ENGLISH VERSION...

Escala visual para evaluación de pavimentos urbanos: Una validación en oficina

Visual scale for evaluating urban pavements: An office validation

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Abstract

To restrain the total deterioration of the roads is important to develop procedures to support quality control, with respect to maintenance and rehabilitation of the pavement. Such procedures are performed empirically and incorrectly, leading to an increase in the deterioration rate and, consequently, an increase in costs for users and public management. The aim of this research is to validate in the office a visual scale composed of photographs representing each classification interval adopted to verify pavements condition. Basic information about the evaluation process was showed to both rating panels selected. The visual scale used as reference in this study was also presented to only one of the panels. Both panels rated photographs of various surface conditions of urban roads, classifying them by assigning grades from 0 (zero) to 10 (ten). It was concluded that it is possible to use a visual scale for classification urban pavements due its influence on reducing dispersion in the judgment of the raters.

Keywords: *Subjective evaluation, pavement condition, panel of raters, urban roads, pavement management system*

Resumen

Para contener el total deterioro de las vías, es importante el desarrollo de procedimientos que apoyen el control de calidad, en lo que se refiere a mantenimiento y rehabilitación del pavimento. El mantenimiento de vías generalmente se realiza de forma empírica e incorrecta, acarreando en la intensificación de la tasa de deterioro y, consecuentemente, aumento de costos a los usuarios y a la gestión pública. El objetivo de esta investigación es validar en oficina una escala visual compuesta por fotografías representativas de cada intervalo de clasificación adoptado para verificación de la condición de los pavimentos. Informaciones básicas acerca del proceso de evaluación han sido mostradas a los dos paneles. Se presentó la escala visual usada como referencia en este estudio solamente a uno de los paneles. Ambos paneles evaluaron fotografías de variadas condiciones de la superficie de vías urbanas, clasificándolas por medio de asignación de notas entre 0 (cero) y 10 (diez). Se concluyó que es posible utilizar una escala visual de clasificación para pavimentos urbanos debido a su influencia en la reducción de la dispersión en el juicio de los evaluadores.

Palabras clave: *Evaluación subjetiva, condición del pavimento, panel de evaluadores, vías urbanas, gestión de pavimentos*

1. Introduction

The maintenance activities of urban roads are usually carried out without proper planning, that is, they are done empirically and incorrectly, which entails negative consequences that increase the deterioration rate of the pavement and, therefore, the cost of users and public management.

Thus, it is important and necessary to develop simple, efficient and reliable procedures to improve the quality control regarding the pavement maintenance and rehabilitation.

With the aim of making up for these planning deficiencies in the maintenance and rehabilitation activities, it is extremely relevant to develop and implement a proper Pavement Management System (PMS).

Meanwhile, it is important to highlight certain peculiarities of urban roads, since they have an impact on the necessary maintenance activities. These features involve aspects such as a high percent of areas allocated to intersections, which increases the stopping frequency; interference of the underground infrastructure of the cities; traffic segregation, with exclusive lanes for buses and the presence of vegetation at the sides of the pavement.

In this manner, the purpose of the present work is to contribute to the subjective evaluation procedure, applied in the Urban Pavement Management System (UPMS), based on the validation of a visual scale to help classify the surface of urban road pavements.

2. Pavement Management System

The Pavement Management System (PMS) can be understood as a set of integrated activities embracing planning, construction, maintenance, evaluation and research. These activities are linked to a database with the purpose of improving the efficiency of the decision made by the managers and providing feedback of the consequence of

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the decision made at different levels, thereby optimizing the resources for the development of maintenance programs (Hass, Hudson and Zaniewski, 1994).

Overall, pavement management concepts are valid for both highways and urban roads. However, urban roads have certain particularities. One of the most important, according to Bertollo and Fernandes (1997), is the existence of public infrastructure running parallel or perpendicular to the roads.

The Urban Pavement Management System (UPMS) is a tool that can help public and private sectors to manage the cities' road network efficiently and effectively. Its purpose is to implement management processes based on documentation and updating of inventory data, periodic evaluation of pavement conditions, criteria for selecting pavement maintenance and rehabilitation strategies and prioritizing sections for using the available resources (J. J. Oliveira, Lopes, Souza, Pereira and Fernandes, 2012).

In this context, the study of Hosten et al. (2013) discussed the development of a pavement management system for the city of Christiansburg, in Virgina, USA, which highlights the use of pavement management applications for verifying the efficiency of the implementation of preventive maintenance in the city streets. The results of this work indicated that the implementation of a UPMS in the city of Christiansburg can help the city engineers to determine what are the types of interventions needed, thereby objectifying a preventive maintenance, which has the potential to significantly reduce the cost of the city road network.

J. J. Oliveira et al. (2012) studied the introduction of a Dynamic Urban Pavement Management System in the city of Annapolis, in the State of Goiás, Brazil. According to the authors, the results of the DUPMS allow elaborating documents with technical justification that enable the city hall to obtain supplementary resources, accelerate the bids for works, increase the control of the bidding process, and improve the quality control of the execution services along with the pavements' performance.

Furthermore, the introduction of the DUPMS in Annapolis, allowed J. J. Oliveira et al. (2012) to highlight the following positive aspects: bidding and contracting of preventive maintenance works; incentive for including pavement development in the Civil Engineer courses available in the city; incentive for introducing urban infrastructure management, with the agreement of all sectors using the road system.

For Páez, Lopes and Fernandes (2015), the UPMS efficiency is directly connected to a good inventory of the road network. Likewise, Arguelles, Fuentes and Aldana (2011) stress that the most complex and relevant factors in a management system are the development of deterioration models and the definition of conservation standards.

Thus, goals and strategies should be designed for the identification and localization of problems, by verifying the actual condition of the pavement in question, which evidences how important it is to rely on pavement evaluation data.

3. Pavement Subjective Evaluation

Between 1958 and 1961, a test was run on the experimental lane of the American Association of State Highway Officials (AASHO Road Test), which evidenced the role of the user in the pavement evaluation.

According to Carey and Irick (1960), the AASHO Road Test allowed defining the Present Serviceability Ratio (PSR). This methodology deals with the evaluations undertaken by a commission that judges the pavement capacity to serve the traffic from the user's perspective, considering the comfort provided by the road.

These are the subjective evaluations, which help to determine the condition of the pavement surface by assigning scores related to the travelling comfort.

Subjective evaluations are very helpful for mapping the state of deterioration of the pavement and, according to Fontenele and Fernandes (2013), they can play an important role in the UPMS, since the sections that need improvements can be more easily detected and thus prioritized.

In order to assess the coherence of subjective evaluations in unpaved roads, Fontenele, Silva and Piton (2007) subjected 14 experimental sections of the municipality of São Carlos, in the State of São Paulo, to the judgement of a panel of raters who assigned scores to the surface condition of the sections in question.

In the study, Fontenele et al. (2007) concluded that it is possible to evaluate unpaved roads through a panel of users, because the obtained subjective evaluations were considered consistent and valid to represent the conditions of the studied experimental sections.

4. Visual scales

With the purpose of enabling the subjective evaluations in place, studies were carried out to design and develop visual scales that would help in the road classification process.

While concerned with the conditions and maintenance of the roads in New York City, Hartgen, Shufon, Parrella and Koeppel (1982) developed, together with the NY Department of Transportation, a subjective evaluation method for paved roadways, which consisted in reviewing photographs that were classified by a group of experts in the matter. Once the group had made the evaluation, a set of representative photos was obtained for each position of the scale of values adopted, thereby designing a visual scale for classifying the surface conditions of pavements.

In this respect, Fontenele and Fernandes (2013), in the same way as Hartgen et al. (1982), developed a visual scale with the aim of contributing to subjective evaluations of unpaved roadways. Therefore, photographs of unpaved roads were obtained, and then classified by a group of individuals in the study region, with experience in the field of soils and roadways.

Likewise, F. M. Oliveira, Silva and Fontenele (2013) developed a visual scale for classifying urban road surfaces. Approximately 60 photos were taken and selected for the study, and a group of experts in the matter classified them. After the evaluations by experts, the final photos that best represented the categories were selected, thereby making a visual scale for evaluating urban roads.

5. Methodology

This chapter deals with the method used during the research, which involved the use of a visual scale in the process of subjective evaluations of urban pavements, by means of photographs.

5.1 Visual scale

The procedure used the visual scale designed by F. M. Oliveira et al. (2013), with the help of experts in the transportation area. Figure 1 shows a visual scale composed of 10 photos, where two are representative of each interval of the adopted classification scale.

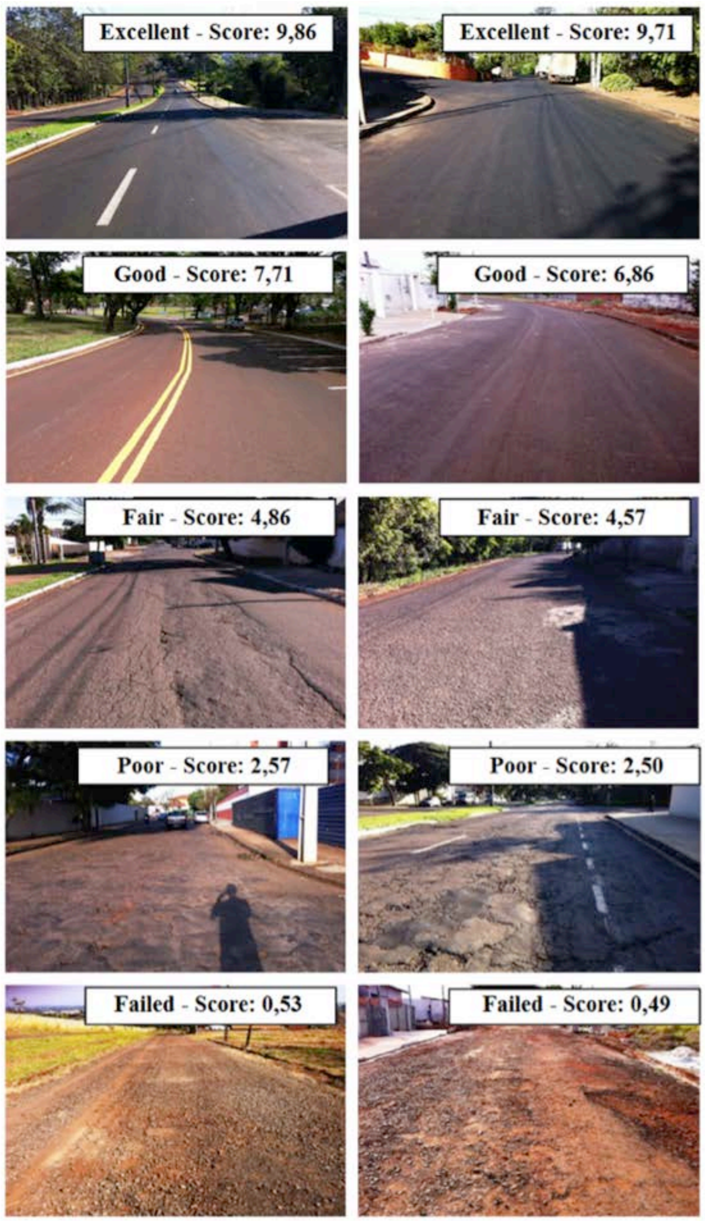

Figure 1. *Visual scale for evaluating urban pavements*

5.2 Photographical Records of Urban Roads

Approximately 100 photographs were taken from different surface conditions of urban roads in a municipality in the hinterland of the State of Parana, in Brazil. From the total number of photos, 60 were selected, organized and numbered for a subsequent classification by a group of raters.

5.3 Rating Panel Selection and Instructions

Two rating panels, each one composed of 11 Civil Engineering students, performed the evaluation of the photographs.

In addition to receiving instructions concerning the subjective evaluation procedures, one panel ($panel_{visual\_scale}$) was informed about the visual scale developed by F. M. Oliveira et al. (2013), and the other group ($panel_{basic\_info}$) just received basic information of the evaluation procedure.

During the basic information stage for the $panel_{basic\_info}$, the purpose was to clearly transmit guidelines to classify the photographs, and to clarify possible doubts. On a different date, and in addition to this information, a visual scale for pavement surface conditions was submitted to the $panel_{visual\_scale}$ who would later use it as score references.

5.4 Evaluating the Pavement Condition through Photographs

The two panels did the evaluations on a different date, previously scheduled with each group. The photographs were shown to the raters through a multimedia projector, and each rater recorded the scores on the individual form handed out to them.

Two months after the first evaluation, both panels repeated the procedures, thereby establishing the second evaluation with the same members.

Additionally, the $panel_{isual\_scale}$ did a third evaluation (three months later), where each member of the panel received the printed scale they would use during the procedure.

5.5 Data Processing

The obtained data was processed based on descriptive statistics (average, standard deviation and correlation coefficient) and nonparametric statistics with the Kolmogorov-Smirnov test (K-S test).

The two-sample K-S test was used to compare the panels. The aim was to verify if they were taken from the same population, by comparing the corresponding cumulative frequency distributions.

The following hypotheses were tested: H_0: the evaluations of both panels are equal and H_1: the evaluations of both panels show a significant statistical difference.

First, in order to do the K-S test, and using Equation 1, the maximum absolute difference among the cumulative distribution functions of the two samples was calculated, ($S_{n1}(X)$ and $S_{n2}(X)$):

$$\boldsymbol{D} = \boldsymbol{m}\acute{a}\boldsymbol{x}\ |\boldsymbol{S_{n1}}(\boldsymbol{X}) - \boldsymbol{S_{n2}}(\boldsymbol{X})| \qquad (1)$$

Next, the maximum differences (D) between the cumulative functions must be compared with the critical values ($D_{critical}$), which is determined by Equation 2.

$$\boldsymbol{D_{crítico}} = \frac{\boldsymbol{Kd}}{\boldsymbol{n}} \qquad (2)$$

Where K_d is the numerator of the highest difference between cumulative distributions and n is the number of samples by group.

6. Results

This section presents the results obtained in the evaluations performed by the panels throughout the present research.

6.1 First evaluation

In the first evaluation, each rater's individual scores were correlated with the average scores, thereby obtaining the graphs shown in Figure 2.

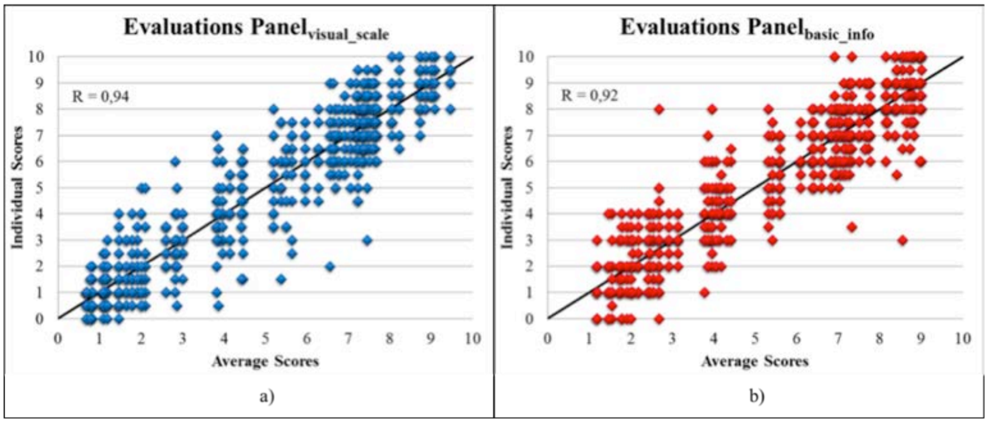

Figure 2. *Score correlation graphs for the first evaluation a) panel$_{visual_scale}$ b) panel$_{basic_info}$*

The graphs in Figure 2 show that data are concentrated around the line of equality, which reflects a satisfactory correlation between the scores, with 94% for the panel$_{visual_scale}$ and 92% for the panel$_{basic_info}$.

In this research, the maximum acceptable value of 10% of the adopted numerical scale was considered for the analysis of the standard deviation. Thus, Figures 3 and 4 show the standard deviation graphs for each photograph, according to each panel.

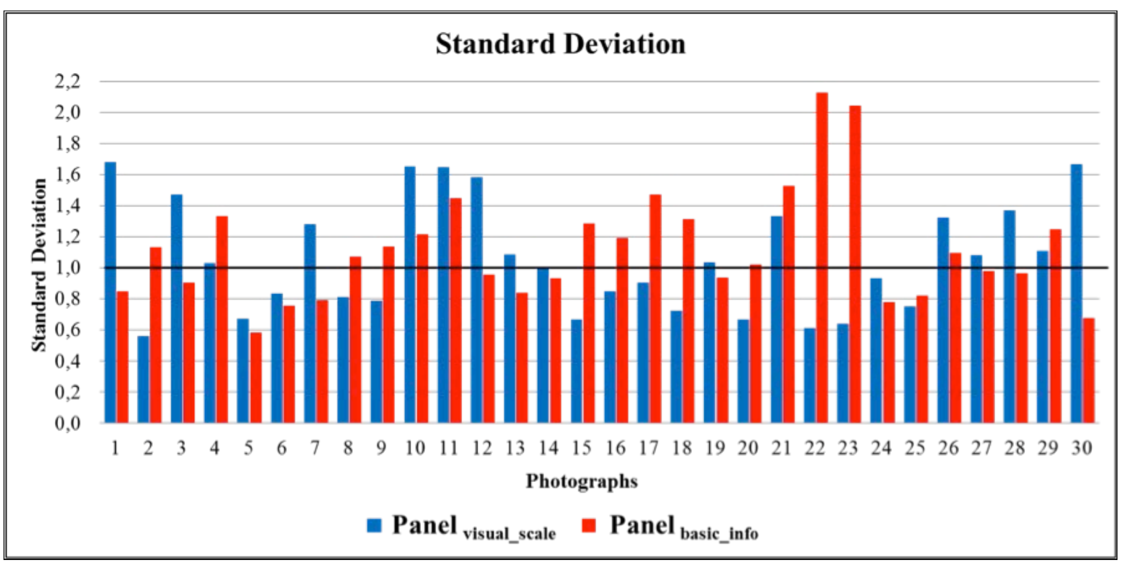

***Figure 3**. Standard deviation graph for the scores of the first evaluation (photos 1 to 30)*

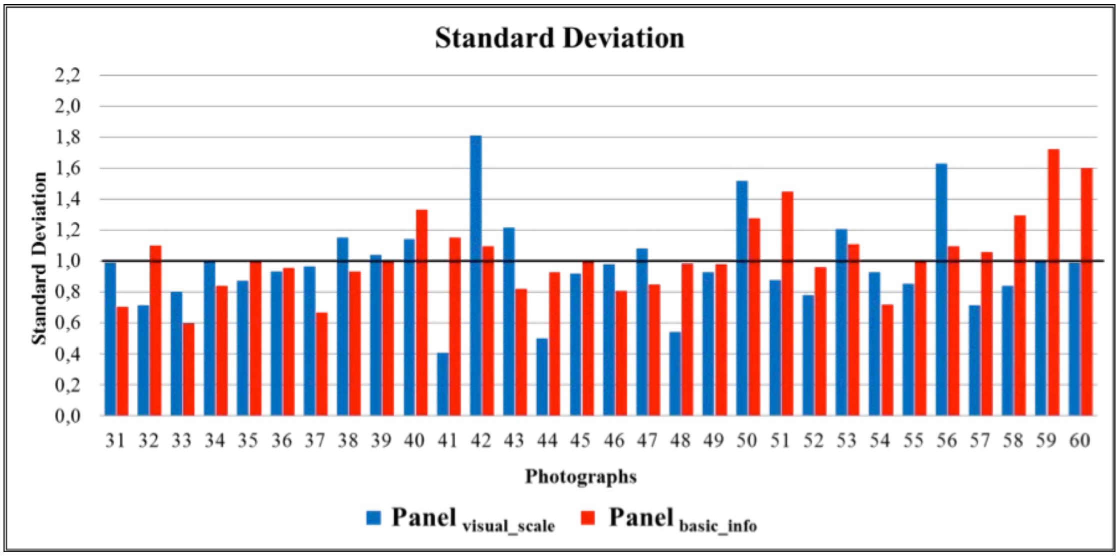

Figure 4. *Standard deviation graph for the scores of the first evaluation (photos 31 to 60)*

The analysis of the results of the panel$_{visual_scale}$ allows establishing that the maximum standard deviation values, associated to photos 1 and 42, are lower that the maximum deviations of the panel$_{basic_info}$. Considering the maximum acceptable value for the standard deviation, the scores from 35 photos (approximately 58%) show a standard deviation below or equal to 1.0 points, where photograph 42 is the only one with a value higher than 1.7 points.

With regard to the panel$_{basic_info}$, 29 photos (48%) present a standard deviation below or equal to 1.0 points. Photographs 22 and 23 show the highest standard deviation rates, around 2.0 points.

6.2 Second evaluation

The scores obtained in the second evaluation with both panels were correlated, thereby obtaining the graphs shown in Figure 5.

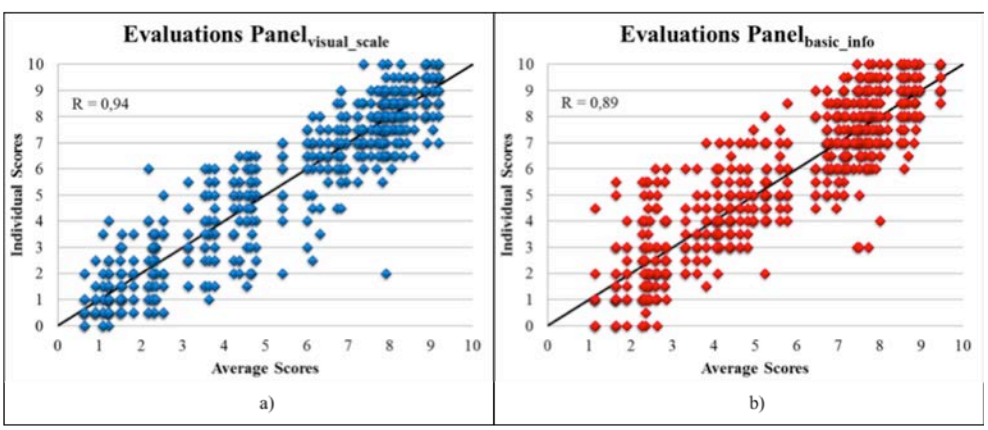

Figure 5. *Correlation graphs for the scores of the second evaluation a) panel$_{visual_scale}$ b) panel$_{basic_info}$*

The graphs allowed confirming that the 94% correlation of the panel$_{visual_scale}$ remained the same, and that the correlation of the panel$_{basic_info}$ slightly decreased to 89%.

Once again, the standard deviation graphs were obtained for each photograph, according to each panel, and presented in Figures 6 and 7.

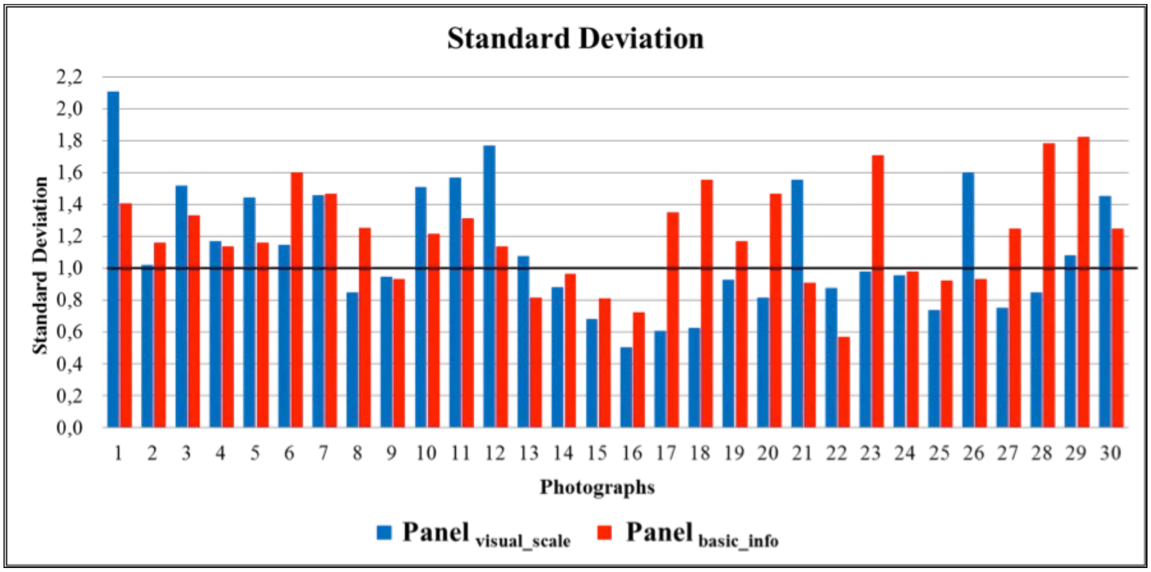

Figure 6. *Standard deviation graph for the scores of the second evaluation (photos 1 to 30)*

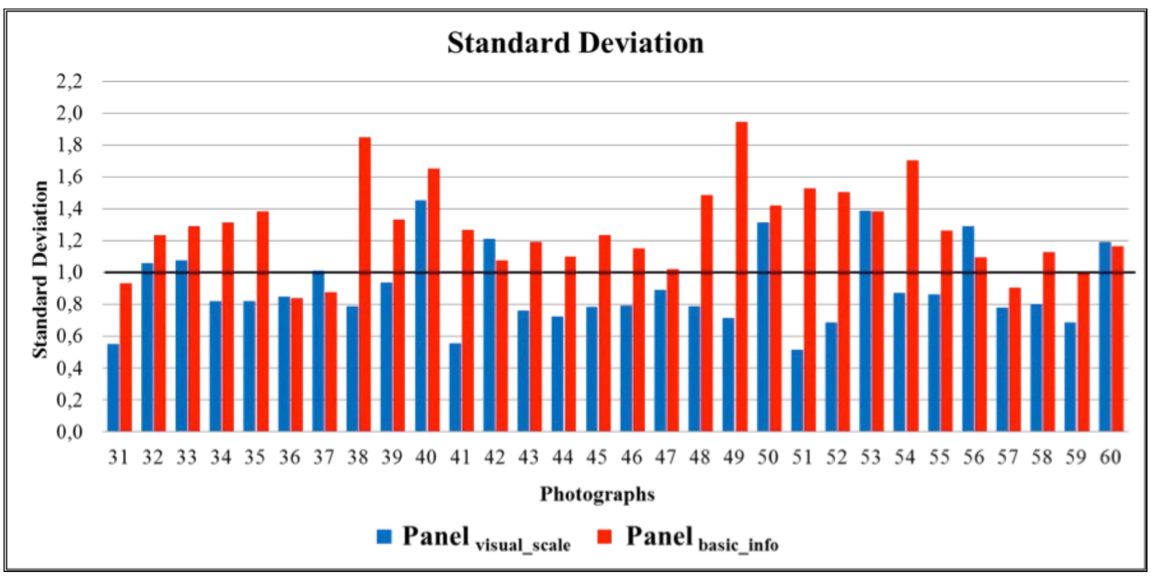

Figure 7. *Standard deviation graph for the scores of the second evaluation (photos 31 to 60)*

The analysis of the results for the panel$_{visual_scale}$ allowed verifying that the scores related to 36 photos (60%) show a standard deviation lower or equal to 1.0 points, which makes it relatively constant. Photograph 1 was the only one presenting a value higher than 2.0 points.

Regarding the panel$_{basic_info}$, 15 photos (25%) presented a standard deviation below or equal to 1.0, which represents a decrease of almost 50%.

The standard deviation comparisons between the two panels show that the number of photos with standard deviations below 10% of the classification scale (maximum acceptable value) is higher for the panel$_{visual_scale}$.

Therefore, the evaluations of the panel$_{basic_info}$ showed more significant variations in both evaluations, while the results of the panel$_{visual_scale}$ did not show considerable alterations; consequently, they are more cohesive and stable over time.

6.3 Third evaluation

The third evaluation was undertaken with the panel$_{visual_scale}$ only. As in previous evaluations, the scores assigned were correlated and the graph in Figure 8 was obtained.

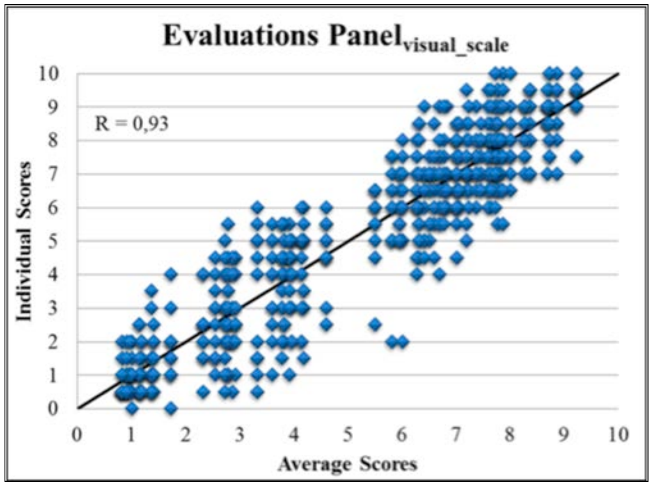

Figure 8. *Correlation graph for the scores of the third evaluation of the panel$_{visual_scale}$*

The graph allowed verifying that the correlation of the panel$_{visual_scale}$ suffered an insignificant variation compared with the first two evaluations, from 94% to 93%.

Again, this shows that the evaluations with the visual scale are stable over time and, therefore, it can be used in subsequent evaluations with a satisfactory confidence level.

6.4 Kolmogorov-Smirnov test

Since we are dealing with a test for comparing two panels, the K-S test was performed only for the first two evaluations, because the third was applied to the panel$_{visual_scale}$ only.

The two panels were composed of 11 members (n = 11), so the corresponding Kd was 8. Thus, a value of $D_{critical}$ = 0.73 was reached for the significance value of α = 0.01. The test results for the first two evaluations are shown in Figures 9 and 10.

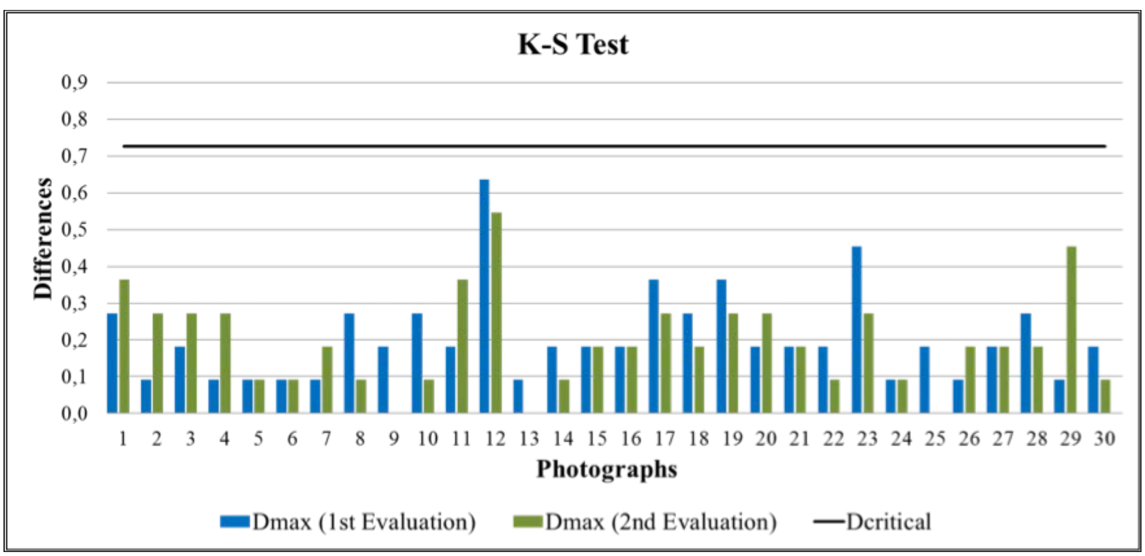

Figure 9. *Results of the K-S test in the first two evaluations (photos 1 to 30)*

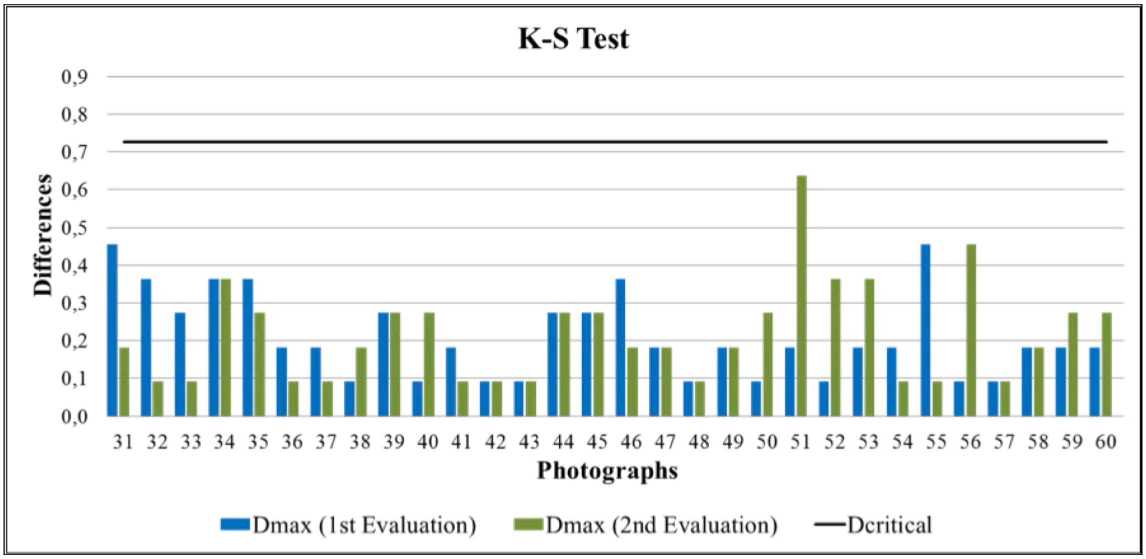

Figure 10. *Results of the K-S test in the first two evaluations (photos 31 to 60)*

Based on the analysis of the test results, and considering that all photographs showed values of D_{max} lower than the $D_{critica}$, it is possible to confirm that the hypothesis H_0 is accepted for both evaluations; that is, the evaluations of both panels can be considered equivalents.

7. Conclusion

This study was able to test a visual scale developed with photos of different pavement surface conditions for office validation purposes. The raters of each panel, individually, show consistency between them, considering the satisfactory value of the obtained correlation coefficient. Furthermore, when both panels were compared, a coherence between them was also confirmed, since the obtained correlations were close.

On the other hand, just analyzing the correlation coefficient is not enough; therefore, it is important to analyze the standard deviation for each panel as well. In this regard, the effect of using the visual scale as a reference is perceived, where standard deviation values were lower in the $panel_{visual\_scale}$ than in the $panel_{basic\_info}$ which allows concluding that the scale is a helpful tool for the subjective evaluation process of pavements.

Additionally, the used visual scale is stable over time, because in all three evaluations with the $panel_{visual\_scale}$, the correlation coefficient remained practically constant, ranging between 94% and 93%.

In order to complement the statistical analysis, the Kolmogorov-Smirnov hypothesis test was carried out, which allowed concluding that the evaluations of both panels can be considered equivalent, since the null hypothesis was accepted for all photographs.

The comparison of the correlation values, and the results of the K-S test for each panel, allow establishing that both evaluation modes can be used at the office, given the fact that the coherence of the evaluations was satisfactory with both procedures.

Moreover, it should be highlighted that a field study is planned to give continuity to the validation process, with the aim of verifying if there is any divergence or adjustments are needed.

8. Acknowledgements

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