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IDENTIFICATION OF TYRE FAILURE RISK FACTORS IN AUTOMOBILE CRASHES: A MLR MODEL TECHNIQUE

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Abstract: Appropriate tyre safety practices are among the fundamental approaches that minimize technical failure risk factors in automobiles. This study developed a multiple linear regression (MLR) model that depicts the effect of tyre safety awareness and consequent approach predictor variables on technical failure risk response variable in automobile crashes. The data for this study was obtained from a total number of one hundred and thirteen (113) vehicle owners in Abeokuta metropolis of Ogun state Nigeria using a mixed-method quantitative research approach. Data analysis showed that the level of awareness and the consequent approaches regarding tyre failure risk factors in automobile crashes significantly affect automobile technical failure risk crashes. The technical failure risk response variable of the MLR model developed, and the survey data recorded a percentage variation of 3.54% with a strong positive correlation between the two datasets significant at $p < 0.01$ for a value of $r = 0.962$. This, therefore, demands adequate public sensitization measures on tyre safety and its implication in failure risk crash factors as well as stringent enforcement by relevant agencies as this study has revealed that tyre safety awareness and handling approaches have a significant effect on technical failure risk factors in automobiles.
Keywords: safety, awareness, approaches, tyre, multiple linear regression

1. INTRODUCTION

Model basis of all cultural, political and socio-economic physical contact or meeting between two or more people in different geographical locations is only possible with a viable means of movement (Azodo and Mezue, 2016). According to Sumaila (2013), the road mode of transportation is the greatest culprit of all the transportation modes depicted in the associated most disturbing repercussion traffic accident of its use. Despite the policies and approaches to check and reduce the incidence rate in road accidents in Nigeria, the nation has continued ranking as one of the worst affected countries in the world (Ukoji, 2014). A nation with a human population of about 167 million people with a vehicular population estimated at over 7.6 million used on a total road length of about 194,000 kilometres (comprising 34,120 km of federal, 30,500 km of state, and 129,580 km of local roads) has suffered severe losses to fatal car accidents (as cited on Ukoji, 2014). Iteke *et al*. (2011) stated that road traffic accidents, especially the avertable ones, have continued to amplify morbidity and mortality records in most sub-Saharan African countries. The direct implication of road traffic causalities is depicted in the loss of a competent and capable labour force, which affects the nation's economy and, consequently, results in low productivity.

Road accidents are generally associated with one or a combination of the following factors; human, vehicle, road and environmental factors (AUSTROADS, 1994). These road traffic accidents were also presented in research studies as driver, highway, and motor vehicle variables (Aaron and Strasser, 1990; Balogun and Abereoje, 1992; Luby *et al*., 1997; Mock *et al*., 1999). The outlined accident causation factors in the developing nations of the world conscientiously and expansively represented in works of literature include low road construction standards, poor road conditions and traffic infrastructure, poor maintenance culture, the rapid urbanization process, high population growth rates, reckless driving, little or no appropriate safety measures, non-adherence to the road traffic safety rules and regulations and high dependency on public transport for daily movement (Pierce and Maunder, 1998; Nantulya and Reich, 2002; WHO, 2009 and Yankson *et al*., 2010). In addition to the above factors considered in the literature found in the literature is the vehicle's roadworthiness. Maintaining one vehicle by paying particular attention to the tyres, brakes, steering, and other safety systems enhances vehicle safety.

The fundamental aspects of tyre-related usage and safety maintenance factors that collectively effectuate automobile technical failure risk crashes include tyre inflation pressure, tyre tread depth, tyre age, and meteorological influence (Scott and Compton, 1978). The roadworthiness of road vehicle is a combination of these tyre condition (tyre inflation pressure, tyre treads depth, tyre age, and meteorological influence) as it affects the grip level and the wear pattern of tyre-road contact for road vehicle steerability, stability, driving comfort and ride safety (Jansen *et al*., 2016; Azodo, 2017; Lupker *et al*., 2002). The benefit of these standards goes beyond safety advantages to economic and security paybacks. Studies in the literature highlighted fuel consumption efficiency, normal tyre wear, attainment of tyre lifetime expectancy, load-carrying ability, nominal rolling resistance, reduced noise and carbon dioxide emissions as some benefits of effective tyre-related usage and safety maintenance (Hamed *et al*., 2014; Kubba and Jiang, 2014; Varghese, 2013; Guvenc. 2008; Mock and Vollm, 1997). The consequences of non-compliance to tyre-related usage and safety maintenance factors result in diverse functional dimensions of technical failures of tyres in automobile crash incidences, including tyre blowout, flat tyres, and tyre deficiency tyre failure and tyre degradation. Not roadworthy accident category is significantly attributed to tyres that burst because of their being severely worn or incorrectly inflated. Blow out of tyres was attributed by Obuekwe *et al*. (2003) as the main mechanism responsible for technical failure associated crashes. Brittle and cracked outer edges, water permeation tendency into the tyre, and lack of heat resistance and strength of the polymers of the rubber tyre are degradation of tyre attributes that result in technical failures of tyres in automobile crash incidences (Azodo *et al*., 2018). Structural failure of tyre witnessed in deficiency in increased vehicle vibrations, impact breaks, tread separation, bruise damage, and tread cuts/penetration, in-vehicle performances usually emanates from inappropriate inflation pressure thereby inducing internal structure fatigue breakdown on the tyres and consequent tyre structural failure (Daws, 2010; Hamed *et al*., 2014). Tyres that have outlived useful working life have a deficiency in their usefulness and safety standard as they are to be defective in their intended functions such as vibration-reduction ability, cushioning effect, potential hydroplaning and flexing action (Azodo *et al*., 2018). According to the national highway traffic safety administration, a flat tyre has contributed significantly to the road vehicle crashes statistics. These diverse functional dimensions of technical failures of tyres in automobile crash incidences outline the significance of conforming to the road vehicle tyre standard road through regular observation and prompt maintenance.

Inspection and identification of vehicle tyres for operation status and defect by drivers/vehicle owners' are safe practices towards eliminating the potential technical failure in automobiles. However, averting or minimising technical failure risk factors in automobiles through effective tyre safety practices depends on the concerned individual's awareness and compliance to safe operation-specific vehicle tyres. This study, therefore, developed a multiple linear regression (MLR) model that depicts the effect of tyre safety awareness and consequent approach predictor variables on technical failure risk response variable in automobile crashes.

2. MATERIALS AND METHOD

The sequence followed in achieving the objective of this study is presented in figure 1. These include data collection, computation and analysis of obtained data, development of MLR model using the dataset, evaluation of MLR model developed and result presentation.

Figure 1. The process flow diagram in achieving the objective of this study

This was primary data from a total of one hundred and thirteen (113) vehicle owners in Abeokuta, Ogun State, Nigeria. Abeokuta metropolis was considered the study site location as it is the capital city and largest metropolis in Ogun State. The city has land transportation mode as the only mode of transportation within the city through privately owned/commercial motorcycles and cars (Adeyemi, 2018; Oladipo, 2012). The participants were sampled using a purposive multistage sampling technique across gender, educational qualification and occupation. The designed instrumentation for this study was based on the conceptual basis of the study objective adopted from the established operational road traffic safety standards of the nation (Sangofadeji, 2013). This was tested for reliability and validated. The mixed-method quantitative research approaches used involved subjective techniques, physical measurement and observation. The physical measurement for the relevant facts, valid evidence, and logical implications on the accepted standard of tyre handling approach issues were through the research instrumentation of digital tyre treads and pressure gauges. For the reliable participants' inner states, potential knowledge and introspective reports about conscious experiences on tyre safety awareness and technical failure incidences were subjectively obtained using questionnaire administration. The flowchart in figure 2 shows the primary data variables assessed for this study. The data collection process was at the participants' homes of residences in the morning hours when the vehicles had not been driven to avoid built-up heat effect from road-tyre contact patch on the air tyre pressure by heat radiation effect from the sun. Informed consent was obtained from the participants. Participation in the study was voluntary, and no incentive was offered. However, anonymity was guaranteed, and they were encouraged to respond to all items enumerated in the questionnaire. The analysis and presentation of the participants responses on the tyre technical failures risks which exclusively focused on the range of the response spectrum of the predictor variables for safety awareness, approaches and implications regarding tyre failure risk factors, were computed and scaled for each participant on a five-point Likert scale and presented in table 1.

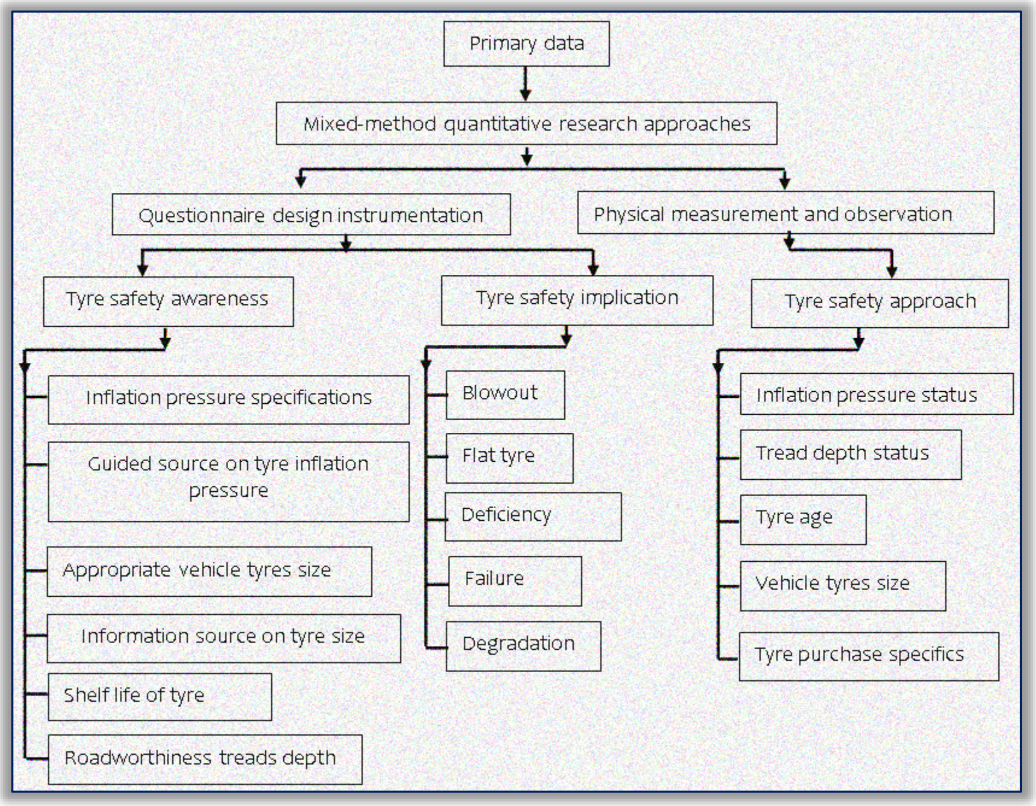

Figure 2. Flow chart for research approach

Table1. Computed and scaling range of tyre technical failure risk factors

Five-point likert scale	Safety awareness	Tyre handling approaches	Implications
1	Poor	Very low	Insignificant
2	Fair	Low	Slightly significant
3	Good	Average	Moderately significant
4	Very good	High	Significant
5	Excellent	Very high	Very significant

Multiple linear regression was employed in the model development as it has been widely used for many risk assessment kinds of research in different professions in which the outcome is dependent on two or more variables. The MLR model used the survey results to explain the linear relationship between the dependent response variable (technical failure risk variable) and two independent predictor variables (awareness and safety practices).

The form for the proposed MLR model is in the following design

$$TTFR = f\,(TSA_f, THA_f) \quad (1)$$

The expression in equation 1 above indicates that tyre safety awareness (TSA_f) and tyre handling approaches (THA_f) can ascertain the tyre technical failure risk in road vehicles. The MLR mathematical framework expression (linear regression fit) with yielded predicted response and exact confidence intervals for regression coefficients from the predictor variables dataset is presented below as

$$TTFR = \alpha_0 + \alpha_1 TSA_f + \alpha_2 THA_f \quad (2)$$

where: TTFR = tyre technical failure risk; TSA_f = tyre safety awareness; THA_f = tyre handling approaches; α_0, α_1, α_2 and α_n = coefficient for the MLR model fit

The model was obtained for the technical failure risk variable (responses), at significance level of $p < 0.05$. The statistical parameters used for the model fitting in a linear equation order to observed data include multiple correlation coefficient (R^2), adjusted multiple correlation coefficient (adjusted R^2), and regression (*P*-value and *F*-value).

One-way analysis of variance (ANOVA) test was used to determine if predictor variables, tyres safety awareness and tyre handling approaches statistically significant to fits in the regression model.

The MLR model developed was evaluated. The results obtained from the MLR model developed were compared to values obtained from the subjective survey data. Significance tests was carried out to determine the strength of the relationship between the technical failure risk variable response output of the MLR model developed and the subjective survey data using Pearson product moment correlation coefficients (*r*) at a *P*-value of less than 0.05. All the analysis carried out were on Microsoft office excel 2016 version and statistical package for social science version 16.0.

3. RESULTS AND DISCUSSIONS

— Road vehicle tyre safety awareness

Table 2 shows the levels of awareness of the vehicle owners' responses to the categories of established operational road traffic safety standards information variables considered to play key roles in technical failure risk factors in automobiles. The awareness ranking according to mean average of the responses of the participants showed that the source of "informed guide on appropriate size of vehicle tyre" had the highest mean value (3.85) with "how to check expiry date of tyres" having the least mean value (0.58) for the level of awareness of established operational road traffic safety standards (Table 2).

Table 2. Operational road vehicle safety awareness on tyre technical failure risk

Items	Attributes of road tyre safety awareness	Mean score	Rank	Remark
1	Vehicle owners precautionary instructed guide to tyre purchase	2.26	6	Low
2	Factors that necessitates change of vehicle tyre	2.26	6	Low
3	Informed knowledge on specific and required vehicle tyre inflation pressure	3.27	2	High
4	Source of informed guide on specific and required vehicle tyre inflation pressure	1.99	7	Low
5	Effective shelf life of tyre	3.01	4	High
6	How to check expiry date	0.58	9	Low
7	Appropriate size of vehicle tyre	2.65	5	High
8	Source of informed guide on appropriate size of vehicle tyre	3.85	1	High
9	Road worthiness of vehicle tyre tread depth	3.27	2	High

Awareness of the factors that necessitates vehicles' tyre ability to serve its intended purpose in keeping vehicles safely and securely on the road were assessed under some known prevailing tyre safety specification factors like life span of tyre, tyre inflation pressure, tread wear and dimensions/sizes (highlighted in table 2). The computation and the scaling analysis of the range of the response spectrum of the predictor variables regarding tyre safety awareness factors showed that highest proportion of the participants (26.5%) had fair tyre safety awareness level. This was followed by 25.70% of the study population that have good level of awareness regarding tyre safety. The proportion which had excellent level of awareness concerning tyre safety was 9.7% (Figure 2). This result do not totally agree with Asalor (2010) that Nigerians are very knowledgeable about road traffic accident causation factors as awareness of tyre failure risk factors in automobile crashes assessed in this study showed high fair knowledge and relatively low excellent awareness on tyre safety handlings among the participants. It however agreed with (Jansen *et al.*, 2016) that end-users (passenger car) are still lacking awareness on the importance of tyre properties and tyre use in relation to safety.

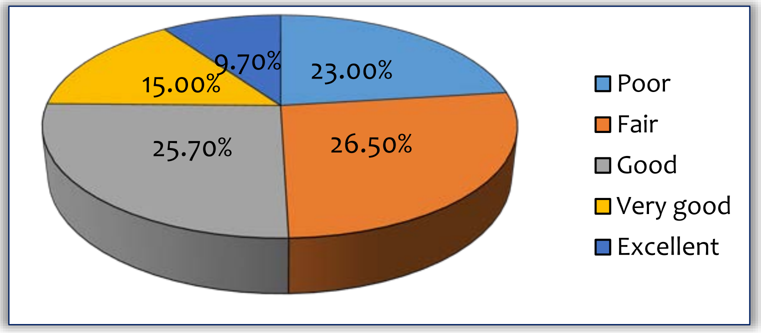

Figure 3. Level of road vehicle tyre safety awareness

— Operational tyre safety and compliance approaches with the specifics for tyre condition standard

When safety measures are ignored, several failure risk factors are associated; these include near miss and accident (human injury, property damage and in some cases, loss of life) (Ukoji, 2014). Awareness, irrespective of its level, does not necessarily translate to appropriate actions (Azodo and Ismaila, 2016). The operational tyre safety and compliance approaches with the specifics for tyre condition standard were assessed. The number of tyre safety handling approaches to tyre technical failure risk factors in automobile crashes assessed ranges from tyres purchase to discard time. The highest mean value of participants who reported operational tyre safety and compliance approaches with the specifics for tyre condition standard was "appropriate tyre size by vehicle specifications" (4.65), while "appropriate vehicle tyre inflation pressure" was the least (0.84) (Table 3).

The various tyre handling approaches regarding tyre failure-risk factors in automobile crashes assessed from the physical measurement and observation on the tyre inflation pressure, tyre tread depth, tyre age and tyre sizes computed and scaled to determine the level of operational tyre safety and compliance approaches with the specifics for tyre condition standard. The number of owners of the vehicle that participated in this study showed that 0.9% of the study population had very high operational tyre safety and compliance approaches with the specifics for tyre condition standard. The highest proportion of the study population (38.1%) was found to have very low operational tyre safety and compliance approaches with the specifics for tyre condition standard (Figure 4).

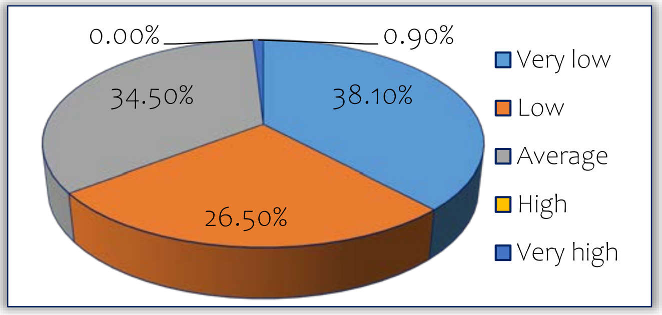

Figure 4. Operational tyre safety and compliance approaches with the specifics for tyre condition standard

Table 3. Approaches on tyre technical failure risk

Items	Attribute	Mean score	Rank	Remark
1	Appropriate vehicle tyre inflation pressure	0.84	5	Low
2	Tyre in good working life status	2.21	4	Low
3	Appropriate tyre size by vehicle specifications	4.65	1	High
4	Legal minimum tread depth (1.6 mm) on dry road conditions	3.76	2	High
5	Legal minimum tread depth (3.0 mm) on wet road conditions	2.43	3	Low

— The diverse functional dimensions of technical failures of tyres in automobile crash incidences

The average mean of the implication of tyre safety and compliance approaches with the specifics for tyre condition standard approaches regarding tyre failure risk factors in automobile crashes assessed showed that all the implication variable were high but for tyre deficiency with the flat being the worst case incidence with an average mean of 4.65 while tyre deficiency was the lowest (2.17) (Table 4). High as the tyre failure risk factors in automobile crashes in this study, they are preventable through tyre safety and compliance approaches with the specifics for tyre condition standard approach.

Table 4. Experience of tyre technical failure risks

Items	Tyre technical failure attributes	Mean score	Rank	Remark
1	Tyre blowout	2.74	3	High
2	Flat tyres	4.65	1	High
3	Tyre deficiency	2.17	5	Low
4	Tyre failure	3.14	2	High
5	Tyre degradation	2.7	4	High

A scaling approach was used to analyse and present the participant's responses on the tyre technical failures risks. This exclusively focused on the range of the response spectrum (tyre blowout, flat tyres, tyre deficiency, tyre failure and tyre degradation). The result obtained showed that the implication of the road vehicle tyre-safety awareness and tyre handling approaches witnessed 37.2% cases of very significant tyre technical failures risks, followed by significant cases (35.4%). There were no moderately significant cases of tyre technical failures risks (0.0%).

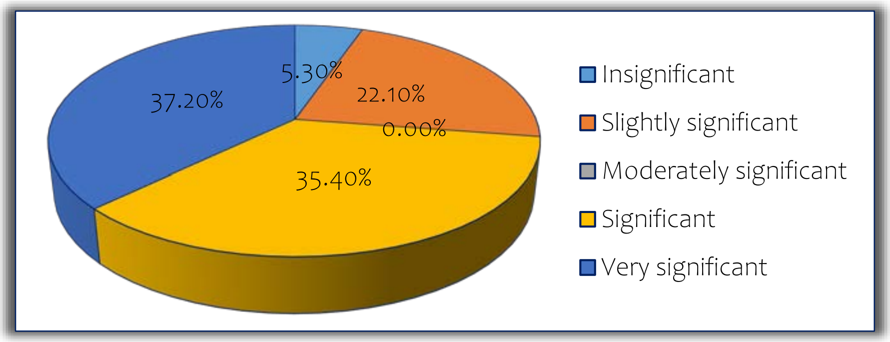

Figure 4. levels of technical failures of tyres in automobile crash incidences which

— Analysis and modeling of tyre failure risk factors in automobile crashes

The summary of the analysis of variance (ANOVA) for tyre technical failure risk is shown in Table 5. *F*-value is the ratio of variance group means to the mean within-group variances used to decide whether to accept or reject the null hypothesis. The *P*-values were used as a tool to check the significance of each of the coefficients, which is necessary to understand the pattern of the mutual interactions between the test variables. A significance level of 5% was used, implying that all terms whose *P*-value are less than 0.05 are considered significant. The coefficient significance from the predictor variables dataset is observed at a larger *F*-value and the smaller the magnitude of *P*-values. The model regression *F*-values of 677.300 imply that the model is significant, validated by the *P*-value being less than 0.05. The ANOVA indicates that the two variables used in determining the tyre technical failure risk were all significant (*P*-value < 0.05). The predictor variables, tyre safety awareness and tyre handling approaches, were statistically significant in determining tyre technical failure risk at the confidence level of 95% (Table 5).

Table 5. Analysis of variance (ANOVA) for tyre technical failure risk

Model	Df	Adj SS	Adj MS	*F*-value	*P*-value
Regression	2	175.746	87.873	677.300	0.000
Residual	110	14.271	.130		
Total	112	190.018			

a. Predictors: (Constant), TSA_f, THA_f

The tests for the adequacy of the regression models, the significance of model coefficients, and the lack of fit test were performed using the same statistical package. The MLR analysis established the tyre technical failure risk from the road-vehicle tyre safety awareness, and the tyre handling approach variables gave an R^2 value of 0.925. The 0.925 R^2 value obtained was relatively high and close to unity which, according to Lee and Wang (1997) and Zaibunnisa *et al*. (2009), will give a very good empirical model fit. The adequacy of the model ascertained from the R^2adj showed a value of 0.924. The adjusted R2value obtained is above 90%, which according to Koocheki *et al*. (2009), is appropriate to evaluate the model adequacy.

Table 6. Model summary for the tyre technical failure risk

Term	Coef	SE Coef	T-value	*P*-value	Beta Coef
Constant	-0.243	0.146	-1.664	0.099	
TSA_f	-0.006	0.024	-0.262	0.794	-0.007
THA_f	1.312	0.036	36.454	0.000	0.963

$R = 0.962$, $R^2 = 0.925$, $R^2adj = 0.924$

The fit regression model using the MLR model mathematical framework expression use done by substituting the regression coefficient for the MLR model fit from the predictor variables from the dataset in Table 6. This yielded the regression equation as

$$TTFR = -0.243 + -0.006TSA_f + 1.312THA_f \quad (3)$$

where: TTFR = tyre technical failure risk; TSA_f = tyre safety awareness; THA_f = tyre handling approaches

This implies that the various categories of tyre technical failure risk differential in automobile crashes are attributes of the vehicle owners tyre safety awareness and operational tyre safety and compliance approaches with the specifics for tyre condition standard.

— Comparison of predicted responses from the MLR model developed and survey responses of tyre failure risk factors

The comparison of predicted and survey dataset response values showed an indication of an association between the predictor variables and the response variable percentage variation of 3.54%, respectively, between the developed and measured values. The Pearson Product-moment correlation coefficient was used to measure the strength of a linear association between the model developed and the measured value of tyre technical failure risk. The analysis showed a strong positive correlation between the survey dataset and the predicted values with an "*r*" value of 0.962 significant at $P < 0.01$. This confirmed the acceptability of the developed MLR model (Table 7).

Table 7. Correlation between predicted mlr model and survey dataset response values

No of subjects	MLR model	Survey dataset	*r*-value	*P*-value
1200	3.81	3.77	0.962**	0.00

**. Correlation is significant at the 0.01 level (2-tailed).

4. CONCLUSION

Vehicle tyres are a very significant part of the automobile that plays a vital role in the enhancement of safe road trip and road traffic accident causation resulting from tyre failure risk since they are the only contact the vehicle has with the road. The safety aspect of road transportation and its operation is very important as it is closely related to human lives. Awareness and compliance operational tyre safety and compliance approaches with the specifics for tyre condition standard of accident causation factors and important contribution towards the safe practices eliminate potential accident causes. This study revealed that the level of awareness and the consequent approaches regarding tyre failure risk factors in automobile crashes significantly translate into technical failure in tyres. The MLR model developed to identify tyre failure risk factors in automobile crashes obtained values closed to the survey dataset with little variation. Consequently, the response variables in the two datasets significantly correlated, showing acceptance of the model. From the result obtained in this study, there is a need for adequate public sensitization measures on tyre safety and its implication in failure risk factors in automobile crashes for compliance to operational tyre safety approaches with the specifics to established on-road standard tyre condition.

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