition of all the evaluated elements was maximum, being "excellent" for the pavements and "good" for the storm drains and gutters. However, even if the best pavements evaluation as well has been achieved in sections 7, 8 and 13, the condition of the drainage elements no reached the same classification, varying between "regular" and "terrible".

It is necessary to highlight the situation presented by excerpts 15 and 17, which, even with none of the drainage elements evaluated in the research present in the roads, the pavement presented itself in conditions acceptable to users, with second- best classification on the previously presented scale at Table 2. This result conflicts in the sense in which it is suggested that for a good functioning of the roads is necessary the direction adequate amount of water present in the pavement surface.

Table 9 presents the average values, deviation pattern and variance of the results found for each evaluated element. the deviation standard it was considered of the sampling type (n-1).

Table 9. Mean and Deviation Standard Element Condition Indices

Element	Average (μ)	Detour Standard sample (σ)	variance (σ^2)
Pavements (PCI)	3.03	0.89	0.79
Mouths of Wolf	2.16	1.17	1.37
gutters	2.05	0.91	0.82

It is possible to observe that for the three evaluated elements (Table 9), the deviation standard was high , indicating high dispersion between the values collected in the field.
Also he was A comparison is made between the elements based on the difference between the averages of the results of each evaluation to verify the previously determined null hypothesis presented at Table 10.

Table 10. Difference of Means and Null Hypothesis Analysis _

Analysis	**Difference of Means (μd) _**	**null hypothesis (H_0)**
Pavements x Bocas de Lobo	0.88	reject
Pavements x Gutters	0.98	reject

It is possible to check in Table 10 rejection of the null hypothesis in both analyzes carried out, since the difference between the evaluated elements was presented above 0.5. Therefore, the values found do not can be considered acceptable for the correlation between the elements.
To assess the level of correlation, the analysis was carried out separately for each drainage element combined with the pavement condition index, or i.e., the correlation between the condition of the pavements and the storm drains was verified, and then the correlation between the pavements and the gutters. The results found are presented at Table 11.

Table 11. Pearson's Correlation and Determination Coefficients

Combination	**Correlation Coefficient (r)**	**Coefficient of Determination (r^2)**
Pavements x Bocas de Lobo	0.14	0.02
Pavementss x Gutters	0.39	0.15

From Table 11, it is possible to verify that both correlations were within the interval of $0.1 \leq r \leq 0.5$, being thus considered as weak and positive. However, it is necessary to point out that the comparison with the interpretation of Francisco and Dantas Neto (2021) is considered arbitrary, since the values do not take into account the context of the study.
Although the results do not show clear behavior of a 3rd degree equation, in an attempt to improve the value of r^2, a degree 3 polynomial regression for both analyses. From Figure 2, it is possible to observe the dispersion between the condition of the pavements related to the condition of the culverts (Figure 2-A) and gutters (Figure 2-B), respectively.

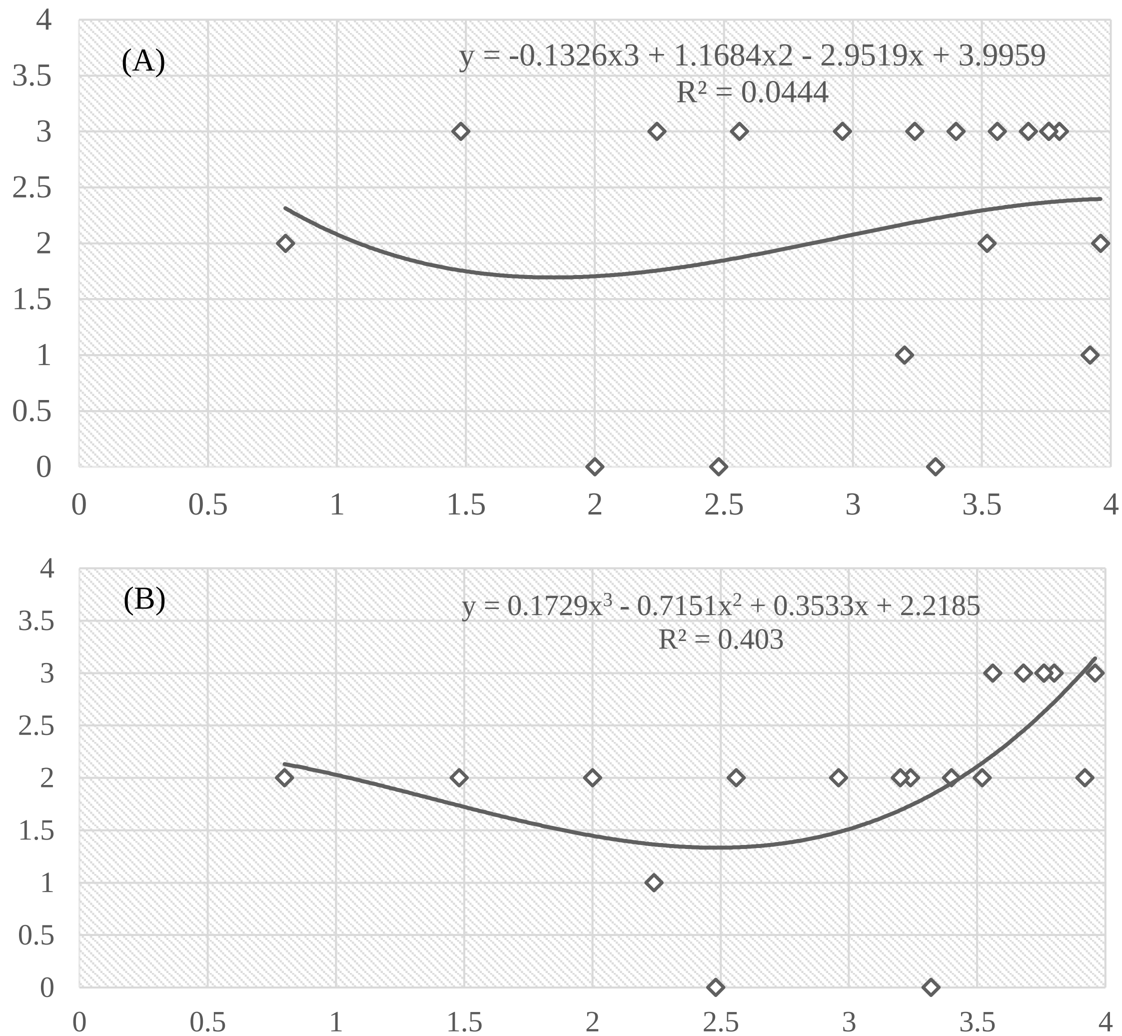

Figure 2. Polynomial Regression: A) Pavements x Gutters, B) Pavements x Gutters

From the analysis of the results it is possible to verify that for the first verification (Figure 2-A) data dispersion is presented with accuracy low, in which the attempt of polynomial adjustment of the curve did not prove to be adequate , with a value of $r^2<0.1$, considered low . In the second case (Figure 2-B), the results showed better accuracy when compared to the first analysis. In the case of curve fitting, the result showed moderately satisfactory behavior, achieving an $r^2=0.4$.

5. FINAL CONSIDERATIONS

From the bibliographic survey, the drainage elements were presented as primordial criteria for the good performance of the pavements, and, although the statistical evaluation has shown a weak correlation between the condition of the pavements and the evaluated drainage elements, it is necessary to highlight the level of complexity of urban road elements, such as the presence of other infrastructure systems (water distribution, sewage collection, energy, gas, etc.) use, frequency of corrective maintenance, existence of preventive maintenance, among others.

With regard to the condition of the analyzed infrastructure, the data collected and evaluated present a comprehensive overview of the assessment of the situation, since for each element all types of conditions existing in the assessment forms were found, from systems considered in good condition to those classified as the worst condition. Therefore, this holistic representation of infrastructure systems could provide combinations of situations to exemplify the need and importance of monitoring the condition of the elements.

The indication of the severity, scope and extent proved to be adequate for the context of the work, however, to make it even more coherent with the recorded reality, it is recommended to calculate the condition of the pavements by other methods, such as Distress Manifestation Index Network Level (DMINL, 2010) and Urban Pavement Condition Index (UPCI, 2015), in addition to surveying the condition of other elements present on the road that may influence the condition of the pavements.

Although it was not the objective of the research to suggest maintenance proposals for the evaluated elements, the classification of severity levels together with the integration of the data of the elements, presented itself as a viable instrument for planning and pointing out priorities for intervention in the roads, as well as acceptability assessments of the state of functionality and usefulness of the elements, thus being able to establish goals for possible maintenance interventions by the responsible bodies.

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