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Vehicle Road Worthiness Performance Indicator

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Abstract

The percentage of accidents on road because of failure of components of vehicle is 3.6% out of entire accidents that are occurring on road and there is need to address this problem so that the number of accidents on roads is drastically brought down. Hence a systematic scientific study is necessitated to identify the necessary measures which will result in reduction of number of accidents on road due failure of components of vehicle. So in order to decrease the number of accidents on road it is absolutely important that enhancement of reliability of operational condition of vehicles. So the main aim of this work is to evolve a an empirical frame work for measurement of reliability of the vehicle which directly affects safety on roads. It is observed that there are many parameters which have conflicting nature and have influence towards the safety in vehicle operations. The interrelations between the parameters of vehicle which are responsible for causing accidents are very tricky in nature on the application of the conventional decision techniques.. The study findings indicate that the braking system is identified as the most critical parameter effecting the safety of vehicle, and the fuel supply and electrical systems are also found to be key parameters of vehicle.

Keywords: *Vehicle Safety,MCDM,PCA,AHP.*

1. Introduction

Every year approximately nearly 10 lakh fatal deaths happening due to traffic accidents worldwide. Approximately 240 lakhs people suffer hurts and injuries as per Government of India extracts. the increase in road traffic toll is 40 percent in Asia alone during period of 1986-1995 The condition of road suitability also a reason for this. it is sad that adequate awareness of the problems pertaining to road accidents, its size and severity of danger is absent in in many countries, hence it needs an immediate and reasonable solution to minimize the accidents, the problem is not only to India, it is spread across worldwide.

The prime responsibility of governments of the states is to reduce the negative/ undesired effects of road accidents. The conformance to traffic safety depends primarily on

- human-related (behavior and errors)like driver fitness, public adherence to traffic rules at traffic junctions, cycle movements, proper parking, adherence to traffic signals, etc.,

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- vehicle-related, such as maintenance of proper braking systems, warning lights, indicator lights etc.,
- and environmental factors such as road condition, traffic lights maintenance on junctions, notice boards of traffic signals, speed brakers, caution boards etc.

The road crash/smash involving drive ract or damage before the crash/smash was almost 95% [1] S. Singh,

Even though driver behavior is the major reason for accident while driving, sometimes the vehicle road worthiness, road condition and public violation of traffic rules are also playing some role. In this paper, assessment of the road worthiness of vehicle is dealt.

As per government reports many vehicles are not in roadworthy condition in developing countries including India. Insufficient vehicle health is mainly responsible for maximum number of accidents on road. The proper inspection system only ensures compliance of adherence to standards of vehicle exhaust emissions. Ever increasing demand for public transportation causes a necessity for improvement of vehicle performance and roadworthiness. This is possible only by proper and effective vehicle inspection system.

The quality and reliability of motor vehicles deteriorates over period because of use, and maintenance has to be carried out regularly to bring it for back road worthy condition t regular safety inspections will ensure proper working of components. Information about vehicle-related breakdowns that causes accidents on road is an important task together, it is really a constraint to conduct Vehicle Safety Assessment.

Every Vehicle should be checked for its salient features which influence its proper running on roads. Every vehicle should be inspected by authorized agency for its satisfaction on the suitability of vehicle condition for its movement on roads. Every vehicle should carry with it the certificate given by the proper government agency for its approval for running on roads along with pollution related certification.

Vehicles which are having technical defects that are mainly responsible for accidents on roads as per Juraj H and Branislav Šarkan (2022) are tire damages with sudden air leakages, wheel drop out steering failure, fuel system failure, brake failures trailer and truck connection failure suspension failure wind shield damages, tail lamp failures etc., brake system failures are the result of failure in brake pads, brake hoses, brake pipes, break cylinders.

The sub area of failures noted on tyres, electrical equipment, brake systems, steering, car suspension, transmission, body and engine etc. Vehicles produced in India must have certification by agencies like Indian Standards and Automotive Industry Standards .

After 2000 the vehicle manufacturers in India have to adhere to ECE Regulations and also with GTR/ ECE. Any deviation from GTR/ECE allowed only in the area of administration category. The existing road conditions forced the manufacturers to incorporate many safety features in the vehicle production stage itself so that they will alert the driver whenever he makes any mistake.

Some of the vehicle related safety requirements are as follows.

a) Safety towards environment: The exhaust released by the vehicle should not contain substances that are inimical to human health and also noise level also should not exceed permissible limits

b) Active safety requirements: Control over braking system, control over rotation of steering, and lighting system incorporated should not be inconvenient to opposite vehicle user and also noise created by horn also should be in permissible limits

c) Passive safety requirements: An alarm for non usage of safety belt to the people inside the vehicle and also automated door locking systems along with safety features should be incorporated at the time of production of vehicle.

d) Post-accident requirements: Existence of first aid kit along with accident toll numbers and also provision for emergency exits.

e) Fire safety requirements: Existence of firefighting systems and their usage training must be made as a part of safety issues.

2. Literature Review

2.1 Assessment of Vehicle safety

It is a wrong concept to view that all the accidents occurred on road are caused by human error alone. The most of the studies on accident ignored or paid little attention towards vehicle factor. Some of the research findings illustrated that regular periodical inspections and maintenance can reduce road traffic accidents in frequency as well as its gravity.

Byun (2001) used the AHP method for choosing of vehicle and ignored the emission issues in his study which is very vital for roadworthiness. Repin, et al.,(2017) determined that Failure in Vehicle systems, is the popular cause of accidents on roads. Sergei Repin, et al., (2018) in their work have concluded that sudden failures of vehicle occurred due to the faulty vital components of vehicle, and they have concluded this applying the theory of reliability on failure analysis. JurajHudec and Branislav Šarkan(2022) examined data on accidents on road which are related to technical defects and concerned periodical technical inspection, they made two observations. The occurrence of accidents increases because of technical defects, the number of accidents decreases if the vehicle is declared temporarily not fit after finding defects during periodical inspection and declaring fit after doing the necessary repair. Authors conducted regression analysis on number of accidents versus road worthiness. The various technical defects noticed are tire damages, wheel drop out steering failure, fuel system failure, brake failures trailer and truck connection failure suspension failure wind shield damages, tail lamp failures etc. European commission in 2019found that trailers and three-wheel vehicles also to be included in road worthiness testing to reduce the accidents. Schulz W. H, and Scheller S (2019) found that40 percent of accidents are result of non-roadworthiness vehicles. Found that considerable economic gains are obtained by putting periodical inspection in place. Miculic, etal.,(2020) concluded that awareness to vehicle users on the necessity of having periodical inspection of their vehicle on their own in a preventive manner to mitigate the defect in the nascent stage before being carried out by inspection of road authorities and contribute to the safety of self and others.

MCDM technique:

Saaty (2008) suggested the AHP, which can address complicated decision making problems

G. Sakthivel, et al.,(2013) have used hybrid model containing FAHP with PROM in Enrichment Evaluation technique while evaluating the purchase of vehicle and considered all issues except safety on road. Rassafi, et al.,(2017) in their work have concentrated only on road safety evaluation as a main issue with certain uncertainty and exhibited road safety evaluation by applying Dempster-Shaffer theory. S.R. Seyedalizadeh Ganji, et al.,(2018)has prioritized vehicles on safety by conducting MCDM techniques DEMATE,ANP and ERP. Sergey, et al.,(2018) formulated a system of safety characteristics of vehicle to assesses the relative important of factors of safety requirements ignoring the age of vehicle, periodical inspection etc. Krishina ,et al.,(2015a) in their work have concentrated on development of empirical frame work for deciding on suitability of vehicle movement on roads depended on the FAHP-DEA. They considered only but in reality many other factors are there, six vehicle roadworthiness indicators like vehicle age, mileage, history, accident history, modifications, vehicle systems and devices.

Sergey et ,al(2017) stated in their theoretical paper, that dynamic condition of motor vehicles can be ameliorated by incorporating condition based monitoring. Okafor Kingsley Chinedu, et al.,(2018) carried out descriptive and inferential analysis on the data collected on passenger vehicles and found that 10% of vehicles are found to be in not fit condition for usage on road. They also concluded that the vehicle usage period and its fitness and driver condition are found to be very important in the reduction of accidents on road. Sachin, et al.,(2022)have used multiple regression method while estimating the clutch life by incorporating different vehicle parameters like temperature of transmission oil, speed of the vehicle, torque of the vehicle, speed of the vehicle engine, since failure of clutch impacts vehicle operation including human safety.

Kristina, et al.,(2017) proposed FAHP to assess the real worth of vehicle road worthiness performance indicator and later applied TOPSIS to rank the vehicles based on indicators. Kristina, et al.,(2013) in their study have used the failures number per verified vehicles in ready road condition as a starting point, they applied FUZZY-TOPSIS method to evaluate suitability of Vehicle movement on roads. Mustapha, et al.,(2016) in their study applied logit regression analysis on the relationships between emissions characteristics of vehicle, with consumption of fuel by vehicle, and the costs occurring for maintenance of vehicle. Guha Roy, et al.,(2023) presented paper on vehicle fitness test using convolution neural network technique based on the age of vehicle and motor vehicle act in India. It mainly focuses on the identification of body structure damages such as dents, bends, weld cracks etc.on automatic equipment and assessing the fit condition.

3. Methodology

Thestudy analysed the priority of the various safety elements to asess the road worthy ness of vehicles. The road worthiness score is calculatedusing principle component analsis and the analyical heirarchy process.

1) Determination of factors to be considered for assemnt of road worthiness of vehicle and collection of data.on 5 point likart scale.

2) Normalisation of data.

3) Application of Principal component analysis

3.1 Determination of weights of design element

3.1.1 Determination of weights by PCA method

Step-1:Determination of the linear combination coefficients.

It is evaluated by using the Eq(1)

$$U_{ij} = \frac{f_{ij}}{\sqrt{\lambda_j}} \qquad (i = 1,2,\ldots,h;\ j = 1,2,\ldots,m) \qquad (1)$$

U_{ij}:It indicates the value of the coefficient between the j^{th} variable and the i^{th} indicator

f_{ij}: It is the rotated loading factor.

λ_j: It represents the eigen value of the posterior interpretation rate which is rotated.

h: It represents the elements of design under consideration.

m: It indicates principal components under consideration

Step-2:Estimation of the coefficient score which is comprehensive in nature

It is evaluated by using the Eq(2)

$$Z_i = \frac{\sum_{j=1`}^{m} U_{ij}\, p_{ij}}{\sum p_{ij}} \tag{2}$$

Z_i: It indicates the value of score of coefficient of a single design element which is comprehensive in nature for each and every principal component.

p_{ij}: It represents the variance-explained rate for every principal component after rotation as shown in Table-3

Step-3: Computation of Weight

It is evaluated using the Eq(3) and findings are presented in Table-4.

$$w_j = \frac{Z_i}{\sum_{i=1}^{h} Z_i} \tag{3}$$

w_j: It is the value of weight which is normalized for every individual design elements

The technique of PCA is applied before the usage of AHP. It results in reduction of design elements and the AHP will be evaluating their subjective weights only.

3.1.2 Estimation of weights by AHP process

The principal components derived from PCA process and related elements of design are applied in the process of AHP, and the values of weights for every level are estimated. The present work requires opinions from experts and hence twenty experts were asked to answer the set of questions given to them, and the weights determination process was explained below stepwise.

Step-1:Development of a judgment matrix which is consistent in nature

Here the answers provided by specialist in the area are transformed into judgment matrix for comparison of elements which are pair wise at all levels.. One of the , the judgment matrix is:

$$A = (a_{ij})n \times n = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, a_{ii} = 1,\ a_{ij} = \frac{1}{a_{ji}} \ (i, j = 1,2,\ldots,n) \tag{4}$$

Scale	Meaning
1	Both metrics have been given equal importance.
3	When the purpose of comparison the two metrics, the former is given sparingly given more weight age than the latter.
5	When comparison of both metrics is done , the first one is essential than the second one.
7	When comparison of both metrics is done, the first one is more essential than the second one.

9	When comparison of both metrics is done, the first one is absolutely essential than the second one.
2,4,6,8	When the value of the metrics is exceeding the values indicated in scales.
Reciprocal	a_{ij} is used when it is between i and j and $1/a_{ij}$ is used when it is between j and i

Step-2: Computation of Weight.

Before the application of AHP to determine the weights of element at every level, the data is subjected to normalization process with Eq. (5), and all elements of every row are added to determine the value relating to feature vector ω. The evaluation of the weights of the elements at every level is determined by using the Eq. (6).

$$b_{ij} = \frac{a_{ij}}{\sum a_{ij}} \tag{5}$$

$$w_{ij} = \frac{\omega}{\sum \omega} \tag{6}$$

Step-3:Verification of Consistency

Eq. (7) estimates the peak eigenvalue of every judgment matrix, and Eq. (8) results the consistency index CI . The output of Eq. (9) is consistency. The correctness of consistency test is ok only when the value of the consistency ratio is less than 0.1.

$$\lambda_{max} = \frac{\sum (aw)_i}{nw_i} \tag{7}$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{8}$$

$$CR = \frac{CI}{RI} \tag{9}$$

λ_{max} : It indicates the judgment matrix peak eigen value

A : It represents the Judgment matrix.

w_i : It shows the each indicator Weight value

n : the value of n shows the order of the judgment matrix.

Composite score is determined using PCA and AHP weights.

Calculation of combined weights:

Here due non uniform distribution weights even after the existence many items. Heve linear combination methods are adopted to evaluate the combination weights , inspite of several items, the distribution of weights is not done uniformly; and hence, weighted linear combination procedures will be applied to estimate the Weighted combination weights. These are obtained by using Eq. (10). And results are presented in Table-13

$$W = aw_j + (1 - a)\, w_i, \qquad (a = 0.5) \tag{10}$$

4. Case Study

1. The preliminary data collected for the vehicle and tabulated as below:

Condition of the Vehicle depending on indicators					
Estimate of risk	Very low	Low	Moderate	High	Very high
Life span of the Vehicle (*) [Years]`	0-2.5	3.5-5.5	6.5-10.5	11.5-15.5	≥ 15.5
Cumulative mile run by the vehicle [000 km]	<26	26-55	55-110	110-210	>210
Safety Index (**)	≥6	5	4	3	2
Executor of repair work Records of vehicle (***)	Govt Licensed producers	Mixed GLP and PLA	Private legalised Agency	Outsider or by himself	Not known
Repair records of the vehicle (****)	Privatel legalised producer	Mixed GLP and PLA	Private legalised Agency	Outsider or by himself	Not known
Data regarding the Accident made by the vehicle	Not involved	Only minor	Minor &moderate	Serious	Not known
Data regarding the problems per failed vehicle	None	2	3	4	≥5
Status of braking	Always	over 96% cases	89-96% cases	Less than 89% cases	Not known
Status of steering	Always	over 96% cases	89-96% cases	less than 89% cases	Not known
Status of Tyre	Always	over 96% cases	89-96% cases	less than 89% cases	Not known
Status of lighting	Always	over 96% cases	89-96% cases	less than 89% cases	Not known
Status of exahust control	Always	over 96% cases	89-96% cases	less than 89% cases	Not known
Any changes which are legally not permissible	No	Active safety systems	Lighting	Passive safety systems	Other
Status of restraint systems	Always	over 96% cases	89-96% cases	less than 89% cases	Unknown
Over all estimate of risk	Very low	Low	Moderate	High	Very high

2. Based on the analysis of it the following factors are considered for vehicle roadworthiness assessment:

Braking system: Proper functioning of brakes to be checked

Tyres: Tyres & Road wheels are to be inspected before use

Wheel balancing:It is to be done as per manual and necessary adjustment of wheels need to be made

Lighting and alarming:It is absolutely important to avoid accidents during night time.

Visibility: all parts relating to visibility are need to be checked. All these parts are essential for safe running of vehicle

Structure:The condition of the chassis frame are checked.

Seat belts and its fasteners: Status of all the parts need to be checked for safety of driver.

Door locking:It is needed to be checked and verified

Steering System: The steering system needed to be verified for its proper movment

Suspension: Proper condition of suspension is to be verified

Propulsion system:It is to be checked for proper running of the vehicle

Mileage: The total distance travelled.

Age:The number of years put on road.

Emission:The emission is to be checked by authorised agency

Fuel system: the accessories handling the fuel system need to be checked for any leakages.

Electrical system:The electrical system is essential for starting of the vehicle many different systems are linked to it

Each vehicle is rated against the factors on a likart scale 1-5.depending on the safety aspects with safeone on scale of low -1 and high is 5.

Cronbach's alpha test and KMO test are used to test the suitability before the application of PCA.

Table-1: Design elements factor loadings (varimax with Kaiser normalization);

		Factor loading				
		pc1	pc2	pc3	pc4	pc5
CC1	Braking system	0.748	0.139	0.109	0.019	0.118
CC2	Lighting and alarming	0.73	-0.089	0.218	0.058	-0.037
CC3	Tyre pressure and treads	0.555	0.418	0.165	-0.107	0.056
CC4	Wheel balancing	0.699	0.27	0.024	-0.073	-0.11
CC5	Visibility	0.784	0.15	0.127	-0.01	-0.118
CC6	Structural rigidity	0.196	0.724	0.06	-0.021	0.06
CC7	Seatbelts	0.034	0.675	0.196	0.18	0.083
CC8	Doorlocks, devices fastening	0.173	0.763	-0.028	-0.076	0.01
CC9	Steering system	0.139	0.044	0.781	-0.092	-0.05
CC10	Suspension system	0.182	0.064	0.716	-0.079	0.066
CC11	Propulsion	0.151	0.414	0.546	-0.045	-0.107
CC12	Mileage	-0.138	0.105	-0.37	0.684	0.003
CC13	Age	0.023	-0.042	-0.228	0.743	-0.032
CC14	Emission	0.044	-0.007	0.281	0.722	0.061

CC15	Fuel system	0.007	0.047	0.02	0.04	0.774
CC16	Electrical system	0.009	0.146	0.022	0.003	0.785
CC17	First aid kits/safety exit	0.295	0.273	0.356	0.059	-0.508

pc1 : First principle component explains active safety requirements (CC1,CC2,CC3,CC4,CC5)

pc2 : 2nd principle component explains passive safety requirement(CC6,CC7,CC8)

pc3 : 3rd component explains transmission safety requirements

pc4 : Explains environment safety requirements

pc5 : Explains fire safety requirements

Table-2: PCA designing elements weighing results

			pci	pc2	pc3	pc4	pc5	Score coefficient	Weights
Eigenvalue			2.756	2.148	1.962	1.622	1.551		
Variance	Contribution	Rate	16.21%	12.64%	11.54%	9.54%	9.12%		
Weights			0.2746	0.2139	0.1945	0.1616	0.1545		
CC1			0.4501	0.0949	0.0783	0.0149	0.0944	0.1762	0.0813
CC2			0.4399	-0.0614	0.156	0.0457	-0.0292	0.141	0.0651
CC3			0.0263	-0.0042	0.201	0.567	0.0483	0.1447	0.0668
CC4			0.0908	0.2823	0.3897	-0.0356	-0.086	0.1425	0.0658
CC5			0.0138	0.0293	-0.1624	0.5832	-0.0252	0.0562	0.0259
CC6			0.1099	0.0436	0.5116	-0.0625	0.0532	0.1376	0.0635
CC7			-0.083	0.0714	-0.264	0.537	0.0024	0.0281	0.013
CC8			0.0835	0.0304	0.5573	-0.0727	-0.0406	0.1203	0.0556
CC9			0.0043	0.0323	0.0147	0.0315	0.6211	0.112	0.0517
CC10			0.0055	0.1	0.0154	0.0022	0.6299	0.1236	0.0571
CC11			0.1772	0.1868	0.2538	0.0462	-0.4087	0.0826	0.0381
CC12			0.1045	0.5204	-0.0199	-0.0598	0.0081	0.1277	0.059
CC13			0.0203	0.4609	0.14	0.1409	0.0657	0.1645	0.0759
CC14			0.3341	0.2854	0.1172	-0.0843	0.0449	0.169	0.078
CC15			0.1184	0.4936	0.0429	-0.0167	0.0489	0.1513	0.0699
CC16			0.4722	0.1029	0.0902	0.0079	-0.0953	0.1533	0.0708
CC17			0.4211	0.1842	0.0168	0.0569	-0.0889	0.1354	0.06251

AHP weight calculation:

	CCl	CC2	CC3	CC4	CC5	w_i
CCl	1	7	3	9	5	0.5075
CC2	1/7	1	1/5	3	1/3	0.0698
CC3	1/3	5	1	5	3	0.2472
CC4	1/9	1/3	1/5	1	1/5	0.0379
CC5	1/5	3	1/3	5	1	0.1376

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	CC6	CC7	CC8	w_i
CC6	1	3	3	0.2605
CC7	3	1	5	0.6334
CC8	1/3	1/5	1	0.1061

	CC9	CC10	CC11	w_i
CC9	1	1/3	1/4	0.1199
CC10	3	1	1/3	0.2721
CC11	4	3	1	0.6080

	CC12	CC13	CC14	w_i
CC12	1	1/3	3	0.2605
CC13	3	1	5	0.6334
CC14	1/3	1/5	1	0.1061

	CC15	CC16	CC17	w_i
CC15	1	1/2	3	0.3092
CC16	2	1	5	0.5813
CC17	1/3	1/5	1	0.1095

	PCA1	PCA3	PC A 5	PCA4	PCA2	w_i
PCA1	1	3	5	7	1/3	0.2719
PCA3	1/3	1	3	5	1/5	0.1419
PCA5	1/5	1/3	1	3	1/5	0.0769
PCA4	1/7	1/5	1/3	1	1/7	0.0389
PCA2	3	5	5	7	1	0.4704

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n	1	2	3	4	5	6	7	8	9	10
RL	0.00	0.00	0.52	0.89	1.12	1.24	1.36	1.41	1.46	1.49

Table-3: Composite weights

Primary	Weights	Secondary elements	Weights
Activesafety	0.2733	CC1	0.1097
		CC2	0.0421
		CC3	0.0726
		CC4	0.0364
		CC5	0.0541
Passivesafety	0.3422		
		CC6	0.0962
		CC7	0.187
		CC8	0.0545
Propulsionsafety	0.1686		
		CC9	0.0363
		CC10	0.0511
		CC11	0.0761
Environment	0.0967		
		CC12	0.0116
		CC13	0.0253
		CC14	0.0355
Firesafety	1192		
		CC15	0.0378
		CC16	0.051
		CC17	0.0233

Vehicle road worthiness score

= 0.1097*CC1 +0.0421*CC2 + 0.0726*CC3 +0.0364*CC4 + 0.0541*CC5 +0.0962*CC6 +0.187*CC7 +0.0545*CC8 +0.0363*CC9 +0.0511*CC10 +0.0761*CC11 +0.0116*CC12 +0.0253*CC13+0.0355*CC14 + 0.0378*CC15 +0.051*CC16 +0.0233 *CC17

The vehicle which pases the statuory testmay get a maximum score of 5 and minimum score of 1.

5. Results and Conclusions

The vehicle roadworthiness indicator demonstrates how good the vehicle fit for travel on road can be decided by substituting the vehicle scores on the equation formulated above, In addition to the fit certificate issued by road transport authorities.the reasonable score shall be between 4 and 5 indicates it is a better vehicle.if the score is between 2 and 4,necessary rectification is to be done to bring the score above 4, if it is below 2,it needs thorough examination and if repair is not possible to repair same shall be declared as unfit and not roadworthy enough. The major finding of the study is brake failure and non use of seat belts and driving at high speed are responsible majority of accidents on roads. The number of road accidents can be decreased only through vehicle reliability enhancement.

Future Scope of the study; In corporating the conditions of the road will be able consolidate the elimination of accidents on roads.

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