Trial of Roughness Detection of Principal Shared Paths to Conduct Condition Assessments

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Abstract

The surface condition of pedestrian and cyclist paths is critical for user safety and comfort. The existing method of measuring the condition of such paths is based on visual inspection. Visual inspection is expensive, time consuming, and requires skilled labour. The purpose of this project is to verify the feasibility and repeatability of using roughness data collected via the smartphone app Roadroid on a mobile phone attached to a mobility scooter as a viable alternative to conducting visual assessments. In this project, a clustering method is utilised to select the most representative routes for data collection. The survey data is subsequently cleaned, after which analysis and evaluation are carried out. The analysis and evaluation reveals that compared to the current visual assessment, the roughness data collected via Roadroid provides a more granular and concrete path condition assessment. However, the evaluation indicates that roughness data collected via Roadroid cannot be conducted to an appropriate level of accuracy with the current visual assessment as the reference.

1. Introduction

Principal Shared Paths (PSPs) are paths shared by cyclists and pedestrians (Government of Western Australia, Department of Justice, 2000). They form the backbone of Perth's cycling network and are important for access to recreation, commuting and sport (Government of Western Australia, Department of Transport, 2016). With the expansion of the paths, their quality has become a concern. This is particularly the case with pavement condition, which is critical for path safety and comfort (Hull et al., 2014). Currently, existing methods of gauging PSP condition are based on visual inspection (S. Beard, personal communication, September, 2020). Once a set of measurement standards are determined, a skilled labourer will manually inspect the path surface and record the condition based on a 1-5 ranking system (1 is excellent, 5 is very poor). However, visual inspections are expensive and time consuming, with a high degree of subjectivity. Resources such as skilled labour are allocated in a less efficient manner as well. Therefore, a more economical and accurate assessment method is needed to measure the surface condition of Principal Shared Paths (PSPs).

Prior research (Sayers 1986; Sayers 1998) has established that pavement roughness is one of the most important indicators for the overall evaluation of pavement surface condition. There are a number of research projects that use various methods to estimate pavement roughness.

However, very few studies focus on surveying pedestrian and bicycle paths using low-speed carrying platforms such as mobility scooters. A team from the Central Otago District Council from New Zealand has conducted and carried out such a project, using the smartphone app ‘Roadroid’. The phone was attached to a mobility scooter to measure the roughness of the footpath surface condition. The outcome has been validated by the same team via visual inspection (A. Bartlett, personal communication, September, 2020).

In order to verify the feasibility and repeatability of such methodology on PSPs, the objective of this trial is to test the hypotheses that:

1) the roughness will be an accurate and quantifiable way of verifying the condition of PSPs
2) a roughness assessment can be conducted to an appropriate level of accuracy using the proposed method
3) a roughness assessment using Roadroid will be a viable alternative to conducting visual assessments of PSPs

2. Process

2.1 Data Collection

2.1.1 Device - Mobility Scooter, Smartphone and Roadroid

In this trial, the model of the mobility scooter is the Shoprider GK10 Crossover. It has a weight of 78kg with two batteries. The maximum speed of the scooter is 8km/h on flat ground. The version Pro2 v2.4.6. “Roadroid” was installed on a Samsung SM-G930F phone with Android 7.0. Roadroid uses a smartphone embedded tri-axial accelerometer to evaluate pavement smoothness.

During data collection, the phone running “Roadroid” was mounted on the left front handle of the scooter as shown in Figure 1.

Figure 1 The location of the device.

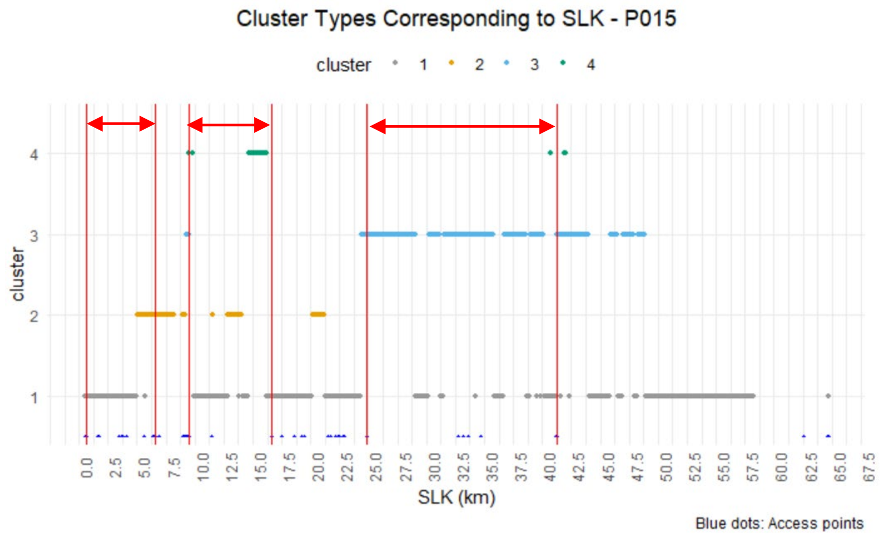

Figure 2 The 4 clusters of P015 and their corresponding SLK**.**

2.1.2 Route Selection

In order to select sufficient and representative sections of each PSP, a clustering method combined with manual selection is utilised to ensure that the sections have sufficient variation with respects to the various combinations of the visual assessment scores as well as installation year (surface), path width (surface) and their combinations of pavement and surface materials. For clustering, Gower distance is utilised to calculate the distance among categorical and numeric data points. Then the Partitioning Around Medoids (PAM) algorithm alone with silhouette width is used to conduct the clustering. The sections of PSPs were selected manually to ensure physical accessability to the path. This method reduces the workload during the selection process as well. Figure 2 shows the outcome of clustering over P015 and their corresponding SLK (Straight Line Kilometre).

2.2 Data Cleaning

Two types of data cleaning were carried out prior to further analysis. The initial data cleaning was to handle issues such as misconversion and redundant data due to various survey conditions. Further data cleaning was subsequently carried out to remove high roughness values due to irrelevant events or objects on the ground such as bridge connections, manholes and branches (roughness values are represented by eIRI values in this project due to how Roadroid indicates the surface roughness).

2.3 Data Analysis

The aim of this section is to investigate the relationship between the collected data (eIRI values) and the visual assessment scores via statistical analysis as well as relating these two sets of datasets. Given that visual assessment was conducted for every 100 meter section of the PSP, and that the survey data was generated for every 5 meter, the eIRI values were aggregated into 100 meter sections using 13 summary statistics: mean, trimmed mean, minimum, maximum, the first, second, third quartile, 10th percentile, 30th percentile, 40th percentile, 60th percentile, 80th percentile and 90th percentile. There are in total 13 eIRI variants for each 100 meter section of PSP.

2.3.1 Statistical Analysis

The Pearson Correlation Coefficient (r) and the Coefficient of Determination (R^2) calculated using Python pandas package were used for Statistical analysis. The Pearson Correlation Coefficient was used to reveal the pairwise relationship between each eIRI variant and the corresponding roughness score. And The coefficient of determination (R^2) between the eIRI variants and the roughness scores measures the variability in the roughness score caused by its relationship to the eIRI variants.

2.3.2 Relate eIRI Values to Visual Assessment Roughness Scores

To relate the collected data to the visual assessment, the second approach was to treat the distribution of the visual assessment roughness scores as an approximate statistical fit to the collected data. Based on this approach, a set of the cut-off points of the eIRI values was obtained and used as a reference for visual condition rating.

3. Results and Discussion

3.1 Statistical Analysis Results

Table 1 and 2 display the results of statistical analysis for both directions of the survey data. It can be observed from Table 1 that all eIRI variants are positively correlated with the roughness score. However, the highest coefficient is 0.201 which indicates weak relationship between these two sets of data. Table 2 shows the coefficient of determination between the eIRI variants and the roughness score. There is no R^2 which is higher than 0.05. This indicates a very small explanatory power in the eIRI variants to the roughness score.

	trimmed mean	max	mean	min	perc_10	perc_25	perc_30	perc_40	perc_50	perc_60	perc_75	perc_80	perc_90
Direction 1 * SLK low to high	0.200	0.120	0.198	0.160	0.176	0.184	0.187	0.198	0.199	0.198	0.192	0.193	0.177
Direction 2 * SLK high to low	0.186	0.048	0.173	0.157	0.181	0.201	0.201	0.201	0.198	0.201	0.179	0.171	0.127

Table 1 The Pearson Correlation Coefficient between the eIRI variants and Roughness Score.

	trimmed mean	max	mean	min	perc_10	perc_25	perc_30	perc_40	perc_50	perc_60	perc_75	perc_80	perc_90
Direction 1 * SLK low to high	0.040	0.014	0.039	0.026	0.031	0.034	0.035	0.039	0.040	0.039	0.037	0.037	0.031
Direction 2 * SLK high to low	0.035	0.002	0.030	0.025	0.033	0.040	0.041	0.040	0.039	0.041	0.032	0.029	0.016

Table 2 The Coefficient of Determination between the eIRI variants and Roughness Score.

3.2 Relate eIRI Values to Visual Assessment Roughness Scores

After applying the method discussed in 2.3.2 to both the initial cleaned data (operation errors removed) and further cleaned data (irrelevant high roughness scores removed), the final cut-off points for both data were obtained in Table 3.

The gap between score 3 (2.21) and score 4 (4.3) is relatively large for the initial cleaned data. As discovered during the data cleaning stage, there are a considerable number of high eIRI values which were generated due to irrelevant objects such as seeds and branches. The gap between score 3 (2.15) and score 4 (3.77) became smaller after the data had been further cleaned. This indicates that high eIRI values caused by irrelevant events did skew the distribution and have an impact on determining the cut-off points, especially for poor and very poor roughness conditions.

Roughness Score	**1**	**2**	**3**	**4**	**5**
Initial Cleaned	1.28	1.49	2.21	4.30	10.36
Further Cleaned	1.28	1.48	2.15	3.77	8.64

Table 3 The cut-off points for initial cleaned and further cleaned datasets.

Based on the cut-off points, a roughness score can be assigned to the corresponding eIRI variants of each 100 meter interval. Then the evaluation is carried out to determine which variant match or do not match the actual visual assessment score. Table 4 shows that for surveys carried out from SLK low to high, when using the 80th percentile of the eIRI values, the accuracy is the highest, which is 41.9%. For another direction, the highest accuracy 34.2% is reached when using the 75th percentile of the eIRI values.

	trimmed mean	**max**	**mean**	**min**	**perc_10**	**perc_25**	**perc_30**	**perc_40**	**perc_50**	**perc_60**	**perc_75**	**perc_80**	**perc_90**
Direction 1 * SLK low to high	39.1%	23.7%	40.9%	21.0%	24.1%	28.3%	29.3%	31.9%	34.9%	39.0%	40.0%	41.9%	37.7%
Direction 2 * SLK high to low	33.1%	26.5%	33.1%	24.6%	27.6%	29.5%	30.0%	31.6%	32.8%	33.9%	34.2%	33.0%	32.8%

Table 4 The accuracy of each eIRI variant based on the cut-off points.

The above evaluation indicates that using the 75th or 80th percentile of the eIRI values result in higher accuracy. Within each 100 meter interval the higher eIRI values are more representative for roughness conditions. On the other hand, less than 40% accuracy was reached when using the cut-off points based on visual assessment scores.There are a few possible causes.

Firstly, the visual assessment used in this study was conducted a few years ago. Given the roughness data was collected recently, the correlation between these two datasets might not be reliable. Secondly, although data cleaning has been conducted, there is still unclean data in the sample which skews the distribution. Furthermore, some path conditions have not been successfully captured via Roadroid. In fact, due to safety reasons, the scooter is required to stay in the middle of the path. This makes it impossible for the app to detect edge breaks, as well as some potholes and cracking due to the randomness in their positions. Lacking this information might lead to low accuracy.

4. Conclusions and Future Work

Compared to the 1-5 ranking score from visual assessment, eIRI values provide a more granular and concrete path condition assessment. The cut-off points also offer a more precise indicator, and could be treated as a quantifiable way of verifying the condition of PSPs. However, the analysis and evaluation indicate that roughness assessment using Roadroid cannot be used to reproduce visual inspection with the current visual assessment as the reference.

Other than roughness, visual assessment also includes edge breaks, subsidence, patching, ravelling and cracking. As eIRI values only provide a measurement of surface roughness, as well as the limitation of the app for detecting some path conditions due to their positions, we cannot conclude that roughness assessment via Roadroid will be a viable alternative to conducting visual assessments.

In order to gain a more reliable correlation between visual assessment and collected roughness data, a recent visual inspection is needed. Once the latest visual assessment is available, the methodology proposed in this study can be applied and the accuracy can be assessed again.

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