Journal of Engineering and Technology for Industrial Applications

ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.12 n.58, p.1179-1187. March/April, 2026.
DOI: https://doi.org/10.5935/jetia.v12i58.3282

RESEARCH ARTICLE OPEN ACCESS

EXPERIMENTAL STUDY ON STEERING WHEEL PULSE MEASUREMENT-BASED ACTIVE SAFETY SYSTEMS FOR COLLISION PREVENTION

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ARTICLE INFO

Article History
Received: January 10, 2026
Reviewed: February 12, 2026
Accepted: March 24, 2026
Published: April 30, 2026

Keywords:
Active safety,
Steering wheel,
Measuring device,
Positioning of hands,
Fatality.

ABSTRACT

Active safety system plays a vital role in automobile to enhance the safety to prevent the accidents and fatalities. Therefore, accidents are increased day by day and rider safety is striving hard to improve in an automobile. Researchers reported that more than 20 percentage of accidents occurs due to fault of the driver during driving like inattention and health related issues are the predominate one in accidents. The above issues are reduced by using the preferred system and analyze the driver condition while driving. The system shows the health condition in dashboard and displays the heart rate and warns the driver whenever the pulse range is varied more than the normal range. The measuring device mounted in driving wheel and pulse is measured using throb measuring device. The driver positioning his hand on driving wheel and considered as clock position “10 and 12”. The system warns not only to the driver and it warns to the co passengers for indicates the driver is in health issues. The research is carried out especially to prevent the fatality, severe injury and damage to the vehicle in the event of collision.

I. INTRODUCTION

Modern vehicles depend on automotive safety systems besides to enhance active safety features due to increased rate of accidents. This paper introduces a complete system based on the Internet of Medical Things (IoMT) that uses non-invasive sensors in the steering wheel to track vital signs like heart rate and blood oxygen levels. The goal is to spot health issues as they happen and send warnings to both the driver and passengers to make driving safer [1]. The automotive safety system had developed widely in costlier vehicles only but unfortunately not in low end vehicles. The causes of the accidents are widely investigated and the fatality rate is increased day by day. The statistics describes that safety systems in the low-cost vehicles are lower than the high-cost vehicles and therefore fatality rate also is more than the high-cost vehicles in the event of collision. Every safety feature cannot be incorporated in low-cost vehicles and the research is carried out what kind of safety system can be used to reduce the fatality rate in the low-cost vehicles.

The investigation carried out to reduce the fatality rate and literature points out some causes of collisions in past five years. There the different cases such as drivers fault, over speed, alcohol consumption during driving the vehicle, abnormal health issues, pedestrian crossing and mechanical error in India. The drivers fault fatality rate is 77% more than the other causes it depends on driver violating traffic law mostly responsible for resulting accident, running light in high beam, without experience driving the vehicle and health related issues etc [2]. The article talks about creating a smart steering wheel with sensors that check the driver's health and find signs of sleepiness. It measures things like heart rate, variability, and blood oxygen to quietly evaluate the driver's state, helping to stop accidents from tiredness or sudden health problems [3]. The drunk and driver fatality rate of 16% is raised day today and the system is incorporated to reduce the accidents during consuming alcohol.

The 16 to 20% of fatality is occurred is due to health issues i.e. abnormal health condition of the driver during driving the vehicle it comes under the fault of driver. Another cause of collision is 16 to 20% of due to health issues and the diagnosed health issues are heart attack, hypertension, hyper lipidemia, diabetes mellitus, and gastro intensimal ulcer [4]. The paper explains the design of a smart system that monitors a driver's health in real time from a distance. It uses a smart steering wheel with sensors to keep track of vital signs and sends information to a mobile app to warn the driver or call for help if something is wrong with their health [5]. The monitoring system can spot the behavior signs that a driver is getting fatigue, which can help stop accidents caused by sleepiness [6]. Testing showed that this system can lower the chance of accidents by catching strange driving behavior as it happens during driving and it prevents the collision act as active safety [7]. The analysis found that this system makes braking quicker and more stable, which helps stop the vehicle smoothly and prevent skidding when stopping suddenly using this braking system [8].

This paper looked at how metal and rubber materials design affect how much tools used for boring can dampen vibrations [9]. The research studied the properties of bio-composites made from Aloe vera and hemp fibres [10].The hybrid method was found to be stronger and longer-lasting than other methods, making the joints work better [11]. The study found that this kind of seat belt greatly reduces movement and the risk of injury compared to regular seat belts [12]. The study showed that using IoT improves car performance, makes driving safer, and gives a better driving experience [13]. The results showed that this method is more efficient and produces more water than traditional systems [14]. The findings showed that this system can stop the car automatically to prevent collisions, without the driver needing to do anything [15]. The study explained how continuous monitoring can improve road safety by finding early signs of tiredness or other health issues [16]. The results showed common signs of fatigue, which showed the need for monitoring systems to help prevent accidents caused by reduced alertness.

Testing showed that the system can spot unsafe driving situations and help prevent accidents by acting on its own [17]. Recent studies have focused on improving vehicle performance, safety, and efficiency through numerical analysis and experimental validation. Computational investigations using RANS models indicate that vortex generators can improve airflow behaviour and aerodynamic characteristics in simplified vehicle configurations [18]. Experimental work on diesel engines shows that changes in intake manifold design, along with the use of alternative fuels, can lead to better combustion and improved engine performance [19]. In electric two-wheelers, venturi duct–integrated cooling systems have been reported to enhance thermal regulation and operating efficiency of PMSM units [20]. Research on braking and structural systems highlights their importance in vehicle safety. Experimental evaluation of semi-automatic parking brake systems confirms reliable braking performance while maintaining cost effectiveness [21]. Structural analysis of heavy vehicle chassis demonstrates that appropriate selection of geometry and materials improves stress distribution and load-carrying capacity [22].

Studies using ANSYS optimisation techniques show that advanced materials can improve suspension performance and durability in two-wheelers [23]. Thermal performance improvements using variable geometry micro-channel heat exchangers further support enhanced energy efficiency in automotive air-conditioning systems [24]. Work on active safety systems indicates that hydraulic actuator–based automatic emergency braking systems can improve braking response and reduce accident risk [25]. Studies related to data security highlight the need for privacy-preserving methods in health and monitoring applications [26]. Integration of driver condition monitoring with safety-enhanced braking systems has been shown to improve accident prevention capability [27]. Continued development of automotive braking systems contributes to improved passenger vehicle safety and braking reliability [28]. Combined driver monitoring and active braking strategies further support enhanced overall vehicle safety performance and study shows the measuring devices used for analysising the output results from motorised accurancy is due to sensors [29], [30].

II. MATERIALS AND METHODS

The effective system is one which employed not only to minimize driver injuries but this also protects the driver’s mortality during sudden health concerns. The current systems have numerous auxiliary systems to slow down vehicles; however, they are insufficient to stop injuries or health complications in typical Indian vehicles. The literature points out the condition of driver, leading causes of fatalities and measuring methods of human pulse rate of using sensor-based technology were reported. The collision warning system or object detection system gives the warning signal before collision. Even though systems are placed in the vehicle, collision occurs frequently were reported. Research has shown that the drivers suffering from health diseases are more than 16 to 20 percentage involved in road accident rising day-by-day to drivers even though automatic braking in health issue not yet reported.

The health-related accidents were caused by drivers’ fault while driving were reported and steps to reduce not yet reported (The driver who suddenly suffers from health issues during driving the driver cannot handle the vehicle because during heartache the movement of hands is difficult towards control of the vehicle which results accident). The proposed study consists of a cardiac monitoring device that detects the driver's rhythm under dynamic events. The heartbeat (HB) measurement tool installed in the driver's wheel enable the motorist to place their hands in a specific sensing element. Therefore, the HB measuring device monitors the pumping of the heart beats continuously. The system is built especially for health issues drivers who had already had affected gets advantage. The sensing element is then interfaced to a microcontroller that enables detecting pulse rate in Bpm.

The user can set the high level heart beat and low level of heart beat (say ex.100 beats for high and 60 beats low) After setting the limits, the measuring device starts monitoring 35 the driver, if the driving force heart beat goes on top of a particular limit; the system sends a responsive to the controller that transmits the signal to the actuator to the braking system (future work to design and development of actuator). The system alerts the pedestrian by giving alarm and stoplight for the following vehicle. The flow chart system of a pulse sensor measuring (HB measuring device) shown in figure 1. The HB measuring device detects the driver’s beats drop significantly during driving when they are become low, it alerts the co passenger and the driver who slowly starts to fall in sleep or unconscious if the pulse is low.

In this preferred system the HB measuring device in the driving wheel that senses the sensing area of the fingers and palm area to test the pulse and temperature of the driver. Therefore, the measuring device works as like exercise equipment on a treadmill or a bike user places their hands or fingers over the measuring device to get a pulse rate reading and displayed. So, the driver can place his hand on the driving wheel as they sense the pulse from the driver fingers. Normally HB measuring devices are bulk and large and take too much space to accommodate but for this system a small one is selected that connects to the driving wheel where the driver can hold with the fingers. There are two sensing area on the driving wheel which can sense the both hand or fingers which rest on the diodes of the driving wheel. There it is compatible with an Arduino board and the driver's health condition is monitored and reading is taken from the measuring device as output. The signal information is passed to the Arduino board and it interpret the pulse is low or high depends on the condition. If it is low the system interprets that the rider or driver will be in unconscious or fall as sleep and the signal sends an alert to the driver through display LCD and alarm. The driver monitoring system monitors the health condition and sends messages to nearby hospitals were reported and the decelerating the vehicle not yet reported.

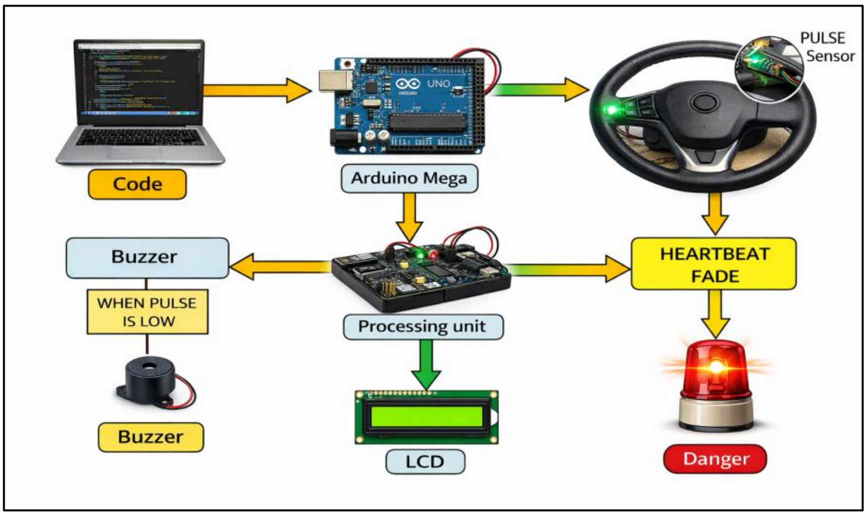

Figure 1: Flowchart of pulse sensing system.
Source: Authors, (2026).

The figure 2 describes the temperature sensor that consists of a lens to focus the infrared (IR) energy on to a detector which converts the energy to an electrical signal that can be displayed in units of temperature after being compensated for ambient temperature variation. The average human body temperature is 37 °C (98.6-degree Fahrenheit). The LM-35 is employed to observe the body temperature. The operative temperature ranges of LM-35 from -55 °C to 150 °C. The output voltage varies by 10 mV in response to every degree Celsius rise or fall in close temperature, accuracy level of ±0.25 to ±0.75°C. MLX90614 temperature sensor is used. The body temperature varies depending on the body, a person takes a measurement. The research is carried on 40-60 age groups, (healthy temperature 97.6 – 99.6-degree Fahrenheit). When the health condition changed the body temperature is changed. The normal temperature ranges for the adult 97.6-degree Fahrenheit to 99-degree Fahrenheit as reported as average range by the doctors and literature review. The range for testing in research is less than 96.5 - greater than 102-degree Fahrenheit. When a person's body temperature is dangerously lower than 96-degree Fahrenheit, the brain and body cannot function properly. If left untreated, hypothermia can lead to cardiac arrest (heart stops beating) and leads to death. During heartache the temperature of the body is increased to more than 102-degree Fahrenheit or if driver fall asleep the temperature of body lowers than the normal body temperature which is less than 97-degree Fahrenheit and makes the driver less active. The both sensors (pulse & temperature) act simultaneously at same time, measures the health condition of the driver.

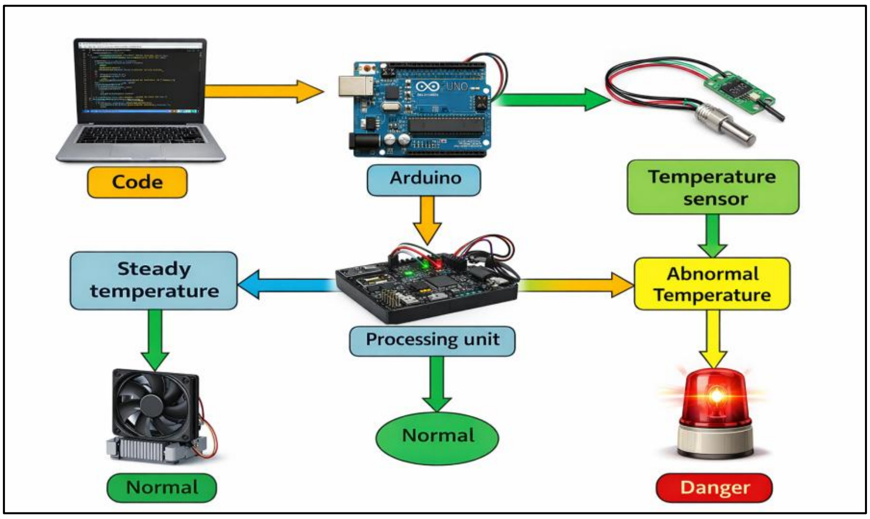

Figure 2: Block diagram of arduino-based real-time temperature monitoring and alert system.
Source: Authors, (2026).

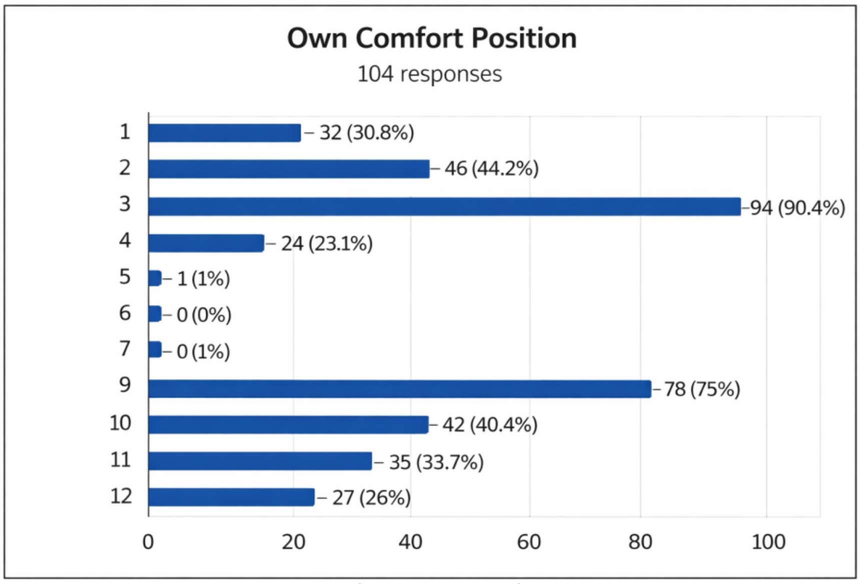

Figure 3: Survey and standards for Driver comfort position on steering wheel.
Source: Authors, (2026).

The figure 3. Shows the driver comfort position. The driving wheel denotes as face of the clock and the positioning of left hand 9, 10 & 8 clock and the positioning of right-hand side is 2, 3 & 4 o'clock. Today, the (NHTSA) recommends the driver to hold the driving wheel in 9 and 3 o'clock positions because lowering the hands on the driving wheel and there is the reason is airbag deploys during an accident. Therefore, placing the hands different positions except 9 and 3 O' clock should not use in the event of safety the study surveyed the positions of hands also and chart shows the maximum placing hand positions and best positions and it defines that NHTSA standard position is the best and safest position to prevent the accident. Figure 4 shows the placement of sensors on the steering wheel using a clock-face representation to indicate hand positions. The IR pulse and Temperature sensors are mounted on the left and right sides of the steering wheel at the 9 o'clock and 3 o'clock positions, which are commonly recommended for safe driving. These positions allow continuous monitoring of the driver's pulse rate and hand temperature during vehicle operation. The selected locations ensure stable hand contact and reliable signal acquisition without interfering with steering control. This arrangement also supports safety considerations related to airbag deployment and driver comfort.

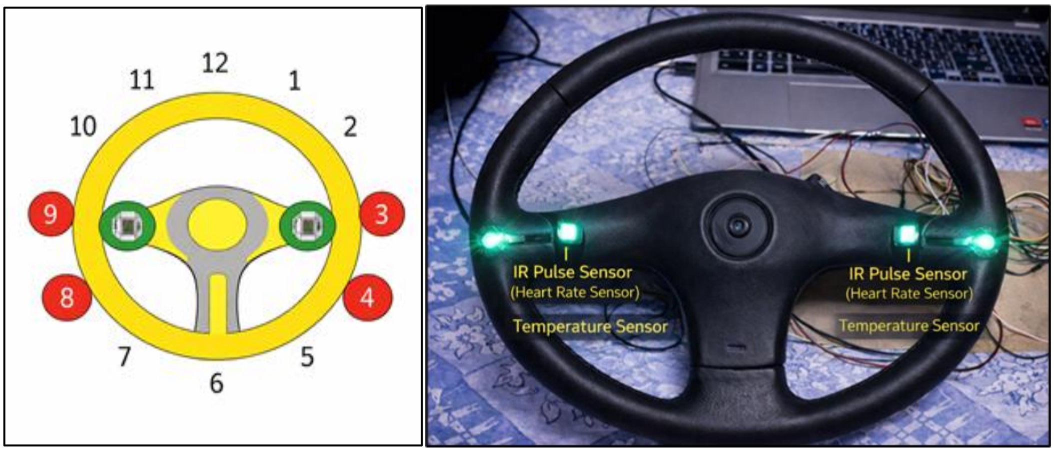

Figure 4: Sensor positions on steering wheel.
Source: Authors, (2026).

The infrared sensor is responsible for sending infrared light to the body shown in figure 5. This sensor has a pair of transmitter and receiver. Using photodiode detect reflective light from the body and this signal is sent to the microcontroller to detect heartbeat. AT mega 328P, CMOS 8-bit AVR micro-controller with LM324 32KB bytes of in-system programmable ISP Flash memory, 2KB bytes of RAM, 32 I/O lines. A Liquid emitting diode is used to display the heart beat in Beats per Minute (bpm). Operating Voltage: +5V or +3.3V, Current Consumption: 4mA Inbuilt Amplification and Noise cancellation circuit. Diameter: 0.625", Thickness: 0.125" Thick, the accuracy level of pulse sensor is 2-3%. The proposed system is to collect the driver's data samples in age group from 40 – 60 (adults). The drivers are selected on these age groups for research by consulting the cardiologist and from literature review. The prevalence report says that maximum collision occurs in the adult age group, therefore maximum and minimum pulse range is more than 100bpm and less than 60bpm which is abnormal or dangerous for the drivers. Normally pulse sensors are bulk and large and take too much space to accommodate but for this system a smaller one has been selected that hooked to the steering wheel where the driver can place the finger or palm over sensor.

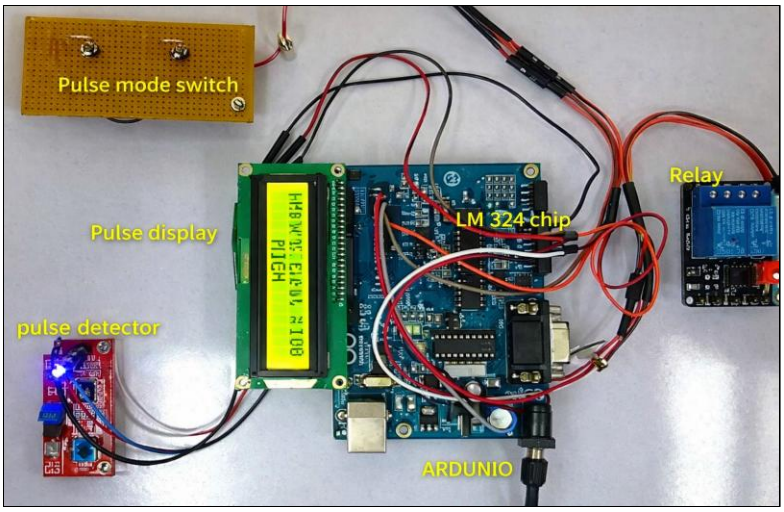

Figure 5: Controller of HB measuring device.
Source: Authors, (2026).

III. RESULTS AND DISCUSSIONS

The developed system sensing the sensor output is tested the efficiency of the measuring device with the conventional system and tested in prototype and real time model. The vehicle tested with the sensor sensing technology on static condition by cranking the engine in idling stage for measuring the condition of the driver. The sensor accuarcy aslo tested during the static condition and by considering the atmospheric temperature and wind condition. The sensor compatibilty is tested in idling condition because of vibration and noise from the engine comparetment to find any changes in sensor accuracy is analysed and validated the accuracy. If the pulse is abnormal the indication is displayed in dashboard and warning signal will be given in the event of emergency. Its unpredictable or measure the abnormal person for testing the developed system. For alerting or warning, the normal pulse rate set as abnormal rate for testing purpose. Therefore warning signal as alarm with stopping light had indicated for safety and pulse displayed in the dashboard.

The throb measuring device or HB measuring device output is tested and validated with the conventional electrocardiogram. The temperature measuring device also tested and validated with the conventional type thermometer. Both the measuring devices are tested the efficiency and got the output values of the proposed measuring device system. The system is tested with maximum trials for the individual people of the age group and the average pulse rate is taken for the research as shown in table 1 and plotted in figure 6. The table 1 shows the various pulse readings obtained from ECG and HB measuring device with the error rate. The table indicates the pulse rate of the conventional type of monitoring the heartbeats by using electrocardiogram. The HB measuring device which consists of photo diode it measures the pulse rate of the driver.

The HB measuring device which is tested for the propose system and to find the efficiency of the measuring device. The HB measuring device output is measured or tested using the adult age groups for the research and the measured pulse rate listed. The error rate of the measuring device is validated by using the error rate formula during static condition [11-22]. The adult age from 40 to 60 is taken for the research for testing the pulse rate of the individuals is show in table. The accurate pulse rate and measured pulse rate shows the variation of pulse and the maximum error 0.02 for the HB measuring device reading. The testing of pulse rate of the adult age groups also tested in real time model for measuring the error during dynamic condition. The HB measuring device is mounted in the driving wheel of a car and this measuring device is contact type measuring device which is to be hold during driving.

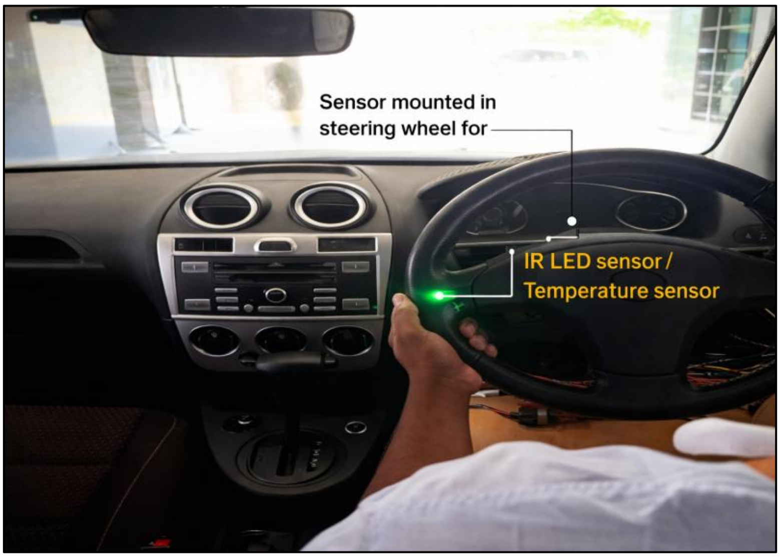

Figure 6: In-vehicle testing of steering wheel-integrated IR pulse and temperature sensing unit.
Source: Authors, (2026).

Table 1: Comparison of pulse rate measurement with ECG.

Age	Actual pulse rate from ECG (Bpm)	Measured pulse rate from Pulse sensor (Bpm)	Error	Body Temperature (*F)
40	76	77	0.013	97.6
45	75	77	0.026	98.7
48	75	74	0.013	97.6
50	82	83	0.012	99.2
54	83	84	0.012	98.1
58	86	87	0.011	97.8
60	79	78	0.012	99.6

Source: Authors, (2026).

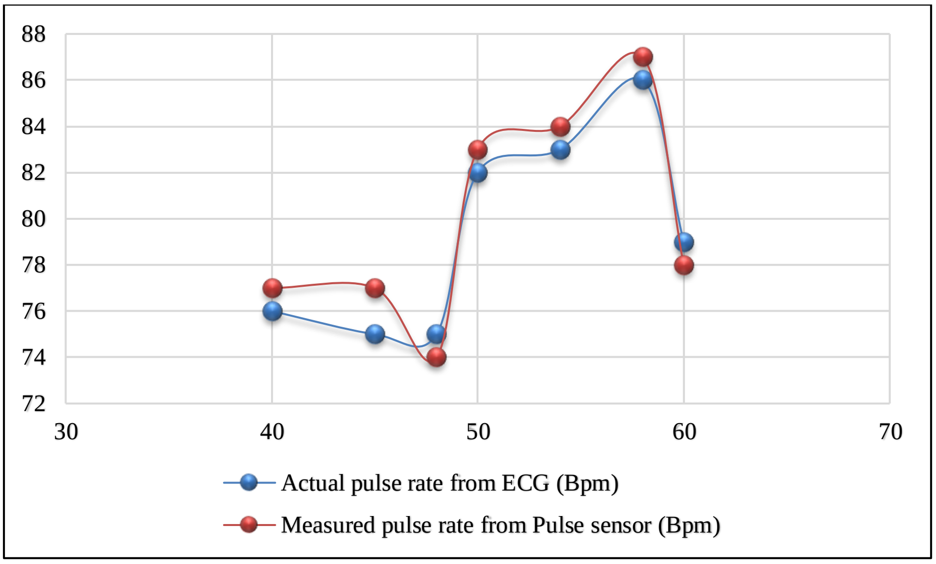

Figure 7: Effect of pulse rate on age group.
Source: Authors, (2026).

The figure 7. compares the actual pulse rate obtained from ECG with the pulse rate measured using the pulse sensor for different test conditions. Both curves show a similar trend, indicating close agreement between the measured and reference values. Minor deviations are observed at a few points, but the overall difference remains small across the range. The measured pulse rate follows changes in the actual heart rate effectively. These results indicate that the pulse sensor provides reliable pulse measurements for real-time monitoring.

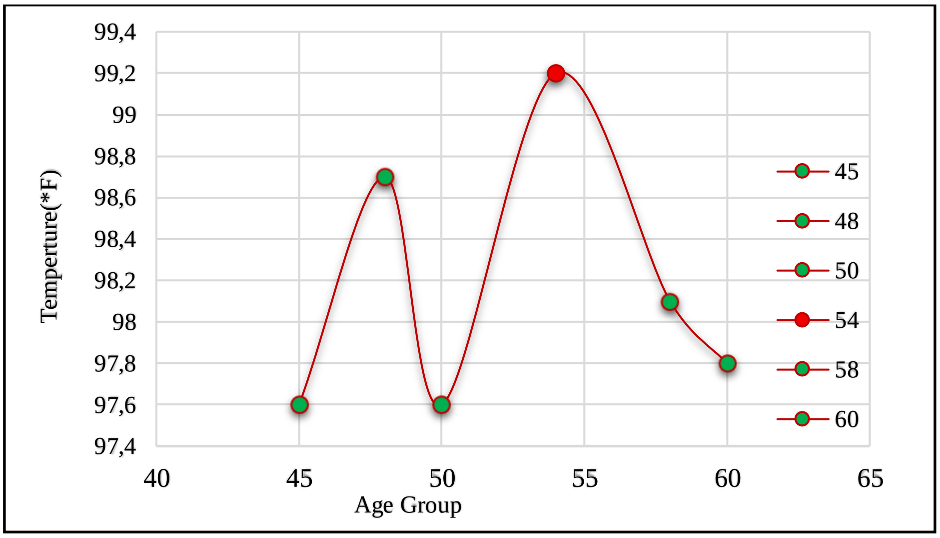

Figure 8: Driver temperature measurement during idling condition.
Source: Authors, (2026).

Figure 8. presents the variation of driver body temperature measured during idling conditions across different age groups. The recorded temperature values remain within a narrow range, indicating stable physiological conditions during idle operation. A slight rise in temperature is observed in the middle age group, followed by a gradual decrease at higher ages. No sudden or abnormal temperature fluctuations are noted in the measurements. Overall, the results indicate that idling conditions have minimal influence on driver body temperature.

If the temperature is abnormal the indication is displayed in dashboard and warning signal will be given in the event of emergency vice versa to pulse sensor measurement. Its unpredictable or measure the abnormal person for testing the developed system for alerting or warning the normal temperture set as abnormal tempetrature for testing purpose the warning signal as alarm with stopping light had indicated for safety and temperature displayed in the dashboard.

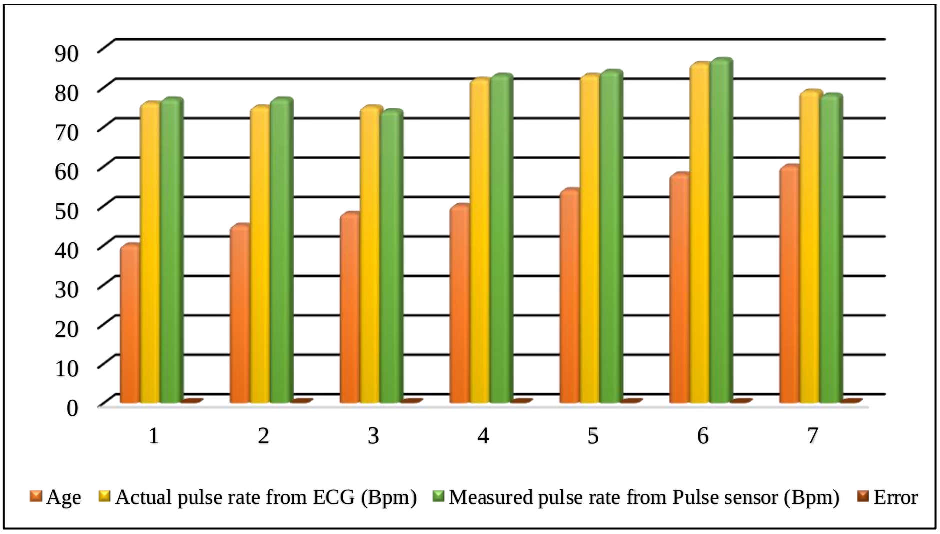

Figure 9: Comparison of actual and measured pulse rate with error variation across test subjects.
Source: Authors, (2026).

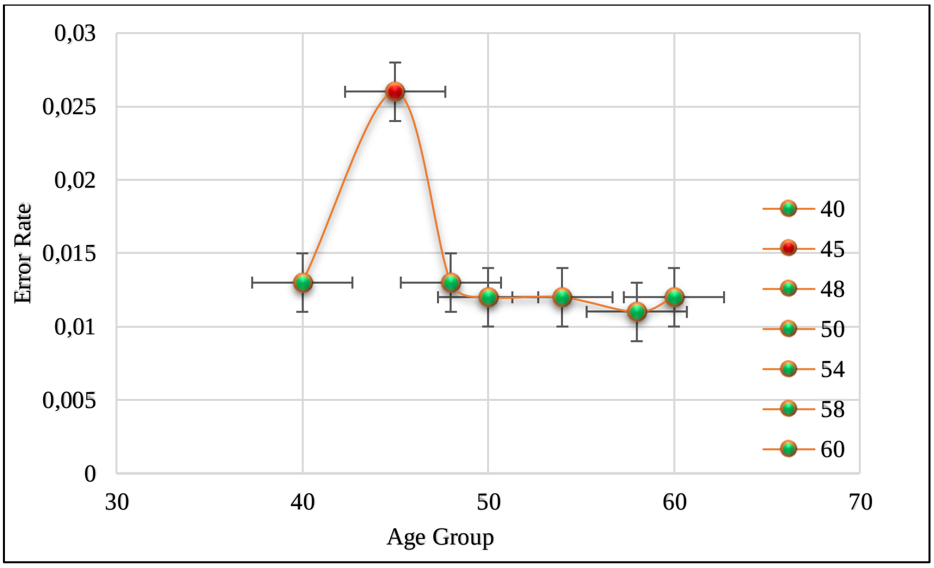

Figure 10: Error rate of proposed system over conventional system.
Source: Authors, (2026).

The figure 9 shows a comparison of actual pulse rate measured using ECG and the pulse rate obtained from the pulse sensor for different test cases. The measured values closely match the ECG readings, indicating good agreement between the two measurement methods. The error values remain small across all cases, showing consistent sensor accuracy. The results also indicate stable pulse measurement over different age groups. Overall, the pulse sensor demonstrates reliable performance for real-time heart rate monitoring applications. The figure 10. compares the actual pulse rate obtained from ECG measurements with the pulse rate measured using the pulse sensor for different test cases. The results show that the measured pulse rate closely follows the ECG values across all cases, with only minor deviations. The error values remain low, indicating good accuracy and reliability of the pulse sensor for monitoring heart rate under the tested conditions.

IV. CONCLUSION

The developed system senses the condition of driver and enchances the active safety systems to prevents collision using the sensor based technology. The displayed system shows the pulse and temperature rate of the driver in the dashboard in order to know the condition of the driver to the co passengers in the vehicle. The preferred system is designed elegance and accurately monitors the condition of the driver in static and dynamic condtions under limited speeds. The system explicitly enhanced sophisticatedly with an active safety system and alert mechanism is developed for the indian vehicles and for the auto industry manuafactures to reduce the fatality rate. The fatality rate is reduced by monitoring the fault of driver and the life of the rider is safe by preventing the collision in the emergency sistuations. The system supports to reduce the fatality, severe injury and vehicle damage. These developed sensor based technology is combined with the actuator in future work , where it activates the brake to stop down the vehicle gradually.

V. AUTHOR'S CONTRIBUTION

Conceptualization: C. Dineshkumar, Ibrahim Yakoopali.
Methodology: C. Dineshkumar, Ibrahim Yakoopali.
Investigation: Ibrahim Yakoopali, P D Jeyakumar.
Discussion of results: C. Dineshkumar, Ibrahim Yakoopali, P D Jeyakumar.
Writing – Original Draft: Mohammed Rizwan, T E Sarankishore, A Mohamed Ibrahim.
Writing – Review and Editing: Mohammed Rizwan, T E Sarankishore
Resources: C. Dineshkumar, P D Jeyakumar, A Mohamed Ibrahim.
Supervision: P D Jeyakumar, Mohammed Rizwan, A Mohamed Ibrahim.
Approval of the final text: C. Dineshkumar, Ibrahim Yakoopali.

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