ROAD PAVEMENT DISTRESS CONDITIONS AND TOURIST VISITATIONS IN A RURAL SOUTH AFRICAN TOWN: A HIERARCHICAL SEGMENTATION ANALYSIS

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ABSTRACT

There is increasing realization among development and tourism experts that road pavements in distress are not ideal for tourism development. It is argued in principle that optimizing road pavement management guarantees satisfactory mobility conditions that may result in increased tourists' visitations. We however know less about the intricate connections that exist, owing to dearth of research in this area. This study sought to analyse the effect of observable road distress conditions on a sample of eighteen (18) tourism sites in Makhado district municipality of South Africa. Data were gathered using a carefully structured distress detection template. Survey data targeting a sample of seventy one (71) tourists were used to complement the analysis. Common pavement distress conditions affecting defined clusters of tourism sites were analysed using the Hierarchical Cluster Analysis (HCA) method. The study results generated two distinct clusters of tourist's sites depicting contrasting pavement distress conditions and associated impacts on tourist willingness to visit the sites again. Significant pavement distress conditions limiting tourist visitations included pavement cracks and potholes, road width, signage and pavement markings. The study recommends optimizing pavement maintenance and management to address possible safety, comfort, traffic and travel time, and vehicles operating cost concerns to increase tourists' visitations.

Keywords: Road pavement, Pavement distress, Tourism development, Pavement management.

1. INTRODUCTION

The condition of a road pavement has a significant bearing on travel experiences of tourists who seek to access site attractions of their choice. Road pavement conditions according to Ragnoli et al. (2018) play a significant role in shaping 'travelling experiences' – an attribute that affects safety and comfort, traffic, and travel times, as well vehicles operating costs. Such sentiments are also shared my many other Researchers that have observed that road pavement systems that are effectively and efficiently managed will yield positive travelling experiences since the comfort and safety of the road users is assured (Zakeri, Nejad & Fahimifar, A. 2017). Road user experiences induced by road pavement conditions are also widely discussed in studies that explore road maintenance interventions where they are hypothetically linked to tourist travelling experiences (Deluka-Tibljaš et al., 2013; Marcelino, 2018). Travelling experiences when shaped by distressed road pavement conditions can arguably be a significant deterrent to tourism development.

Conversely, when shaped by optimal road conditions they may play a decisive role in boosting tourism development. Such view aligns well with most research findings on tourism travel behaviour that concur that road infrastructure context conditions affects post travel decisions of tourists. The most significant post travel decision that tourists must make is whether to revisit the attraction or to recommend visitation (Gossling & Hall, 2006; Lin et al., 2018; Han et al., 2020).

1.1 Aim of Paper

This paper seeks to analyze the effect of observable road distress conditions on a sample of 18 tourism sites in Makhado district municipality of South Africa.

1.1.1 Problem Statement

Since visitation statistics are a good proxy measure to gauge a region's tourism development status, an understanding of road pavement conditions and their influence on tourist travel behaviour may guide the development of effective pavement management systems that may benefit the tourism sector. Despite this benefit there has been a dearth of studies seeking to draw intricate connections that may exist between road pavement distress and tourist travel behaviour decisions. We consider this to be an unfortunate development as irrefutable evidence of the existence of such relationship is widespread in travel avoidance literature (Han et al., 2020; Yang et al., 2020; Wiradnyana et al., 2021; Zhu et al., 2022).). Assessing optimal or unacceptable road pavement conditions that may shape tourist travel behaviour decisions will certainly benefit tourism development. This study therefore seeks to bridge this knowledge gap by addressing the following important research questions:

- What road pavement attributes are critical in shaping tourist travel behaviour decisions?
- What road pavement attributes can enhance the willingness of tourists to revisit or recommend visitation?

2. CONCEPTS AND HYPOTHESIS DEVELOPMENT

The relationship between road pavement distress conditions and travellers' satisfaction experiences is widely acknowledged in tourism development research. It is widely acknowledged that road pavement conditions have decisive on influence which tourist destinations a tourist decides to choose and possible revisit. This is partly because road pavement conditions in distress limit accessibility – a road transportation attribute that most studies acknowledge is a major predictor of willingness to revisit or recommend visitation (R.-Toubes et al., 2020; Zeng & Li, 2021). Ridership safety and comfort are other travelling experiences that are in many literatures directly linked to road pavement conditions (Marcelino et al., 2018).

Road maintenance is seen as an integral part of road pavement integrity. Functional road systems are usually linked to well-maintained roads that in-turn define what Khahro et al., (2021) has termed a healthy road network system (Du et al., 2020). Type of pavement surfaces may have a strong bearing on the safety of travellers. According to Chen et al., (2022) the incidence of traffic accidents is expected to be higher on asphalt surfaces as opposed to untarred roads. Several other researchers have also weighed in on the subject by analysing the relationship between road pavement conditions and traffic accidents (Khan et al., 2013).

Intricate connections between pavement roughness, ride quality, comfort, and safety are widely reported by other studies (Žuraulis et al., 2021). Loprencipe et al. (2017) observed for instance that increased road irregularities were linked to ride quality and the perceived level of comfort by the road users. A study by Žuraulis et al. (2021) also revealed that variations of gravel pavement roughness had an impact on vehicle dynamic response and driving comfort.

Road pavement surfaces leading to various site attractions offer different travel experiences to road users in terms of safety, comfort and quality in ridership. Most researchers concur that gravelled surfaces offer reduced travelling experiences (Žuraulis et al., 2021). A study by Žuraulis et al. (2021) revealed that gravel pavement surfaces offer the poorest performance in terms of strength, environmental impact, and driving conditions when compared to other pavement surfaces. It is also argued that the risk of rollover and skidding increases as one moves from even to uneven pavements (Sun et al., 2021). Stone paved surfaces are known to reduce unsafe conditions for motorcyclists by reducing the amount of friction or skid resistance (Organisation for Economic Co-Operation and Development - OECD, 2015).

Visibility of Pavement Surface Features via road markings and road signs play a significant role in traffic control and in ensuring the safety of road users (Babic et al., 2022). According to Babic et al. (2022), road markings and signs represent basic means of communication between the road authorities and road users. Such communication is said to improve safety experiences of travellers as it provides road users with critical information about the rules, warnings, and other obligations related to the upcoming situations and road alignment.

The quality and the level of tourism travel services provisioned along pavement have a dramatic influence on tourist satisfaction and loyalty (Li et al., 2022). Mobility provisions such as street furniture may also play a secondary tourist attraction role that may compel the tourist to revisit or recommend visitation. Attributes associated with pavements, including attributes such as roadway geometry, visibility issues, and pavement surface conditions are intricately connected to road safety conditions (Bennett et al., 2006).

How tourists respond to road pavement conditions they encounter during travel experience and consequent changes in their intention to revisit or recommend a visit, constitute a field that in our view is still developing and not sufficiently understood. This study hypothesizes that road pavements in distress will lower tourists' willingness to revisit or recommend visitation.

3. MATERIALS AND METHODS

Empirical evidence was gathered on eighteen (18) randomly selected small and medium sized tourist destinations using a carefully structured pavement distress detection template. Survey data targeting a sample of seventy-one (71) tourists complemented this analysis. Seventy-one (71) tourists were conveniently targeted given the resources available. A bias was made to tap into travel experiences of tourist who were travelling by car, cycling or by public transport as opposed to those were walking on foot. We expected travel choice made by car travellers and cyclist to objectively reflect travel choices conditioned by experiences in using different types of road pavements. Such bias was required since other scholars have observed that holiday travel behaviour is different from commuter travel behaviour (Kaplan et al., 2015; Lia et al., 2016). We expected tourist travelling by car or cycling to show greater sensitivity to road pavement distress dynamics (Cools, 2010; Zhu et al., 2022).

3.1 Assessment of Road Pavement Distress Conditions

Due to constrained access to automated pavement defect detection methods in South Africa and, we opted to use manual pavement condition assessment. While such an approach is usually criticised on relying on the observer's subjectivity, we tried to minimize bias by using a carefully structured distress detection template informed by the works of Ragnoli et al., (2018). Subjectivity was also minimized by developing a comprehensive indicator system for each distress condition that later allowed us to calculate an average rating value based on the severity scores given to each of the observable indicators. Road user perceptions from the questionnaire survey were used to complement researcher's own visual – a practice that further affirmed the reliability of our assessments.

The researchers observed and recorded defects along a sample of points leading to each of the tourist attraction using a variety of Likert scales ranging from 2 point to 5- point scales. A nine-variable indicator system was identified through a critical analysis of pavement distress literature (Marcelino et al., 2018) - (Table 1). The measurement and interpretation of severity and expected impact on travel experience was aided by a 3-point Likert system (i.e., where 1 = low, 2= medium and 3 = high).

Table 1: Study variables and measurement

Pavement distress variable	Observable pavement distress indicator system used.	Supporting references
Pavement integrity (PI)	degree of pavement surface maintenance and deterioration (surface defects, plastic deformations, and cracking)	Du et al., 2020; Khahro et al., 2021.
Pavement geometric design (PG)	Width of lane and shoulders, pedestrian paths. gravel or paved shoulders	Bennett et al., 2006; Li et al., 2022
Pavement surface (PS)	Type, severity, amount of distress	OECD, 2015; Žuraulis et al., 2021; Chen et al., 2022.
Ride quality (RQ)	Riding comfort rating or roughness; roughness vs speed	Wiradnyana et al., 2021; Žuraulis et al., 2021.
Road safety Measures and Facilities (RS)	Safety warning signs; safety protection facilities, side parking, road safety reserves, storm water management	Wiradnyana et al., 2021; Žuraulis et al., 2021
Pothole intensity (PIN)	Number and distribution of potholes	Du et al., 2020; Chen et al; 2022.
Comprehensibility of road signage (CR)	Incomprehensible versus comprehensible terms, symbols, and colours. Detectability by automated vehicles, availability and adequacy	Babic et al., 2022
Mobility provisions along pavement (MP)	Quality of street furniture, provision of tourism travel services and other attractions	Bennett et al., 2006; Li et al., 2022
Visibility of Pavement Surface Features (VP)	Pavement surface colour and reflectivity; lane markings and signings; visibility at night and in bad weather conditions	Bennett et al., 2006; Babic et al., 2022.

Since pavement conditions in distress are often seen as a risk to road users, there was a need to calculate the amount of risk associated with roads leading to each tourist attraction. Two types of risks were calculated.

3.1.1 Type 1 Risk

This type of risk relates to the likelihood of pavement distress conditions having a negative impact on tourist travelling experience. Since data on pavement distress conditions was based on observed sample points, there was need to calculate the likelihood of such sampled distress conditions having an impact of travelling. We borrowed insights from a combination of utility theory and the Single Loss Expectancy (SLE) approach to define risk as in the following formula:

Risk = Experience value (EV) (depicting travellers' experience value) x Exposure Factor (EF)

We assumed that an individual in deciding whether to revisit or recommend visitation will maximise his/her utility (i.e., travel experience) based on the amount of threat imposed by pavement conditions and other factors. We focused on the deterministic part of utility by using data from questionnaire where we asked tourists if they were willing to revisit or recommend visitation. Such willingness was captured using a 5-point Likert scale with 1 depicting low willingness and 5 depicting high willingness. While the SLE approach requires that we capture asset value, we captured EV and calculated the probability that such value will be lost because of the prevailing pavement distress conditions. A 3-point Likert scale was used to capture such (i.e., 1 = low, 2= medium and 3 = high). The EF depicts the number of tourists exposed to the threat while travelling to each site. Such type of risk was not only important in depicting association between road pavement distress and tourist's travelling experience, it became an important input variable into the calculation of inherent risk and the generation of a road pavement cluster segmented heatmap.

3.1.2 Type 2 Risk

Type 1 risk was however not sufficient in depicting the association between road pavement distress conditions and tourist travel behavioral choices. This required that we equate this hypothesized relationship as an input-output relationship where input variables would be the road pavement distress conditions and the output variables would be the post travel decision choices made, including the decision to revisit or recommend visitation. To calculate risk, we followed the cue by Shah et al., (2018) and adopted a quasi - Data Envelop Analysis (DEA) approach that required us to calculate type 2 risk using the following formula:

$$\text{Risk} = \frac{\text{Weighted Output}}{\text{Weighted Input}} = \frac{\text{Road user experience outcome}}{\text{Exposure to pavement distress conditions}}$$

Instead of using such DEA parameters as technical efficiency to apply weights to the risk factors, we used factor loadings from the method of Principal Components Analysis (PCA). The scores obtained from PCA made it possible to calculate weighted input and weighted output considered. A more detailed representation of the same formular is as follows.

$$\text{Risk} = \frac{\mathrm{u_l y_{1j} + u_2 y_{2j} + \ldots + u_k y_{kj}}}{\mathrm{v_l y_{1j} + v_2 y_{2j} + \ldots + v_l y_{lj}}}$$

Where,

u_k = weight of output k,
y_{kj} = amount of output k from unit j,
u_l = weight of output l,
y_{lj} = amount of output l from unit j.

The factor loading scores obtained from the 1st component of PCA made it possible to calculate weighted input and weighted output considered.

3.1.3 Travel Choice Selection Tree Structure

Most studies on tourism travel behaviour analysis employ a statistical method in predicting post travel visitation based on an explicit selection tree structure. The adopted selection tree structure in this study is shown in Figure 1.

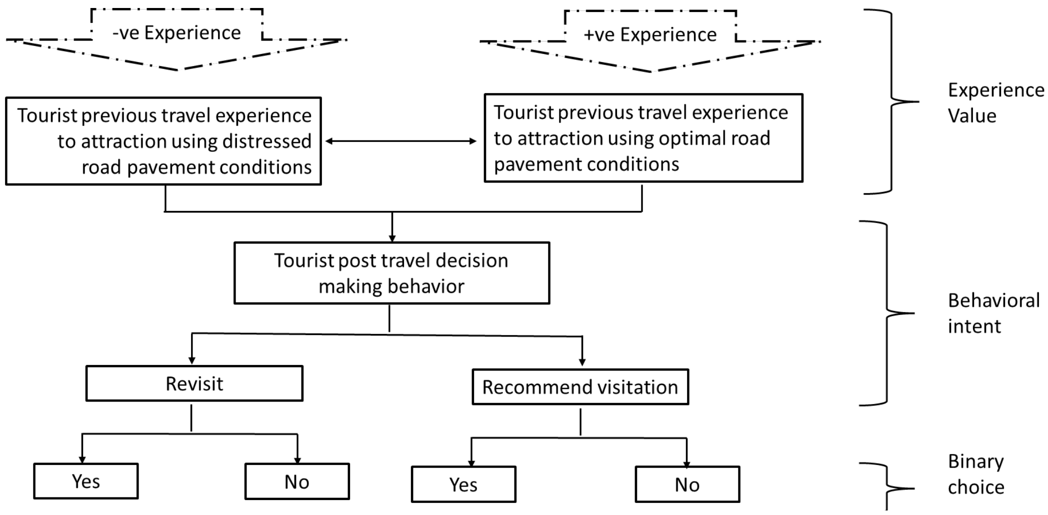

Figure 1: Selection tree structure depicting post travel decision making

As seen in the selection tree diagram in figure 1, accurately measuring tourist post travel visitation requires us to segment previous travel experience that in this study is hypothetically shaped by the type of pavement distress conditions that the traveller has encountered. Such experience can either be negative or positive. Such two possible outcomes are discrete choices that as observed in other literatures require a closer inspection of their association with a segmented population group of tourists (Zeng & Man, 2021).

3.1.4 Hierarchical Cluster Analysis

The study employed Hierarchical Cluster Analysis (HCA) to segment the eighteen (18) sampled tourism sites into unique clusters that depicted common pavement distress conditions that we hypothesised to be a significant predictor of tourist travel decisions. Conceptually, the analysis denoted associated post travel decision outcome for pavement distress variable i in tourist site j as Yij. This outcome is represented in Equation 1 as a function of the individual pavement distress characteristics, Xqij, and a model error rij (Bryk & Raudenbush 1992):

$$Yij = \beta 0j + \beta 1jX1ij + \beta 2jX2ij + \ldots + \beta njXnij + rij$$

where $rij \sim N(0, \sigma 2)$.

The 18 tourist destinations were progressively combined based on a linkage algorithm that used the distance measures to determine the proximity of objects and then clusters to each other. The analysis adopted 'Euclidean distance' as a standard metric to calculate distances between all objects in a data matrix. For each unique cluster we calculated the inherent risk posed by road distress condition and used it as a proxy index measure to objectively establish unique differences. A segmented heatmap was therefore constructed for this purpose.

4. RESULTS

It is common practice to assess reliability of measurement scales used before any meaningful statistical analysis is conducted. Reliability analysis was conducted using the Cronbach Alpha statistics (see Table 2).

Table 2: Reliability test results

Study Construct	Number of variables before screening	Number of variables after screening	Cronbach Alpha statistic	Remark
Output (The dependent study construct)	3	2	0.927	Highly acceptably
Input (the independent study construct)	9	9	0.728	Acceptable

Three output variables that were assumed to be linked to pavement distress conditions were considered including willingness to revisit, willingness to recommend visitation and travelling experience. Travelling experience did not yield an acceptable reliability score and was therefore left out. All 9-pavement distress predicter variables yielded an acceptable reliability score. Results from HCA yielded a 3-cluster solution. The Silhouette measure of cohesion and separation was used to measure the stability of the resulting cluster solution and to determine the existence of any overlaps. It yielded a value of 0.4 indicating structural stability within each unique cluster. Three unique clusters of road pavement distress conditions associated with 18 tourist destinations are therefore distinguishable. Figure 2 gives details of cluster size and cluster membership details.

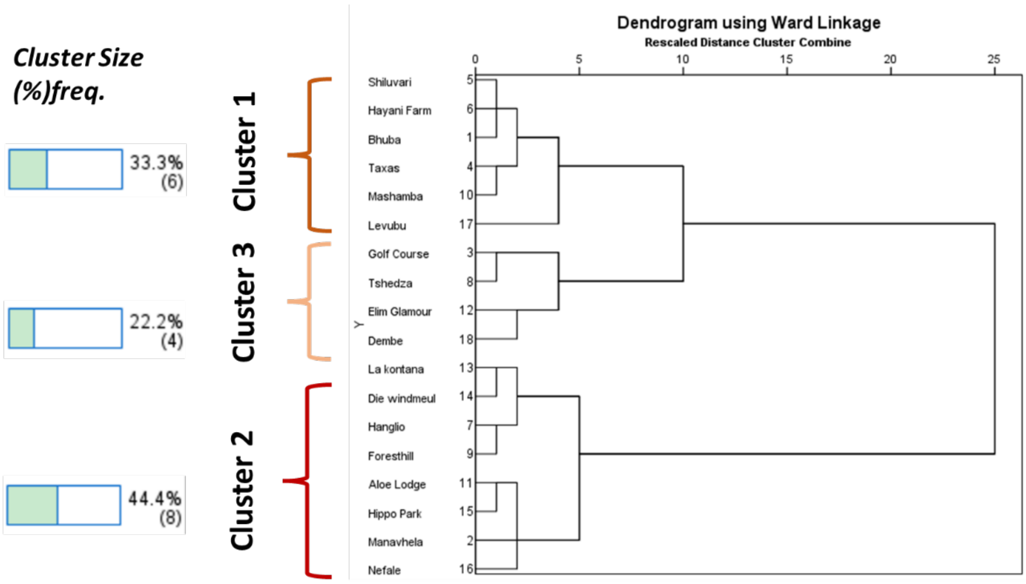

Figure 2: Cluster size and membership

Cluster 2 is the largest of all (44.4%) with 8 tourist attractions, followed by cluster 1 (33.3%) with 6 attractions. The smallest cluster is cluster 3 (22.2%) comprised of 4 tourist attractions. Predictor importance details associated were discerned. The most important predictors included pavement integrity, pavement surface, ride quality, pothole intensity and to some extent road safety in that order. It was possible to rescale the severity of the road pavement condition in each cluster to a -1,1 scale. A comparison of the resulting scales according to each cluster is shown in Figure 3.

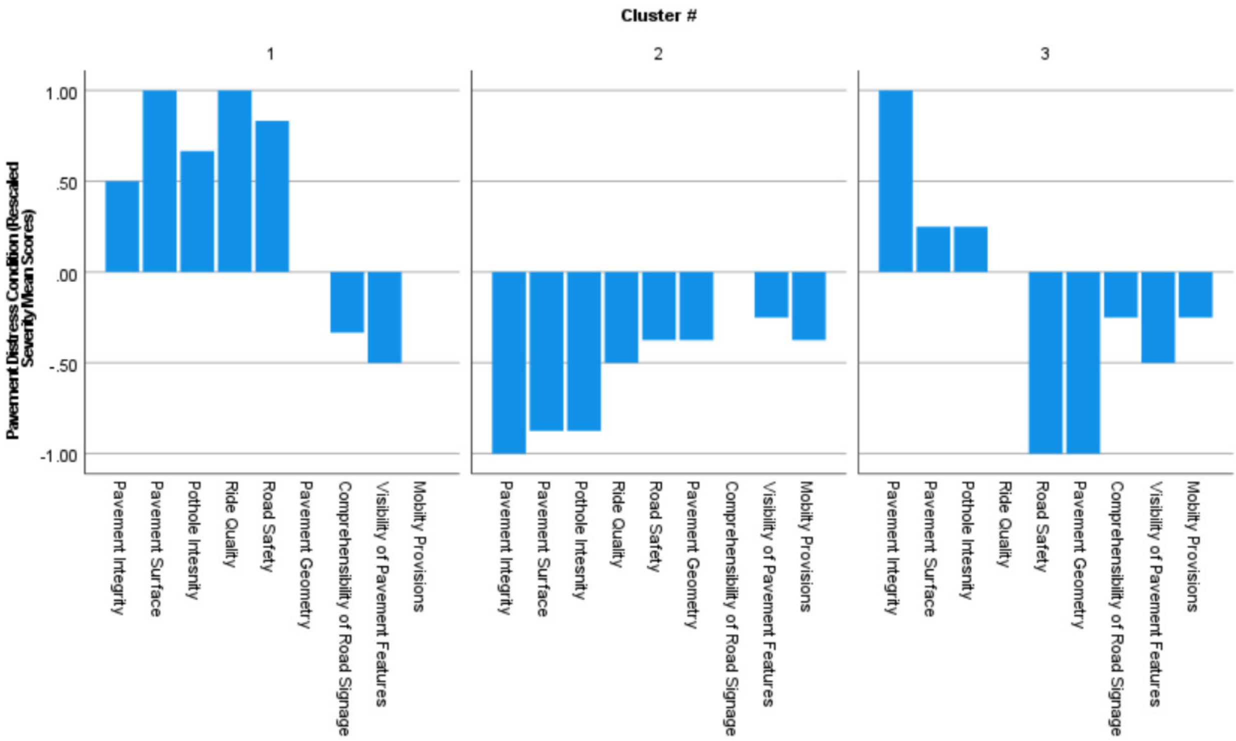

Figure 3: Cluster performance according to distress conditions

Results suggest that most of the tourist attraction (44.4%), associated with cluster 2 are characterized by severe road pavement distress conditions. All 9 pavement distress variables under analysis yielded negative severity scores. Road pavement performance was the worst in such attributes as road pavement integrity, pavement surface, pothole intensity and ride quality. Pavement conditions associated with cluster 1 type of tourist attractions were of less concern when compared with other clusters. Acceptable pavement conditions were recorded on observable attributes that included pavement integrity, pavement surface, pothole intensity and road safety. Serious problems regarding mobility provisions, visibility of pavement features and pavement geometric conditions were however observed. The second worst performing pavements are those leading to cluster 1 type of attractions where the severity situation associated with road safety, pavement geometry, visibility of road pavement features, comprehensibility of road signage, mobility provisions and ride quality was concerning. Pavement integrity, pavement surface and pothole intensity were however of less concern as depicted by positive severity mean score values. The inherent risk associated with pavement distress conditions in all tourist destination was found to be moderate in all clusters (Table 2).

Table 2: A cluster segmented pavement distress heatmap

Road pavement Distress segment	Number of tourist attractions	Statistical measure	Pavement distress parameter		
			Risk	Impact	Inherent risk
Cluster 1	6	Mean	2.3519	1.83	4.3519
		Std. Deviation	.10924	.753	1.84112
Cluster 2	8	Mean	1.4861	2.00	3.1250
		Std. Deviation	.23710	1.069	1.93313
Cluster 3	4	Mean	1.8333	2.00	3.5000
		Std. Deviation	.21276	1.155	1.75330

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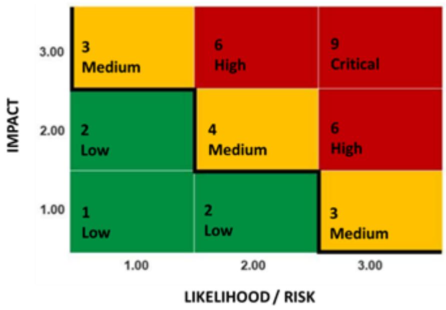

Inherent risk = risk x Impact
NB: Heat map colors based on rounded off (discrete) mean scores values

Despite having the worst road distress conditions tourist sites associated with cluster 2 type scored a low inherent risk when compared to other clusters. These results mean that the likelihood of pavement conditions having an impact of travelling experience is relatively lower because of other context factors making travelling experience less sensitive to pavement conditions. These include average length of pavements and a host of attraction quality offering a high pulling factor to tourists. Despite there being an expected negative correlation between cluster type and inherent risk, we found significant association between weighted pavement distress conditions and post travel choice (Figure 4).

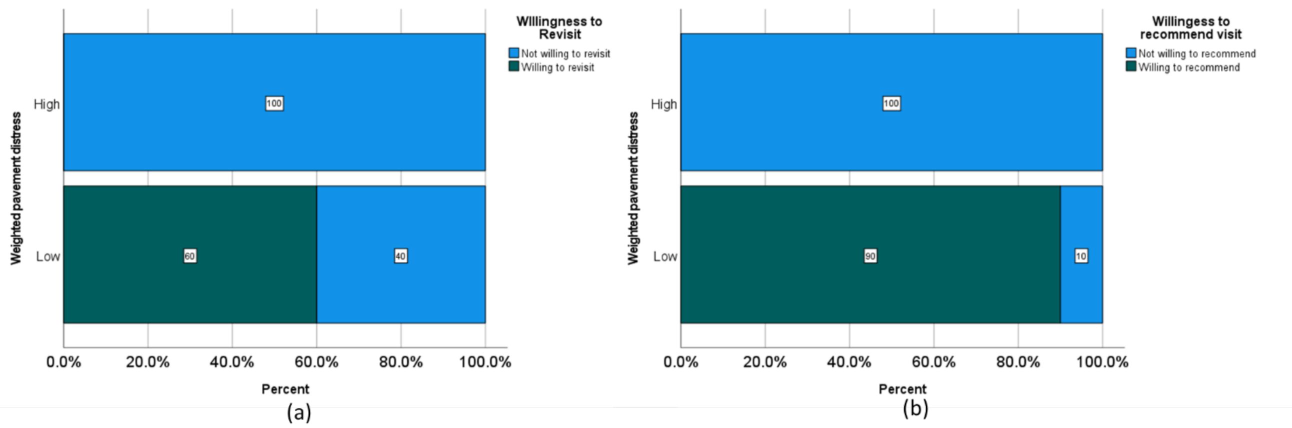

Figure 4: Relationship between weighted road distress condition and tourist travel choice

A two step-clustering algorithm that included ‘willingness to revisit’ and ‘willingness to recommend visitation’ as additional two input variables yielded a two-cluster solution, each composed of 9 tourist attractions with a silhouette measure of separation and cohesion of 0.5 (Figure 5).

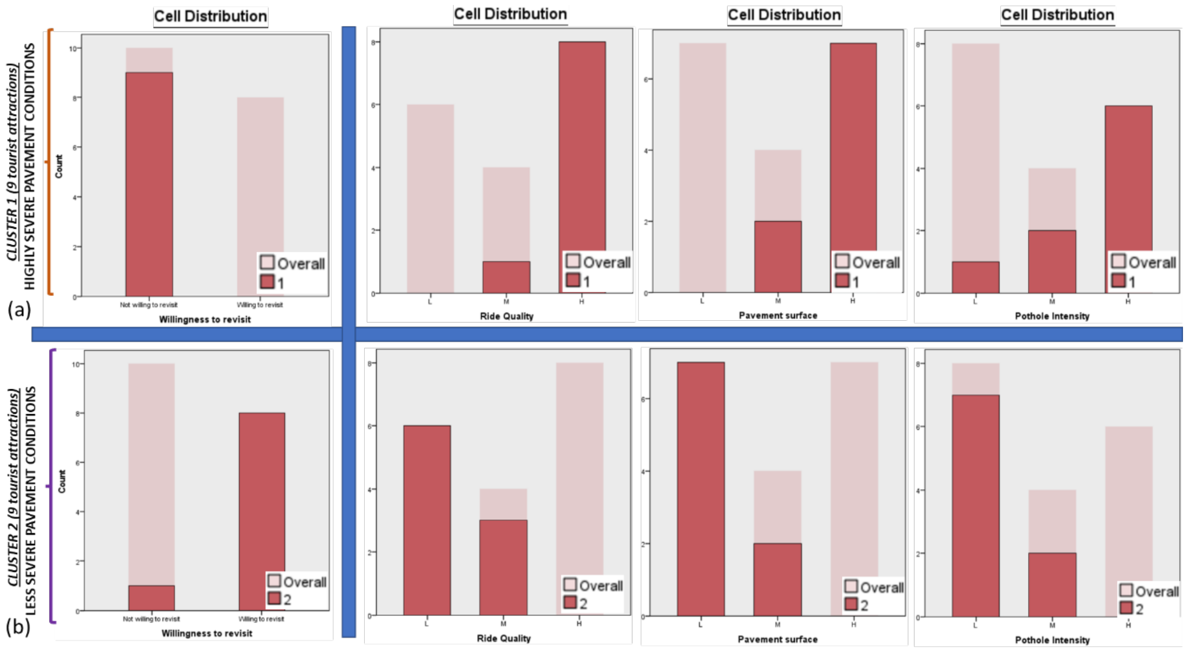

Figure 5: Cell distribution changes according to willingness to revisit and severity of pavement conditions

A closer look at cell distribution statistics reveals that tourists travelling on severely distressed road pavement surfaces (Figure 5a) are less willing to revisit when compared to those travelling on less severe road pavement conditions (Figure 5b). Sharp differences are also observable in changes in cell distribution statistics according to severity scores for each road pavement variable. Only four major predictor variables in order of their importance are shown in Figure 5 including rider quality, pavement surface, and pothole intensity. Pavement integrity and Road safety were other important factors considered important in predicting decision to revisit. High severity scores in all pavement distress variables are intricately associated with a low willingness to revisit while low severity scores are linked to a high willingness to revisit (Figure 5).

4.1 Recommendations

As argued by Zhu et al., (2022), it is imperative that effective countermeasures to address the road pavement distress condition and consequently improve the travel experience of tourists are put in place. Tourism development through increased and repeated visitations will be realized by building resilient road pavement infrastructure that not only ensure rider comfort but also road safety. Maintaining pavement integrity and periodic monitoring of pavement surface conditions is required particularly in cluster 2 type of tourist attractions associated with very poor pavement conditions if tourist visitation statistics are to improve. Such efforts should be complemented by implementation of structural measures to reduce the risk of road damage in highly distressed and unpaved road surfaces characterizing road pavements leading to cluster 2 and some parts of cluster 3 type of tourist destinations. Conducting risk assessment of geohazards and planning for both new and existing roads should be a priority.

In addition, non-structural risk reduction measures should be implemented. Non-structural measures that may include information induction, vehicle type restrictions are known in other literatures to be crucial in increasing tourist visitation (Zhu et al., 2019). Other non-structural measures may also include creating an accessible network data platform informing tourists of various space-time restrictions associated with severely distressed road pavement conditions. Space restrictions include indicating which pavements are ideal or not Ideal for accessing certain attractions. This is because, certain pavement conditions may be efficient during certain periods of time but may be inefficient in others. Examples may include variations in climate conditions in different seasons that may limit visibility or comprehensibility of road markings and signage as observed by Zeng and Li, (2021).

Since this study used tourist visitation as a proxy measure of tourism development, there is need for future studies to use more objective measures such as the contribution of the tourism sector to Gross Domestic Product (GDP) as a dependent variable to gauge accurately the extent to which pavement distress affects tourism development.

5. CONCLUSIONS

Our analysis revealed that pavement distress conditions influence the decision by tourist to revisit attraction or to recommend. Both inherent risk statistics and weighted risk statistics which both incorporated an aspect of road pavement distress and its expected impact on travel choice have predicted a travel avoidance behaviour associated with tourists that have visited attraction sites that are severely distressed in terms road pavement conditions. Such impact as observed in other travel avoidance behaviour literature is not uniform across tourism sites but segmented according to unique clusters exhibiting common pavement distress conditions (Zeng & Man, 2021). Results from both hierarchical cluster analysis and the two-step clustering algorithm, revealed ride quality, pavement surface, pothole intensity, pavement integrity and road safety as pavement distress variables significantly shaping post travel choices by tourists. Our analysis complements related observations in other countries, where road pavement distress factors such as pavement roughness and ride quality, comfort, safety (Loprencipe et al., 2017; Žuraulis et al., 2021), type of pavement surface, road markings and signs (Babic et al., 2022), road maintenance and road pavement integrity Du et al., 2020; Khahro et al., 2021) among others were found to be significant deterrents to tourist ‘s willingness to repeat same travel experience.

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