Real Time Fitness Analysis of Bitumen Road and Vehicle through Their Acoustic Signals

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Abstract: Accidents occur due to road and vehicle conditions. Need to know how fast the vehicle is traveling on the road and how fast the vehicle is running; what speed vehicle brake system is exactly applicable. Vehicle owners and riders need to know these two things. Knowing these two things will reduce the risks by a maximum of 96%. The main reason is that the roughness of the road and the condition of the vehicle can save the global economy, improve supply time and save millions of lives if these two things are adjusted. Hence vehicle efficiency and repair cost are greatly reduced. The road roughness is good when we are traveling on the road, at that time the vehicle noise is less and the movement of vehicles is very smooth. At that time when the road roughness is average the vehicle noise will increase slightly and the movement of the vehicles will be rough. At that time when the road roughness is less than average the vehicle makes more noise and the movement of vehicles becomes more difficult. We propose a mathematical analysis of the International Roughness Index (IRI) and road roughness impedance. Scale ranges from 1 to 5 to assess road condition according to IRI. The road condition scale was excellent on the 1st, very good on the 2nd, good on the 3rd, fair on the 4th and poor on the 5th. These measured values actually calculate the road roughness impedance (RRI). If the RRI value is low, the road condition is excellent, if the RRI value is low, the road condition is good, if the RRI value is medium, if the road condition is good, if the RRI value is high, the road condition is good and if the RRI value is high the condition is low. This information and vehicle condition are displayed on the vehicle dashboard. This will enable us and the government to find out the information of the damaged roads and take immediate action to rectify the problems without making extra effort.

1. Introduction
Defective geometric design of pavement or mechanical defects in vehicles is one of the inappropriate driving behaviors for road crashes in India. About 65% of road accidents on Indian roads are due to other factors such as road user error, road design error, road maintenance and vehicle conditions. Therefore, as a starting point, it seemed prudent to assess the mental and physical abilities of commodity vehicle drivers, as this category of drivers in the country is not fully literate, with the extended duration of time they spend on wheels sometimes exceeding 8 hours to 12 hours of driving. Improved driver screening facilities along with the availability of better driving aids such as anti-glare glasses are expected to be an effective and preventive measures to prevent crash accidents. To properly monitor, plan and maintain road infrastructure for maintenance, substantial data is always required, especially time range and latest road status data. Road condition would be change over time; since it requires a very significant investment and time to collect data on a daily basis, obtaining such
data is a challenge faced by many governments, especially in countries where budget constraints and advanced technology are still unaffordable. The International Roughness Index (IRI) is a widely accepted indicator of road surface roughness. IRI is considered a very important road forecast as it affects fuel consumption, comfort, safety and vehicle maintenance costs. IRI measurement is usually done through a combination of one or two main procedures, including subjective rating or visual inspection, which is a laborious and time consuming procedure; and the use of advanced profilers, which are very precise but expensive to obtain, operate and maintain, requires skilled operators and cumbersome calibration prior to deployment. Detect road surface irregularities (potholes, speed bumps, joints, railroad crossings) and their proper localization to improve driver safety and optimize road maintenance activities [1, 8, 9, 10, and 11]. Road quality assessment is related to the possibility of making the transportation system safer, more efficient and convenient. The presence of a variety of damages or irregularities on the road surface, in fact, further degrades the energy efficiency of the transport, as it determines the increase in fuel and vehicle component consumption, especially in relation to brakes and suspensions [2,3,4,]. Crossing bumps and / or potholes produce not only vibration inputs in the tires and suspension system, but also deformation of the rubber and with help of IOT [5, 6, and 7], increasing power losses and rolling resistance.

2. Mathematical analysis of IRI and equating impedance

The mathematical analysis of bitumen road IRI and service index (SI) is derived. The following equations are given below and simulated results plotted with help of Matlab2015b.

\[ SI = 5.0e^{-0.18 \times IRI} \]  
\[ IRI = 5.51 \ln \left( \frac{5.0}{SI} \right) \]  
\[ R_n = 5 \times e^{-160(PSI)} \]  
\[ PSI = 5.03 - 1.91 \log(1 + sv) - 1.38RD - 0.01\sqrt{C} + P \]  
\[ PSI = 5.41 - 1.78 \log(1 + sv) - 0.09\sqrt{C} + P \]  
\[ IRI = 0.4718 + 0.0585 \times D \]  
\[ z = \frac{1}{2 \pi f \sqrt{IRI \times v}} \]

![Figure: 1. Bitumen road serviceable standards](image)

The above figure1 a bitumen road standard, the mathematical analysis equation1&2 is benchmarks of bitumen road international roughness index is 1 – 5 indexes and service index (speed of vehicle...
travelling on road) service index are speed of vehicle travelling capability SI-1 express way speed limit 100 kmph to 120 kmph, SI-2 national highways speed limits 80 kmph to 100 kmph, SI-3 urban roads speed limit 60 kmph to 80 kmph, SI-4 rural area roads speed limits 40 kmph to 60 kmph with limited loads but each and every road specification wise we have to apply load due to imperceptions road and vehicle circumstances more roads are damages. Once above standards are violated road accidents, vehicle efficiency, maintenance cost and environmental pollution increases these are the things rises. Within range the road quality and serviceable access is good above things are 100% secure.

My analyses are estimated through vehicle acoustic signal and composed bitumen road serviceable access. When our journey travel on road the road roughness is good at that time the vehicle sound is less and vehicle movement is very smooth. When road roughness is average at that time the vehicle sound is slightly increase and vehicle movement hard. When the road roughness is below average at that time the vehicle sound more and vehicle movement very hard.

The estimated speed (SI) versus international roughness index, here y-axis IRI-1 the x-axis speed maximum 120 kmph, IRI-2 speed maximum 80 kmph to 100 kmph, IRI-3 speed 60 kmph to 70 kmph, IRI-4 speed 40 kmph to 60 kmph, IRI-5 speed 30 kmph to 40 kmph above IRI is to danger to drive.

The figure 2 road riding number is one of the mathematical expression3 &4 to estimate bitumen present serviceability access versus riding number (RN) for similar to above, here clearly mentioned that at what level of riding number to travel speed limits and RN-6 below and PSI green color shows good for travelling road, RN-6 above and PSI shows red color hazardous for travelling road. Any riding people to follow these benchmarks 90% of above problems avoided. This method is to estimate on road analysis of bitumen road year wise and road property year wise will be reduces due to heavy load and natural things, every three years to do maintenance process this process missing due to lack of manpower.
Figure 3. Road density

The figure 3 road riding number is one of the mathematical expressions to estimate bitumen present serviceability access versus international roughness index for similar to above, here clearly mentioned at what level of international roughness index to travel speed limits and IRI below and PSI green color shows good for travelling road, IRI-6 above and PSI shows red color hazardous for travelling road. Any driver to follow these benchmarks 90% of above problems avoided.

Figure 4. IRI vs. vehicle vibration to impedance on road

Actually D is golden (meridian) car reading. Mathematical expressions is equating the meridian car reading into mechanical Impedance for bitumen road. The bitumen road surface is good at the bitumen road impedance is less around 45 ohms figure 4 shows green color, the bitumen road surface is above average the bitumen road impedance is around 50 ohms. Then the bitumen road surface is below average the bitumen road impedance is above 60 ohms figure 4 shown red color. These conditions of bitumen road travelling is too difficult and accidents occurring percentages more than 80%.

3. On road travelling vehicle vibration to mechanical impedance analysis

For vehicle vibration analysis, it is more appropriate to state the energy spectral density of the bitumen road surface profiles in terms of the transient frequency in Hz rather than in terms of spatial frequency, because the work of the moment of vehicle pulsation time. The spatial frequency $\Omega$ in cycles/m is the transition vehicle speed of the temporal frequency $f$ in Hz.
Consider a plane rising and falling perpendicular to the road, on a level road where the braking or traumatic moment does not apply. Therefore, remembering the relationship between the angular velocity and the forward velocity of the optical wheel as \( u = \omega R \), the effective rolling radius of a type \( R_r \) can be defined as the ratio between the same velocity but the wheel: \( w_{ru} R = \omega \) where \( R_r \) is the effective rolling radius and \( \omega \) is the wheel Speed.

Mechanical resistance is generally considered to be a specific type of friction. However, mechanical resistance (actually any liquid resistance) is a unique form of friction, because, unlike friction caused by solid-to-solid contact, there is a mechanical resistance variation that increases the relative velocity between the object and the air.

\[
Z_m = \mu m a_g \quad (8)
\]
\[
\mu = w_{ru} R_r \quad (9)
\]
\[
a_w = 0.16 \times \left( \frac{V}{80} \right)^{\left( \frac{n-1}{2} \right)} \times IRI \quad (10)
\]
\[
VSP = 10N \log_{10}(V) + a_w \quad (11)
\]
\[
Z = \frac{f_r}{(\log(VSP))} \quad (12)
\]

A bitumen road is mathematically derived to standard form equations are 8 to 12 and simulation results composed of international roughness index versus mechanical impedance with the help of vehicle vibration signals. These analyses help out to drivers to alert real time happening things like vehicle and bitumen road circumstances. The figure 5 is shown IRI vs. vehicle vibration to impedance on road.

4. Real time bitumen road and vehicle tested results by using mobile app
The real time observation results are given below with the help of mobile App Vibration meter.
5. Conclusion
The proposed work Real Time Bitumen Road and Vehicle Fitness Mathematical Analysis Results are generated with the help of Matlab and International Roughness Index versus Service Index, Current Service Index, Riding Number, Road Impedance and Mechanical Impedance. This helps to the community. Real time bitumen road and vehicle results can be tested using a mobile app. The condition of the road is physically observed, a system that is in line with the future. We must adopt such technology to save millions of lives, vehicle efficiency, and huge repair costs.

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