

# Design, construction, and in-service causes of premature pavement deterioration: a fuzzy Delphi application

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1	Design, construction, and in-service causes of premature pavement deterioration – A Fuzzy
2	Delphi application
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4

## 5 Abstract

6 Flexible pavements are prone to premature deterioration, and researchers are unresolved regarding the 7 importance of the underlying causes resulting in inappropriately selected modelling parameters and 8 increased uncertainty in predicting subsequent behaviour and performance. A windshield survey, literature 9 survey, and fuzzy Delphi study are undertaken as complementary approaches to costly conventional 10 investigations to identify reasons for flexible pavement deterioration in the design, construction and lifespan 11 phases. Overall, the results revealed that the lifespan phase consists of the most contributors to pavement 12 deterioration, which is approximately twice as much as the design and construction phases. However, the 13 findings suggest that most causes of deterioration in the lifespan phase can be attributed to deficiencies in 14 the preceding phases. Experts believe that structural and traffic are the most significant contributors to 15 pavement deterioration, more so than construction, environment and maintenance factors. Additionally, the 16 surface and subgrade layers were deemed to be the most problematic. Applying the Fuzzy Delphi method 17 minimises the ambiguities associated with the causes of pavement deterioration identified in the literature 18 and is advantageous for limited data. This study proposes measures for improving the design and 19 construction of more sustainable tropical pavements. Improved knowledge of the causes of deterioration is 20 vital for selecting the appropriate design, construction, and maintenance strategies.

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Keywords: Asphalt pavement; deterioration; distress; design; construction; lifecycle; fuzzy Delphi

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## 23 Introduction

24 The deterioration of hot mixed asphalt (HMA) pavements is inevitable (Garber and Hoel 2009) and has 25 been problematic for years. Signs of deterioration are usually visible on the pavement surface layer and 26 manifest as distress -distortion, disintegration and fracture (Attoh-Okine and Adarkwa 2013). Pavement deterioration causes unnecessary delays in traffic flow, road traffic accidents and the consequent loss of life 27 28 and property damage (Eijnde 2015; Ogundipe 2008; Rashid and Gupta 2017; Tarawneh and Sarireh 2013). 29 Apart from being aesthetically unpleasing, damaged flexible pavements continue to be unsustainable 30 because of their premature deterioration-unfortunately, forthcoming solutions on factors affecting defect 31 occurrence and a consensus on explanations for conditions leading to their manifestation are limited 32 throughout the project lifecycle. Evidently, the myriad of factors proposed for modelling pavement 33 behaviour and performance predictions and for explaining deterioration varies among authors. See, for 34 example, the factors to explain rutting proposed by Xu and Huang (2012), Gao et al. (2009), Walker (2009), 35 Huang et al. (2009), Ling et al. (2020), and Sybilski et al. (2013). Such variance exists because it is difficult 36 to determine which pavement layer contributes the most to surface deformations (Walker 2009). After all, 37 faults are interconnected, and focusing on one problem without considering others occurring throughout 38 the pavement life cycle restricts interpretation (Chilukwa and Lungu 2019).

39 Previous studies have identified flexible pavement deteriorating conditions using windshield 40 surveys (Alaamri et al. 2017; Scholz and Rajendran 2009; Zumrawi 2015); visual inspection (Al-Arkawazi 41 2017; Alaamri et al. 2017; Chen et al. 2003; Rashid and Gupta 2017), condition surveys (Scholz and 42 Rajendran 2009; Stallings 2016); and secondary methods (Afolayan and Abidoye 2017; Farouq et al. 2017). 43 In these investigations, the causes of distress were determined through literature reviews (Afolayan and 44 Abidove 2017; Kumar and Gupta 2010; Rashid and Gupta 2017); forensic investigations (Chen et al. 2003; 45 Zumrawi 2015); questionnaire surveys (Farouq et al. 2017; Ibraheem and Gani 2014); 46 observations/opinions (Adlinge and Gupta 2013; Okigbo 2012); and miscellaneous methods (Rather and 47 Lateef 2016; Tarawneh and Sarireh 2013). These approaches acknowledge in principle that several factors

48 are responsible for pavement deterioration and that no solitary method is confirmatory, as deterioration is 49 a complex and sometimes unpredictable phenomenon. The resulting lack of consensus on the causes of 50 pavement deterioration has led to neglect (Al-Arkawazi 2017; Rashid and Gupta 2017; Wada 2016), 51 omission, and poorly described data collection approaches (Acimovic et al. 2007; Adlinge and Gupta 2013; 52 Imran et al. 2015; Wada 2016).

53 The methodologies employed to identify distress causes were further constrained by 54 incompleteness, close-endedness of questionnaires, and a lack of data triangulation. Some of the reported 55 reasons for degradation are vague and wide in scope, such as inadequate drainage and poor construction. 56 Other variables, such as poor road alignment and geometric design, are redundant (Tarawneh and Sarireh 57 2013). Also, there is sparse mention of climate change as a critical factor, despite it being an urgent eminent 58 challenge (UN 2016) and is likely to have accelerated effects on deterioration. It is unclear which lifecycle 59 phase causes the most deterioration or where some factors are most pronounced. The reasons for these 60 misconceptions may be a lack of knowledge, literature, techniques, popularity, or misguided interpretation. 61 This study addresses these issues for additional reflections and critical analysis by updating the pavement 62 deterioration literature using an empirical method. Providing an improved understanding of pavement 63 deterioration is needed to make accurate judgements of its weakening behaviour (Eijnde 2015), that is, to correctly identify the signs of deterioration and their causes. 64

65 The types, severity, and reasons for pavement distress varies; hence, researchers and organisations 66 have offered regional or country-specific guidelines (Llopis-Castelló et al. 2020). The intent of which is to 67 provide objective criteria for assessing pavement quality, defining management strategies, and providing 68 guidance on deterioration factors. Such provisions facilitate model development that advances state of the 69 art, which relies on the use of AI to diagnose failures (Alzraiee et al. 2021; Praticò et al. 2020). However, 70 AI systems are limited because of the complex and dynamic environmental circumstances. For example, 71 diagnosing cracks while water is on the road surface may be inaccurate when using these systems (Cao et 72 al. 2020). Detecting faults requires human intervention; therefore, real-time performance is 73 currently unfeasible. Consequently, manual pavement surveys are often employed to discover, categorise,

and measure pavement defects (Ouma and Hahn 2017). The lack of data from expensive preparations,
including non-destructive and destructive testing, exacerbates this dependency (Johnson et al. 2017).
Moreover, Llopis-Castelló et al. (2020) claimed that financial restrictions and a lack of historical data make
assessing pavement deterioration problematic.

78 The performance assessment of pavements is unpredictable owing to the substantial variability 79 associated with pavement life and traffic repetitions. Uncertainty exists in traffic estimation, variability in 80 material parameters and various assumptions, approximations and empiricisms involved in the analysis and 81 design process. The complexity of pavement construction, material behaviour, traffic characteristics, and 82 quality control variables necessitates consideration of such uncertainties (Kalita and Rajbongshi 2015). The 83 impetuous goal is to encourage consideration of a comprehensive set of factors which provide an 84 understanding to quantify the typical variability associated with pavement throughout its life cycle 85 (Stubstad, Tayabji, & Lukanen (2002). Fortunately, existing non-destructive approaches already recognise 86 this uncertainty as the imprecise language used to describe pavement conditions demonstrates this. For example, the terms "poor," "very bad," "good," and "outstanding" are often used to describe pavement 87 88 conditions are subjectively uncertain. Fuzzy sets adequately describe this range (Elton and Jung 1988) as 89 fuzzy numbers can effectively categorise pavement degradation, as it accounts for the uncertainty 90 associated with evaluating engineering parameters (Bui et al. 2020; Elton and Jung 1988). Thus, experts' 91 subjective views can describe objective measures within acceptable statistical means (Martin et al. 2017).

92 Pavement degradation varies due to differences in economies, climatic conditions, geology, design, 93 construction, and maintenance practices. Despite several studies on tropical pavement deterioration, this 94 problem persists, prompting the need to explain the most important design, construction, and lifespan 95 factors affecting its deterioration and in-service quality. A windshield survey and visual inspection of 96 flexible pavement distress along the highways in Trinidad were conducted. The identified causes of distress 97 were determined from a literature review and then presented to experts involved in the design, construction, 98 and lifespan phases to obtain a consensus on inclusivity and ranking using the fuzzy-Delphi approach. The 99 proposed approach minimises professional judgement uncertainty. Ambiguity regarding the underlying

reasons for the early degradation of flexible pavements leads to incorrectly chosen modelling parameters and increased uncertainty in projecting future behaviour. Understanding pavement disintegration is critical for optimising maintenance expenditures, addressing underlying causes, improving design and construction quality (Fwa 2006; Rashid and Gupta 2017; Schlotjes et al. 2011), and, more importantly, extending the useful life of pavements. This study confirms that expert judgement is useful in understanding pavement deteriorations and in guiding deterioration interventions.

106

# 107 Methodology

108 Figure 1 shows an overview of the research methodology applied in this study.

109

#### 110 Field Survey

111 The Churchill-Roosevelt (CRH) and Beetham highways in Trinidad were used as case studies to identify 112 the distress types. While these highways were constructed a decade apart, they were chosen because they 113 are most similar in composition and function, and one exists as a continuation of the other. They commonly 114 have six lanes, signalised intersections, and a similar traffic volume and load intensity. These highways 115 connect Port of Spain (the Capital City of Trinidad and Tobago) and Arima (the second largest borough). 116 Both the eastbound and westbound directions of the highways were surveyed. As shown in Figure 2, the 117 road under inspection extends from the west at the beginning of the Beetham Highway (land marked by the 118 South Quay Lighthouse) (A) and ends in the east at the Mausica Road/ Churchill Roosevelt Highway (CRH) 119 intersection (J), where the six lanes of traffic end on the CRH. The length of the pavement under scrutiny 120 was divided into nine sections for observation and recording of distress. The highways' major entrance and 121 exit points were chosen as the beginning and ending points, respectively, to ensure that each section was 122 subjected to a common traffic volume and intensity. Work by Attoh-Okine and Adarkwa (2013) was 123 adopted for the windshield surveys to identify the distresses present on the highways. Instead of a walking 124 survey, a windshield survey was selected for this study because of the highway's proximity to high-crime 125 neighbourhoods, and safety was the decisive consideration (Miller and Bellinger 2014). The degree of 126 distress along a particular section of the highway was observed. However, the density or precise distress 127 locations limit the findings' interpretation. In this survey, an observer (a civil engineer) was seated in the 128 passenger seat of a car moving at approximately 30 km/hr. in the slowest lane of traffic as the car stopped, 129 photographically documenting the distress and severity while standing along the pavement edge. The 130 survey was conducted on a national holiday when the traffic volume was comparatively lower than that on 131 a regular day, which facilitated the visibility of all pavement lanes. Subjectivity in distress identification 132 and severity was reduced using the guidelines provided by ASTM International (2018), Miller and Bellinger 133 (2014), NAASRA (1987), and the Federal Highway Administration (2009).

134

## 135 Fuzzy Delphi Method (FDM)

136 The Delphi method is a decision support tool to assess group thinking by taking each expert's opinion 137 individually and anonymously and subsequently merging them into one group opinion (Adler and Ziglio 138 1996; Habibi et al. 2015). It is recommended for situations where data are insufficient or when models for 139 statistical prediction or judgment are non-existent (Gupta and Clarke 1996). Ishikawa proposed the fuzzy-140 Delphi approach (Hsu et al. 2010), which changes the standard Delphi method by accounting for expert 141 judgement uncertainty (McKenna 1994), improving convergence, and decreasing high execution costs (Ma 142 et al. 2011). Including fuzzy settings decreases inaccuracies because they are more linguistically 143 ambiguous, as humans cannot resist vagueness, the antithesis of exactness (Novák and Dvorák 2011). The 144 Fuzzy-Delphi method provides a more current scientific or technical information interchange than a 145 literature study or the conventional Delphi (Delbecq et al. 1975). Fuzzy-Delphi has been used to 146 determine road safety performance indicators (Ma et al. 2011), sustainable solid waste management barriers 147 (Bui et al. 2020), and assess service industry mobility performance indicators (Kuo and Chen 2008), 148 thereby, justifying its use in determining pavement deterioration factors.

149

# 150 *Expert identification and panel composition*

There are no exact criteria listed in the literature concerning Delphi expert selection (Hsu and Sandford 2007). The researcher's responsibility is to choose the most appropriate experts and defend that choice (Sumsion 1998). This study adopted the following requirements for 'expertise' as defined by Adler and Ziglio (1996):

- i. knowledge and experience with the issue under investigation;
- 156 ii. capacity and willingness of the experts to participate;
- 157 iii. sufficient time to participate; and
- 158 iv. effective communication skills

159 It is important to have appropriate distinctions among expert groups to have significant conclusions; using 160 heterogeneous groups may result in either no mutual agreement or meaningless aggregated results (Kuo 161 and Chen 2008). For this reason, three homogenous panels of experts were engaged based on their 162 involvement in different road lifecycle phases: design, construction, and lifespan. See Table 1. Ten design, 163 thirteen construction, and thirteen lifespan experts participated in Tier 1 of the survey. However, only nine, 164 seven, and eight design, construction and lifespan experts, respectively, responded to Tier 2. These 165 'dropout' rates were not expected to affect the study outcome because the panel sizes were satisfactory. 166 According to Cantrill et al. (1996) and Mullen (2003), the panel size has no strict rules. Linstone (1978) 167 added that a suitable minimum panel size is seven, but panel sizes range from 4 to 3000. Therefore, the 168 panel size decision is empirical and pragmatic, considering factors such as time and expense. Usually, the 169 time required to administer a Delphi survey is two weeks (Delbecq et al. 1975). In this study, time was not 170 considered an influencing factor in dropout rates because the respondents were provided adequate time 171 (three weeks) for each round. Reasons for participants' dropout included the change of work organisation 172 and the inability to access the survey due to remote fieldwork location.

173

175 The literature review identified and summarised the existing research relating to HMA flexible pavement 176 distresses and their contributing deterioration factors. An initial list was created to define the abstraction 177 level at which participants added missing factors (Schmidt et al. 2001). Pavement deterioration can be 178 approached from a very detailed or a much more generic viewpoint. The level of approach determines the 179 eventual outcome and usability of the results. There was a search for a detailed level of deterioration factors 180 in this study. The lists of factors obtained from the literature review were scanned thoroughly to ensure that 181 duplicate, indistinguishable or inapplicable factors (e.g. ice, snow, and frost action) were not presented to 182 the panellists as Trinidad is a tropical country. Examples of predefined factors were provided to guide the 183 participants.

184

# 185 *Questionnaire construction*

186 Questionnaire 1 identified all relevant factors that generally contribute to pavement deterioration in the 187 design, construction, and lifespan phases. Three separate questionnaires were created as the factors were 188 considered per lifecycle phase rather than all together. Separate questionnaires were used for two reasons. 189 First, using three different questionnaires prevented some participants from leaning toward one of the three 190 phases. Creating three different homogenous groups yielded more reliable results, as participants answered questions within their field of expertise. According to Rowe et al. (1991), sensible questions are only 191 192 sensible and pertinent to the panellist knowledge realm. Second, it would have been too intensive and 193 demotivating if panellists had to rank all factors of the phases. Each of the three questionnaires contained 194 two sections; section one sought to collect the participants' background information. Section two lists the 195 general factors that originate during each lifecycle phase.

The experts were asked to appraise the list of factors by validating, deleting and adding missing deterioration factors from the initial lists derived from the literature review. In addition, to maximise the chance of defining all relevant factors, participants could submit as many suggestions as possible (Schmidt 1997). Their vagueness, phase of origin, or redundancy was considered for adding to or excluding the suggested factors from the list. Questionnaire 1 was created using Adobe Acrobat and was administered 201 mainly online via email. Also, in some instances, the participants expressed a preference for physical copies. 202 Feedback received from Section 2 for each questionnaire 1 (design, construction and lifespan) was analysed 203 by adopting Alexandrov et al. (1996), Sinha et al. (2011), and Morris et al. (2014) criteria. The criterion for 204 an agreement was that at least 67% of the respondents gave the same response. This criterion was used 205 because these studies had similar 'nominal' (yes/no) scales as this study. With the condensed results 206 gathered from Questionnaire 1, three subsequent Questionnaire 2 were presented to the experts. They were 207 asked to use either Google Forms or Adobe Acrobat to rank the identified factors on a seven-point Likert 208 scale. Google Forms was used in this round because some participants expressed issues using Adobe 209 Acrobat online.

210

# 211 Identifying an appropriate spectrum for fuzzification of linguistic expressions

212 A triangular fuzzy membership function was established to fuzzify respondents' linguistic expressions 213 taken from a set of acceptable values (no effect, little effect, ... medium effect, ... extreme effect). The 214 linguistic variable was defined as the number of years of shortening the pavement lifespan. The rationale 215 for using a scale with the linguistic variable "shortening in lifespan" was that it would be more intuitive for 216 participants if they could express the severity of deterioration in years (Eijnde 2015). In addition, the shortening in lifespan provides a uniform measure across all defects and reduces the uncertainties associated 217 218 with terminologies such as extremes, which may vary among different defects. Therefore, this study used 219 a shortened lifespan as the term set  $T = \{0 \text{ years}, 0 \text{ to } 1 \text{ years}...4 \text{ to } 5 \text{ years}, >5 \text{ Years}\}$ . Choosing a Likert 220 scale is advantageous and is a reliable data collection approach because it can access both observable and 221 latent variables that are not directly observable, and the consequent results can be utilised for statistical 222 inference (Li 2013).

Higher-order scales increase reliability but begin to plateau at 7 with no further increase beyond 11 (Finstad 2010). However, there are intense criticisms of increasing scale because of the difficulties in resolving the intensity of feelings, measurement errors, and confusion from too many choices, which induces laziness (Li 2013). Besides, the seven-point scale provided the best direct rating and was 227 determined to be the most accurate and easy to use (Diefenbach et al. 1993). A seven-point scale was chosen 228 because 0 to > 5 years can be evenly distributed over a seven-point scale while maintaining a range of 1 229 year. According to Eijnde (2015), discussions with experts confirm that a range of one year is the desired 230 level of granularity, and there is no reason to go beyond '> 5' years as this is very exceptional to happen in 231 real life. There is a corresponding triangular fuzzy number (TFN) for each year of life span shortening, as 232 shown in Table 2. Each identified factor was ranked by requesting participants to select the most probable 233 'shortening in lifespan' effect on the pavement life. Hence, all experts' Likert scale responses for each factor 234 were fuzzified. The first, second and third values are referred to as the 'minimum fuzzy value (a)', 'optimal 235 fuzzy value (b)' and 'maximum fuzzy value (c)', respectively. The minimum value represents the minimum 236 shortening in lifespan that can occur as a result of a factor. Similarly, the optimal (b) and maximum (c)237 values are the respective most probable and maximal shortening in lifespan due to a factor.

238

# 239 The consensus of Questionnaire 2

This study utilises triangulation statistics to determine the distance between expert panel members' levels of consensus. The feedback received from Questionnaire 2 was screened for consensus. A consensus was reached if at least 70% of the responses for each factor were within one standard deviation of the mean response (average fuzzy number) (Diamond et al. 2014; Hasson et al. 2000; Henderson and Rubin 2012; Slade et al. 2014; Vogel et al. 2019). The average fuzzy number (TFN<sub>average</sub>) was determined for the minimum, optimum and maximum fuzzy values using equation (1).

246 
$$TFN_{average} = \frac{\sum Fuzzy \ values}{Number \ of \ Experts}$$
(1)

For each factor, the distance (d) between the respondents' TFN and the average TFN was determined, followed by the average distance ( $\tilde{d}$ ). Next, the standard deviations (s) of the responses were calculated, followed by the lower ( $\tilde{d} - \sigma$ ) and upper ( $\tilde{d} - \sigma$ ) limits for acceptance. The distance (d) between the two triangulated fuzzy numbers m = (m<sub>1</sub>, m<sub>2</sub>, m<sub>3</sub>) and n = (n<sub>1</sub>, n<sub>2</sub>, n<sub>3</sub>), as expressed by Abdulkareem et al. (2020), is given by equation (2): 252

253 
$$d(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3} \left[ (m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2 \right]}$$
(2)

254

The standard deviation, s, is calculated using equation (3), where N = number of experts; x = distance between the average response and the respective expert's response; and  $\mu$  = average distance for the factor.

258 
$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \mu)^2}$$
(3)

259

# 260 Aggregation of fuzzified values

For the factors of questionnaire two that achieved consensus, the group opinion of (i = n) experts for each factor (j) was aggregated using the geometric mean adopted from Hsu et al. (2010) and Chen (2014), see equation (4).

264 
$$\tilde{w_j} = (a_j, b_j, c_j) \tag{4}$$

265 Where: $\tilde{w_j} = aggregated triangular fuzzy number; a_j = min \{a_{ij}\}; b_j = \frac{1}{n} \sum_{i=1}^n b_{ij}; \text{ and } c_j = \max \{c_{ij}\}.$ 

# 266 Defuzzification

Defuzzification is required because fuzzy numbers cannot be ranked because they are not crisp (precise) values. The graded mean integration representation method, proposed by Chen and Hsieh (1999) and described in equation (5), is used to aggregate the fuzzy triangular numbers for each factor in the process of defuzzification.

271 
$$S_j(expert \ group \ opinion) = \frac{a_j + 4b_j + c_j}{6}$$
(5)

This defuzzification equation weighs the optimal value (b) four times that of the minimum (a) and maximum value (c). This weighting was appropriate because the most probable value was the most valuable for this study.

# 275 Selecting the threshold /screening criteria and ranking

A screening threshold was established to determine the significant deterioration factors. The threshold is typically 0.7, but it varies based on the researcher's opinion in different studies (Habibi, Jahantigh, and Sarafrazi 2015). In this study, the threshold value used to eliminate the least significant factors was one standard deviation below the mean. If the crisp value of the defuzzification of aggregated experts' opinions is larger than the threshold, the criterion is confirmed. If the criterion was less than the threshold value, the factor was removed. Finally, the factors were ranked from highest to lowest by ranking their crisp values (Sj).

283

284 Bias

285 According to Hallowell and Gambatese (2010), eight different types of bias may influence the outcome of 286 a Delph study: Collective Unconscious, Contrast Effect, Neglect of Probability, Von Restorff Effect, 287 Myside Bias, Recency Effect, Primacy Effect and Dominance. Collective unconsciousness arises when 288 participants conform to popular trends selected by their peers without being objective. This bias was 289 reduced by gathering the experts' responses online via 'Google Survey'. In cases where physical 290 questionnaires were delivered, the participants were allowed to complete the questionnaires at their 291 convenience. Contrast effect occurs when a given subject's perception is enhanced or diminished by the 292 immediately preceding subject's value. Using the same scales for Questionnaire 1 and Questionnaire 2 293 items minimised this bias. The participants' ability to disregard the probability of certain occurrences is 294 termed Neglect of Probability. This bias considers the scenario where individuals focus on the potential 295 consequences of an outcome without examining the probability of its occurrence. This bias did not affect 296 this study since the probability or frequency of the factors were not considered. The following biases were 297 reduced by checking the consensus of the panellists for both rounds of the study: Von Restroff Effect - a 298 person's recall of extreme events over lesser events; Myside - occurs when someone has a one-sided 299 perspective of an issue; Recency Effect - an individual's recall of only recent events; and Primacy -300 participants placing unconscious importance on initial questions. Dominance arises when one group

301 member exerts significant influence over the other members' evaluations: anonymity and equal weighing
 302 of answers control this frequent bias source.

303

304 Validation

The group thinking approach assured the validity of the deterioration causes derived from the fuzzy Delphi method (Skinner et al. 2015). According to the defined criteria, group consensus for the factors in each phase was determined at the end of both rounds of the study.

308

## 309 **Results**

310 Of the seventeen types of flexible pavement distresses identified from the literature, the windshield survey,

which included visual inspection, found longitudinal cracking, fatigue cracking, rutting, polishing, and potholes most prevalent along the highway sections. Table 3 identifies the severity of the distress throughout the respective sections of the highway.

314

Table 4, Table 5, and Table 6 present the experts' fuzzified responses to the causes of pavement deterioration for the design, construction and lifespan phases. Table 7 shows the ranked causes of deterioration for each distress.

318

The ranked factors for the general causes of deterioration in the design, construction and lifespan phases are shown in Table 8. For each of the distresses identified in Table 3, the experts' ranked causes are presented in Table 9.

322

# 323 Causes of premature highway pavement deterioration

Three panels of experts with design, construction, and lifespan phases identified and ranked the causes of highway pavement deterioration. In their opinion, structure, traffic, construction, environment, and maintenance are the major categories contributing to premature highway pavement deterioration.

327

# 328 Structure

329 A pavement's structural soundness is critical to its performance throughout its lifespan, where most design 330 inadequacies are manifested. The experts believe that pavements are structurally inadequate owing to 331 insufficient design knowledge, faulty design parameters, and poor preliminary geological investigation. 332 These factors are antecedent to other causes, which are related to pavement thickness and properties. Design 333 and construction experts consider inadequate layer thicknesses a pivotal contributor to deterioration, as 334 previously acknowledged by (Zhao and Al-Qadi 2016), as the most crucial factor for the majority of asphalt 335 pavement design methods. In the general list of design factors, inadequate base and pavement layer 336 thicknesses were ranked third and fifth, respectively. Similarly, a thin asphalt layer over bridges and 337 roadways was identified as contributing to both meandering cracks and potholes. When the pavement 338 thickness is insufficient, the subgrade applied stress is more significant than it can resist, resulting in 339 deflection and premature pavement failure (MAPA 2014). The lifespan experts believed that such 340 behaviour could account for structural failure/movement of the bottom layers and the resulting fatigue 341 cracking, rutting and depressions. Hence, the experts deemed the subgrade one of the most problematic 342 components.

Unstable/expansive subgrade soils were ranked as the primary cause of bumps, depressions, longitudinal, transverse, and block cracking. Similar observations were noted by (Uge 2017) in Ethiopia, where such soils experience more than usual differential settlement. Unstable/expansive subgrade soil is ranked as a general cause of deterioration and the primary reason for meandering cracking. Expansive soils are common along the case study route, often inflicting substantial pavement damage in the island's northern, central and southern regions (Ramana 1993; Venkatarama 2003). Therefore, the strength of the subgrade must be thoroughly evaluated before commencing the structural design of the pavement. Notably,
poor preliminary geological investigation was ranked among the general causes of deterioration.

It is not surprising that inadequate pavement design for specific soil conditions was ranked as the leading cause of rutting, bumps, depressions, fatigue, and longitudinal and transverse cracking. For highways not affected by expansive soils, their unstable subgrade may be due to inadequately prepared subgrades, more specifically, inadequate compaction (ACI Asphalt & Concrete Inc. 2017; Clarke 2015; Powell 2018) or poor subsurface and surface drainage (Clarke 2015; Lavin 2003; Roadex Network 2014). Overall, the results suggest that inadequacies in the design and construction phases can be the root of this in-service problem.

The quality of pavement materials was also identified as a significant contributor to structural deterioration. The design and construction experts conveyed that the quality of the HMA mix and aggregates used for construction compromises the pavement's structural integrity. The lifespan experts affirm that the deterioration was largely due to the degradation of the pavement materials initially used.

362 Experts identified the bitumen mix's lack of stability in the design phase as the primary cause of 363 corrugation and shoving, confirming Wada (2016) findings. The findings demonstrate that both defects are 364 of a similar origin (Adlinge and Gupta 2013). In contrast, in the construction phase, poor binder to stone 365 adhesion' was identified as the third most significant cause of raveling and the ninth general cause of 366 deterioration. In addition, the low binder content in the HMA mix was ranked as the seventh general cause 367 of deterioration. Inappropriate aggregates were ranked as the second most significant general cause of 368 deterioration. Construction experts ranked it as the leading cause of rutting, bumps, shoving, and ravelling, 369 affirming the influence of aggregates on these defects as unquestionable (Adlinge and Gupta 2013; Huang 370 et al. 2009). The degradation of the pavement materials described as deterioration of aggregates and ageing 371 of binder in the surface course was ranked as the third and fifth general cause of deterioration in the lifespan 372 phase. The loss of adhesion in the surface layer and ageing of the binder in the surface course were identified as specific contributors to edge breakage, fatigue cracking, and raveling. The emergence of cracks results 373 374 from the increased stiffness from the binder ageing process (Anderson et al. 2001).

375 Finally, the results suggest that drainability greatly influences the highway pavement's lifecycle 376 structural performances; as Rasol et al. (2022) explain, water may enter between layers, accelerating asphalt 377 interface degradation. In the design phase, inadequate surface drainage was ranked as one of the leading 378 causes of fatigue cracking, bumps, and delamination. Such assertions are validated by Alber et al. (2020), 379 Wang et al. (2018) and (Alber et al. 2020; Wang et al. 2018); Zhang et al. (2020). Poor drainage was also 380 ranked the fourth most significant general cause of deterioration. Additionally, poorly designed subbase 381 drainage was identified as a contributory factor to rutting, whereas poorly constructed surface drainage has 382 been highlighted as a contributory factor to bumps, rutting, and delamination. The lifespan experts identified and ranked poorly maintained drains as the 16<sup>th</sup> general cause of deterioration and a specific cause 383 384 of longitudinal cracking.

385

## 386 Traffic

387 Traffic is considered the most important factor in pavement design (Huang 2004); this study's design 388 experts affirmed this position. Underestimated traffic loads and inadequate future traffic forecasts were 389 ranked as the top two causes of pavement deterioration in the design phase. Also, vehicular traffic's 390 phenomenal growth was ranked as the most significant cause of deterioration in the lifespan phase. In addition, the lack of control regarding the load limit carried by vehicles, over-weight vehicles and high 391 392 traffic volume were ranked fourth, eighth and fourteenth respectively. Regarding the individual causes of 393 distress, growth in vehicular traffic was ranked as the number one cause of fatigue cracking. Growth in 394 vehicular traffic has predicted fatigue cracking performance (Dinegdae and Birgisson 2018). With a 395 population of 1.4 million and over one million automobiles on the road, a predicted monthly vehicle growth 396 of 2,000, and a vehicle density per 1000 person of 770 (Central Statistical Office 2019; Nanton 397 2019), increasing vehicle density on 8320 km of paved road might lead to traffic saturation or acute traffic 398 constipation ('stopping and standing traffic') (Shah 2014).

The resulting high traffic volume was identified as a cause of longitudinal cracking, transverse cracking, rutting, potholes, and delamination. The stopping and standing traffic' was identified as a cause 401 of rutting, which was also confirmed by Kandhal et al. (1998) in hot climates. Stopping and standing or 402 even slow-moving traffic imposes greater damage than fast-moving traffic; for instance, an increased speed 403 from 2 km/hr to 24 km/hr reduces the stress and pavement deflection by 40% (Chu 2010). Reversible 404 stopping and standing traffic is currently a major problem observed daily during rush hours (6 am to 9 am 405 and 3 pm to 6 pm) on the highways leading to and from Port of Spain city.

406 The pushing action by wheels of heavy vehicles at the time of acceleration and deceleration was 407 identified by this study as a cause of shoving. In this scenario, the adhesion between adjacent layers is 408 inadequate to produce the required shear strength to resist slippage under horizontal thrust (Kandhal et al. 409 1998). During traffic checks, 90% of trucks departing or entering the Solomon Hochoy Highway had loads 410 exceeding their gross weight limit (MGW). They were sometimes 100% above their MGW (Felmine 2019). 411 Overweight vehicles cause exponential pavement destruction (Luskin and Walton 2001), with pavement 412 damage proportional to the vehicle's axle weight difference to the fourth power (IPWEA 2017). During the 413 field survey, rutting and shoving were observed mostly at signalised intersections, where traffic was 414 required to stop. This cause appears to be a combined effect of stopping heavy and overweight vehicles in 415 the wheel path at signalised intersections.

The overloading issue is directly linked to the lack of control regarding the load limit of vehicles, as existing regulations provide for penalties. The problem is not non-existent control regulations but the enforcement of these regulations. First, the availability of weighbridges across the country is limited; as of February 2019, only three were reportedly functional (Felmine 2019), and second, enforcement exercises are arbitrary (Furlonge 2017). One of the delinquent drivers in those mentioned above "pull over" exercise expressed the unavailability of scales at pick-up locations as a major difficulty in adhering to the regulation (Felmine 2019).

423

#### 424 *Construction (Process)*

425 The panel identified poor quality control as one of five general construction causes of pavement 426 degradation. A pavement will not satisfy the required construction and performance requirements if all 427 materials procedures, inspection, monitoring and testing are not carried out (Kuennen 2013), making it 428 more probable for early failure. Outdated local standards lead to poor quality control but adopting 429 international practice standards overlooks local variability such as aggregate specifications and 430 environmental circumstances, making it improbable to obtain the desired quality.

Poor supervision and craftsmanship were rated third in overall pavement degradation. Poor
craftsmanship indicates insufficient supervision and monitoring (Uff and Thornhill 2010) and management
inadequacies (Hickson and Ellis 2014), features of which are common to Trinidad's construction industry.
Bad communication, documentation, work system/methodology, worker performance, and planning may
result from poor craftsmanship (Chong 2006).

436 The degree of compaction reflects the quality of supervision as it is essential to achieve the desired 437 air void content as pavements with a high or low air-void content will not perform effectively. The 438 respondents confirmed that insufficient surface/subbase/base compaction causes fatigue cracking, 439 transverse cracking, rutting, depression, and ravelling. The amount of air gaps in a pavement affects its 440 fatigue life, permanent deformation, oxidation, moisture damage, distortion, and disintegration. Reducing 441 an asphalt mix's air-void percentage from 8% to 5% doubles fatigue life (Roy et al. 2013). Like permanent 442 deformation (rutting and depression), lowering air-void content below 3% lowers the rutting rate (Brown 443 and Cross 1992). Less air in the HMA material means slower oxidation but pavements become susceptible 444 to water damage and ravelling with increased air above 8% Scherocman (2000). Reduced air-void content 445 reduces distortion, especially while stopping or turning.

The base layer distributes the generated stresses from the traffic load and prevents the underlying subgrade from failing. Insufficient compacting of this layer reduces shear strength, stability and stiffness and increases permanent deformation (Titi et al. 2012). Inadequate initial density and shear strength allow for lateral movement of particles, resulting in rutting and depression (Saeed et al. 2001). High deflection in the HMA layer owing to base instability causes fatigue cracking.

The subbase, like the base, has to be rigid and robust to avoid deformation (rutting and depression)
(Liley 2008), but Abd El Halim and Mostafa (2006) showed that compaction equipment like steel roller

drums leads to early surface deterioration. Drum rollers increase permeability, layer permeability, and compaction near unsupported edges of paved lanes. However, the subgrade preparation should be adequate to deliver the required compaction and moisture content. Insufficient levels of these elements may cause excessive deformation (rutting) under high loads. Inadequate subgrade preparation causes shoving and potholes, weakening the bond between the pavement layers (Tamrakar 2019).

Longitudinal and transverse slopes affect surface drainage and, therefore, pavement deterioration. Sharp longitudinal slopes increase surface water movement and erosion. Flooding or ponding occurs when moderate transverse slopes or flat surfaces do not allow timely drainage. The quality of surface drainage is affected by collector drains. The pavement becomes saturated if collector drains are not deep enough (Sanborn 1963). Experts express that poor surface drainage causes bumps, rutting, and delamination.

463

#### 464 Environment

Only in the lifespan phase were environmental elements recognised as degrading factors. Global warming, 465 466 natural disasters, and moisture were all general causes of deterioration, with global warming placing in the 467 top ten degradation causes. The effects of the increased temperatures are manifested on Trinidad's 468 highways as fatigue cracking and ravelling. From 1961 to 2008, the meteorological data revealed that 469 the average ambient temperature in Trinidad climbed by 1.7 °C (Environmental Management Authority 470 2019). Heat accelerates the ageing of the binder, reducing asphalt durability and increasing its 471 susceptibility to deterioration (Emery 2011; Wilway et al. 2008). The experts regarded the ageing of the 472 surface course binder as the third most important cause of pavement degradation in-service. As pavements 473 age, they become stiffer and more brittle as the stiffness modulus is lowered (Halle et al. 2012), increasing 474 the risk of pavement failure (Lu et al. 2008). Rutting, corrugation, and shoving may have been caused by 475 low rigidity modulus in combination with traffic, although they were not identified by this study as the 476 specific cause of these distresses.

477

478

479 The Intergovernmental Panel on Climate Change (IPCC) (2007) predicts that severe weather events and 480 heavy rains will increase in the Caribbean owing to global warming. Moisture damage to asphalt mixtures 481 is proportional to water content Schmidt and Graf (1972). The effects are already seen from the four days of 482 October 2018 flooding of the Uriah Butler Highway, causing structural damage to the pavement (Trinidad 483 and Tobago Guardian 2018). Moisture may adversely affect the characteristics of pavement materials and 484 hence, the overall structural performance of a pavement system (FHWA 2017). Water seepage via 485 longitudinal joints has been linked to ravelling, potholes, and rutting. Moisture in the surface layer promotes 486 stripping and loss of asphalt cement-aggregate adhesion (McGennis et al. 1984). Fatigue cracking and edge 487 break were found as reasons for stripping on the HMA surface layer and loss of adhesion in the surface 488 layer. 'Trapped moisture in the lower layers of the pavement' causes rutting and weakens the surface 489 (Bonaquist 2016). Base layer and subgrade moisture may also contribute to structural failure or movement 490 of the bottom layers (fatigue cracking and depression). Trinidad's highways are also at danger from 491 earthquakes. In August 2018, a 6.9 magnitude earthquake occured, and examining the nation's key 492 roadways revealed minimal structural damage from the event (T&T News 2018).

493

# 494 Maintenance

495 'Shortage of maintenance training activities', 'lack of supervision or supervision by unqualified personnel', 496 'insufficient funding', 'not involving local professional bodies in highway maintenance', and 'poorly 497 maintained drains' were identified as general deterioration causes resulting from poor maintenance. From 498 2019 to fiscal 2021, government funding for road construction and renovation fell 42%, while funding for 499 municipal roads and bridges fell 20%. Due to a lack of funding for road repair, many of the roads under the 500 government agency's jurisdiction require rehabilitation. Experts believe that maintenance does not 501 significantly affect Trinidad's pavement deterioration compared to the other major general factors since the 502 mentioned factors received low rankings (see Table 9). In addition to these factors, untimely maintenance 503 was inferred from potholes' leading cause (the result of fatigue cracking). Failure to promptly repair fatigue

504 cracks worsens the severity. As a result, the interconnected cracks form small chunks of dislodged pavement
505 from vehicles that drive over them, resulting in potholes.

506

# 507 Practical lifecycle recommendations

508 This research highlighted the surface and subgrade layers as the most problematic pavement components 509 because of their many contributions to deterioration. The causes of deterioration related to the surface layer 510 included inadequacies in the bitumen mix's properties and content, aggregates, drainage, layer thickness, 511 compaction, and material degradation. In examining the layers, the subgrade was deemed problematic due 512 to its unstable or expansive behaviour, and it was identified as the leading contributor to eight distresses. 513 After characterising highway pavement deterioration manifestations and determining their corresponding 514 causes, several 'remedies' are proposed to improve highway pavements' longevity. The proposed design 515 phase measures include pavement design reviews performed exclusively by local experienced and 516 knowledgeable engineers, continuous knowledge improvement for pavement design engineers, improved 517 accuracy of design considerations (traffic data and soil conditions), improved designs for pavement (surface 518 and subbase) drainage and longitudinal joints between adjoining pavement layers, proper material 519 specifications (aggregates and binder), changes to intersectional traffic control methods (grade-separated intersection control is favoured), and adoption of design strategies to make future pavements adaptable to 520 521 global warming impacts. For the construction phase, recommendations are made for agencies to upgrade 522 the local standards and specifications, embody quality within their value system, adopt a quality-based 523 selection approach for contractors, and cater to adequate construction supervision independent of the 524 contractor (FIDIC 2004). Contractors are also implored to embrace advanced technologies in the field, 525 which will reduce pavement deterioration. Technologies such as the asphalt multi-integrated roller (AMIR) 526 have significantly reduced pavements' deterioration.

Lastly, in the lifespan phase, measures to preserve the pavements include reducing the pavement loading (traffic weight and volume), protecting the pavements from environmental factors, and improving maintenance practices. Checks for overweight vehicles need to be consistent and not sporadic by 530 implementing an in-road weight in motion (WIM) system similar to the existing spot speed camera system. 531 The WIM system allows for simultaneous dynamic weighing of vehicles and photographic recording 24/7 532 (Traffic Data Systems 2019). In cases where vehicles are found to be overloaded, they should be required 533 to off-load excess goods to another vehicle and not allowed to proceed until the weight limit is satisfied. 534 Implementing car usage control strategies such as an Area License Scheme (ALS) or an Electric Road 535 Pricing System (ERP) reduce high traffic volume. An ALS discourages vehicles from entering congested 536 central areas during peak hours. This scheme has reportedly caused traffic flow during peak hours to drop 537 by 40% in Singapore (Lam and Toan 2006).

Similarly, the ERP system motivates drivers to avoid certain areas at peak hours by changing modes 538 539 of transport, route, or travel time. This system is based on the pay-as-you-use principle. To curtail the 540 phenomenal growth of vehicular traffic, agencies can control private transportation demand by altering the 541 existing menu of taxes for vehicle importation and /or considering a car ownership control strategy, such 542 as Singapore's Vehicle Quota Scheme' (VQS). Such approaches can push the price so high that only those 543 with the highest willingness to pay can own a car (Koh and Lee 1994; Land Transport Authority 2015; 544 Trinh Toan 2018). Pavements can be protected from increased temperature using pavement surface 545 reflectance technologies that do not require altering the existing pavement structure. Such heat-blocking coating technology applied on the pavement surface reduces the surface temperature by  $10^{\circ}$ C or more. 546 547 Measures to reduce water ingress into the pavement structure include routine drainage maintenance and 548 repairing distress (especially cracks) as soon as they arise and as reported by citizens. Finally, the distress 549 manual used by agencies for highway maintenance needs to be updated. The current version does not 550 present all of the distresses on highways in Trinidad. Additionally, the defined causes of these distresses 551 are ambiguous, and there are no defined distress severity levels.

552

## 553 Conclusion

This study examined pavement conditions along the east-west transportation corridor of Trinidad. Three panels of 24 specialists engaged in highway design, construction, and maintenance phases identified and 556 rated the particular causes of pavement distress, as well as the overall reasons for pavement deterioration. 557 This study used an advanced method to address the global and local issues of inadequate HMA pavement 558 degradation data. It is the first in the field to comprehensively address pavement deterioration throughout 559 the design, construction, and lifespan phases. Considering just one phase of the lifecycle, as in most existing 560 studies, does not adequately address the issue of pavement degradation. Unlike historical documents and 561 expensive field investigations, this method relied on professional knowledge gained through time. With the 562 help of a group of specialists, the fuzzy-Delphi method facilitates the sharing of scientific or technical 563 information. This comprehensive method may be used in developing nations when studies are expensive 564 and there is a need to reduce traditional deterioration factor ambiguity by specifying the origin phase.

565 With the help of design, construction, and maintenance specialists, this research addressed the 566 indistinctness associated with insufficient drainage. The design panel agreed that poor surface drainage was 567 a deterioration factor, but it was excluded in the other two phases. This detailed analysis of deterioration 568 reasons is very useful for designing and building new roadway pavements. This information will enhance 569 the accuracy of flexible pavement failure prediction models, allowing for better construction and quality 570 control procedures. Understanding flexible pavement distresses, and their sources can help preserve them. 571 Furthermore, improved maintenance and rehabilitation operations planning may save substantial money for 572 infrastructure management organisations (Li 2005).

573 Overall, the lifespan phase had the most contributions, almost twice as many as the design and 574 building stages. However, the results indicate that most lifespan degradation is due to inadequacies in earlier 575 stages. Experts agree that 'structure', 'traffic', 'construction', 'environment', and 'maintenance' are 576 significant contributors to pavement degradation, with structural factors predominating. All distress has 577 structural causes (from all three stages). Similarly, six design phase contributions were structural for general 578 aspects, while four were structural for construction and lifespan. Traffic issues were recognised as the 579 second leading cause of pavement deterioration. Traffic throughout the lifespan or user phase was 580 recognised as a factor in several distresses. Similarly, the two most important causes of pavement 581 degradation in the design phase were traffic-related, which was likewise the top and fourth most significant reason in the lifespan phase. Environmental and maintenance reasons for deterioration were only addressed in the lifespan phase and heralded a need for earlier consideration. In addition to improving pavement performance prediction models, researchers may also enhance construction and maintenance methods. This research suggests ways to extend the life of HMA pavements in the tropics by reducing distress vulnerabilities.

587

# 588 Limitations and future research

More studies are needed to understand the interplay of pavement degradation causes. Understanding how these variables interact is essential to understanding how they affect pavement deterioration. Due to limited field studies, specific reasons for degradation for many identified distresses were not found; further work should be done to address this deficiency. With so many deterioration reasons, finding effective remedies proved difficult.

# 595 Conflict of interest

596 The authors declare that there is no conflict of interest or ethical issues regarding the publication of this

597 manuscript.

598

599 Data availability

All Fuzzy data, models, or codes that support the findings of this study are available from the corresponding

601 author.

602

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917

Organization	Position/Role	Years of Experience	Highest level Academic Achievement
	Design Experts		
Trintoplan Consultants Limited	Managing Director	33	MSc
Trintoplan Consultants Limited	Civil Engineer	2	BSc
Trintoplan Consultants Limited	Civil Engineer	8	MSc
Danny's Enterprises Company Ltd	Civil Engineer Consultant	9	MSc
HM Engineering and Construction Ltd.	Director	4	PhD
Beston Consulting Limited	Civil Engineer	5	BSc
Super pave Ltd	Civil Engineer	50	Postgraduate Diploma
KallCo	Senior Project Engineer	20	BSc
CARIRI (Caribbean Industrial Research Institute)*	Department Lab Manager/Senior Technician	37	BSc
The University of the West Indies	Lecturer	11	MSc
Со	nstruction Experts		
Ministry of Works & Transport		0	146
(Highways Division)	Civil Engineer I	8	MSc
Ministry of Works & Transport*	Civil Engineer I	2	BSc
(Highways Division) Ministry of Works & Trongenert*			
(Highways Division)	Civil Engineer	7	MSc
Ministry of Works & Transport	Chief Planning Engineer	10	
(Highways Division)	(Ag)	10	-
Ministry of Works & Transport	Civil Engineer II (Ag)	14	-
(Highways Division) Ministry of Works & Transmort*			Dialama/Associate
(St. George West District)	Engineer Assistant III	1	Diploma/Associate
Ministry of Works & Transport*			Diploma/Associate
(St. George East District)	Works Supervisor	5	Degree
Ministry of Works & Transport*	Circil Englisher H	15	MG-
(St. George East District)	Civil Engineer II	15	MSc
Ministry of Works & Transport	District Engineer	5	BSc
(St. George East District) Ministry of Works & Transport*	č		
(Caroni District)	Works Supervisor I	2	BSc
Super pave Ltd	Civil Engineer	50	Postgraduate Diploma
CARIRI (Caribbean Industrial Research Institute)	Laboratory Manager	10	MSc
HM Engineering and Construction Ltd.	Director	4	PhD
	Lifespan Experts		
Ministry of Works & Transport	Senior Project Manager		MSc
(PURE – Programme for Upgrading Roads Efficiency)			
Ministry of Works & Transport*	Associate Engineer	4	BSc
(PURE – Programme for Upgrading Roads Efficiency)	Desired Engineer	0	DC-
(PURE – Programme for Ungrading Roads Efficiency)	Project Engineer	9	DSC
Ministry of Works & Transport	Project Engineer	5	BSc
(PURE – Programme for Upgrading Roads Efficiency)		-	
Ministry of Works & Transport	Project Manager	-	-
(PURE – Programme for Upgrading Roads Efficiency)			~~~
Ministry of Works & Transport (PUDE – Programme for Unarrading Paada Efficiency)	Project Manager	12	BSc
(PURE – Programme for Upgrading Roads Efficiency)	Construction Technician	25	Dinlama / Associate
(PURE – Programme for Ungrading Roads Efficiency)	Construction Technician	23	Dipiona/Associate Degree
Ministry of Works & Transport (St. George East District)	Civil Engineer II	15	MSc
Ministry of Works & Transport (St. George East	Works Supervisor I	2	Diploma/Associate
District)*	0: 110 : 1	-	Degree
Ministry of Works & Transport (St. George East District)*	Civil Engineer I	5	BSc
Ministry of Works & Transport (Caroni District)*	Works Supervisor I	2	BSc
Ministry of Works & Transport (Caroni District)*	Civil Engineer	15	BSc
Super pave Ltd	Civil Engineer	50	Postgraduate Diploma
Indicates persons dropping out after the first	stage		<u> </u>

Table 1: Panel of highway pavement design, construction, and lifespan experts

Likert Scale	Linguistic Variables (Shortening in lifespan - years)	Triangular Fuzzy Number (TFN) (Habibi, Jahantigh and Sarafrazi 2015)
1	0	(0.00,0.00,0.10)
2	0 to 1	(0.00,0.10,0.30)
3	1 to 2	(0.10, 0.30, 0.50)
4	2 to 3	(0.30,0.50,0.75)
5	3 to 4	(0.50, 0.75, 0.9)
6	4 to 5	(0.75,0.90,1.00)
7	> 5	(0.90,1.00,1.00)

Table 2: Triangular fuzzy spectrum for a seven-point Likert

Ref.	East Bo	AB	BC	8 8	U. H	1	EF	FG	GН	Η	п	West B	BA	CB	БС	Ð		H	GF	БН	Ξ	=	KEY
Sec	From	South Quay	Lighthouse Beetham/POS	Flyover	Darataria Overpass Uriah Butler	Highway	Southern Main Rd.	Intersection College Road	Macoya	Trincity	Golden Grove Road	lound	Beetham/POS Flyover	Barataria Overnass	Uriah Butler	Highway Southern	Main Rd.	Intersection College Road	Macoya	Trincity	Golden Grove Road	Mausica Road	
ction	٩	Beetham/POS	Flyover Barataria	Overpass	Urian Butter Highway Southern	Main Rd.	College Road	Macoya	Trincity	Golden Grove	Mausica Road		South Quay Lighthouse	Beetham/POS Flvover	Barataria	Overpass Uriah Butler	Highway	Southern Main Rd.	College Road	Macoya	Trincity	Golden Grove Road	
	Fatigue	c	c	c	c	c		م	c		*			U	*				U	U	U	C	* m
	IsnibutignoJ	¢	د	c	c			c	c		c		C	U	Ĺ	د د		U	U	U	υ	C	
	Transverse							c						*	*				U				
	Block	*		*						*										*		*	N
	Slippage																						Severity Severity
	Reflective																						
	леалdering Меалdering			3	0						2			q						U		C	
	Diagonal																						
	guittuA	¢	د		*	c		0	c	*	*		٩				U	U	*			C	υq
	SnothegurroD				×			*			×												
	gnivodZ			c	c			c	c						Ĺ	,	U		C			*	
Dis	Depressions					*	*	c	c	×					L.	2				*			Mediu Hizh
tre sses	laveanqU \zllaw2																						um Severity Severity
	sdung				3	*		*					C							*		c	٨
	Potholes		2	0	*	c		*					0		*		*		U	U	q	C	
	Raveling			2	*		0	۹ د	2				5	U		2	U	0		5	U		
	guibsəld ilanqaA					*								U				U				*	
	Water bleeding																						
	Water pumping																						
	gnideiloq			e B	a	а	а	а		а			в		n	5	e		a	в		в	
	Delamination					*		S												U	*	C	
	Edge Break						c								*								
	Edge drop off	c	د	c	c	c		٩	c		*			U	*				U	U	U	C	
	Fatigue	c	د	c	c			c	c		c		c	U	Ĺ	2		υ	U	U	U	c	
	Longitudinal							c						*	*				U				

Table 3: Identified distresses and severity in westbound and eastbound directions

Table 4: Fuzzy triangula	ar nui	mber	yd s'	desig	gn ex	perts																					
Factors		Expert 1			Expert 2			Expert 3		E	xpert 4		E	pert 5		E	pert 6		Ext	ert 7		Exp	ert 8		Exp	ert 9	
Structure	000						000	- 00	. 00	000						-			0	0	0	4	0				e e
Inadequate thickness of pavement layers	0.90	1.00	1.00	0.30	0.50	0.75	0.90	1.00	1.00	0.90	1.00	1.00	0.10	0.30	0.50	0.10	0.30	0.50	0.10	30	50 0	.10	30	50 0	1 06	00	8
Inadequate base thickness	0.90	1.00	1.00	0.90	1.00	1.00	0.50	0.75	06.0	0.90	1.00	1.00	0.10	0.30	0.50	0.10	0.30	0.50	0.30 0	.50 0	.75 0	.10 0.	.30 0	50 0	.75 0	90 1.	8
Inadequate sub base thickness	0.90	1.00	1.00	06.0	1.00	1.00	0.75	0.90	1.00	0.90	1.00	1.00	0.10	0.30	0.50	0.30	0.50	0.75	0.30 0	.50 0	.75 0	.10 0.	.30 0	.50 0	0 00.	10 0.	30
Inadequate pavement mix design	0.50	0.75	06.0	0.30	0.50	0.75	0.10	0.30	0.50	0.90	1.00	1.00	0.75	0.90	1.00	0.10	0.30	0.50	0.00 0	.10 0	.30 0	.10 0.	.30 0	.50 0	.90 1	00 1.	8
Inadequate preliminary geological	0.50	0.75	0.90	0.50	0.75	0.90	0.30	0.50	0.75	06.0	1.00	1.00	0.90	1.00	1.00	0.30	0.50	0.75	0.00	00.	.10 0	.10 0.	.30 0	50 0	50 0	75 0.	06
investigation Inadequate design knowledge	0.75	0.90	1.00	0.50	0.75	0.90	0.75	0.90	1.00	06.0	1.00	1.00	0.00	1.00	1.00	0.00	0.10	0.30	0.00	.10 0	30 0	.10 0.	.30 0	50 0	0 00	10 0.	30
Inadequate surface drainage	0.90	1.00	1.00	0.50	0.75	0.90	06.0	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	0.00	0.10	0.30	0.30 0	.50 0	.75 0	.10 0.	.30 0	.50 0	.30 0	50 0.	75
Poor drainability of the subbase	0.75	06.0	1.00	06.0	1.00	1.00	0.75	06.0	1.00	0.90	1.00	1.00	0.75	0.90	1.00	0.10	0.30	0.50	0.30 0	.50 0	.75 0	.10 0.	.30 0	.50 0	0 00.	10 0.	30
Inadequate pavement design for soil	0.90	1.00	1.00	0.90	1.00	1.00	0.50	0.75	0.90	06.0	1.00	1.00	06.0	1.00	1.00	0.30	0.50	0.75	0.30 0	.50 0	.75 0	.10 0.	.30 0	.50 0	.90 1	00	8
condition Weak joints between the adjoining	0.90	1.00	1.00	0.30	0.50	0.75	0.10	0.30	0.50	06.0	1.00	1.00	0.10	0.30	0.50	0.10	0.30	0.50	0.00	0 00.	.10 0	00.00	.10 0	.30 0	.10 0	30 0.	50
spread of pavement layers Inadequate stability of the suborade or	0.90	1.00	1.00	0.50	0.75	0.90	0.30	0.50	0.75	0.90	1.00	1.00	0.30	0.50	0.75	0.10	0.30	0.50	0.30 0	50 0	75 0	10	30 0	50 0	00	10	30
sub-base or base course																							, ,				
Weak pavement structure	0.90	1.00	1.00	0.90	1.00	1.00	0.50	0.75	0.90	0.90	1.00	1.00	0.90	1.00	1.00	0.00	0.10	0.30	0.00	.10 0	30 0	00.	.10 0	.30 0	.75 0	90 1.	8
An excess of asphalt in the top layer	0.00	0.00	0.10	0.30	0.50	0.75	0.00	0.10	0.30	0.90	1.00	1.00	0.00	0.10	0.30	0.00	0.00	0.10	0.00	0 00.	.10 0	00.0	.10 0	.30 0	.90 1	00 1.	8
Faulty design Parameters	06.0	1.00	1.00	0.75	0.90	1.00	06.0	1.00	1.00	0.90	1.00	1.00	0.75	0.90	1.00	0.00	0.10	0.30	0.10 0	.30 0	50 0	.00	.10 0	30 0	.75 0	90 1.	8
Inappropriate design procedures	0.90	1.00	1.00	0.50	0.75	0.90	0.75	0.90	1.00	0.90	1.00	1.00	0.10	0.30	0.50	0.00	0.10	0.30	0.00	.10 0	30 0	00.0	.10 0	.30 0	.10 0	30 0.	20
Relatively high fines/asphalt (F/A)	0.00	0.10	0.30	0.30	0.50	0.75	0.30	0.50	0.75	06.0	1.00	1.00	0.00	0.10	0.30	0.00	0.10	0.30	0.30 0	.50 0	.75 0	00.00	.10 0	30 0	50 0	75 0.	6
Lack of stability in the bitumen mix	0.10	0.30	0.50	0.30	0.50	0.75	06.0	1.00	1.00	0.90	1.00	1.00	0.10	0.30	0.50	0.00	0.10	0.30	0.30 0	.50 0	.75 0	.00	.10 0	30 0	.90 1	00	8
Inadequate pavement structure	0.90	1.00	1.00	0.75	0.90	1.00	0.75	06.0	1.00	0.90	1.00	1.00	0.75	0.90	1.00	0.00	0.10	0.30	0.10 0	.30 0	50 0	.10 0.	.30 0	.50 0	.90 1	00 1.	8
Insufficient adhesion between the	0.30	0.50	0.75	0.30	0.50	0.75	0.90	1.00	1.00	0.90	1.00	1.00	0.00	0.10	0.30	0.00	0.10	0.30	0.30 0	.50 0	.75 0	00.	.10 0	.30 0	00.00	10 0.	30
asphalt cement and the aggregates Aggregates not hard enough	0.10	0.30	0.50	0.30	0.50	0.75	0.50	0.75	06.0	0.90	1.00	1.00	0.00	0.10	0.30	0.00	0.10	0.30	0.30 0	.50 0	.75 0	00.00	.10 0	30 0	.10 0	30 0.	50
Traffic																											
Underestimated traffic loads	0.90	1.00	1.00	06.0	1.00	1.00	06.0	1.00	1.00	06.0	1.00	1.00	06.0	1.00	1.00	0.10	0.30	0.50	0.30 0	.50 0	.75 0	.10 0.	.30 0	.50 0	.90 1	00 1.	8
Inadequate future traffic forecast	06.0	1.00	1.00	0.75	0.90	1.00	0.50	0.75	0.90	0.90	1.00	1.00	0.90	1.00	1.00	0.10	0.30	0.50	0.30 0	.50 0	.75 0	00.0	.10 0	30 0	.90 1	00	8
Geometric Design																											
Poor alignment	0.50	0.75	0.90	06.0	1.00	1.00	0.00	0.10	0.30	06.0	1.00	1.00	0.00	0.00	0.10	0.00	0.00	0.10	0 00.0	0 00.	.10 0	0 00.	.10 0	.30 0	0 00	10 0.	30
Inadequate pavement width	0.00	0.00	0.10	0.50	0.75	0.90	0.30	0.50	0.75	0.90	1.00	1.00	0.00	0.10	0.30	0.10	0.30	0.50	0.00 0	0 00.	.10 0	.00	.10 0	.30 0	.10 0	30 0.	20
Inadequate edge support	0.30	0.50	0.75	0.50	0.75	0.90	0.90	1.00	1.00	0.90	1.00	1.00	0.00	0.10	0.30	0.00	0.10	0.30	0.10 0	.30 0	50 0	.10	.30 0	50 0	.10 0	30 0.	50
Other																											
Not involving local professional bodies in highway construction	0.30	0.50	0.75	0.75	0.90	1.00	0.00	0.10	0.30	06.0	1.00	1.00	0.00	0.10	0.30	0.00	0.00	0.10	0 00.0	0 00.	.10 0	0 00	.10 0	.30 0	0 00	00 00	10

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r actors Construction Process		1 moder		1	7 mode			c ind			- 10		Inder	2		inder			/ made	
Inadequate compaction (surface/ subbase / base)	0.75	0.90	1.00	0.75	06.0	1.00	0.00	0.10 0	.30 0.	50 0.	75 0.9	0 0.9	0 1.00	1.00	0.10	0.30	0.50	0.75	0.90	1.00
Compaction procedure (use of conventional steel drum roller)	0.50	0.75	0.90	0.30	0.50	0.75	0.00	0.10 0	.30 0.	30 0.	50 0.3	5 0.5	0.75	06.0				0.50	0.75	0.90
Incorrect blending of binder	0.50	0.75	0.90	0.30	0.50	0.75	0.10 (	0.30 0	.50 0.	30 0.	50 0.3	5 0.7	5 0.90	1.00				0.75	0.90	1.00
Construction during wet weather	0.30	0.50	0.75	0.90	1.00	1.00	0.00	0.10 0	.30 0.	10 0.	30 0.5	0.7	5 0.90	1.00				0.00	0.10	0.30
Poor laboratory and in-situ tests on subgrade soil	0.30	0.50	0.75	0.50	0.75	0.90	0.00	0.10 0	.30 0.	30 0.	50 0.7	5 0.5	0.75	06.0	0.10	0.30	0.50	0.10	0.30	0.50
Low knowledge base	0.50	0.75	0.90	0.75	0.90	1.00	0.00	0.10 0	.30 0.	10 0.	30 0.5	0.5	0.75	06.0				06.0	1.00	1.00
Poor supervision and workmanship	0.75	06.0	1.00	0.75	06.0	1.00	0.00	0.10 0	.30 0.	10 0.	30 0.5	0.7	5 0.90	1.00	06.0	1.00	1.00	0.75	0.90	1.00
Poor quality control	0.75	06.0	1.00	06.0	1.00	1.00	0.00	0.10 0	.30 0.	30 0.	50 0.7	5 0.7	5 0.90	1.00	06.0	1.00	1.00	0.75	06.0	1.00
Poor local standard of practice	0.75	0.90	1.00	0.10	0.30	0.50	0.00	0.10 0	.30 0.	0.0	30 0.5	0.3	0.50	0.75	0.90	1.00	1.00	06.0	1.00	1.00
Varying composition of mix delivered to site (gradation; asphalt content; voids)	0.75	06.0	1.00	0.30	0.50	0.75	0.10 (	0.30 0	.50 0.	50 0.	75 0.9	0 0.3	0.50	0.75				0.75	06.0	1.00
Brittle binder due to initial overheating	0.50	0.75	0.90	06.0	1.00	1.00	0.00	0.10 0	.30 0.	30 0.	50 0.7	5 0.7	5 0.90	1.00				0.75	06.0	1.00
Low (placement) temperature of bitumen	0.50	0.75	06.0	06.0	1.00	1.00	0.00	0.10 0	.30 0.	30 0.	50 0.7	5 0.9	0 1.00	1.00				0.50	0.75	0.90
Faulty laying of surface course	0.30	0.50	0.75	0.30	0.50	0.75	0.00	0.10 0	.30 0.	75 0.	90 1.(	0 0.3	0.50	0.75				0.50	0.75	0.90
Unstable or inadequately prepared subgrade	0.10	0.30	0.50	0.50	0.75	0.90	0.10 (	0.30 0	.50 0.	75 0.	90 1.(	0 0.9	0 1.00	1.00	0.10	0.30	0.50	0.10	0.30	0.50
Structure																				
Use of low-quality construction materials	0.75	0.90	1.00	06.0	1.00	1.00	0.00 (	0.10 0	.30 0.	30 0.	50 0.7	5 0.3	0.50	0.75	0.10	0.30	0.50	0.90	1.00	1.00
Low stiffness of constructed base	0.50	0.75	0.90	0.50	0.75	0.90	0.10 (	0.30 0	.50 0.	30 0.	50 0.7	5 0.9	0 1.00	1.00	0.90	1.00	1.00	0.75	0.90	1.00
Use of inappropriate aggregates (hydrophilic: naturally smooth uncrushed: dusty)	0.75	0.90	1.00	0.75	06.0	1.00	0.10 (	0.30 0	.50 0.	30 0.	50 0.7	5 0.5	0.75	06.0	0.30	0.50	0.75	06.0	1.00	1.00
Inadequate strength (stability) in surface/base lavers	0.75	0.90	1.00	0.50	0.75	0.90	0.00	0.10 0	.30 0.	0.	30 0.5	0.0	0 1.00	1.00	0.30	0.50	0.75	06.0	1.00	1.00
Poor bond between pavement layers	0.50	0.75	0.90	0.75	0.90	1.00	0.00	0.10 0	.30 0.	10 0.	30 0.5	0.0	0 1.00	1.00	0.00	0.00	0.10	0.90	1.00	1.00
Poor binder to stone adhesion	0.75	0.90	1.00	0.50	0.75	0.90	0.10 (	0.30 0	.50 0.	10 0.	30 0.5	0.3	0.50	0.75	0.00	0.00	0.10	0.75	0.90	1.00
Low binder content	0.50	0.75	0.90	0.50	0.75	0.90	0.00	0.10 0	.30 0.	30 0.	50 0.7	5 0.7	5 0.90	1.00	0.00	0.00	0.10	0.75	0.90	1.00
Less bitumen content in localised areas	0.50	0.75	0.90	0.30	0.50	0.75	0.10 (	0.30 0	.50 0.	30 0.	50 0.7	5 0.5	0.75	06.0	0.00	0.00	0.10	0.75	0.90	1.00
Low penetration value of the binder content	0.50	0.75	0.90	0.50	0.75	0.90	0.00	0.10 0	.30 0.	10 0.	30 0.5	0.3	0.50	0.75	0.00	0.00	0.10	0.75	0.90	1.00
Stiff asphalt mixture	0.50	0.75	0.90	0.50	0.75	0.90	0.00	0.10 0	.30 0.	10 0.	30 0.5	0.3	0.50	0.75	0.00	0.00	0.10	0.75	0.90	1.00
Relatively high Fines/Asphalt (F/A) ratio	0.50	0.75	0.90	0.30	0.50	0.75	0.10 (	0.30 0	.50 0.	0.	10 0.3	0 0.7	5 0.90	1.00				0.75	0.90	1.00
Bitumen hardening in asphalt surfacing	0.50	0.75	0.90	0.50	0.75	0.90	0.00	0.10 0	.30 0.	0.	10 0.3	0 0.7	5 0.90	1.00				0.75	0.90	1.00
Construction joints (between the adjoining spread of pavement layers; bridges)	0.50	0.75	0.90	0.30	0.50	0.75	0.00	0.10 0	.30 0.	0.	10 0.3	0 0.1	0.30	0.50	0.00	0.00	0.10	0.75	0.90	1.00
Too thin bituminous surface	0.50	0.75	0.90	0.75	0.90	1.00	0.10 (	0.30 0	.50 0.	10 0.	30 0.5	0 0.1	0.30	0.50				0.75	0.90	1.00
Thin asphalt layer over bridges	0.50	0.75	0.90	0.75	0.90	1.00	0.10 (	0.30 0	.50 0.	0.	30 0.5	0.0	0.30	0.50				0.75	0.90	1.00
Poor drainability of the subbase	06.0	1.00	1.00	0.75	0.90	1.00	0.00	0.10 0	.30 0.	0.	10 0.3	0.0	0.1.00	1.00	0.75	06.0	1.00	06.0	1.00	1.00
An excess of asphalt in the top layer	0.75	0.90	1.00	0.50	0.75	0.90	0.10 (	0.30 0	.50 0.	0.	10 0.3	0 0.1	0.30	0.50				0.50	0.75	0.90
Inadequate surface draina ge	0.50	0.75	0.90	0.75	0.90	1.00	0.10 (	0.30 0	.50 0.	0.	10 0.3	0.0	0.1.00	1.00	0.10	0.30	0.50	0.75	0.90	1.00
Using low viscosity binder	0.50	0.75	0.90	0.50	0.75	0.90	0.00 (	0.10 0	.30 0.	10 0.	30 0.5	0 0.1	0.30	0.50	0.90	1.00	1.00	0.75	0.90	1.00
Other																				
Not involving local professional bodies in highway construction	0.30	0.50	0.75	0.00	0.10	0.30	0.00 (	0.10 0	.30 0.	50 0.	75 0.9	0 0.7	§ 0.90	1.00	0.30	0.50	0.75	0.00	0.00	0.10
Poor laboratory facilities	0.50	0.75	0.90	0.10	0.30	0.50	0.00	0.10 0	.30 0.	30 0.	50 0.3	5 0.1	0.30	0.50	0.30	0.50	0.75	0.00	0.10	0.30
Poorly trained laboratory man power	0.75	0.90	1.00	0.10	0.30	0.50	0.00	0.10 0	.30 0.	30 0.	50 0.3	5 0.3	0.50	0.75	0.30	0.50	0.75	0.00	0.10	0.30

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Factors Traffic		гхреп 1			7 Hadra		1	c trady		EXD	ert 4		EXDEL	61		Expert o		-	xpert /		-	xpert ð	
Over-weight/ over-height vehicles	0.90	1 00	1 00	0 00	0.00	0 10	0.00	0.10	030 (	30 0	50 07	5 0 3	0 20	0 75	0 75	06-0	1 00	0.30	0.50	0.75	0.50	0.75	06.0
High traffic volume	0.90	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	00.	10 0.3	0.0	1.00	0 1.00	0.00	0.00	0.10	0.90	1.00	1.00	0.90	1.00	1.00
Lack of control regarding load limit carried by	0.90	1.00	1.00	06.0	1.00	1.00	0.90	1.00	1.00 (	.90 1.	00 1.0	0 0.5(	0.7	5 0.90	0.50	0.75	0.90	0.30	0.50	0.75	0.90	1.00	1.00
vehicles		000	00 -	000	001	001	000	010	0000	-		000	0	000	000		000	00.0	0	t c	000	001	00.
Phenomenal growth of vehicular traffic	c/.0	06.0	1.00	06.0	1.00	1.00	0.00	0.10	00	.1 06.	00 1.0	0.0	0.10	00 (	00.0	c/ .0	06.0	05.0	00.0	c/.0	06.0	1.00	00.1
Stopping & standing traffic	0.75	0.90	1.00	0.90	1.00	1.00	0.00	0.10	0.30 (	.75 0.	90 1.0	0 0.5(	0.7	5 0.90	0.50	0.75	0.90	0.75	0.90	1.00	0.00	0.00	0.10
Pushing action by wheels of heavy traffic at the time of acceleration and deceleration	0.75	0.90	1.00	0.75	0.90	1.00			0	.90 1.	00 1.0	0.0	0.10	0.30	0.10	0.30	0.50	0.10	0.30	0.50	0.00	0.10	0.30
Traffic travelling on shoulder	0.75	0.90	1.00	0.75	06.0	1.00			0	.30 0.	50 0.7	5 0.90	1.00	0 1.00	0.10	0.30	0.50	0.00	0.00	0.10	0.00	0.00	0.10
Channelized movement of heavy wheel loads causing significant vertical stress on the subsrade	06.0	1.00	1.00	06.0	1.00	1.00	0.00	0.10	0.30 (	.10 0.	30 0.5	0.0	1.00	0 1.00	0.10	0.30	0.50	0.30	0.50	0.75	0.00	0.10	0.30
Environmental																							
Differential settlement	06.0	1.00	1.00	06.0	1.00	1.00	06.0	1.00	1.00 (	.50 0.	75 0.9	0 0.90	1.00	0 1.00	0.10	0.30	0.50	0.10	0.30	0.50	0.00	0.10	0.30
Seepage of water into the subgrade	0.75	0.90	1.00	0.75	06.0	1.00	0.75	06.0	1.00 (	.75 0.	90 1.0	0 0.90	1.00	0 1.00	0.00	0.10	0.30	0.10	0.30	0.50	0.00	0.10	0.30
Seepage of water through asphalt/longitudinal	0.75	06.0	1.00	0.75	06.0	1.00	0.75	0.90	1.00 (	.75 0.	90 1.0	0 0.90	1.00	0 1.00	0.00	0.10	0.30	0.75	0.90	1.00	0.00	0.10	0.30
joints Water pooling on surface	0.30	0.50	0.75	0.50	0.75	0.90	0.30	0.50	0.75 (	.00	10 0.3	0 0.3(	0.5(	0.75	0.00	0.10	0.30	0.30	0.50	0.75	0.00	0.10	0.30
Unstable /Expansive subgrade soils	0.75	0.90	1.00	0.90	1.00	1.00			0	.75 0.	90 1.0	0.0	1.00	00.1	0.10	0.30	0.50	0.75	0.90	1.00	0.75	0.90	1.00
High ground water level	06.0	1.00	1.00	0.75	06.0	1.00	0.10	0.30	0.50 (	.30 0.	50 0.7	5 0.90	1.00	0 1.00	0.00	0.10	0.30	0.00	0.10	0.30	0.00	0.10	0.30
Natural disaster	0.75	0.90	1.00	0.90	1.00	1.00	0.00	0.00	0.10			0.9	1.00	0 1.00	0.10	0.30	0.50	0.00	0.10	0.30	0.00	0.10	0.30
Global warming	0.75	0.90	1.00	0.75	0.90	1.00	0.75	0.90	1.00 (	.75 0.	90 1.0	0 0.50	0.7	5 0.90	0.30	0.50	0.75	0.00	0.00	0.10	0.90	1.00	1.00
Climate fluctuations in temperature and	0.50	0.75	0.90	06.0	1.00	1.00	0.10	0.30	0.50 (	.90 1.	00 1.0	0 0.90	1.00	0 1.00	0.50	0.75	06.0	0.00	0.10	0.30	0.00	0.00	0.10
precipitation Trapped moisture in the bottom layers of the	0.50	0.75	0.90	0.50	0.75	0.90	0.10	0.30	0.50 (	.50 0.	75 0.9	0 0.9(	1.00	0 1.00	0.10	0.30	0.50	0.00	0.10	0.30	0.00	0.10	0.30
pavement																							
Structure																							
Deterioration of aggregates	0.75	0.90	1.00	06.0	1.00	1.00	0.50	0.75	0.90	.90 1.	00 1.0	0.0	1.00	00.1.00	0.90	1.00	1.00	0.00	0.10	0.30	0.90	1.00	1.00
Ageing of brittle base	0.75	0.90	1.00	0.75	0.90	1.00	0.50	0.75	0.90	.90 1.	00 1.0	0 0.7:	90.90	0 1.00	0.90	1.00	1.00	0.00	0.10	0.30	0.00	0.10	0.30
Ageing of binder in the surface course	0.50	0.75	0.90	0.50	0.75	0.90	0.50	0.75	0.90	.75 0.	90 1.0	0.0	1.00	0 1.00	0.90	1.00	1.00	0.50	0.75	0.90	0.00	0.10	0.30
Loss of adhesion in the surface layer	0.75	0.90	1.00	0.50	0.75	0.90	0.50	0.75	0.90 (	.30 0.	50 0.7	5 0.50	0.7	5 0.90	0.90	1.00	1.00	0.10	0.30	0.50	0.00	0.10	0.30
Post-construction compaction	0.75	0.90	1.00	0.00	0.10	0.30	0.10	0.30	0.50 (	.90 1.	00 1.0	0 0.9(	1.00	0 1.00	0.90	1.00	1.00				0.00	0.10	0.30
Structural failure of the bottom layers/movement of the bottom lavers	0.90	1.00	1.00	0.90	1.00	1.00	0.10	0.30	0.50 (	.10 0.	30 0.5	0.0	1.00	0 1.00	0.30	0.50	0.75	0.00	0.10	0.30	0.00	0.10	0.30
Stripping on the bottom of the HMA surface	0.75	0.90	1.00	0.30	0.50	0.75			0	.50 0.	75 0.9	0 0.7:	0.0	0 1.00	0.00	0.10	0.30	0.10	0.30	0.50	0.00	0.10	0.30
Shoulder settlement	0.75	0.90	1.00	06.0	1.00	1.00			0	.90 1.	00 1.0	0 0.30	0.5(	0.75	0.30	0.50	0.75	0.00	0.00	0.10	0.00	0.00	0.10
Unstable base	06.0	1.00	1.00	0.90	1.00	1.00			0	.30 0.	50 0.7	5 0.90	1.00	0 1.00	0.90	1.00	1.00	0.10	0.30	0.50	0.10	0.30	0.50
Pavement widening	0.75	0.90	1.00	0.00	0.00	0.10			Ű	.90 1.	00 1.0	0.00	0.0(	0.10	0.00	0.00	0.10	0.50	0.75	0.90	0.00	0.10	0.30
Inadequate surface drainage	0.50	0.75	0.90	0.75	0.90	1.00			0	.75 0.	90 1.0	0 0.7:	6.0	0 1.00	0.10	0.30	0.50	0.00	0.10	0.30	0.00	0.10	0.30
Reflection of joints or shrink cracking in underlying layers	0.50	0.75	0.90	0.50	0.75	0.90			0	.50 0.	75 0.9	0 0.3(	0.5(	0.75	0.10	0.30	0.50	0.10	0.30	0.50	0.00	0.10	0.30
Maintenance	36.0	00 0	00 -	00 0	VV -	00 +				0 	0 1 00	~	10	100	000	020	36 0	0.0	020	30.0	00 0	VV ,	00,
Lack of routine and periodic maintenance	0.75	0.90	1.00	0.90	1.00	1.00				.75 U.	06 1.0	0.9	0.1 0.1	00.1.00	0.30	0.50	0.75	0.30	0.50	0.75	0.90	1.00	1.00
Poor/Non-existence of updated guideline standards/specifications/policies/ norms	0.75	0.90	1.00	0.50	0.75	0.90			0	.10 0.	30 0.5	0.30	0.5(	0.75	0.30	0.50	0.75	0.10	0.30	0.50	0.00	0.10	0.30
Poor maintenance culture	0.75	0.90	1.00	0.90	1.00	1.00			0	.00	10 0.3	0.0	1.00	0 1.00	0.30	0.50	0.75	0.00	0.10	0.30	0.90	1.00	1.00
Lack of supervision or supervision by	0.75	06.0	1.00	06.0	1.00	1.00			0	.00 0.	10 0.3	0.0	1.00	0 1.00	0.30	0.50	0.75	0.00	0.10	0.30	0.00	0.10	0.30
Insufficient funding	0.75	0.90	1.00	0.75	06.0	1.00			0	.00 0.	10 0.3	0 0.30	0.5(	0.75	0.75	0.90	1.00	0.10	0.30	0.50	0.00	0.10	0.30
Lack of and shortage of qualified maintenance	0.75	06.0	1.00	0.30	0.50	0.75			0	.30 0.	50 0.7	5 0.30	0.50	0.75	0.10	0.30	0.50	0.10	0.30	0.50	0.00	0.10	0.30
engineers Delayed maintenance during their service life	0.75	06.0	1.00	0.00	1.00	1.00			0	.10 0.	30 0.5	0.90	1.00	00 1.00	0.10	0.30	0.50	0.10	0.30	0.50	0.00	0.10	0.30
until they reach the state of major failure that requires rehabilitation																							

Table 6: Fuzzy triangular numbers by lifespan experts

1.00	1.00	1.00		0.30	0.30	0.30	0.10	0.30	1.00	1.00
1.00	1.00	1.00		0.10	0.10	0.10	0.00	0.10	1.00	1.00
0.90	0.90	0.90		0.00	0.00	0.00	0.00	0.00	0.90	0.90
0.50	0.75	0.75	0.75	0.50	0.50	0.50	0.30	0.10	0.50	0.50
0.30	0.50	0.50	0.50	0.30	0.30	0.30	0.10	0.00	0.30	0.30
0.10	0.30	0.30	0.30	0.10	0.10	0.10	0.00	0.00	0.10	0.10
0.50	0.50	0.50	0.10	0.50	0.50	0.50	0.50	0.50	0.10	0.90
0.30	0.30	0.30	0.00	0.30	0.30	0.30	0.30	0.30	0.00	0.75
0.10	0.10	0.10	0.00	0.10	0.10	0.10	0.10	0.10	0.00	0.50
1.00	1.00	0.75	0.75	0.75	1.00	06.0	1.00	0.90	0.10	0.90
1.00	1.00	0.50	0.50	0.50	1.00	0.75	1.00	0.75	0.00	0.75
0.90	06.0	0.30	0.30	0.30	0.90	0.50	0.90	0.50	0.00	0.50
0.50	0.50	1.00	1.00	0.75	0.50	0.50	0.30	0.50	0.90	06.0
0.30	0.30	1.00	1.00	0.50	0.30	0.30	0.10	0.30	0.75	0.75
0.10	0.10	0.90	0.90	0.30	0.10	0.10	0.00	0.10	0.50	0.50
1.00	1.00	0.50	0.75	0.75	0.75	1.00	1.00	1.00	1.00	1.00
1.00	0.90	0.30	0.50	0.50	0.50	0.90	1.00	0.90	1.00	1.00
0.90	0.75	0.10	0.30	0.30	0.30	0.75	0.90	0.75	0.90	0.90
1.00	1.00	1.00	1.00	1.00	1.00	0.90	1.00		0.75	1.00
1.00	1.00	1.00	0.90	0.90	0.90	0.75	0.90		0.50	06.0
0.90	0.90	06.0	0.75	0.75	0.75	0.50	0.75		0.30	0.75
of preventative maintenance from the nee policy	ement of maintenance works and	maintenance training activities	dern technology	f skilled equipment labor	t machines and equipment for ce works	ortage in the required spare parts for ce machines	intained drains	es inadequately (without cleaning and n, etc.)	ring local professional bodies in naintenance	of fatigue cracking

# Table 7: Aggregated and ranked defuzzified factors

Structure         (a,b_c)         (c7-ipy Yalue)           Inadequate base thickness         (0.100.65.11.00)         0.666           Inadequate charms of payrement layers         (0.100.65.11.00)         0.673           Inadequate charms of payrement layers         (0.000.65.11.00)         0.578           Inadequate string the denings         (0.000.65.11.00)         0.622           Poor dinarability of the subbase         (0.000.65.11.00)         0.622           Poor dinarability of the subbase         (0.000.78.1.00)         0.622           Poor dinarability of the subbase         (0.000.78.1.00)         0.622           An excess of Saphilit in the bright payr*         (0.000.73.1.00)         0.634           An excess of Saphilit in the bright payr*         (0.000.73.1.00)         0.622           Inadequate payrement structure         (0.000.73.1.00)         0.641           Angeregates not hard enough*         (0.000.73.1.00)         0.652           Construction terminic from terminic forecast         (0.000.73.1.00)         0.652           Construction terminic	DESIGN FACTORS	ŵ,	S,	
Imadeguine bickness of pavement layers         (0.10, 0.61, 100)         0.666           Imadeguine Specify howehedge         (0.00, 0.62, 100)         0.651           Imadeguine Specify howehedge         (0.00, 0.571, 100)         0.548           Imadeguine Specify howehedge         (0.00, 0.571, 100)         0.641           Imadeguine Specify howehedge         (0.00, 0.571, 100)         0.644           Imadeguine Specify of the subbase         (0.00, 0.641, 100)         0.644           Poor drainability of the subbase         (0.00, 0.51, 100)         0.766           Weak joints between the adjoining special of pavement layers         (0.00, 0.21, 100)         0.748           Imadeguine Tayenement structure         (0.00, 0.71, 100)         0.626         1.ack of subbility in the bitmuren mix         (0.00, 0.71, 100)         0.641           Aggingtis not lard enough*         (0.00, 0.71, 100)         0.642         1.000         0.437           Imadeguine Tayenement structure         (0.00, 0.71, 100)         0.641         Aggingtis not large special pavement layers         0.000, 71, 100)         0.641           Aggingtis not large special pavement layers         (0.00, 0.71, 100)         0.642         Constructure artific loads         0.000, 73, 100)         0.652           Constructure tartific loads         (0.000, 73, 100)         0.652	Structure	(a,b,c)	(Crisp Value)	
inadequare the the knows in the process (1) $(0,0,0,51,100)$ 0.6578 inadequare design knowledge investigation (0) $(0,0,0,51,100)$ 0.5788 inadequare stringer deminage (0) $(0,0,0,51,100)$ 0.622 Poor drainability of the subbase (1) $(0,0,0,51,100)$ 0.643 inadequare parameter design for soil condition (1) $(0,0,0,51,100)$ 0.644 in a cross of sapabili in the top pays" (0) $(0,0,0,51,100)$ 0.644 in a cross of sapabili in the top pays" (0) $(0,0,0,51,100)$ 0.643 in a cross of sapabili in the top pays" (0) $(0,0,0,51,100)$ 0.625 inadequare pays that of couples and the same string (0) $(0,0,0,51,100)$ 0.625 inadequare pays that of couples (1) $(0,0,0,51,100)$ 0.625 inadequare pays that of couples (1) $(0,0,0,51,100)$ 0.627 inadequare pays that of couples (1) $(0,0,0,51,100)$ 0.627 inadequare pays that of couples (1) $(0,0,0,51,100)$ 0.627 inadequare pays that of couples (1) $(0,0,0,0,11,00)$ 0.627 inadequare future traffic forecast (1) $(0,0,0,0,11,00)$ 0.637 <b>Traffic</b> (1) Color Sing <b>Countration</b> (1) $(0,0,0,0,11,00)$ 0.739 <b>Inadequare investigation</b> (1) $(0,0,0,0,11,00)$ 0.637 <b>Countration</b> (1) $(0,0,0,0,0,0,0)$ 0.632 <b>Compaction</b> (1) $(0,0,0,0,0,0,0)$ 0.643 <b>Countration</b> (1) $(0,0,0,0,0,0,0)$ 0.643 <b>Countration</b> (1) $(0,0,0,0,0,0,0)$ 0.652 <b>Compaction</b> (1) $(0,0,0,0,0,0,0)$ 0.652 <b>Compaction</b> (1) $(0,0,0,0,1,0,0)$ 0.643 <b>Countration</b> (1) $(0,0,0,0,1,0,0)$ 0.643 <b>Countration</b> (1) $(0,0,0,0,1,0,0)$ 0.655 <b>Countration</b> (1) $(0,0,0,0,1,0,0)$ 0.	Inadequate thickness of pavement lavers	(0.10.0.63.1.00)	0.606	
Insdequate Spring harwellogin $(0.00, 0.67, 10.0)$ $0.578$ Inadequate Surface drainage $(0.00, 0.571, 10.0)$ $0.624$ Poor drainability of the subbase $(0.00, 0.651, 10.0)$ $0.624$ Wesk joints between the algoining spread of pavement layers $(0.00, 0.74, 10.0)$ $0.766$ Wesk joints between the algoining spread of pavement layers $(0.00, 0.74, 10.0)$ $0.766$ Paulty design Parameters $(0.10, 0.78, 10.0)$ $0.764$ Inadequate pavement structure $(0.00, 0.71, 10.0)$ $0.626$ Lack of sublify in the bitramen mix $(0.00, 0.71, 10.0)$ $0.626$ Lack of sublify in the bitramen mix $(0.00, 0.71, 10.0)$ $0.641$ Aggregates not hard enough* $(0.00, 0.71, 10.0)$ $0.641$ Aggregates not hard enough* $(0.00, 0.71, 10.0)$ $0.652$ Geometrik Design $(0.00, 0.73, 10.0)$ $0.652$ Good spinute unfile forecast $(0.00, 0.73, 10.0)$ $0.652$ Good spinute* $(0.00, 0.71, 10.0)$ $0.652$ Construction Precess $(0.00, 0.91, 10.0)$ $0.652$ Construction precess $(0.00, 0.91, 10.0)$ $0.652$ Poor laignance ompaction (surface' subbase/ base) $(0.00, 0.91, 10.0)$ $0.652$ Poor laignance ond workmaniship $(0.00, 0.71, 10.0)$ $0.643$ Poor landstruct and of practice $(0.00, 0.91, 10.0)$ $0.652$ Poor landstructure parcence layers $(0.00, 0.91, 10.0)$ $0.652$ Poor landstructure parcence layers $(0.00, 0.91, 10.0)$ $0.643$ Poor landstower parcence layers $(0.0$	Indequate base thickness	(0.10.0.67.1.00)	0.631	
Inadequise disign knowledge(0.00,0.57,1.00)0.548Inadequise Target drimage(0.00,0.68,1.00)0.602Poor drimability of the subbase(0.00,0.68,1.00)0.604Inadequise payment disign for soil condition(0.10,0.78,1.00)0.706Weak joints between the adjoining spread of payment layers(0.00,0.42,1.00)0.448An excess of applit in the top layer*(0.00,0.31,1.00)0.622Lack of subbility in the bizume mix(0.00,0.31,1.00)0.621Lack of subbility in the bizume mix(0.00,0.31,1.00)0.622Inadeguise payment structure(0.00,0.31,1.00)0.621Aggregates and hard enough*(0.00,0.31,1.00)0.637Traffic(0.00,0.34,1.00)0.652Underestimated traffic locks(0.00,0.34,1.00)0.307Not myoling local professional bodies in highway design*(0.00,0.31,1.00)0.367Construction Processional bodies in highway design*(0.00,0.30,1.00)0.457Construction professional bodies in highway design*(0.00,0.56,0.90)0.522Post highmant betas on subgade soil*(0.00,0.56,0.90)0.522Post bodiated or professional bodies in highway design*(0.00,0.71,1.00)0.643Post calisationad of professional bodies on subgade soil*(0.00,0.71,1.00)0.643Post calisation and workmaniapi(0.00,0.71,1.00)0.643Poor bodiated of profesional bodies on subgade soil*(0.00,0.58,1.00)0.552Poor bodiated of profesional bodies in highway design*(0.00,0.58,1.00)0.655Poor bo	Inadequate preliminary geological investigation	(0.00,0.62,1.00)	0.578	
Inadeque surface drainage $(0.00, 0.66, 1.00)$ $0.622$ Deor drainability of the subbase $(0.00, 0.66, 1.00)$ $0.644$ Inadequate pavement dispin for soil condition $(0.10, 0.78, 1.00)$ $0.706$ Wesk joints between the adjoining spread of pavement layers $(0.00, 0.24, 1.00)$ $0.448$ An excess of asphali in the top layer* $(0.00, 0.51, 1.00)$ $0.626$ Lack of sublify in the bitnmen mix $(0.00, 0.71, 1.00)$ $0.626$ Lack of sublify in the bitnmen mix $(0.00, 0.71, 1.00)$ $0.626$ Lack of sublify in the bitnmen mix $(0.00, 0.71, 1.00)$ $0.641$ Aggregates not hard enough* $(0.00, 0.71, 1.00)$ $0.641$ TardfifeUnderstring the foresast $(0.00, 0.71, 1.00)$ $0.522$ Geometrit Design $(0.00, 0.73, 1.00)$ $0.552$ Geometrit Design $(0.00, 0.73, 1.00)$ $0.562$ Geometrit Design $(0.00, 0.71, 1.00)$ $0.562$ Construction plocal uniface/ subbase / base) $(0.00, 0.91, 1.00)$ $0.562$ Construction plocal uniface/ subbase / base) $(0.00, 0.91, 1.00)$ $0.522$ Poor laboratory and in-situ tests on subgrade solf* $(0.00, 0.91, 1.00)$ $0.622$ Poor laboratory and in-situ tests on subgrade solf* $(0.00, 0.71, 1.00)$ $0.643$ Poor laboratory and in-situ tests on subgrade solf* $(0.00, 0.51, 1.00)$ $0.552$ Poor laboratory and in-situ tests on subgrade solf* $(0.00, 0.51, 1.00)$ $0.552$ Poor laboratory and vorkmanichip $(0.00, 0.51, 1.00)$ $0.551$ Poor laboratory and vorkmani	Inadequate design knowledge	(0.00,0.57,1.00)	0.548	
Poor dnimbility of the subbase         (0.00.06,1.00)         0.604           Inadequita pavement disgin for soil condition         (0.10.78,1.00)         0.706           Weak joints between the adjoining spead of pavement layers         (0.00.04,21.00)         0.437           An excess of adpall in the top pay**         (0.00.05,11.00)         0.622           Lack of subbility in the bitrame mix         (0.00.05,11.00)         0.621           Lack of subbility in the bitrame mix         (0.00.07,11.00)         0.641           Aggregates not hard enough*         (0.00.04,11.00)         0.437           Traffic         (0.00.04,11.00)         0.437           Indecestination for forecast         (0.00.07,11.00)         0.452           Construction Frocess         (0.00.02,11.00)         0.397           Other         (0.00.09,1.00)         0.522           Construction Process         (0.00.09,1.00)         0.629           Construction procedure (use of conventional steel drum roller)         (0.00.09,1.00)         0.629           Construction procedure (use of conventional steel drum roller)         (0.00.09,1.00)         0.629           Construction procedure (use of conventional steel drum roller)         (0.00.09,1.00)         0.625           Poor slastindard of practice         (0.00.09,1.00)         0.625	Inadequate surface drainage	(0.00,0.68,1.00)	0.622	
Inadequate pavement design for soil condition         (0.10.0.7.81, 1.00)         0.706           Weak joints between the adjoints gread of pavement layers         (0.00.0.421, 1.00)         0.374           Faulty design Parameters         (0.10.0.691, 1.00)         0.522           Inadequate pavement structure         (0.00.0.711, 1.00)         0.641           Aggregates not hard enough*         (0.00.0.711, 1.00)         0.641           Tanffic         (0.00.0.731, 1.00)         0.670           Underestimated traffic loads         (0.00.0.731, 1.00)         0.709           Inadequate pavement structure         (0.00.0.731, 1.00)         0.709           Inadequate pavement*         (0.00.0.731, 1.00)         0.709           Poor alignment*         (0.00.0.731, 1.00)         0.709           Not involving local professional bodies in highway design*         (0.00.0.51, 1.00)         0.622           Construction Process         (0.00.0.561, 1.00)         0.622           Inadequate compaction (surface' subbase / base)         (0.00.0.561, 1.00)         0.643           Poor supervision and workmanship         (0.00.0.561, 1.00)         0.671           Poor tool stathord of practice         (0.00.0.51, 1.00)         0.551           Unstructure         (0.00.0.51, 1.00)         0.552           Poor tool	Poor drainability of the subbase	(0.00,0.66,1.00)	0.604	
Weak joints between the adjoining spread of pavement layers         (0.00.03.11, 00)         0.374           Faulty design Parameters         (0.10.06.91, 100)         0.522           Lack of stability in the bitmen mix         (0.00.03.51, 100)         0.522           Inadequate pavement structure         (0.00.07, 11, 00)         0.643           Underestimated traffic loads         (0.10.0.79, 10)         0.641           Underestimated traffic loads         (0.00.0.71, 100)         0.652           Geometric Design         (0.00.0.31, 100)         0.307           Total gument*         (0.00.0.31, 100)         0.307           Other         (0.00.0.31, 100)         0.367           CONSTRUCTION FACTORS         Total gument*         (0.00.0.69, 100)         0.679           Inadequate compaction (strifec' subbase / base)         (0.000.0.69, 100)         0.679           Construction Process         Inadequate compaction (strifec' subbase / base)         (0.000.0.69, 100)         0.629           Compaction procedure (use of conventional steel drum roller)         (0.000.46, 0.90)         0.625           Poor subparts on admeguately prepared subgrade         (0.000.71, 1.00)         0.645           Poor subgrade on subgrade sol <sup>4</sup> (0.000.71, 1.00)         0.645           Poor subgrade on subgrade sol <sup>4</sup> (	Inadequate pavement design for soil condition	(0.10,0.78,1.00)	0.706	
An excess of asphalt in the top layer* (0.000.31,1.00) 0.0274 Faulty design Parameters (0.100.69,1.00) 0.622 Lack of stability in the bitumen mix (0.000.31,1.00) 0.623 Lack of stability in the bitumen mix (0.000.31,1.00) 0.641 Aggregates not hard enough* (0.000.41,1.00) 0.643 Traffic Underestimated traffic loads (0.100.79,1.00) 0.645 Geometric Design Poor alignment* (0.000.34,1.00) 0.652 Geometric Design Poor alignment* (0.000.34,1.00) 0.653 Geometric Design Poor alignment* (0.000.34,1.00) 0.652 Construction Process (0.000.61,1.00) 0.652 Construction Process (0.000.62,1.00) 0.652 Compaction procedure (use of conventional steel durn roller) (0.000.64,0.00) 0.652 Poor alignment for exes (0.000.67,1.00) 0.652 Poor alignment process (0.000.67,1.00) 0.652 Compaction procedure (use of conventional steel durn roller) (0.000.67,1.00) 0.643 Poor against to sub on subgrade soil* (0.000.67,1.00) 0.645 Poor against onted or practice (0.000.65,1.00) 0.652 Compaction practice (0.000.65,1.00) 0.652 Poor baloexity prepared subgrade (0.100.55,1.00) 0.653 Poor topal student of practice (0.000.65,1.00) 0.655 Poor topal student of practice (0.000.65,1.00) 0.652 Poor topal student of practice (0.000.65,1.00) 0.652 Poor topal student of practice (0.000.65,1.00) 0.653 Poor topal student of practice (0.000.55,1.00) 0.553 Pructure Use of inappropriate aggregates (hydrophilic, naturally smooth uncrushed; dust) (0.100.65,1.00) 0.654 Poor equality control (0.000.71,1.00) 0.643 Poor equality control (0.000.71,1.00) 0.643 Poor equality control (0.000.71,1.00) 0.645 Poor on adverse nativent* (0.000.65,1.00) 0.551 Poor binder to store adhesion (0.000.55,1.00) 0.551 Poor binder to store adhesion (0.000.51,1.00) 0.643 Poor equality control (0.000.51,1.00) 0.643 Poor equality control (0.000.51,1.00) 0.645 Poor on adverse nativent (0.000.51,1.00) 0.645 Poor on adverse nativent (0.000.51,1.00) 0.645 Poor on adverse nativent (0.000.51,1.00) 0.561 Poor bool devise nativent (0.000.51,1.00) 0.561 Poor bool devise nativent (0.000.51,1.00) 0.563 Poor d	Weak joints between the adjoining spread of pavement layers	(0.00,0.42,1.00)	0.448	
Faulty design Parameters         (0.10.0.69.1.00)         0.622           Lack of stability in the bitumen mix         (0.00.0.51,1.00)         0.641           Aggregates to Ind enough*         (0.00.0.71,1.00)         0.641           Madgrequits future raffic loads         (0.10.0.79,1.00)         0.652           Commetric Design	An excess of asphalt in the top layer*	(0.00,0.31,1.00)	0.374	
Lack of stability in the bitumen mix         (0.000.51,1.00)         0.641           Aggregates not hard enough*         (0.000.71,1.00)         0.437           Traffic	Faulty design Parameters	(0.10,0.69,1.00)	0.626	
Inatequite pavement structure (0000,471,100) 0.447 Traffic (0000,471,100) 0.447 Traffic (0000,471,100) 0.457 Traffic (0000,73,100) 0.652 Generative Design (0000,73,100) 0.652 Generative Design (0000,73,100) 0.552 Poor alignment* (0000,34,100) 0.367 CONSTRUCTION FACTORS CONSTRUCTION FACTORS CONSTRUCTION FACTORS CONSTRUCTION FACTORS Construction Process Inadequise compaction (usrice/ subbase / base) (0000,66,100) 0.652 Compaction procedure (use of conventional steel drum roller) (0000,66,100) 0.652 Compaction procedure (use of conventional steel drum roller) (0000,46,000) 0.522 Poor laboratory and in-situ tests on subgrade solt* (0000,37,11,00) 0.643 Poor guality control (0000,37,11,00) 0.657 Unstable or inadequise to prepared subgrade (0100,05,100) 0.557 Unstable or inadequise to prepared subgrade (01000,57,100) 0.557 Vincture Use of inappropriate aggregates (bydrophilic, naturally smooth uncrushed; dusty) (010,0.69,100) 0.551 Poor bay to store adhesion (0000,37,100) 0.557 Vincture Use of inappropriate aggregates (bydrophilic, naturally smooth uncrushed; dusty) (010,0.69,100) 0.551 Poor bay testing aggregates (bydrophilic, naturally smooth uncrushed; dusty) (010,0.69,100) 0.551 Poor bay to store adhesion (0000,051,100) 0.551 Poor bay testing aggregates (bydrophilic, naturally smooth uncrushed; dusty) (010,0.69,100) 0.552 Poor bay to store adhesion (0000,051,100) 0.551 Poor bay to store adhesion (0000,051,100) 0.552 Poor bay to store adhesion (0000,051,100) 0.552 Poor bay to store adhesion (0000,051,100) 0.551 Poor bay to store adhesion (0000,051,100) 0.552 Poor bay to store adhesion (0000,051,100) 0.552 Poor bay to store adhesion (0000,051,100) 0.551 Poor bay to store adhesion (0000,051,100) 0.552 Poor bay to store adhesion (0000,051,100) 0.552 Poor bay to store adhesion (0000,051,100) 0.553 Poor dust to store adhesion (0000,051,100) 0.553 Poor dust to store adhesion (0000,051,100) 0.553 Poor dust through adhesion highway design* (0.000,051,00) 0.553 Poor dust through adhesion transity design* (0.000,051,00) 0.5	Lack of stability in the bitumen mix	(0.00,0.53,1.00)	0.522	
Aggregates not nucle couge*         (0000,041,100)         0.437           Traffic         0         0.709           Inadequist funct traffic forecast         (0000,731,100)         0.537           Geometric Design         0         0.393           Other         0         0.301,000         0.537           CONSTRUCTION FACTORS         0         0.629           Compaction process         0         0.000,050,100)         0.629           Compaction procedure (use of conventional steel drum roller)         0.000,050,000         0.522           Poor subordision and workmanship         0.000,07,000         0.6453           Poor supervision and workmanship         0.000,07,1000         0.6451           Poor togetary to superportize aggregates (hydrophilic; naturally smooth uncunshed; dusty)         0.10,06,01,000         0.6452           Poor binder to stone adhesion         0.000,051,000         0.552           Strift aphalt mixture*         0.000,071,000         0.4451           Low binder content*         0.000,071,000         0.448	Inadequate pavement structure	(0.00,0.71,1.00)	0.641	
Traile         (0.10, 0.79, 1.00)         0.709           Inadequate future traffic forecast         (0.00, 0.73, 1.00)         0.652           Geometric Design         0         0           Poor alignment*         (0.00, 0.34, 1.00)         0.393           Other         0         0         0.367           CONSTRUCTION FACTORS         0         0         0.522           Compaction process         Inadequate compaction (surface' subbase / base)         (0.00, 0.69, 1.00)         0.622           Compaction procedure (use of conventional steel drum roller)         (0.00, 0.69, 1.00)         0.622           Poor laboratory and in-situ tests to subsgrade soil*         (0.00, 0.69, 1.00)         0.643           Poor quarity control         (0.00, 0.71, 1.00)         0.644           Poor aquity control         (0.00, 0.51, 1.00)         0.551           Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty)         (0.10, 0.51, 1.00)         0.552           Poor toind between pavement layers         (0.00, 0.00, 0.1, 1.00)         0.452           Poor toind between pavement layers         (0.00, 0.00, 0.00, 0.1, 1.00)         0.514           Low binder content         (0.00, 0.52, 1.00)         0.514           Low binder content         (0.00, 0.41, 1.00)         0.481     <	Aggregates not hard enough*	(0.00,0.41,1.00)	0.437	
Observation         (0):00.791.1001         0.799           Inadequise function transfer         (00.00.731.1001)         0.652           Geometric Design         (00.00.341.000)         0.393           Ohr in working local professional bodies in highway design*         (00.00.301.00)         0.367           Not involving local professional bodies in highway design*         (00.00.691.00)         0.367           CONSTRUCTION FACTORS         Construction for process         (00.00.50.00)         0.522           Compaction procedure (use of conventional steel drum roller)         (00.00.761.00)         0.643           Poor supervision and workmanship         (00.00.761.00)         0.6571           Poor local standard of practice         (00.00.51.00)         0.550           Structure         Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty)         (01.00.691.00)         0.545           Poor budd between pase ment layers         (00.00.31.00)         0.553         Destructure         0.000.031.00)         0.545           Poor budd between pase ment layers         (00.00.471.00)         0.4481         Dool 0.541.000         0.543           Low bunder content*         (00.00.471.00)         0.4481         Dool 0.5671         Dool 0.5671           Poor budd between pase menent layers         (00.00.071.00)	Iramic Undersectionstad ter file loads	(0 10 0 70 1 00)	0.700	
Interval         (0000,751,00)         0.002           Geometric Design         0         0.393           Poor alignment*         (0.00,0.34,1.00)         0.393           Other         0         0.367           CONSTRUCTION FACTORS         0         0.362           Construction Process         (0.00,0.59,1.00)         0.522           Poor laboratory and in-situ tests on subgrade soil*         (0.00,0.40,00)         0.453           Poor quality control         (0.00,0.59,1.00)         0.552           Poor supervision and workmanship         (0.00,0.71,1.00)         0.643           Poor quality control         (0.00,0.55,1.00)         0.557           Unstable or inadequately prepared subgrade         (0.10,0.51,0.00)         0.557           Unstable or indequately prepared subgrade         (0.00,0.51,0.00)         0.551           Structure         (0.00,0.51,0.00)         0.551           Use of inappropriate aggregates (hydrophilic; naturally smooth unenshed; dusty)         (0.10,0.51,0.00)         0.552           Poor bindle to stone adhesion         (0.00,0.31,0.00)         0.541           Low binder content         (0.00,0.41,0.00)         0.481           To thin bituminous surface         (0.00,0.41,0.00)         0.567           Thin asphali layer over	Underestimated traffic forecast	(0.10, 0.79, 1.00)	0.709	
Own inferment*         (00.00, 34, 1.00)         0.393           Oter         0.393         0.393           Otter         0.301, 000         0.367           Not involving local professional bodies in highway design*         (0.00, 30, 1.00)         0.367           CONSTRUCTION FACTORS         0.000, 550, 000         0.522           Compaction process         (0.000, 560, 000, 052, 000         0.522           Poor iadportsion and workmanship         (0.000, 71, 100)         0.643           Poor supervision and workmanship         (0.000, 71, 100)         0.643           Poor supervision and workmanship         (0.000, 71, 100)         0.643           Poor supervision and workmanship         (0.000, 521, 000)         0.550           Structure         Use of imappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty)         (0.10, 0.651, 000)         0.645           Poor binder to stone adhesion         (0.000, 521, 000)         0.512         Poor binder to stone adhesion         (0.000, 521, 000)         0.522           Poor binder to stone adhesion         (0.000, 521, 000)         0.567         Structure         (0.000, 511, 000)         0.643           Low binder content         (0.000, 511, 000)         0.567         Thin asphalt layer over bridges         (0.000, 511, 000)         0.643	Coometric Design	(0.00,0.75,1.00)	0.032	
Other         (000005 (1.00)         0.057           Not involving local professional bodies in highway design*         (0.00.0.30,1.00)         0.367           CONSTRUCTION FACTORS         (0.00.0.59,1.00)         0.629           Compaction process         (0.00.0.50,1.00)         0.629           Compaction procedure (use of conventional steel drun roller)         (0.00.0.50,0.90)         0.455           Poor aloarotry and in-situ test on subgrade soil*         (0.00.0.76,1.00)         0.6671           Poor supervision and workmanship         (0.00.0.76,1.00)         0.6671           Poor guarty control         (0.00.0.59,1.00)         0.552           Unstable or inadegately prepared subgrade         (0.10.0.51,00)         0.552           Poor binder to stone adhesion         (0.00.0.32,1.00)         0.552           Poor binder to stone adhesion         (0.00.0.32,1.00)         0.538           Low binder content         (0.00.0.47,1.00)         0.481           Too thin bituminous surface         (0.00.0.41,1.00)         0.463           Too thin bituminous surface         (0.00.0.41,1.00)         0.667           Thor aniability of the subbase         (0.00.0.41,1.00)         0.667           Thor thin bituminous surface         (0.00.0.41,1.00)         0.667           Thor atinability of the subbase	Poor alignment*	(0.00.0.34.1.00)	0.393	
Not involving local professional bodies in highway design*         (0.00,0.30,1.00)         0.367           CONSTRUCTION FACTORS           Construction Process           Inadequate compaction (surface' subbase / base)         (0.00,0.69,1.00)         0.629           Compaction procedure (use of conventional stell drum roller)         (0.00,0.46,0.90)         0.552           Poor supervision and workmanship         (0.00,0.76,1.00)         0.643           Poor quality control         (0.00,0.76,1.00)         0.643           Poor local standard of practice         (0.00,0.53,1.00)         0.557           Urstable or inadequately prepared subgrade         (0.00,0.51,100)         0.645           Poor bind between pavement layers         (0.00,0.34,1.00)         0.552           Poor binder to stone adbasion         (0.00,0.34,1.00)         0.541           Low penetration value of the binder content*         (0.00,0.47,1.00)         0.481           Stiff asphalt mixture*         (0.00,0.47,1.00)         0.567           Than sphalt layer over bridges         (0.10,0.58,1.00)         0.567           This naphalt layer over bridges         (0.00,0.61,1.00)         0.567           This naphalt layer over bridges         (0.00,0.61,1.00)         0.567           Tho or drainability of the subbase         (0.00,0.	Other	(0.00,0.54,1.00)	0.575	
CONSTRUCTION FACTORS         (0.001057100)         0.0510           Construction Process         (0.000.691.100)         0.629           Compaction procedure (use of conventional steel drum roller)         (0.000.650.90)         0.452           Poor laboratory and in-situe ston subgrade soil*         (0.000.761.00)         0.671           Poor aboratory and in-situe ston subgrade soil*         (0.000.761.00)         0.671           Poor quality control         (0.000.761.00)         0.572           Unstable or indequately prepared subgrade         (0.100.551.100)         0.550           Structure         (0.000.781.00)         0.551           Door boal between pavement layers         (0.000.781.00)         0.552           Poor binder to stone adhesion         (0.000.71.100)         0.551           Low binder content         (0.000.71.00)         0.541           Low binder content         (0.000.71.00)         0.481           Too thin bituminous surface         (0.000.71.100)         0.481           Too thin bituminous surface         (0.000.71.100)         0.663           Inadequate surface drainage         (0.000.71.100)         0.643           To thin bituminous surface         (0.000.71.100)         0.6567           Poor drainability of the subbase         (0.000.71.100) <t< td=""><td>Not involving local professional bodies in highway design*</td><td>(0.00.0.30.1.00)</td><td>0.367</td></t<>	Not involving local professional bodies in highway design*	(0.00.0.30.1.00)	0.367	
Construction Process         0.000.691.000         0.629           Inadequate compaction (surface' subbase / base)         (0.000.69.1.00)         0.522           Poor supervision and workmanship         (0.000.76.1.00)         0.643           Poor supervision and workmanship         (0.000.76.1.00)         0.671           Poor supervision and workmanship         (0.000.76.1.00)         0.671           Poor quality control         (0.000.551.00)         0.557           Unstable or inadequately prepared subgrade         (0.100.551.100)         0.565           Structure         (0.000.58.1.00)         0.551           Door bold structure averment layers         (0.000.38.1.00)         0.514           Low binder content         (0.000.47.1.00)         0.481           Stiff aphalt mixture*         (0.000.47.1.00)         0.481           Too thin bitruminous surface         (0.100.58.1.00)         0.567           Thin aphalt layer over bridges         (0.100.58.1.00)         0.567           Poor tainater tartec drainage         (0.000.47.1.00)         0.481           Stiff aphalt mixture*         (0.000.71.1.00)         0.643           Thin aphalt layer over bridges         (0.000.67.1.00)         0.567           Poor trained tractec drainage         (0.000.71.1.00)         0.643	CONSTRUCTION FACTORS	(0100,0120,1100)	0.007	
Indequate compaction (surface' subbase / base)         (0.00,0.650,00)         0.629           Compaction procedure (use of conventional steel drum roller)         (0.00,0.650,00)         0.522           Poor laboratory and in-situ tests on subgrade soil*         (0.00,0.45,0.90)         0.455           Poor quality control         (0.00,0.71,1.00)         0.647           Poor quality control         (0.00,0.75,1.00)         0.671           Poor quality control         (0.00,0.55,1.00)         0.550           Structure         Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty)         (0.10,0.69,1.00)         0.552           Poor bond between pavement layers         (0.00,0.41,00)         0.554           Poor toinder to stone adhesion         (0.00,0.41,00)         0.558           Low binder content         (0.00,0.41,00)         0.5514           Low binder content*         (0.00,0.41,00)         0.541           To thin bituminous surface         (0.10,0.58,1.00)         0.567           Poor dianibility of the subbase         (0.00,0.71,1.00)         0.481           To thin bituminous surface         (0.00,0.61,1.00)         0.571           Other         (0.00,0.61,1.00)         0.571           Not         molessinal bodies in highway design*         (0.00,0.61,1.00)	Construction Process			
Compaction procedure ( use of conventional steel drum roller)         (0.00,0.56,0.90)         0.522           Poor laboratory and in-situ tests on subgrade soil*         (0.00,0.46,0.90)         0.455           Poor supervision and workmanship         (0.00,0.71,1.00)         0.663           Poor quality control         (0.00,0.71,1.00)         0.671           Poor local standard of practice         (0.00,0.551,100)         0.557           Unstable or inadequately prepared subgrade         (0.10,0.551,100)         0.645           Poor bond between pavement layers         (0.00,0.52,1.00)         0.552           Poor bond between pavement layers         (0.00,0.25,1.00)         0.552           Poor bond between pavement layers         (0.00,0.25,1.00)         0.552           Poor bond between pavement layers         (0.00,0.25,1.00)         0.552           Poor binder to stone adhesion         (0.00,0.25,1.00)         0.551           Low penetration value of the binder content*         (0.00,0.47,1.00)         0.481           Stiff asphalt mixture*         (0.00,0.51,1.00)         0.567           Ton tan bitury of the subbase         (0.00,0.61,1.00)         0.571           Dot desceree pave bridges         (0.00,0.61,1.00)         0.571           Not anyolving local professional bodies in highway design*         (0.00,0.71,1.00) </td <td>Inadequate compaction (surface/ subbase / base)</td> <td>(0.00,0.69,1.00)</td> <td>0.629</td>	Inadequate compaction (surface/ subbase / base)	(0.00,0.69,1.00)	0.629	
Poor laboratory and in-situ tests on subgrade soil* $(0.00, 0.46, 0.90)$ $0.455$ Poor supervision and workmanship $(0.00, 0.71, 1.00)$ $0.643$ Poor quality control $(0.00, 0.57, 1.00)$ $0.671$ Poor quality control $(0.00, 0.551, 1.00)$ $0.557$ Unstable or inadequately prepared subgrade $(0.10, 0.551, 1.00)$ $0.552$ Structure $(0.00, 0.551, 1.00)$ $0.552$ Poor binder to stone adhesion $(0.00, 0.541, 1.00)$ $0.552$ Poor binder to stone adhesion $(0.00, 0.541, 1.00)$ $0.541$ Low binder content $(0.00, 0.471, 1.00)$ $0.481$ Too thinh bituminous surface $(0.10, 0.581, 1.00)$ $0.567$ Thin asphalt layer over bridges $(0.10, 0.581, 1.00)$ $0.567$ Thin asphalt layer over bridges $(0.00, 0.61, 1.00)$ $0.571$ Not involving local professional bodies in highway design* $(0.00, 0.61, 1.00)$ $0.571$ Taffic $(0.00, 0.51, 1.00)$ $0.643$ Imadequate surface drainage $(0.00, 0.51, 1.00)$ $0.643$ Imadequate surface drainage $(0.00, 0.61, 1.00)$	Compaction procedure ( use of conventional steel drum roller)	(0.00,0.56,0.90)	0.522	
Poor supervision and workmanship         (0.00,0.71,1.00)         0.643           Poor quality control         (0.00,0.75,1.00)         0.671           Poor local standard of practice         (0.00,0.59,1.00)         0.557           Unstable or inadequately prepared subgrade         (0.10,0.55,1.00)         0.557           Structure         (0.00,0.55,1.00)         0.645           Door bond between pavement layers         (0.00,0.55,1.00)         0.645           Poor bond between pavement layers         (0.00,0.52,1.00)         0.552           Poor bond between pavement layers         (0.00,0.0,0.51,100)         0.552           Poor bond between pavement layers         (0.00,0.0,0.71,1.00)         0.481           Stiff asphalt mixture*         (0.00,0.47,1.00)         0.481           Stiff asphalt mixture*         (0.00,0.47,1.00)         0.481           Stiff asphalt mixture*         (0.00,0.61,1.00)         0.567           Thin asphalt layer over bridges         (0.10,0.58,1.00)         0.567           Poor dminability of the subbase         (0.00,0.61,1.00)         0.643           Inadequate surface dminage         (0.00,0.61,1.00)         0.643           UFESPAN FACTORS         (0.00,0.61,1.00)         0.643           UFESPAN FACTORS         (0.00,0.51,1.00)         0.659	Poor laboratory and in-situ tests on subgrade soil*	(0.00,0.46,0.90)	0.455	
Poor quality control         (0.000.75.1.00)         0.671           Poor local standard of practice         (0.000.75.1.00)         0.557           Unstable or inadequately prepared subgrade         (0.10.0.55.1.00)         0.557           Structure         (0.000.55.1.00)         0.655           Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty)         (0.10.0.69.1.00)         0.645           Poor binder to stone adhesion         (0.000.52.1.00)         0.514           Low binder content         (0.000.34.1.00)         0.481           Stiff asphal insiture*         (0.000.47.1.00)         0.481           To thin bituminous surface         (0.10.0.58.1.00)         0.567           Thin asphal layer over bridges         (0.10.0.58.1.00)         0.571           Other         0.000.61.1.00)         0.571           Other         0.000.61.1.00)         0.571           Other         0.000.61.1.00)         0.571           Other         0.000.61.1.00)         0.508           Tarffic         0.000.69.1.00)         0.629           High traffic value         (0.000.69.1.00)         0.629           High traffic value         (0.000.69.1.00)         0.508           Lack of control regarding load limit carried by vehicles <td< td=""><td>Poor supervision and workmanship</td><td>(0.00, 0.71, 1.00)</td><td>0.643</td></td<>	Poor supervision and workmanship	(0.00, 0.71, 1.00)	0.643	
Poor local standard of practice         (0.00.557.1.00)         0.557           Unstable or inadequately prepared subgrade         (0.10.0.55.1.00)         0.550           Structure         (0.00.0.58.1.00)         0.645           Poor bond between pavement layers         (0.00.0.58.1.00)         0.514           Low binder content         (0.00.0.58.1.00)         0.514           Low binder content         (0.00.0.47.1.00)         0.481           Too thin bituminous surface         (0.10.0.58.1.00)         0.567           Poor admability of the subbase         (0.00.0.71.1.00)         0.643           Inadequate surface drainage         (0.00.0.71.1.00)         0.643           Inadequate surface drainage         (0.00.0.61.1.00)         0.629           Were-weight/ over-height vehicles         (0.00.0.57.1.00)         0.643           Inadequate surface drainage         (0.00.0.61.1.00)         0.629           Were-weight/ over-height vehicles         (0.00.0.57.1.00)         0.629           Hight traffic volume         (0.00.0.57.1.00)         0.6663	Poor quality control	(0.00, 0.76, 1.00)	0.671	
Unstable or inadequately prepared subgrade         (0.10.0.55,1.00)         0.550           Structure         Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty)         (0.10.0.69,1.00)         0.645           Poor binder to stone adhesion         (0.00.0.52,1.00)         0.514           Low binder content         (0.00.0.52,1.00)         0.538           Low penetration value of the binder content*         (0.00.0.47,1.00)         0.481           Stiff asphal mixture*         (0.00.0.47,1.00)         0.481           To thin bituminous surface         (0.10.0.58,1.00)         0.567           Poor drainability of the subbase         (0.00.0.71,1.00)         0.643           Inadequate surface drainage         (0.00.0.61,1.00)         0.571           Other         Not involving local professional bodies in highway design*         (0.00.0.61,1.00)         0.571           Taffic         (0.00.0.51,1.00)         0.629         High traffic volume         0.000,0.51,1.00)         0.596           Phenomenal growth of venicular traffic         (0.00,0.51,1.00)         0.508         Lack of control regarding load limit carried by vehicles         (0.00,0.59,1.00)         0.529           Fuight mark to vehicular traffic         (0.00,0.59,1.00)         0.529         Exironmenal growth of vehicular traffic         0.000,0.51,1.00)         0	Poor local standard of practice	(0.00,0.59,1.00)	0.557	
Structure           Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty) $(0.10, 0.69, 1.00)$ $0.645$ Poor bond between pavement layers $(0.00, 0.52, 1.00)$ $0.514$ Low binder content $(0.00, 0.34, 1.00)$ $0.538$ Low binder content $(0.00, 0.34, 1.00)$ $0.481$ Stiff asphalt mixture* $(0.00, 0.47, 1.00)$ $0.481$ Too thin bituminous surface $(0.10, 0.58, 1.00)$ $0.567$ Phor drainability of the subbase $(0.00, 0.71, 1.00)$ $0.643$ Inadequate surface drainage $(0.00, 0.71, 1.00)$ $0.643$ Indequate surface drainage $(0.00, 0.61, 1.00)$ $0.643$ Introl         Indequate surface drainage $(0.00, 0.61, 1.00)$ $0.443$ ILFESPAN FACTORS         Traffic $(0.00, 0.61, 1.00)$ $0.629$ High traffic vor-height vehicles $(0.00, 0.61, 1.00)$ $0.630$ Lack of control regarding load limit carried by vehicles $(0.00, 0.51, 1.00)$ $0.508$ Lack of control regarding load limit carried by vehicles $(0.00, 0.51, 1.00)$ $0.529$ Everyeight/ over-height vehicles the time of a	Unstable or inadequately prepared subgrade	(0.10,0.55,1.00)	0.550	
Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty) (0.10,0.61,00) 0.552 Poor bold between pavement layers (0.000,0.52,1.00) 0.551 Low binder content (0.000,0.52,1.00) 0.514 Low binder content (0.000,0.41,00) 0.481 Stiff asphalt mixture* (0.000,0.41,00) 0.481 Too thin bituminous surface (0.10,0.58,1.00) 0.567 Thin asphalt layer over bridges (0.00,0.71,1.00) 0.481 Not involving local professional bodies in highway design* (0.000,0.61,1.00) 0.571 Other (0.000,0.61,1.00) 0.571 Other (0.000,0.61,1.00) 0.571 Other (0.000,0.61,1.00) 0.571 Other (0.000,0.61,1.00) 0.643 LIFESPAN FACTORS Traffic (0.000,0.61,1.00) 0.629 High traffic volume (0.000,0.51,1.00) 0.508 Lack of control regarding load limit carried by vehicles (0.000,0.51,1.00) 0.508 Lack of control regarding load limit carried by vehicles (0.000,0.51,1.00) 0.563 Phenomental growth of vehicular traffic (0.000,0.51,1.00) 0.563 Pushing action by wheels of heavy traffic at the time of acceleration and (0.000,0.51,1.00) 0.563 Pushing action by wheels of heavy traffic at the time of acceleration and (0.000,0.51,1.00) 0.563 Pushing action by wheels of heavy traffic at the time of acceleration and (0.000,0.51,1.00) 0.563 Pushing action by wheels of heavy traffic at the time of acceleration and (0.000,0.51,1.00) 0.563 Pushing action by wheels of heavy traffic at the time of acceleration and (0.000,0.51,1.00) 0.563 Pushing action by wheels of heavy traffic at the time of acceleration and (0.000,0.51,1.00) 0.563 Pushing action by the asphalt/longitudinal joints (0.000,0.51,1.00) 0.563 Stepping on surface* (0.000,0.51,1.00) 0.564 Trapped moisture in the buttom layers of the pavement (0.000,0.51,1.00) 0.571 Natural disaster (0.000,0.51,1.00) 0.525 Stripping on the bottom layers/movement of the bottom layers (0.000,0.51,1.00)	Structure			
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Poor binder to stone adhesion $(0.00, 0.34, 1.00)$ $0.514$ Low binder content $(0.00, 0.34, 1.00)$ $0.481$ Stiff asphalt mixture* $(0.00, 0.47, 1.00)$ $0.481$ Too thin bituminous surface $(0.10, 0.58, 1.00)$ $0.567$ Thin asphalt layer over bridges $(0.10, 0.58, 1.00)$ $0.567$ Poor drainability of the subbase $(0.00, 0.71, 1.00)$ $0.643$ Inadequate surface drainage $(0.00, 0.61, 1.00)$ $0.643$ Index problem in the subbase $(0.00, 0.61, 1.00)$ $0.643$ Index problem in the subbase $(0.00, 0.61, 1.00)$ $0.643$ Index problem in the subbase $(0.00, 0.69, 1.00)$ $0.629$ High traffic volume $(0.00, 0.69, 1.00)$ $0.629$ High traffic volume $(0.00, 0.51, 1.00)$ $0.508$ Lack of control regarding load limit carried by vehicles $(0.00, 0.51, 1.00)$ $0.566$ Phenomenal growth of vehicular traffic $(0.00, 0.54, 1.00)$ $0.629$ Environmental $0.529$ Environmental $0.529$ Environmental settlement $0.00, 0.54, 1.00)$ $0.666$ Stopping & standing traffic $0.03, 0.88, $	Poor bond between pavement layers	(0.00,0.58,1.00)	0.552	
Low binder content         (0.00.0.34,1.00)         0.538           Low penetration value of the binder content*         (0.00.0.47,1.00)         0.481           Stiff asphalt mixture*         (0.00.0.47,1.00)         0.481           Too thin bituminous surface         (0.10.0.58,1.00)         0.567           Poor drainability of the subbase         (0.00.0.71,1.00)         0.643           Inadequate surface drainage         (0.00.0.61,1.00)         0.571           Other         0         0.00.0.61,1.00)         0.571           Not involving local professional bodies in highway design*         (0.00.0.61,1.00)         0.643           LIFESPAN FACTORS         Traffic         0.00.0.51,1.00)         0.629           High traffic volume         (0.00.0.69,1.00)         0.629         0.508           Lack of control regarding load limit carried by vehicles         (0.00.0.59,1.00)         0.508           Stopping & standing traffic         (0.00.0.54,1.00)         0.503           Pushing action by wheels of heavy traffic at the time of acceleration and (0.00.0.54,1.00)         0.529           Environmental         Differential settlement         (0.10.0.68,1.00)         0.529           Steppage of water into the subgrade         (0.00.0.51,1.00)         0.642           Water pooling on surface*         (0.00.0.0	Poor binder to stone adhesion	(0.00,0.52,1.00)	0.514	
Low penetration value of the binder content $(0.00, 0.47, 1.00)$ $0.481$ Too thin bituminous surface $(0.10, 0.58, 1.00)$ $0.567$ Thin asphalt layer over bridges $(0.10, 0.58, 1.00)$ $0.567$ Poor drainability of the subbase $(0.00, 0.71, 1.00)$ $0.643$ Inadequate surface drainage $(0.00, 0.71, 1.00)$ $0.643$ Not involving local professional bodies in highway design* $(0.00, 0.41, 1.00)$ $0.443$ <b>LIFESPAN FACTORS Traffie Over</b> -weight/ over-height vehicles $(0.00, 0.51, 1.00)$ $0.629$ High traffic volume $(0.00, 0.51, 1.00)$ $0.636$ <b>Depring weight/ over-height vehicles</b> $(0.00, 0.79, 1.00)$ $0.696$ Phenomenal growth of vehicular traffic $(0.00, 0.54, 1.00)$ $0.563$ <b>Depring &amp; standing traffic</b> $(0.00, 0.54, 1.00)$ $0.529$ <b>Environmental Differential settlement</b> $(0.00, 0.54, 1.00)$ $0.529$ <b>Environmental Outor into the subgrade</b> $(0.00, 0.54, 1.00)$ $0.529$ Seepage of water into the subgrade $(0.00, 0.38, 0.90)$ $0.404$ Unstable //Expansive subgrade soils $(0.00, 0.75, 1.00$	Low binder content	(0.00,0.34,1.00)	0.538	
Similar linkture(0.00.0-7,1.00)0.431Too thin bituminous surface(0.10,0.58,1.00)0.567Thin asphalt layer over bridges(0.10,0.58,1.00)0.567Poor drainability of the subbase(0.00,0.71,1.00)0.643Inadequate surface drainage(0.00,0.61,1.00)0.571OtherNot involving local professional bodies in highway design*(0.00,0.61,1.00)0.443LIFESPAN FACTORSTrafficOver-weight/ over-height vehicles(0.00,0.69,1.00)0.629High traffic volume(0.00,0.79,1.00)0.696Phenomenal growth of vehicular traffic(0.00,0.79,1.00)0.696Phenomenal growth of vehicular traffic(0.00,0.59,1.00)0.663Stopping & standing traffic(0.00,0.59,1.00)0.563Pushing action by wheels of heavy traffic at the time of acceleration and deceleration0.529Environmental(0.10,0.68,1.00)0.521Seepage of water into the subgrade(0.00,0.71,1.00)0.642Water pooling on surface*(0.00,0.38,0.90)0.404Unstable (Expansive subgrade soils(0.10,0.68,1.00)0.592Seepage of water into the subgrade(0.00,0.73,1.00)0.642Natural disaster(0.00,0.73,1.00)0.642Natural disaster(0.00,0.73,1.00)0.642Natural disaster(0.00,0.73,1.00)0.541StructureDeterioration of aggregates(0.00,0.73,1.00)0.542Structure <td< td=""><td>Low penetration value of the binder content*</td><td>(0.00, 0.47, 1.00)</td><td>0.481</td></td<>	Low penetration value of the binder content*	(0.00, 0.47, 1.00)	0.481	
Tot unit of unit of the subbase(0.100.58,1.00)0.567Poor drainability of the subbase(0.00,0.71,1.00)0.643Inadequate surface drainage(0.00,0.61,1.00)0.571OtherNot involving local professional bodies in highway design*(0.00,0.61,1.00)0.443LIFESPAN FACTORSTrafficOver-weight/ over-height vehicles(0.00,0.69,1.00)0.629High traffic volume(0.00,0.51,1.00)0.508Lack of control regarding load limit carried by vehicles(0.00,0.59,1.00)0.696Phenomenal growth of vehicular traffic(0.00,0.59,1.00)0.669Pushing action by wheels of heavy traffic at the time of acceleration and deceleration(0.00,0.54,1.00)0.529Environmental0.529Differential settlement(0.10,0.68,1.00)0.621Seepage of water into the subgrade(0.00,0.71,1.00)0.642Water pooling on surface*(0.00,0.44,1.00)0.592Seepage of water into the subgrade soils(0.10,0.84,1.00)0.745Natural disaster(0.00,0.73,1.00)0.654Trapped moisture in the bottom layers of the pavement(0.00,0.54,1.00)0.529Ageing of binder in the surface course(0.00,0.54,1.00)0.525Stripping on the bottom of the pavement of the bottom layers of the pavement(0.00,0.51,1.00)0.641Unstable /Expansive subgrade soils(0.10,0.84,1.00)0.729Ageing of binder in the surface course(0.00,0.51,1.00)0	Too thin bituminous surface	(0.00, 0.47, 1.00)	0.461	
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Inadequate surface drainage $(0.00, 0.61, 1.00)$ $0.571$ Other	Poor drainability of the subbase	(0.00.0.71.1.00)	0.643	
OtherControl of the second secon	Inadequate surface drainage	(0.00.0.61.1.00)	0.571	
Not involving local professional bodies in highway design* $(0.00, 0.41, 1.00)$ $0.443$ LIFESPAN FACTORSTraffic $0$ Over-weight/ over-height vehicles $(0.00, 0.59, 1.00)$ $0.629$ High traffic volume $(0.00, 0.51, 1.00)$ $0.508$ Lack of control regarding load limit carried by vehicles $(0.00, 0.79, 1.00)$ $0.696$ Phenomenal growth of vehicular traffic $(0.00, 0.59, 1.00)$ $0.563$ Stopping & standing traffic $(0.00, 0.59, 1.00)$ $0.563$ Pushing action by wheels of heavy traffic at the time of acceleration and $(0.00, 0.54, 1.00)$ $0.529$ Environmental $0.529$ Differential settlement $(0.10, 0.68, 1.00)$ $0.621$ Seepage of water into the subgrade $(0.00, 0.71, 1.00)$ $0.642$ Water pooling on surface* $(0.00, 0.38, 0.90)$ $0.404$ Unstable /Expansive subgrade soils $(0.10, 0.84, 1.00)$ $0.745$ Natural disaster $(0.00, 0.73, 1.00)$ $0.654$ Trapped moisture in the bottom layers of the pavement $(0.00, 0.75, 1.00)$ $0.504$ Structure $0.00, 0.75, 1.00)$ $0.525$ Deterioration of aggregates $(0.00, 0.51, 1.00)$ $0.525$ Stripping on the bottom layers/movement of the bottom layers $(0.00, 0.53, 1.00)$ $0.525$ Stripping on the bottom of the HMA surface layer $(0.00, 0.53, 1.00)$ $0.525$ Stripping on the bottom of the thMA surface layer $(0.00, 0.53, 1.00)$ $0.525$ Stripping on the bottom of upers/movement of the bottom layers $(0.00, 0.53,$	Other	(****,****,****)		
LIFESPAN FACTORSTrafficOver-weight/ over-height vehicles $(0.00, 0.69, 1.00)$ $0.629$ High traffic volume $(0.00, 0.51, 1.00)$ $0.508$ Lack of control regarding load limit carried by vehicles $(0.00, 0.79, 1.00)$ $0.696$ Phenomenal growth of vehicular traffic $(0.00, 0.59, 1.00)$ $0.696$ Pushing action by wheels of heavy traffic at the time of acceleration and $(0.00, 0.59, 1.00)$ $0.563$ Pushing action by wheels of heavy traffic at the time of acceleration and $(0.00, 0.59, 1.00)$ $0.563$ Pushing action by wheels of heavy traffic at the time of acceleration and $(0.00, 0.54, 1.00)$ $0.529$ Environmental $0.00, 0.641, 1.00)$ $0.592$ Seepage of water through asphalt/longitudinal joints $(0.00, 0.71, 1.00)$ $0.642$ Water pooling on surface* $(0.10, 0.84, 1.00)$ $0.745$ Natural disaster $(0.00, 0.73, 1.00)$ $0.654$ Trapped moisture in the bottom layers of the pavement $(0.00, 0.73, 1.00)$ $0.654$ Structure $0.00, 0.75, 1.00)$ $0.504$ Structure $0.00, 0.51, 1.00)$ $0.505$ Mairtenance $0.00, 0.53, 1.00)$ $0.519$ Lack of supervision or supervision by unprofessional personnel $(0.00, 0.53, 1.00)$ $0.519$ Insufficient funding $(0.00, 0.51, 1.00)$ $0.519$ Natural failure of the bottom layers/movement of the bottom layers $(0.00, 0.53, 1.00)$ $0.519$ Insufficient funding $(0.00, 0.51, 1.00)$ $0.519$ Insufficient funding $($	Not involving local professional bodies in highway design*	(0.00,0.41,1.00)	0.443	
TrafficOver-weight/over-height vehicles $(0.00, 0.69, 1.00)$ $0.629$ High traffic volume $(0.00, 0.51, 1.00)$ $0.508$ Lack of control regarding load limit carried by vehicles $(0.00, 0.79, 1.00)$ $0.696$ Phenomenal growth of vehicular traffic $(0.00, 0.59, 1.00)$ $0.696$ Phenomenal growth of vehicular traffic $(0.00, 0.59, 1.00)$ $0.6563$ Pushing action by wheels of heavy traffic at the time of acceleration and $(0.00, 0.54, 1.00)$ $0.529$ Environmental $0.529$ $0.00, 0.641, 1.00)$ $0.6211$ Seepage of water into the subgrade $(0.00, 0.64, 1.00)$ $0.692$ Seepage of water through asphalt/longitudinal joints $(0.00, 0.71, 1.00)$ $0.642$ Water pooling on surface* $(0.00, 0.49, 1.00)$ $0.745$ Natural disaster $(0.00, 0.49, 1.00)$ $0.490$ Global warming $(0.00, 0.73, 1.00)$ $0.654$ Trapped moisture in the bottom layers of the pavement $(0.00, 0.71, 1.00)$ $0.667$ Loss of adhesion in the surface course $(0.00, 0.73, 1.00)$ $0.667$ Loss of adhesion in the surface layer $(0.00, 0.51, 1.00)$ $0.525$ Stripping on the bottom layers/movement of the bottom layers $(0.00, 0.53, 1.00)$ $0.563$ StructureUUU $0.525$ Maintenance $0.00, 0.53, 1.00)$ $0.567$ Loss of adhesion in the surface layer $(0.00, 0.53, 1.00)$ $0.505$ Maintenance $0.00, 0.51, 1.00)$ $0.519$ Lack of supervision or supervision by unprofessional personne	LIFESPAN FACTORS			
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High traffic volume $(0.00, 0.51, 1.00)$ $0.508$ Lack of control regarding load limit carried by vehicles $(0.00, 0.79, 1.00)$ $0.696$ Phenomenal growth of vehicular traffic $(0.03, 0.88, 1.00)$ $0.800$ Stopping & standing traffic $(0.00, 0.59, 1.00)$ $0.553$ Pushing action by wheels of heavy traffic at the time of acceleration and $(0.00, 0.54, 1.00)$ $0.cceleration$ Differential settlement $(0.10, 0.68, 1.00)$ $0.621$ Seepage of water into the subgrade $(0.00, 0.71, 1.00)$ $0.642$ Water pooling on surface* $(0.00, 0.38, 0.90)$ $0.404$ Unstable (Expansive subgrade soils $(0.10, 0.84, 1.00)$ $0.745$ Natural disaster $(0.00, 0.73, 1.00)$ $0.654$ Trapped moisture in the bottom layers of the pavement $(0.00, 0.73, 1.00)$ $0.654$ Structure       Deterioration of aggregates $(0.00, 0.75, 1.00)$ $0.667$ Loss of adhesion in the surface layer $(0.00, 0.54, 1.00)$ $0.525$ Structure failure of the bottom layers/movement of the bottom layers $(0.00, 0.53, 1.00)$ $0.588$ Structure failure of the bottom layers/movement of the bottom layers $(0.000, 0.51, 1.00)$ $0.505$	Over-weight/ over-height vehicles	(0.00,0.69,1.00)	0.629	
Lack of control regarding load limit carried by vehicles $(0.00, 0.79, 1.00)$ $0.696$ Phenomenal growth of vehicular traffic $(0.03, 0.88, 1.00)$ $0.800$ Stopping & standing traffic $(0.00, 0.59, 1.00)$ $0.563$ Pushing action by wheels of heavy traffic at the time of acceleration and $(0.00, 0.54, 1.00)$ $0.529$ Environmental $0.529$ $0.529$ Environmental $0.00, 0.64, 1.00)$ $0.621$ Seepage of water into the subgrade $(0.00, 0.64, 1.00)$ $0.642$ Water pooling on surface* $(0.00, 0.71, 1.00)$ $0.642$ Water pooling on surface* $(0.00, 0.73, 1.00)$ $0.745$ Natural disaster $(0.00, 0.73, 1.00)$ $0.654$ Trapped moisture in the bottom layers of the pavement $(0.00, 0.73, 1.00)$ $0.654$ Structure $0.00, 0.73, 1.00)$ $0.667$ Deterioration of aggregates $(0.00, 0.73, 1.00)$ $0.729$ Ageing of binder in the surface course $(0.00, 0.54, 1.00)$ $0.729$ Ageing of binder in the surface layer $(0.00, 0.53, 1.00)$ $0.504$ Structural failure of the bottom layers/movement of the bottom layers $(0.00, 0.53, 1.00)$ $0.525$ Stripping on the bottom of the HMA surface layer $(0.00, 0.53, 1.00)$ $0.519$ Insufficient funding $(0.00, 0.53, 1.00)$ $0.519$ Insufficient funding $(0.00, 0.53, 1.00)$ $0.519$ Shortage of maintenance training activities $(0.10, 0.66, 1.00)$ $0.519$ Insufficient funding $(0.00, 0.51, 1.00)$ $0.505$ Maintenance<	High traffic volume	(0.00,0.51,1.00)	0.508	
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Stopping & standing traffic $(0.00, 0.59, 1.00)$ $0.563$ Pushing action by wheels of heavy traffic at the time of acceleration and deceleration $(0.00, 0.54, 1.00)$ $0.529$ Environmental $0.10, 0.68, 1.00)$ $0.621$ Seepage of water into the subgrade $(0.00, 0.64, 1.00)$ $0.592$ Seepage of water through asphalt/longitudinal joints $(0.00, 0.71, 1.00)$ $0.642$ Water pooling on surface* $(0.00, 0.38, 0.90)$ $0.404$ Unstable /Expansive subgrade soils $(0.10, 0.84, 1.00)$ $0.745$ Natural disaster $(0.00, 0.73, 1.00)$ $0.490$ Global warming $(0.00, 0.73, 1.00)$ $0.654$ Trapped moisture in the bottom layers of the pavement $(0.00, 0.51, 1.00)$ $0.504$ Structure $0.00, 0.75, 1.00)$ $0.667$ Loss of adhesion in the surface course $(0.00, 0.53, 1.00)$ $0.525$ Stripping on the bottom layers/movement of the bottom layers $(0.00, 0.51, 1.00)$ $0.505$ Maintenance $0.00, 0.53, 1.00)$ $0.519$ Insufficient funding $(0.00, 0.53, 1.00)$ $0.519$ Shortage of maintenance training activities $(0.10, 0.65, 1.00)$ $0.519$ Not involving local professional bodies in highway maintenance $(0.00, 0.53, 1.00)$ $0.519$ Not involving local professional bodies in highway maintenance $(0.00, 0.51, 1.00)$ $0.505$ End case of maintenance training activities $(0.10, 0.78, 1.00)$ $0.505$ End case of maintenance training activities $(0.10, 0.78, 1.00)$ $0.505$ End case of maintenance	Phenomenal growth of vehicular traffic	(0.03,0.88,1.00)	0.800	
Pushing action by wheels of heavy traffic at the time of acceleration and deceleration $(0.00,0.54,1.00)$ deceleration0.529Environmental0Differential settlement $(0.10,0.68,1.00)$ 0.621Seepage of water into the subgrade $(0.00,0.64,1.00)$ 0.592Seepage of water through asphalt/longitudinal joints $(0.00,0.38,0.90)$ 0.404Unstable /Expansive subgrade soils $(0.10,0.84,1.00)$ 0.745Natural disaster $(0.00,0.73,1.00)$ 0.490Global warming $(0.00,0.73,1.00)$ 0.490Global warming $(0.00,0.73,1.00)$ 0.654Trapped moisture in the bottom layers of the pavement $(0.00,0.51,1.00)$ 0.504Structure $\mathbf{Structure}$ $\mathbf{Structure}$ Deterioration of aggregates $(0.00,0.75,1.00)$ 0.667Loss of adhesion in the surface course $(0.00,0.51,1.00)$ 0.525Stripping on the bottom layers/movement of the bottom layers $(0.00,0.51,1.00)$ 0.519Insufficient funding $(0.00,0.53,1.00)$ 0.519Insufficient funding $(0.00,0.53,1.00)$ 0.519Insufficient funding $(0.00,0.51,1.00)$ 0.525Stripping on the bottom of the HMA surface layer $(0.00,0.53,1.00)$ 0.519Insufficient funding $(0.00,0.53,1.00)$ 0.519Insufficient funding $(0.00,0.54,1.00)$ 0.521Poorly maintained drains $(0.00,0.54,1.00)$ 0.505Maintenance $(0.00,0.53,1.00)$ 0.519Insufficient funding $(0.00,0.53,1.00)$ 0.519<	Stopping & standing traffic	(0.00,0.59,1.00)	0.563	
decertation0.229EnvironmentalDifferential settlement( $0.10, 0.68, 1.00$ )0.621Seepage of water into the subgrade( $0.00, 0.64, 1.00$ )0.621Seepage of water through asphalt/longitudinal joints( $0.00, 0.64, 1.00$ )0.621Water pooling on surface*( $0.00, 0.71, 1.00$ )0.642Water pooling on surface*( $0.00, 0.71, 1.00$ )0.642Water pooling on surface*( $0.00, 0.71, 1.00$ )0.642Water pooling on surface*( $0.00, 0.38, 0.90$ )0.404Unstable /Expansive subgrade soils( $0.00, 0.38, 0.90$ )0.404Unstable /Expansive subgrade soils( $0.00, 0.38, 0.90$ )0.404Unstable /Expansive subgrade soils( $0.00, 0.42, 1.00$ )0.4490Global warming( $0.00, 0.43, 1.00$ )0.654Trapped moisture in the bottom layers of the pavement( $0.00, 0.73, 1.00$ )0.6667Loss of adhesion in the surface layer( $0.00, 0.73, 1.00$ )0.525Stripping on the bottom layers/movement of the bottom layers( $0.00, 0.53, 1.00$ )0.519Insufficient funding( $0.00, 0.53, 1.00$ ) <th co<="" td=""><td>Pushing action by wheels of heavy traffic at the time of acceleration and</td><td>(0.00,0.54,1.00)</td><td>0.520</td></th>	<td>Pushing action by wheels of heavy traffic at the time of acceleration and</td> <td>(0.00,0.54,1.00)</td> <td>0.520</td>	Pushing action by wheels of heavy traffic at the time of acceleration and	(0.00,0.54,1.00)	0.520
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The property interval $(0.00, 0.38, 0.90)$ $0.042$ Water pooling on surface* $(0.00, 0.38, 0.90)$ $0.404$ Unstable /Expansive subgrade soils $(0.10, 0.84, 1.00)$ $0.745$ Natural disaster $(0.00, 0.38, 0.90)$ $0.404$ Global warning $(0.00, 0.38, 1.00)$ $0.745$ Trapped moisture in the bottom layers of the pavement $(0.00, 0.73, 1.00)$ $0.654$ Structure $0.00, 0.51, 1.00)$ $0.504$ Structure $0.00, 0.75, 1.00)$ $0.667$ Loss of adhesion in the surface course $(0.00, 0.63, 1.00)$ $0.588$ Structural failure of the bottom layers/movement of the bottom layers $(0.00, 0.54, 1.00)$ $0.525$ Stripping on the bottom of the HMA surface layer $(0.00, 0.53, 1.00)$ $0.505$ Maintenance $0.00, 0.53, 1.00)$ $0.519$ Insufficient funding $(0.00, 0.63, 1.00)$ $0.519$ Shortage of maintenance training activities $(0.10, 0.66, 1.00)$ $0.521$ Poorly maintained drains $(0.00, 0.51, 1.00)$ $0.505$ Mot involving local professional bodies in highway maintenance $(0.00, 0.51, 1.00)$ $0.505$ End result of fatigue cracking $(0.10, 0.78, 1.00)$ $0.505$	Seepage of water through asphalt/longitudinal joints	(0.00, 0.04, 1.00) (0.00, 0.71, 1.00)	0.592	
Instription of the product of the	Water pooling on surface*	(0.00, 0.71, 1.00) (0.00, 0.38, 0.90)	0.404	
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Trapped moisture in the bottom layers of the pavement $(0.00,0.51,1.00)$ $0.504$ StructureDeterioration of aggregates $(0.00,0.84,1.00)$ $0.729$ Ageing of binder in the surface course $(0.00,0.75,1.00)$ $0.667$ Loss of adhesion in the surface layer $(0.00,0.54,1.00)$ $0.588$ Structural failure of the bottom layers/movement of the bottom layers $(0.00,0.54,1.00)$ $0.525$ Stripping on the bottom of the HMA surface layer $(0.00,0.54,1.00)$ $0.525$ MaintenanceLack of supervision or supervision by unprofessional personnel $(0.00,0.53,1.00)$ $0.519$ Insufficient funding $(0.10,0.66,1.00)$ $0.621$ Poorly maintained drains $(0.00,0.49,1.00)$ $0.490$ Not involving local professional bodies in highway maintenance $(0.00,0.51,1.00)$ $0.505$ End result of fatigue cracking $(0.10,0.78,1.00)$ $0.702$	Global warming	(0.00,0.73,1.00)	0.654	
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Stripping on the bottom of the HMA surface layer       (0.00,0.51,1.00)       0.505         Maintenance	Structural failure of the bottom layers/movement of the bottom layers	(0.00,0.54,1.00)	0.525	
Maintenance         Lack of supervision or supervision by unprofessional personnel       (0.00,0.53,1.00)       0.519         Insufficient funding       (0.00,0.53,1.00)       0.519         Shortage of maintenance training activities       (0.10,0.66,1.00)       0.621         Poorly maintained drains       (0.00,0.51,1.00)       0.490         Not involving local professional bodies in highway maintenance       (0.00,0.51,1.00)       0.505         End result of fatigue cracking       (0.10,0.78,1.00)       0.702	Stripping on the bottom of the HMA surface layer	(0.00,0.51,1.00)	0.505	
Lack of supervision or supervision by unprofessional personnel       (0.00,0.53,1.00)       0.519         Insufficient funding       (0.00,0.53,1.00)       0.519         Shortage of maintenance training activities       (0.10,0.66,1.00)       0.621         Poorly maintained drains       (0.00,0.51,1.00)       0.490         Not involving local professional bodies in highway maintenance       (0.00,0.51,1.00)       0.505         End result of fatigue cracking       (0.10,0.78,1.00)       0.702	Maintenance	(0.00.5.55		
Insufficient funding       (0.00,0.53,1.00)       0.519         Shortage of maintenance training activities       (0.10,0.66,1.00)       0.621         Poorly maintained drains       (0.00,0.49,1.00)       0.490         Not involving local professional bodies in highway maintenance       (0.00,0.51,1.00)       0.505         End result of fatigue cracking       (0.10,0.78,1.00)       0.702         *Dispected values are below the phase threshold (\$	Lack of supervision or supervision by unprofessional personnel	(0.00,0.53,1.00)	0.519	
Shortage of maintenance training activities       (0.10,0.66,1.00)       0.621         Poorly maintained drains       (0.00,0.49,1.00)       0.490         Not involving local professional bodies in highway maintenance       (0.00,0.51,1.00)       0.505         End result of fatigue cracking       (0.10,0.78,1.00)       0.702         *Dispatch values are below the phase, threshold (\$	Insutticient funding	(0.00,0.53,1.00)	0.519	
Poorty maintained drams $(0.00, 0.49, 1.00)$ $0.490$ Not involving local professional bodies in highway maintenance $(0.00, 0.51, 1.00)$ $0.505$ End result of fatigue cracking $(0.10, 0.78, 1.00)$ $0.702$ *Dispatch values are below the phase, threshold $(\mathbf{\hat{f}}, \mathbf{\sigma})$ $\mathbf{\sigma}$	Shortage of maintenance training activities	(0.10, 0.66, 1.00)	0.621	
Not involving local professional bodies in highway maintenance $(0.00, 0.51, 1.00)$ $0.505$ End result of fatigue cracking $(0.10, 0.78, 1.00)$ $0.702$ *Disorder duplices are below the phase, threshold $(\mathbf{\hat{f}}, \mathbf{\sigma})$ $\mathbf{\sigma}$	Not involving local professional hadias in history maintenance	(0.00, 0.49, 1.00)	0.490	
End result of falling graph law the phase threshold $(\mathbf{\tilde{s}} - \boldsymbol{\sigma})$ (0.10,0.78,1.00) 0.702	Find result of fotigue cracking	(0.10.0.78.1.00)	0.505	
(1, 1, 2, 2, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3,	*Discorded values are below the phase, threshold ( $\tilde{\mathbf{c}}$ $\sigma$ )	(0.10,0.78,1.00)	0.702	

Table 8: Ranked general causes of pavement distresses

Factors	Category	Sj	Rank
Design			
Underestimated traffic loads	Traffic	0.709	1
Inadequate future traffic forecast	Traffic	0.652	2
Inadequate base thickness	Structural	0.631	3
Inadequate surface drainage	Structural	0.622	4
Inadequate thickness of pavement layers	Structural	0.606	5
Poor drainability of the subbase	Structural	0.604	6
Inadequate preliminary geological investigation	Structural	0.578	7
Inadequate design knowledge	Structural	0.548	8
Construction			
Poor quality control	<b>Construction Process</b>	0.671	1
Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty)	Structural	0.645	2
Poor supervision and workmanship	<b>Construction Process</b>	0.643	3
Inadequate compaction (surface/ subbase / base)	Construction Process	0.629	4
Poor local standard of practice	<b>Construction Process</b>	0.557	5
Poor bond between pavement layers	Structural	0.552	6
Low binder content	Structural	0.538	7
Compaction procedure (use of conventional steel drum roller)	Construction Process	0.522	8
Poor binder to stone adhesion	Structural	0.514	9
Lifespan			
Phenomenal growth of vehicular traffic	Traffic	0.800	1
Unstable /Expansive subgrade soils	Structural	0.745	2
Deterioration of aggregates	Structural	0.729	3
Lack of control regarding load limit carried by vehicles	Traffic	0.696	4
Ageing of binder in the surface course	Structural	0.667	5
Global warming	Environmental	0.654	6
Seepage of water through asphalt/longitudinal joints	Environmental	0.642	7
Over-weight vehicles	Traffic	0.629	8
Shortage of maintenance training activities	Maintenance	0.621	9
Differential settlement	Structural	0.621	10
Seepage of water into the subgrade	Environmental	0.592	11
Lack of supervision or supervision by unprofessional personnel	Maintenance	0.519	12
Insufficient funding	Maintenance	0.519	12
High traffic volume	Traffic	0.508	14
Not involving local professional bodies in highway maintenance	Maintenance	0.505	15
Natural disaster	Environmental	0.490	16
Poorly maintained drains	Maintenance	0.490	16

Distress		Causes	
	nesign	CONSTRUCTION	LITES PAIN
Fatigue/Alligator/ Crocodile Cracking	<ol> <li>Inadequate pavement design for soil condition (0.706)</li> <li>Inadequate surface drainage (0.622)</li> <li>Inadequate thickness of pavement layers (0.606)</li> </ol>	(1) Inadequate compaction (0.629)	<ol> <li>Phenomenal growth of vehicular traffic (0.800)</li> <li>Unstable /Expansive subgrade soils (0.745)</li> <li>Ageing of binder in the surface course (0.667)</li> <li>Astructural failure of the bottom layers/movement of the bottom layers</li> <li>(0.525)</li> <li>(5.525)</li> </ol>
Longitudinal/ Centre Cracking	(1)Inadequate pavement design for soil condition (0.706)		(J)Outsphing on the bottom of the many sources by (10-00) (1)Unstable /Expansive subgrade soils (0.745) (2)High traffic volume (0.508)
	(z) Weak Joints between the adjoining spread of pavement layers (0.448)		(3)Poorly maintained drains (0.490)
Transverse Cracking	(1)Inadequate pavement design for soil condition (0.706)	(1)Inadequate compaction (0.629)	(1)Unstable /Expansive subgrade soils (0.745) (2)High traffic volume (0.508)
Block Cracking			(1)Unstable /Expansive subgrade soils (0.745)
Meandering Cracking	т	(1)Thin asphalt layer over bridges (0.567)	(1)Differential settlement (0.621)
Rutting	<ul> <li>(1)Inadequate pavement design for soil condition</li> <li>(0.706)</li> <li>(2)Faulty design Parameters (0.626)</li> <li>(3)Inadequate thickness of pavement layers (0.606)</li> <li>(4)Poor drainability of the subbase (0.604)</li> </ul>	<ul> <li>(1)Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty) (0.645)</li> <li>(2)Inadequate compaction (0.629)</li> <li>(3)Inadequate constructed surface drainage (0.571)</li> <li>(4)Inadequately prepared subgrade (0.550)</li> </ul>	<ul> <li>(1)Unstable / Expansive subgrade soils (0.745)</li> <li>(2)Seepage of water through longitudinal joints (0.642)</li> <li>(3)Over-weight vehicles (0.629)</li> <li>(4)Stopping &amp; standing traffic (0.563)</li> <li>(5)Structural failure of the bottom layers (0.525)</li> <li>(6)High traffic volume (0.508)</li> <li>(7)Trapped moisture in the bottom layers of the pavement (0.504)</li> </ul>
Bumps	<ul> <li>(1)Inadequate pavement design for soil condition</li> <li>(0.706)</li> <li>(2)Inadequate surface drainage (0.622)</li> </ul>	<ul> <li>(1)Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty) (0.645)</li> <li>(2)Inadequate surface drainage (0.571)</li> </ul>	(1)Unstable /Expansive subgrade soils (0.745)
Corrugations	(1)Lack of stability in the bitumen mix (0.522)		
Shoving	(1)Lack of stability in the bitumen mix (0.522)	(1)Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty) (0.645) (2)Poor bond between pavement layers (0.552)	(1)Unstable /Expansive subgrade soils (0.745) (2)Pushing action by wheels of heavy traffic at the time of acceleration and deceleration (0.529)
Depression	(1)Inadequate pavement design for soil condition (0.706)	<ul><li>(1)Inadequate compaction (surface/ subbase / base)</li><li>(0.629)</li></ul>	(1)Movement of the bottom layers (0.525)
Potholes	<ul> <li>(1)Inadequate pavement structure (0.622)</li> <li>(2)Faulty design Parameters (0.626)</li> <li>(3)Inadequate thickness of pavement layers (0.606)</li> </ul>	(1)Poor bond between pavement layers (0.552) (2)Too thin bituminous surface (0.567)	(1)End result of fatigue cracking (0.702) (2)Seepage of water through asphalt/longitudinal joints (0.642) (3)High traffic volume (0.508)
Patches			
Raveling		<ul> <li>(1)Use of inappropriate aggregates (hydrophilic; naturally smooth uncrushed; dusty) (0.645)</li> <li>(2)Inadequate compaction (surface/ subbase / base)</li> <li>(0.629)</li> <li>(3)Poor binder to stone adhesion (0.514)</li> </ul>	<ul><li>(1)Unstable /Expansive subgrade soils (0.745)</li><li>(2)Ageing of binder in the surface course (0.667)</li><li>(3)Seepage of water through longitudinal joints (0.642)</li></ul>
Asphalt Bleeding			
Polishing			(1)High traffic volume (on an ageing pavement system) (0.508)
Delamination	(1)Inadequate surface drainage (0.622)	(1)Inadequately constructed surface drainage (0.571)	
Edge break	1		(1)Loss of adhesion in the surface layer (0.588)

Table 9: Ranked causes of deterioration for each distress





Figure 1: Overview of the research methodological process

Figure 2: Surveyed highways and locations of the sections (A-J)