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Development Of A Parametric Tool For Road Pavement Failure Assessment: Application Of The Dtcrais Index

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Abstract
This study employs a parametric analysis to refine the Total TDCRAMIS Index (T. TDCRAMIS.I) by Aderinola, 2014 into the Total DTCRAIS Index (T. DTCRAIS.I) for assessing road pavement failure susceptibility. By eliminating the redundant Maximum Dry Density (M) parameter and recalibrating the remaining seven parameters, the DTCRAIS model offers improved accuracy and simplified computation. Field data from 18 monitoring wells across three roads were analyzed, with failure thresholds set at 150 for TDCRAMIS and 120 for DTCRAIS. Results showed a strong correlation between the models, with DTCRAIS consistently identifying failed and stable segments. Validation confirmed the reliability of DTCRAIS, with most segment indices differing by ≤5% compared to TDCRAMIS. DTCRAIS demonstrates a practical and efficient approach for predicting pavement failure, prioritizing road maintenance, and maintaining high accuracy while reducing complexity. This research builds on existing models such as DRAMS (Ola et al., 2009) and TDRAMS (Ola & Olofinmehinti, 2013) and incorporates advancements from TDCRAMIS (Aderinola, 2014), ensuring its relevance for road infrastructure management.

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I. Introduction

Road transportation is essential for efficient mobility and economic development, particularly in urban and rural areas. Globally, it is the most preferred mode of transportation due to its flexibility and ability to meet demand efficiently. Over 90% of domestic passenger and freight movement in Nigeria relies on the road network. However, urban transport challenges, including inadequate infrastructure, congestion, and environmental risks, are compounded by rapid urbanization and unplanned growth. Historically, Nigeria's road transport infrastructure began with mule roads in 1940 and progressed to motor-friendly roads by 1906. Subsequent developments by the Central Government resulted in a coordinated trunk road system linking major administrative centers. By 1980, the road network expanded significantly, with over 114,768 km of roads, including 28,632 km of tarred roads. Despite this expansion, the Nigerian road network has faced persistent issues with design standards, poor drainage, and premature pavement failures.

Road pavement failures are a major concern in Nigeria. They are characterized by potholes, rutting, and cracking, which compromise safety and functionality. These issues result in significant economic losses, including ₦133.8 billion annually from bad roads (Federal Ministry of Works, 2000). The failures often stem from inadequate maintenance and environmental stress. Addressing these challenges requires systematic performance modeling and maintenance planning to effectively predict and prevent road deterioration.

Pavement performance models, such as TDCRAMIS (Aderinola, 2014) and its predecessors (DRAMS (Ola et al., 2009) and TDRAMS (Ola & Olofinmehinti, 2013)), have been developed to evaluate road failure susceptibility. However, existing models often fail to account for complex, interrelated variables and lack accuracy due to unreliable input data and oversimplifications. This research aims to improve the TDCRAMIS model by identifying redundant parameters and developing a refined TDCRAMIS model (DTCRAIS model) to enhance predictive accuracy and assist in prioritizing and optimizing road maintenance.

The Study Area

The study assessed three major federal roads in Ekiti and Ondo States, Nigeria: Akure-Ilesa (68 km), Akure-Ado-Ekiti (45 km), and Akure-Ikare-Akoko (85 km). These roads are strategically positioned within latitudes 7°17'00.85"N to 7°47'22.88"N and longitudes 5°11'11.48"E to 4°30'23.58"E, as determined by survey and topographical maps. Situated within the Precambrian basement complex and the tropical rainforest region of Nigeria, the study area is characterized by a humid climate, dense evergreen vegetation, and an annual rainfall intensity of approximately 1,250 mm. The high moisture content, combined with intense vehicular traffic and geotechnical variations, contributes to recurrent pavement failures in these corridors (Akintorinwa, 2009; Ola et al., 2009; Olofinsae, 2010).

II. Materials And Methods

The development of the DTCRAIS model involved refining the existing TDCRAMIS model to improve its predictive accuracy and eliminate redundant parameters. This process required a systematic approach to reassess the contribution of various factors to road pavement failure, integrate these factors into a cohesive framework, and validate the refined model against field data. Below are the key steps involved:

Field Surveys And Data Collection

Field data were collected from 18 monitoring wells along the selected roads, including 15 failed and 3 stable segments. Data was gathered for the following parameters:

- **Traffic Load (T):** Measured through daily traffic volume counts and converted to Total Equivalent Single Axle Loads (TESA).
- **Depth to Water Table (D):** Monitored over 22 months using wells installed along the road segments.
- **Cross-sectional Area of Drains (C):** Measured to evaluate drainage capacity.
- **Soaked California Bearing Ratio (CBR) (R):** Assessed to determine subgrade soil strength.
- **Cambering (A):** Evaluated using field measurements for cross-slope conformity.
- **Maximum Dry Density (M):** Laboratory-tested for subgrade soil density.
- **Group Index (I):** Calculated based on soil characteristics.
- **Asphalt Thickness (S):** Measured for pavement layer compliance and integrity.

Calibration Of Parameters Using Multiple Regression Analysis

The TDCRAMIS comprises eight parameters contributing to pavement failure: Traffic Load (T), Depth to Water Table (D), Cross-sectional Area of Drains (C), Soaked California Bearing Ratio (CBR) (R), Cambering (A), Maximum Dry Density (M), Group Index (I), and Asphalt Thickness (S). Each parameter was critically evaluated for its significance and interdependence using field data and statistical methods. Parameters with limited impact or significant collinearity, such as Maximum Dry Density, were identified as redundant and removed.

Multiple regression analysis was employed to establish relationships between the parameters and road pavement failure susceptibility. The "Stepwise Method" in SPSS 19.0 was used to identify the most significant predictors, ensuring the elimination of collinear variables through collinearity diagnostics, such as Variance Inflation Factor (VIF). The remaining parameters were assigned relative weights based on their influence on pavement failure. The refined TDCRAMIS model (DTCRAIS model) integrated seven key parameters: Depth to Water Table (D), Traffic Load (T), Cross-sectional Area of Drains (C), Soaked CBR (R), Cambering (A), Group Index (I), and Asphalt Thickness (S). The model used a numerical ranking system, where each parameter is assigned a range subdivided into hierarchical intervals (Table 4). These intervals are rated based on failure susceptibility, and their ratings are multiplied by assigned weights to compute the Total DTCRAIS Index (T. DTCRAIS.I):

DTCRAIS failure susceptibility evaluation model is mathematically expressed thus.

$$T.DTCRAIS.I = D_rD_w + T_rT_w + C_rC_w + R_rR_w + A_rA_w + I_rI_w + S_rS_w$$

Where:

T.DTCRAIS.I is the Total DTCRAIS Index. That is, the total failure susceptibility value

D_r is Rating assigned to Depth to water

D_w is Weight assigned to Depth to the water table

T_r is Rating assigned to the Traffic Load

T_W is Weight assigned to Traffic Load

C_r is Rating assigned to the cross-sectional area of drains C_w is Weight assigned to the cross-sectional area of drains R_r is Rating assigned to CBR

R_w is Weight assigned to CBR

A_r is Rating assigned to Cross-section slope A_w is Weight assigned to Cross-section slope I_r is Rating assigned to Index (Group Index) I_w is Weight assigned to Index (Group Index) S_r is Rating assigned to Asphalt thickness S_w is Weight assigned to Asphalt thickness

Parametric Analysis And Validation

Field-measured data were substituted into the TDCRAMIS and DTCRAIS models to calculate indices for all monitoring wells. These indices were compared to validate the DTCRAIS model's accuracy against TDCRAMIS, particularly in identifying failed and stable segments.

- **TDCRAMIS**: Stable Segments: Total index ≤150, Failed Segments: Total index >150
- **DTCRAIS**: Stable Segments: Total index ≤120, Failed Segments: Total index >120

The comparison focused on evaluating the alignment between TDCRAMIS and DTCRAIS indices to determine if both models consistently identified failed and stable segments.

III. Results And Discussions

Figure 1 shows the Map of Roads under study. The study assessed road pavement failure across three major roads in Ekiti and Ondo states using the TDCRAMIS model, an enhancement of previous point count systems like TDRAMS and DRAMS. The model employed eight parameters (T, D, C, R, A, M, I, S) to calculate a failure susceptibility index. Results were validated using field data.

Regression Analysis

The development of the DTCRAIS model involved a systematic approach using stepwise regression analysis and collinearity diagnostics to refine the original TDCRAMIS model. This process aimed to identify the most significant predictors of pavement failure susceptibility while removing redundant variables to enhance accuracy and efficiency. Tables 1, 2, and 3 collectively outline the key findings from this refinement process, emphasizing the significance of specific parameters and the resolution of multicollinearity issues.

Table 1 details the exclusion of variables from the original TDCRAMIS model. Through stepwise regression, parameters were evaluated for statistical significance ($p < 0.05$), their contribution to the model, and multicollinearity. Depth to Water Table (D) emerged as the strongest predictor across all iterations, demonstrating a high partial correlation and statistical significance ($p < 0.001$). In contrast, Maximum Dry Density (M) was identified as redundant due to its weak correlation (low partial correlation) and lack of significance ($p > 0.05$). Parameters such as Traffic Load (T), Cross-sectional Area of Drains (C), and Soaked CBR (R) were found to be highly significant and were consistently retained in the model, indicating their critical role in assessing pavement performance.

Table 2 further shows the regression coefficients for the refined DTCRAIS model, which quantifies the influence of each parameter on pavement failure susceptibility. Depth to Water Table (D) had the most substantial negative influence, with high standardized Beta coefficients (e.g., -0.519 in the final model), indicating its strong impact on increasing pavement failure susceptibility. Traffic Load (T) consistently showed positive contributions (e.g., Beta = 0.45 in the final model), further reinforcing its importance in determining pavement performance. Cross-sectional Area of Drains (C) had a significant negative impact, highlighting the necessity of adequate drainage systems to mitigate pavement failure. Other parameters, such as Soaked CBR (R), Cambering (A), and Group Index (I), maintained statistical significance, while Asphalt Thickness (S) had a smaller yet relevant role in the model.

Table 3 focuses on collinearity diagnostics, which provided insights into multicollinearity among predictors and confirmed the robustness of the final DTCRAIS model. Early iterations showed high Condition Index values (>15), indicating potential multicollinearity issues. These were resolved by removing redundant variables, such as Maximum Dry Density (M). Depth to Water Table (D) and Traffic Load (T) consistently demonstrated high variance proportions, underscoring their critical contributions to the model. The final model achieved balanced contributions across predictors, with reduced multicollinearity and improved stability.

In summary, the analysis outlined in Tables 1, 2, and 3 highlights the iterative refinement process that led to the development of the DTCRAIS model. By retaining significant predictors such as Depth to Water Table (D), Traffic Load (T), and Cross-sectional Area of Drains (C) while eliminating redundant variables, the model became both statistically valid and practical. The final DTCRAIS model resolves multicollinearity issues and offers improved predictive accuracy and efficiency, making it a reliable tool for evaluating pavement failure susceptibility and prioritizing road maintenance activities.

Model Calibration

Table 4 shows the DTCRAIS Rating System and Weights, which are the calibrated parameters used in the DTCRAIS model to evaluate road pavement failure susceptibility. This table organizes critical variables, including Depth to Water Table (D), Traffic Load (T), Cross- sectional Area of Drains (C), Sub-grade Soaked CBR (R), Cambering (A), Soil Index (I), and Asphalt Thickness (S), into ranges with assigned mean values, ratings, and weights. Each parameter range represents observed real-world variability, ensuring the model reflects actual field conditions. While the DTCRAIS model effectively emulates and enhances the TDCRAMIS model by refining its parameter structure and computational efficiency, it maintains the core methodology of assigning numerical ratings and weights to evaluate pavement failure susceptibility. Both models adopt a hierarchical system where critical parameters influence road stability. This calibration process is crucial for optimizing the DTCRAIS model. It aligns the model's parameters with real-world data, ensuring its predictions are accurate and actionable. By refining parameter ranges and their respective influences, the model eliminates redundancy, as demonstrated by the exclusion of **Maximum Dry Density (M)** due to its negligible contribution. This focus on impactful variables enhances the model's efficiency while maintaining its predictive power.

Parametric Analysis Of The Dtcrais Model

The parametric analysis of the DTCRAIS model evaluates the contribution of individual parameters to the overall failure susceptibility of roads under study. Using Tables 5, 6 and 7, the analysis highlights the impact of seven critical factors: Depth to Water Table (D), Traffic Load (T), Cross-sectional Area of Drains (C), Sub-grade CBR (R), Cambering (A), Index (I), and Asphalt Thickness (S). Each parameter is assigned a rating and weight based on its relative importance, which is then used to compute the Total DTCRAIS Index for monitoring wells along the roads.

The Depth to Water Table (D) emerged as a significant determinant of pavement failure, as shallow water tables consistently received the highest ratings and weights. For example, MW1 on the Akure-Ilesa Road (Table 5) had a depth of 0.32m, receiving a maximum rating of 10 and contributing 70 points to its Total DTCRAIS Index of 294. Similarly, Traffic Load (T) was a dominant factor, with higher traffic loads correlating with greater failure susceptibility. Drainage deficiencies, represented by the Cross-sectional Area of Drains (C), also played a key role in pavement failures. Poor drainage systems, such as those observed in MW3 on the Akure-Ikare-Akoko Road (Table 11) with a cross-sectional area of 0.03m², resulted in low ratings but substantial contributions to the Total DTCRAIS Index. Sub-grade strength, as measured by Soaked CBR (R), was another critical factor. Similarly, poor cambering values and thin asphalt thickness exacerbated the failure susceptibility of road segments, as evidenced by MW3 on the Akure-Ado-Ekiti Road (Table 6).

Failure Analysis

The failure analysis applied the DTCRAIS model classifies the road segments into failed or stable categories based on their Total DTCRAIS Index. As outlined in Tables 8, the model used a threshold of 120 to differentiate between failed (indices above 120) and stable (indices below or equal to 120) segments. On the Akure-Ilesa Road, four out of five monitoring wells (MW1, MW2, MW3, and MW5) were classified as failed, with indices ranging from 185 to 294. Only MW4, with an index of 113, was classified as stable. A similar pattern was observed on Akure- Ad0-Ekiti Road, were five out of six monitoring wells were classified as failed, with MW6 (Index = 111) being the only stable segment. Similarly, the Akure-Ikare-Akoko Road had six of its seven monitoring wells classified as failed, with MW2 (Index = 114) as the sole stable segment.

The DTCRAIS failure threshold of 120 represents a refinement of the threshold used in the TDCRAMIS model, which was set at 150. This lower threshold reflects the improved sensitivity of the DTCRAIS model in detecting failure-prone segments. By capturing more nuanced differences in parameter contributions, the DTCRAIS model ensures a more precise classification of road segments, enhancing its utility for infrastructure management.

IV. Comparison And Validation

Table 9 provides a summary of the Total DTCRAIS Index Failure Susceptibility Analysis across three major roads, offering insights into how the DTCRAIS model compares to the TDCRAMIS model in assessing pavement failure. By analyzing both models' classifications and validation results, their relative performance and reliability in predicting failure-prone segments are better understood.

Comparison

1. **Failure Thresholds**:
   - o **TDCRAMIS**: The failure threshold is set at **150**. Segments with indices ≤150 are classified as stable, while indices >150 indicate failure.
   - o **DTCRAIS**: The failure threshold is refined to **120**, reflecting a more sensitive model that captures subtler variations in road conditions.
2. **Accuracy of Classification**:
   - o Across the three roads, the DTCRAIS model consistently identified the same segments as failed or stable as the TDCRAMIS model but with a more refined threshold.
   - o For example, on the **Akure-Ilesa Road**, DTCRAIS classified MW4 as stable (113) and MW1, MW2, MW3, and MW5 as failed, aligning with TDCRAMIS results but with lower index values due to recalibrated weights and improved parameter sensitivity.
3. **Refined Parameters**:
   - o DTCRAIS eliminated the redundant Maximum Dry Density (M) parameter, which contributed minimally to the failure prediction in TDCRAMIS. This refinement reduced model complexity without compromising accuracy.
   - o The recalibrated weights in DTCRAIS improved its ability to prioritize parameters such as Depth to Water Table (D), Traffic Load (T), and Cross- sectional Area of Drains (C), which have stronger correlations with pavement failure.

Validation

DTCRAIS was validated by comparing its results with TDCRAMIS and field observations. Key findings include:

1. **Correlation**: The DTCRAIS model exhibited a high correlation (R = 0.80) with the TDCRAMIS model, indicating that both models are strongly aligned in their classification of failed and stable segments.
2. **Error Margins**: Most segments analyzed by DTCRAIS showed error margins of ≤5% when compared to TDCRAMIS indices, confirming its reliability. DTCRAIS provided more nuanced classifications, capturing variations within segments that TDCRAMIS overlooked.
3. **Practical Utility**: DTCRAIS's lower failure threshold allows for earlier detection of failure-prone segments, providing an opportunity for proactive maintenance. By aligning closely with observed field conditions, DTCRAIS demonstrated its validity as a predictive tool for pavement failure assessment.

V. Conclusion

This study successfully refined the Total TDCRAMIS Index (T. TDCRAMIS.I) into the Total DTCRAIS Index (T. DTCRAIS.I), addressing redundancies and improving accuracy for evaluating road pavement failure susceptibility. By eliminating the Maximum Dry Density (M) parameter and recalibrating the remaining seven parameters, the DTCRAIS model provided a more streamlined yet robust assessment approach. The comparative analysis showed a strong correlation between the two models, with most segment indices differing by less than 5%. This minor numerical variation demonstrates the improved sensitivity of DTCRAIS, particularly in its emphasis on Depth to Water Table (D) and Traffic Load (T) as significant contributors to failure susceptibility. The refined failure threshold (120 for DTCRAIS compared to 150 for TDCRAMIS) allowed for better differentiation of pavement conditions, ensuring reliable identification of at-risk segments.

Validation confirmed that DTCRAIS effectively replicates the performance of TDCRAMIS while simplifying computation and improving predictive capabilities. These findings established DTCRAIS as a practical and reliable tool for prioritizing and optimizing road maintenance and mitigating pavement failures, making it highly suitable for road infrastructure management in resource-constrained settings. This advancement builds on models like DRAMS and TDRAMS while addressing their limitations, ensuring relevance and applicability in real-world scenarios while future studies could focus on integrating additional environmental factors to further enhance the model's robustness and adaptability.

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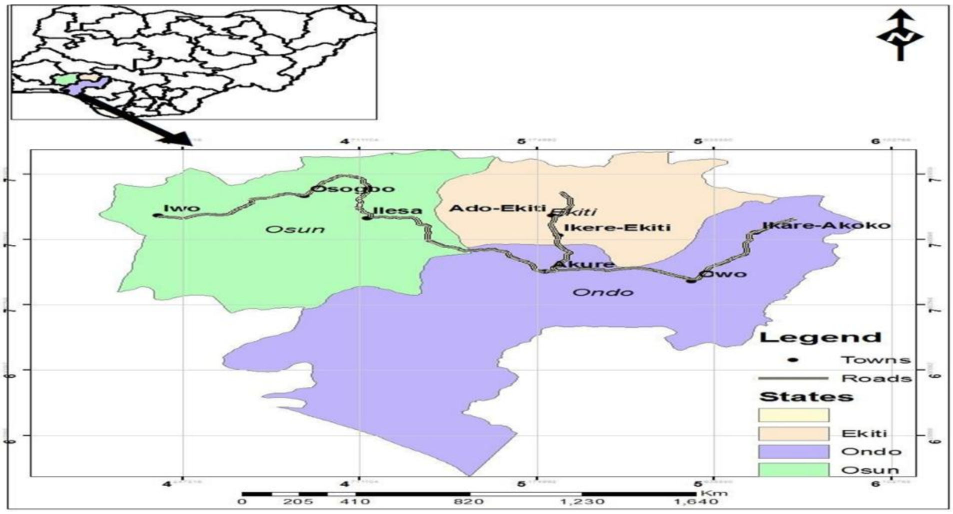

Figure 1: Map of the study area showing the three roads

Table 1: Summary of Excluded Variables from the TDCRAMIS Model.

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	T	.582[a]	6.171	.000	.717	.999	1.001	.999
	C	-.517[a]	-4.950	.000	-.636	.995	1.005	.995
	R	-.453[a]	-4.028	.000	-.557	.997	1.003	.997
	A	-.305[a]	-2.356	.024	-.366	.945	1.058	.945
	M	-.080[a]	-.586	**.562**	-.097	.971	1.030	.971
	I	.369[a]	3.014	.005	.449	.974	1.026	.974
	S	-.418[a]	-3.459	.001	-.499	.941	1.063	.941
2	C	-.408[b]	-5.831	.000	-.702	.946	1.057	.946
	R	-.378[b]	-5.201	.000	-.660	.977	1.024	.977
	A	-.292[b]	-3.434	.002	-.502	.945	1.059	.944
	M	-.102[b]	-1.066	**.294**	-.177	.970	1.031	.970
	I	.245[b]	2.712	.010	.417	.922	1.085	.922
	S	-.363[b]	-4.671	.000	-.620	.932	1.073	.932
3	R	-.313[c]	-6.684	.000	-.754	.942	1.062	.912
	A	-.258[c]	-4.616	.000	-.621	.937	1.067	.937
	M	-.056[c]	-.806	**.426**	-.137	.957	1.045	.934
	I	.152[c]	2.195	.035	.352	.866	1.155	.866
	S	-.173[c]	-1.980	.056	-.322	.563	1.776	.563
4	A	-.153[d]	-3.393	.002	-.509	.771	1.297	.771
	M	.031[d]	.634	**.531**	.110	.885	1.130	.871
	I	.125[d]	2.785	.009	.436	.859	1.164	.859
	S	-.101[d]	-1.680	.102	-.281	.544	1.840	.544
5	M	.019[e]	.445	**.659**	.078	.879	1.138	.713
	I	.120[e]	3.145	.004	.486	.858	1.166	.770
	S	-.091[e]	-1.732	.093	-.293	.542	1.845	.542
6	M	-.019[f]	-.467	**.644**	-.084	.797	1.254	.696
	S	-.123[f]	-2.777	.009	-.446	.523	1.912	.522
7	M	.020[g]	.519	.608	.094	.692	1.445	.454
a. Predictors in the Model: (Constant), D								
b. Predictors in the Model: (Constant), D, T								
c. Predictors in the Model: (Constant), D, T, C								
d. Predictors in the Model: (Constant), D, T, C, R								
e. Predictors in the Model: (Constant), D, T, C, R, A								
f. Predictors in the Model: (Constant), D, T, C, R, A, I								
g. Predictors in the Model: (Constant), D, T, C, R, A, I, S								
Dependent Variable: I								

Table 2: Estimates of the Coefficients for the DTCRAIS Model.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	246.05	10.453		23.539	0		
	D	-29.891	6.812	-0.585	-4.388	0	1	1
	(Constant)	145.195	17.934		8.096	0		
2	D	-30.866	4.816	-0.604	-6.409	0	0.999	1.001
	T	0.84	0.136	0.582	6.171	0	0.999	1.001
	(Constant)	201.948	16.203		12.464	0		
3	D	-32.141	3.486	-0.629	-9.221	0	0.995	1.005
	T	0.709	0.101	0.491	7.035	0	0.95	1.053
	C	-188.932	32.4	-0.408	-5.831	0	0.946	1.057
	(Constant)	226.125	11.396		19.842	0		
	D	-30.996	2.331	-0.607	-13.296	0	0.99	1.01
4	T	0.665	0.068	0.46	9.835	0	0.94	1.063
	C	-160.989	22.011	-0.348	-7.314	0	0.912	1.096
	R	-1.154	0.173	-0.313	-6.684	0	0.942	1.062
	(Constant)	232.769	10.151		22.931	0		
	D	-29.349	2.095	-0.574	-14.012	0	0.937	1.068
5	T	0.673	0.059	0.466	11.391	0	0.939	1.066
	C	-160.514	19.238	-0.347	-8.343	0	0.912	1.096
	R	-0.916	0.166	-0.248	-5.506	0	0.774	1.291

	A	-6.61	1.948	-0.153	-3.393	0.002	0.771	1.297
	(Constant)	225.079	9.335		24.111	0		
	D	-28.32	1.888	-0.554	-15.004	0	0.908	1.101
	T	0.644	0.053	0.446	12.096	0	0.91	1.098
6	C	-147.918	17.538	-0.319	-8.434	0	0.864	1.157
	R	-0.886	0.148	-0.24	-5.985	0	0.771	1.297
	A	-6.417	1.73	-0.149	-3.709	0.001	0.77	1.299
	I	2.274	0.723	0.12	3.145	0.004	0.858	1.166
	(Constant)	242.004	10.449		23.162	0		
	D	-26.506	1.836	-0.519	-14.436	0	0.793	1.26
	T	0.65	0.048	0.45	13.409	0	0.909	1.1
7	C	-112.051	20.519	-0.242	-5.461	0	0.522	1.916
	R	-0.825	0.136	-0.223	-6.051	0	0.751	1.331
	A	-6.134	1.577	-0.142	-3.891	0	0.767	1.304
	I	2.62	0.669	0.138	3.916	0	0.828	1.208
	S	-709.683	255.536	-0.123	-2.777	0.009	0.523	1.912

Table 3: Collinearity Diagnostics for DTCRAIS Model

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions							
				(Constant)	D	T	C	R	A	I	S
1	1	1.698	1	0.15	0.15						
	2	0.302	2.369	0.85	0.85						
2	1	2.555	1	0.01	0.06	0.01					
	2	0.398	2.534	0.03	0.93	0.04					
	3	0.047	7.37	0.96	0.02	0.95					
3	1	3.293	1	0	0.03	0.01	0.02				
	2	0.458	2.68	0	0.85	0	0.09				
	3	0.213	3.935	0.02	0.09	0.15	0.6				
	4	0.035	9.642	0.98	0.03	0.83	0.29				
4	1	4.027	1	0	0.02	0	0.01	0.01			
	2	0.477	2.906	0	0.85	0	0.06	0.04			
	3	0.257	3.962	0.02	0.04	0.09	0	0.74			
	4	0.206	4.421	0.01	0.07	0.09	0.72	0.14			
	5	0.033	10.986	0.97	0.02	0.82	0.21	0.07			
5	1	4.853	1	0	0.01	0	0.01	0.01	0.01		
	2	0.477	3.19	0	0.81	0	0.06	0.03	0		
	3	0.276	4.194	0.02	0	0.07	0.08	0.42	0.1		
	4	0.219	4.712	0.01	0.14	0.1	0.59	0.01	0.08		
	5	0.142	5.844	0	0.03	0.03	0.07	0.51	0.8		
	6	0.033	12.134	0.97	0.01	0.79	0.21	0.03	0.02		
6	1	5.294	1	0	0.01	0	0.01	0.01	0.01	0.01	
	2	0.652	2.849	0	0.13	0	0.01	0.02	0.01	0.49	
	3	0.463	3.38	0	0.65	0	0.08	0.07	0	0.05	
	4	0.259	4.517	0.01	0.01	0.01	0.33	0.31	0.13	0.03	
	5	0.165	5.666	0.01	0.19	0.12	0.15	0.31	0.28	0.25	
	6	0.134	6.28	0.02	0	0.17	0.19	0.26	0.55	0.15	
	7	0.032	12.82	0.97	0.02	0.69	0.24	0.03	0.02	0.03	
7	1	6.251	1	0	0.01	0	0	0	0	0.01	0
	2	0.652	3.095	0	0.11	0	0	0.01	0.01	0.48	0
	3	0.467	3.66	0	0.57	0	0.05	0.05	0	0.05	0
	4	0.274	4.778	0	0.01	0.01	0.15	0.32	0.15	0.03	0
	5	0.165	6.155	0.01	0.16	0.13	0.08	0.3	0.28	0.24	0
	6	0.134	6.821	0.01	0	0.16	0.13	0.26	0.54	0.15	0
	7	0.04	12.502	0.23	0.07	0.61	0.4	0.05	0.01	0.04	0.17
	8	0.017	19.27	0.75	0.07	0.09	0.19	0	0	0.01	0.82

Table 4: DTCRAIS Rating System and Weights

Parameter	Range	Mean	Rating	Weight
[D] Depth to water table (m)	**0 - 0.4**	**0.2**	**10**	**7**
	0.4 - 0.8	**0.6**	**8**	
	0.8 - 1.2	**1**	**6**	
	1.2 - 1.8	**1.5**	**4**	
	1.8 - 2.2	**2**	**3**	
	2.2- 2.6	**2.4**	**2**	
	2.6 – 3.00+	**2.8**	**1**	
	0-25	**12.5**	**1**	
	25-50	**37.5**	**2**	
	50-75	**62.5**	**5**	

[T] Traffic Load (KN)	**75-100**	**87.5**	**8**	**6**
	100-125	**112.5**	**10**	
	125-150	**137.5**	**12**	
	150-175	**165.5**	**14**	
	175-200	**187.5**	**16**	
	200+		**18**	
[C] Cross-sectional Area of Drain (m2)	**0-0.05**	**0..025**	**10**	**5**
	0.05-0.10	**0.075**	**8**	
	0.10-0.15	**0.125**	**6**	
	0.15-0.20	**0.175**	**5**	
	0.20-0.25	**0.225**	**4**	
	0.25-0.30	**0.275**	**3**	
	0.30-0.35	**0.325**	**2**	
	0.35+		**1**	
[R] Sub-grade CBR Soaked (%)	**0-10**	**5**	**9**	**4**
	0-20	**15**	**7**	
	20-30	**25**	**5**	
	30-40	**35**	**4**	
	40-50	**45**	**2**	
	50+		**1**	
[A] Cambering (%)	**0-0.75**	**0.375**	**8**	**3**
	0.75-1.50	**1.125**	**7**	
	1.50-2.25	**1.875**	**5**	
	2.25-3.00	**2.625**	**3**	
	3.00-3.75	**3.375**	**2**	
	3.75+		**1**	
[I] Index (Group)	**0-2**	**1**	**1**	**2**
	2-4	**3**	**2**	
	4-6	**5**	**4**	
	6-8	**7**	**6**	
	8-10	**9**	**7**	
	10-12	**11**	**8**	
	12-14	**13**	**9**	
	14+		**10**	
[S] Asphalt Thickness (m)	**0-0.01**	**0.005**	**7**	**1**
	0.01-0.02	**0.015**	**6**	
	0.02-0.03	**0.025**	**5**	
	0.03-0.04	**0.035**	**4**	
	0.04-0.05	**0.045**	**2**	
	0.05+		**1**	

Table 5: DTCRAIS Index Equation Analysis For Akure – Ilesa Road (Sub-grade)

FACTORS	**Data on monitoring wells**					**Rating**					**Weight**	**Index value for monitoring wells**				
	MW1	**MW2**	**MW3**	**MW4**	**MW5**	**MW1**	**MW2**	**MW3**	**MW4**	**MW5**		**MW1**	**MW2**	**MW3**	**MW4**	**MW5**
D (Depth to water table at Failed Section(m)	0.32	2.78	0.62	2.67	0.39	10	1	8	1	10	7	70	7	56	7	70
T (Traffic load at Failed Section (KN))	190	190	190	144	144	16	16	16	12	12	6	96	96	96	72	72
C (Cross-sectional area of drains at Failed section(m^2))	0	0.2	0.14	0.4	0.13	10	5	6	1	6	5	50	25	30	5	30
R (soaked CBR at Failed section(%))	6	20	21.2	40	26.4	9	7	5	3	5	4	36	28	20	12	20
A (Cambering of failed section (%))	0.8	0	2.3	3.2	1.2	7	8	3	2	5	3	21	24	9	6	15
I (Index of soil(group) at Failed	11	1	1	6	6	8	1	1	5	5	2	16	2	2	10	10

section)																
S (Asphalt Thickness at failed section(m))	0.03	0.04	0.03	0.06	0.04	5	3	5	1	3	1	5	3	5	1	3
						Total DTCRAIS index						**294**	**185**	**218**	**113**	**220**

Table 6: DTCRAIS Index Equation Analysis for Akure – Ado-Ekiti Road (Sub-grade)

FACTORS	**Data on monitoring wells**						**Rating**						**Weight**	**Index value for monitoring wells**					
	MW 1	**MW 2**	**MW 3**	**MW 4**	**MW 5**	**MW 6**	**MW 1**	**MW 2**	**MW 3**	**MW 4**	**MW 5**	**MW 6**		**MW 1**	**MW 2**	**MW 3**	**MW 4**	**MW5**	**MW 6**
D (Depth to water table at Failed Section(m)	0.74	0.2	0.6	1.64	0.91	2.6	8	10	8	4	6	2	7	56	70	56	28	42	14
T (Traffic load at Failed Section (KN))	136	136	136	73	73	73	12	12	12	5	5	5	6	72	72	72	30	30	30
C (Cross-sectional area of drains at Failed section(m^2))	0.12	0.36	0.41	0.17	0.05	0.17	6	1	1	5	9	5	5	30	5	5	25	45	25
R (soaked CBR at Failed section(%))	13	18	11	10	10	19	7	7	7	8	8	7	4	28	28	28	32	32	28
A (Cambering of failed section (%))	0	2.6	2.4	3.6	2.2	2.6	8	3	3	2	5	3	3	24	9	9	6	15	9
I (Index of soil(group) at Failed section)	2	3	2	0	6	0	2	2	2	1	5	1	2	4	4	4	2	10	2
S (Asphalt Thickness at failed section(m))	0.03	0.04	0.05	0.03	0.04	0.04	5	3	2	5	3	3	1	5	3	5	5	3	3
							Total DTCRAIS index							**219**	**191**	**179**	**128**	**177**	**111**

Table 7: DTCRAIS Index Equation Analysis For Akure-Ikare-Akoko Road (Sub-grade)

FACTORS	**Data on monitoring wells**							**Rating**							**Weight**	**Index value for monitoring wells**						
	MW 1	**MW 2**	**MW 3**	**MW 4**	**MW 5**	**MW 6**	**MW 7**	**MW 1**	**MW 2**	**MW 3**	**MW 4**	**MW 5**	**MW 6**	**MW 7**		**MW 1**	**MW 2**	**MW 3**	**MW 4**	**MW 5**	**MW 6**	**MW 7**
D (Depth to water table at Failed Section(m)	0.32	2.7	0.21	0.85	1.13	0.01	0.4	10	1	10	6	4	10	10	7	70	7	70	42	28	70	70
T (Traffic load at Failed Section (KN))	268	149	149	149	79	79	79	18	12	12	12	8	8	8	6	108	72	72	72	48	48	48
C (Cross-sectional area of drains at Failed	0.15	0.33	0.03	0.06	0.18	0.15	0.11	6	2	10	8	5	6	6	5	30	10	50	40	25	30	30

section(m^2))																						
R (soaked CBR at Failed section(%))	8.1	42	5.8	12.5	13.3	10	7.8	9	2	9	7	7	7	9	4	36	8	36	28	28	28	36
A (Cambering of failed section (%))	3.1	3.8	1.6	1.5	0	1.6	0	2	1	5	6	8	5	8	3	6	3	15	18	24	15	24
I (Index of soil(group) at Failed section)	1	7	11	4	1	1	5	1	6	8	3	1	1	4	2	2	12	16	6	2	2	8
S (Asphalt Thickness at failed section(m))	0.035	0.05	0.03	0.03	0.04	0.03	0.02	4	2	5	5	3	5	6	1	4	2	5	5	3	5	6
								Total DTCRAIS index								**256**	**114**	**264**	**211**	**158**	**198**	**222**

Table 8: Total DTCRAIS Index Failure Susceptibility Analysis of the Roads under Study

Roads	Number of Monitoring well	Monitoring Wells Total DTCRAIS Indices	
		FAIL (121 and above)	**PASS (0-120)**
Akure-Ilesha	5	MW1(294),MW2(185), MW3(218), and MW5 (220)	MW4(113)
Akure- Ado-Ekiti	6	MW1(219), MW2(191) , MW3 (176), MW4(128) and MW5(177)	MW6 (111)
Akure-Owo- Ikare	7	MW1(256),MW3(264),MW4 (211),MW5(158),MW6(198) and MW7(222) .	MW2 (114)

Table 9: Total DTCRAIS Index Failure Susceptibility Analysis of the Roads under Study in comparison with TDCRAMIS

Roads	Number of Monitoring well	Monitoring Wells Total TDCRAMIS Indices		Monitoring Wells Total DTCRAIS Indices	
		FAIL (151 and above)	**PASS (0-150)**	**FAIL (121 and above)**	**PASS (0-120)**
Akure-Ilesha	5	MW1(358),MW2(243), MW3(245), and MW5 (266)	MW4(146)	MW1(294),MW2(185), MW3(218), and MW5 (220)	MW4(113)
Akure-Ado-Ekiti	6	MW1(270), MW2(232) , MW3 (217), MW4(162) and MW5(218)	MW6 (141)	MW1(219), MW2(191) , MW3 (176), MW4(128) and MW5(177)	MW6 (111)
Akure-Owo- Ikare	7	MW1(315),MW3(334),MW4 (278),MW5(206),MW6(238) and MW7(267)	MW2(149)	MW1(256),MW3(264),MW4(211), MW5(158),MW6(198) and MW7(222) .	MW2(114)