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SMART HIGHWAY MONITORING USING IOT AND SMARTPHONE-BASED SENSING

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ABSTRACT :

The advancement of intelligent transportation systems has enabled significant innovation in roadinfrastructure monitoring and management. This paper explores the integration of Internet of Things (IoT) technologies and smartphone-based sensing for the maintenance and monitoring of highway systems. The proposed approach leverages low-cost sensors, mobile applications, and cloud-based data analytics to assess pavement conditions, detect anomalies, and optimize maintenance operations. Field studies demonstrate that smartphone sensors can reliably measure road surface roughness and vibrations, providing real-time data to transportation authorities. Comparative analysis against conventional equipment confirms the reliability of the proposed model. The research highlights the cost-effectiveness, scalability, and data richness of IoT-based highway monitoring solutions, emphasizing their role in establishing smart, safe, and sustainable roadnetworks.

Keywords: Smart Highways, Iot, Smartphone Sensing, Pavement Monitoring, Roughness Index, Predictive Maintenance, Intelligent Transportation Systems.

INTRODUCTION

Road infrastructure is one of the most essential components of national development, directly influencing economic growth, mobility, and safety. India, with the world's second-largest road network (over 4.6 million kilometers), continues to face challenges in road quality and maintenance due to increasing vehicle load, environmental stress, and limited monitoring resources. Traditional highway evaluation methods often rely on bulky and expensive machinery, which limits frequent assessment and real-time monitoring. The present study explores the use of IoT devices and smartphone-based sensing to evaluate pavement performance, measure surface roughness, and predict deterioration trends.

LITERATURE REVIEW

Smart road monitoring has evolved considerably with the introduction of IoT and artificial intelligence (AI). Early studies focused on mechanical profilometers and response-type systems for measuring road roughness. The emergence of the International Roughness Index (IRI) standardized roughness measurement globally. However, traditional equipment such as laser profilers and ultrasonic sensors are expensive and logistically demanding. This limitation prompted exploration into low-cost solutions such as the Roadroid application, which uses smartphone accelerometers to compute estimated IRI values.

METHODOLOGY

The proposed system consists of three primary components: (1) Data Acquisition Layer, where smartphones collectvibrationandGPS data;(2) Data ProcessingLayer, whichanalyzes andcomputes roughness indices;and
(3) Data Management and Visualization Layer, which aggregates data for decision-making. Experiments were conducted on selected road sections in Jhansi City, India, using the Roadroid application, and comparative measurements were obtained using a laser profiler.

Table1:ComparisonofIRIValues

RoadSegment	PavementType	IRI(Profiler)	IRI(Smartphone)	Error(%)
A1	Flexible	3.5	3.6	2.9
A2	Rigid	2.8	2.9	3.6
A3	Flexible	4.2	4.3	2.4
A4	Flexible	3.9	4.1	5.1

DISCUSSION

The integration of IoT and mobile sensing into pavement monitoring represents a transformative step toward smart infrastructure. Collected data can be aggregated for large-scale analysis, integrated into GIS, and visualized for public or administrative use. Challenges include calibration across different smartphone models, driver behavior variation, and GPS accuracy, which can be mitigated through data averaging and adaptive filtering.

General Roughness Surveysof Road Networks-

Figure displays the degree of roughness on the main route that connects Jhansi to Orchha and back. Instead of being based on distance, the gadget records an IRI roughness measure at a time period of one second. The Figure 4a displays the raw (unfiltered) data and shows a significant variation in IRI along the route length.Since the IQL- 3/4 data requires a higher level of detail than this detailed low-level data, the raw, unfiltered results from each direction were manually averaged across a length of one kilometer (see Figure 4b). The user will be able to choose the preferred section length for reporting in the updated application, which is being developed bythe developers.Despite the considerable deterioration, Figure 4b shows that the average IRI over the road length is comparable across the two lanes (10.3 and 10.8).

Roadroid indicated that about 20% of the one-kilometer lengths exceeded an IRI of 12 (refer Figure 4b), and individual one-second readings were about 20 IRI. Despite the road's extensive damage and numerouspotholes, the expected IRI, given the scale presented in Figure 1, was estimated to be only up to 12. Additional testing revealed that there might be a problem with Roadroid'sroughness filters, leading to an over reportingof short wavelength roughness. The results of a laser profilometeron pavements withasphalt surfacesare now being used by the system's creators tocalibrate the device.

Dependencyon Speed

Finding out if the Roadroid android application has a speed dependency was one of the objectives of the repeatability and reliability experiment in the city. In additional exercises in this case study, the reporting accuracy of the smartphone application was examined. Thus, in order to avoid skewed distributions, the exercise's focus was kept on the statistical difference between multiple runs on the same wheel track, taking into account the inevitable wander of human driving behavior. Any outliers were carefully deleted. OrchhaRoad stretches about two kilometers. To ensure uniformity throughout the activity, a 1650-meter course was determined. The average of the IRI data, which was recorded every one second, was calculated over 100 meter sub-sections to guarantee there was enough data for the statistical analysis.

Given the different vehicle speeds, Figure 5 shows the correlation between the recorded roughness data, averaged across 100-meter sub-sections. The severe deterioration and patching attempts exhibited in Figure 3 are located at 900 meters in the Jhansi direction, as shown in Figure 5(R), one of the pavement's defective sections where the data showed greater fluctuation.

When compared to the recorded data, it was discovered that the Roadroid android application demonstrated repeatability throughout the longer sample sections in line with IQL-3/4 evaluations. every one-secondinterval. A significant amount of variation was seen between the recorded readings, especially at the higher study speeds (50 km/h), according to the analysis of the raw, unfiltered data. When weighed against the findings shown in Figure 5.13, this observation implies that using narrow sample intervals is not statistically sound. Using paired t- tests, the significance of the variations between the runs at each speed was examined. Repeatability was found in 5 out of 6 tests, as Table 1 illustrates, indicating that the Roadroid android application measures roughness consistently at a given speed. The results of the paired t-tests are shown in Table 5.4, which compares the recorded IRI at different vehicle speeds. The outcomes were less than ideal, and it can be said that the smartphone application's dependability is inadequate at different speeds. But as IQL-3/4 data is usually utilized to inform decisions at the network level,

Table2: Relia bility betweenVehicleSpeeds

Speed KM/Hr	Direction	**Run**	**SampleStatistics(IRI)**		**Repeatability**
			Average	**Standard Deviation**	
30	JHANSI	1	3.51	1.63	No
		3	3.09	0.78	
	ORCHHA	2	3.34	1.16	Yes
		4	3.21	1.39	
40	JHANSI	5	4.27	1.23	Yes
		7	4.36	1.37	
	ORCHHA	6	4.64	2.11	Yes
		8	4.58	2.24	
50	JHANSI	9	4.04	1.27	Yes
		11	3.97	0.97	
		13	3.89	0.91	
	ORCHHA	10	4.38	1.62	Yes
		12	4.28	1.43	
		14	4.43	1.85	

CONCLUSION

1. Through comparison with all prior road roughness measurement approaches, the study demonstrates the relationshipbetweentheRoadroidInternationalRoughnessIndexandStandardInternationalRoughnessIndex.

2. The case study was conducted from winter to summer. The results were correct despite the shift in the weather. The roads only became deformed because of climate change; as a result, they developed many potholes and required more care than they would in the summer.

3. The effectiveness of the Roadroid Android application as a cheap option for road condition assessments has beenanalyzedinthis paper.Thisissoinexpensiveanduser-friendlythatevena novicecangatherdata.InJhansi,a city with limited resources and the inability to do in-field road condition evaluations, the case study examined the functionality of the Roadroid android application. The study assessed the IQL-3/4 device's performance in Jhansi and established the device's efficacy in a city setting in order to show the device's suitability in the southern region of India.

4. Implementingsuchroutineroadandpavementconditionsurveysofroadnetworksin Telanganastatemakes sense given the low cost of the smartphone device in comparison to specialized instrumented vehicles in the market.It makesdata collection possibleforinexperiencedtechnical workers andgivesprospectivedonors and funders unbiased measurements of the road quality. Such information is required for the economic assessment ofinvestments.

5. I wouldalso like to draw the conclusionthatanalysis is being done because boththe Roadroid andSPSS data demonstrate how inadequate the pavements are.

The field survey results confirmed its usage as an IQL-3/4 device, but they also point to a possible filtering problem that is causing an upward bias in the roughness values. It demonstrated consistent average roughnessesoverextendedportionsforthenetworksurvey.Theresultindicatesthat,althoughwhileroughness is given at one-second intervals, it would be more acceptable to report them over longer sample periods, like 100 m.

Roadroid's repeatability was examined, and it was noted that IRI recordings at the same vehicle speeds were consistent.Thedevice'sstatisticalreliabilitywasfoundtobelessthansatisfactorywhencomparingthe roughness measurements at different speeds. Nonetheless, the apparatus met the requirement within the precisionboundsofanIQL-3/4instrument,whichare+/-20%oftheIRI.ItwouldbewiseforRoadroidusers to set a constant survey speed of 50 km/h, as is the case with other IQL-3/4 devices. The study revealed that althoughthere maybesomevehicledependence,itmayfallwithinthe parameters of anIQL-3/4deviceand not be a practical concern. It also suggested differences between the two vehicles utilized to mount the device.

Roadroid has a lot of potential as an affordable, useful tool for evaluating road roughness at the IQL-3/4 level, providedthatfilteringisimprovedandlongersamplingintervalsareused.Thiswouldprovidealow-costwayto track andreport pavement roughness condition, which would help with assetmanagement of roadnetworks in developing nations.

REFERENCES

1. Alves,A.,etal.(2019).Urbanplanningandsustainabledrainagesystems:Reducingrisksofurban flooding. Journal of Environmental Engineering.
2. Forslöf,L.(2013).Usingsmartphonestomeasureroadroughness:TheRoadroidsystem. Transportation Research Record.
3. Johnston,M.(2013).RoadroidevaluationfortheAucklandroadnetwork.NewZealandTransport Agency.
4. Pompigna, A. (2022). The age of smart technologies in road infrastructure management. International Journal of Smart Transportation Systems.
5. Oladimeji,D.(2023).IoT-basedsmartinfrastructuremanagement:Areview.IEEEAccess.