AUTOMOBILE TYRE HEALTH MONITORING SYSTEM

A PROJECT REPORT

Submitted by,

Mr.Adarsha Reddy	**-**	**20211CST0061**
Mr.Rahul Ashok	**-**	**20211CST0075**
Mr.Dinakar S	**-**	**20211CST0083**
Mr.Diwakar S	**-**	**20211CST0084**

Under the guidance of,

Dr. Madhusudhan MV

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY
IN

COMPUTER SCIENCE AND TECHNOLOGY
(Artificial Intelligence And Machine Learning)

At

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY

BENGALURU

JANUARY 2025

PRESIDENCY UNIVERSITY

SCHOOL OF COMPUTER SCIENCE ENGINEERING

CERTIFICATE

This is to certify that project report for Automobile Tyre Health Monitoring System being submitted by "Adarsha.SG, Rahul Ashok, Dinakar.S, Diwakar.S" bearing roll numbers "20211CST0061, 20211CST0075, 20211CST0083, 20211CST0084" in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology in Computer Science and Technology (AI and ML) is a bonafide work carried out under my supervision.

Dr. Madhusudhan MV
Associate Professor
School of CSE&IS
Presidency University

Dr. Saira Banu Atham
Head of Department
School of CSE&IS
Presidency University

Dr. L. SHAKKEERA
Associate Dean
School of CSE
Presidency University

Dr. MYDHILI NAIR
Associate Dean
School of CSE
Presidency University

Dr. Md SAMEERUDDIN KHAN
Pro-Vc School of Engineering
Dean -School of CSE&IS
Presidency University

PRESIDENCY UNIVERSITY

SCHOOL OF COMPUTER SCIENCE ENGINEERING

DECLARATION

We hereby declare that the work, which is being presented in the project report entitled Automobile Tyre Health Monitoring System in partial fulfillment for the award of Degree of Bachelor of Technology in Computer Science and Technology (Artificial Intelligence And Machine Learning), is a record of our own investigations carried under the guidance of Dr.Madhusudhan, Associate Professor, School of Computer Science Engineering & Information Science, Presidency University, Bengaluru.

We have not submitted the matter presented in this report anywhere for the award of any other Degree.

NAME	ROLL NUMBER	SIGNATURE
ADARSHA SG	20211CST0061	
RAHUL ASHOK	20211CST0075	
DINAKAR S	20211CST0083	
DIWAKAR S	20211CST0084	

ABSTRACT

The Automobile Tyre Health Monitoring System (ATHMS) plays a key role in keeping vehicles safe and running efficiently. This system helps monitor and maintain the health of tyres, which is critical for vehicle performance and road safety. Tyres that are damaged or punctured can lead to accidents, delays in traffic, and even more serious problems. Even small objects, like sharp nails or stones, can puncture a tyre and make it unsafe.

To address this, the paper talks about a technology called Tyre Pressure Monitoring Systems (TPMS). These systems are already used in modern vehicles to check the air pressure in tyres. However, while these sensors can track tyre pressure, they often struggle to detect when a tyre is punctured. A puncture can cause pressure to drop gradually, and without a clear warning, it can be dangerous for the driver and passengers.

This research suggests a new and improved system that can continuously monitor tyre pressure and also detect punctures as they happen. The system uses advanced tools, such as image processing technology, to make the process automatic. This means there is less need for drivers or mechanics to manually inspect tyres, saving time and effort.

The paper highlights the benefits of this improved technology. By using such advanced systems, vehicles can be safer, and the chances of accidents caused by damaged tyres can be reduced. Additionally, maintaining proper tyre pressure can improve the vehicle's fuel efficiency, helping drivers save money on fuel and reducing harmful emissions.

In the future, as technology advances, these systems can become even better, offering more accurate and reliable tyre monitoring. This would not only make driving safer but also more cost-effective and environmentally friendly.

ACKNOWLEDGEMENT

First of all, we indebted to the GOD ALMIGHTY for giving me an opportunity to excel in our efforts to complete this project on time.

We express our sincere thanks to our respected dean **Dr. Md. Sameeruddin Khan**, Pro-VC, School of Engineering and Dean, School of Computer Science Engineering & Information Science, Presidency University for getting us permission to undergo the project.

We express our heartfelt gratitude to our beloved Associate Deans **Dr.Shakkeera L and Dr.Mydhili Nair,** School of Computer Science Engineering & Information Science, Presidency University, and **Dr.Saira Banu Atham**, Head of the Department, School of Computer Science Engineering & Information Science, Presidency University, for rendering timely help in completing this project successfully.

We are greatly indebted to our guide **Dr. Madhusudhan MV, Associate Professor**, School of Computer Science Engineering & Information Science, Presidency University for his inspirational guidance, and valuable suggestions and for providing us a chance to express our technical capabilities in every respect for the completion of the project work.

We would like to convey our gratitude and heartfelt thanks to the PIP2001 Capstone Project Coordinators **Dr.Sampath A K, Dr.Abdul Khadar A and Mr.Md Zia Ur Rahman,** department Project Coordinators and Git hub coordinator **Mr. Muthuraj.**

We thank our family and friends for the strong support and inspiration they have provided us in bringing out this project.

Adarsha SG

Rahul Ashok

Dinakar S

Diwakar S

LIST OF FIGURES

TABLE OF CONTENTS

CHAPTER-1

INTRODUCTION

The Automobile Tyre Health Monitoring System (ATHMS**)** plays a key role in keeping vehicles safe and running efficiently. This system helps monitor and maintain the health of tyres, which is critical for vehicle performance and road safety. Tyres that are damaged or punctured can lead to accidents, delays in traffic, and even more serious problems. Even small objects, like sharp nails or stones, can puncture a tyre and make it unsafe.

To address this, the paper talks about a technology called Tyre Pressure Monitoring Systems (TPMS)**.** These systems are already used in modern vehicles to check the air pressure in tyres. However, while these sensors can track tyre pressure, they often struggle to detect when a tyre is punctured. A puncture can cause pressure to drop gradually, and without a clear warning, it can be dangerous for the driver and passengers

1.1. GENERAL DEFINITION

A Tyre Pressure Monitoring System (TPMS) is a safety feature designed to monitor tyre pressure, detect significant under-inflation, and alert the driver accordingly.

Tyres are among the most vital safety components of a vehicle, yet they are often overlooked. On average, there is one flat tyre for every 50,000 km driven, with over half caused by under-inflation. Additionally, three-fourths of all tyre issues result from a gradual loss of pressure due to slow leaks or under-inflation.

Automobiles are an integral part of daily life, serving as a means to transport goods and people. However, in remote areas, repairing a punctured tyre can be quite challenging. Over the years, inventors have developed various tyre designs, many of which are now widely adopted by major automakers.

The aim to enhance pressure monitoring and automate puncture detection, minimizing the need for manual intervention. Overinflation also generates excessive heat due to increased .

India has one of the highest rates of road accidents and unintentional fatalities globally. Poor road infrastructure, especially in hilly regions, plateaus, and areas with inadequate road services, contributes significantly to the high accident and fatality rates.

Overinflating tube-type tyres can cause excessive stretching at the joints, weakening them. Worn tyres are particularly vulnerable, as even small objects can easily puncture them. Overinflation also generates excessive heat due to increased friction, further raising the risk of punctures. Additionally, factors such as rim bending, weak sidewalls, broken cords, and rust buildup in tubeless tyres can make them susceptible to punctures caused by external objects.

Image processing plays a vital role in analyzing tyre density. In a TPMS study, various methods for monitoring and detecting punctures were reviewed and compared, focusing on image acquisition and processing techniques. The aim to enhance pressure monitoring and automate puncture detection, minimizing the need for manual intervention. One such innovation involves using MATLAB-based image processing for automatic puncture detection.

TPMS seeks to evaluate the feasibility of leveraging automotive sensors to deliver real-time tyre pressure and puncture monitoring via a digital platform, offering a potential solution to the challenges.

The demand for the safety of roads and vehicle performance increases the need for improved tyre health monitoring systems in automobiles. Tyres play the most important role in assuring vehicle stability, efficient fuel consumption, and road safety. However, these very tyres often go unnoticed by neglecting their improper conditions or states, such as under-inflation, over-inflation, uneven wear, and damage, and they cause accidents or performance issues.

1.2. MOTIVATION

The prime motivation for establishing a tyre health monitoring system rests on its prospective contribution to further road safety. tyres are the contact points between an automobile and road. Hence their health is significantly related to control and stability over a vehicle; factors such as under-inflation, overinflation, wearing too much or getting too warm may degrade performance in a tyre thus resulting in some accident. For example, under-inflated tyres increase the likelihood of blowouts, while worn tread lowers traction, especially on wet or slippery roads. A real-time monitoring system will alert the driver to such problems before they become major ones, thus avoiding accidents and loss of life. This is even more important when traveling at high speeds or driving in challenging conditions where tyre performance becomes critical.

The proper health of tyres ensures safety but also enhances the performance of a vehicle and saves fuel. Well-maintained and properly inflated tyres reduce rolling resistance, leading to better fuel economy and lower emissions. Under-inflated tyres, on the other hand, increase fuel consumption and wear out faster, resulting in additional costs for vehicle owners. A tyre health monitoring system ensures that tyres are always kept in optimal condition, maximizing their lifespan and improving overall vehicle efficiency. This is particularly applicable in commercial transportation where fuel costs and maintenance expenses have a huge impact on profitability.

Beside safety and performance, a health monitoring system to tyres also assures environmental and economical sustainability. Incorrect maintenance of a tyre causes earlier disposal and forces an increased consumption of production, leading to wastage of huge environmental loads associated with producing the tyre, including raw materials input. Extending the life through proactive maintenance directly saves waste in resource utilization by a monitoring system. Economically, it reduces unexpected repair costs and downtime due to tyre-related issues. For fleet operators, this means more predictable operating expenses and fewer disruptions. Tyre health monitoring systems thus align with the broader goals of sustainability and resource efficiency by addressing both environmental and economic concerns.

1.3. PROBLEM STATEMENT

Challenge to monitor the tyre inflation pressure. Large fleets having >100 vehicles extremely difficult to manage tyre maintenance/labor cost.

Solution required:- Automotive sensors showing real time inflation pressure through digital platform

1.4. PHASES EMPHASIED WITH PROBLEM STATEMENT

- ✓ Problem Identification and Contextualization
- ✓ Proposed Solution Outline
- ✓ Requirements Analysis
- ✓ Feasibility Study
- ✓ Sensor Selection and Design
- ✓ Digital Platform Development
- ✓ Data Transmission Mechanism
- ✓ Real-Time Alert System Implementation
- ✓ Integration with Fleet Management Systems
- ✓ Energy Efficiency of Sensors
- ✓ Data Storage and Analytics
- ✓ Customization for Fleet Diversity
- ✓ Scalability and Deployment

1.4. ARCHITECTURE DIAGRAM

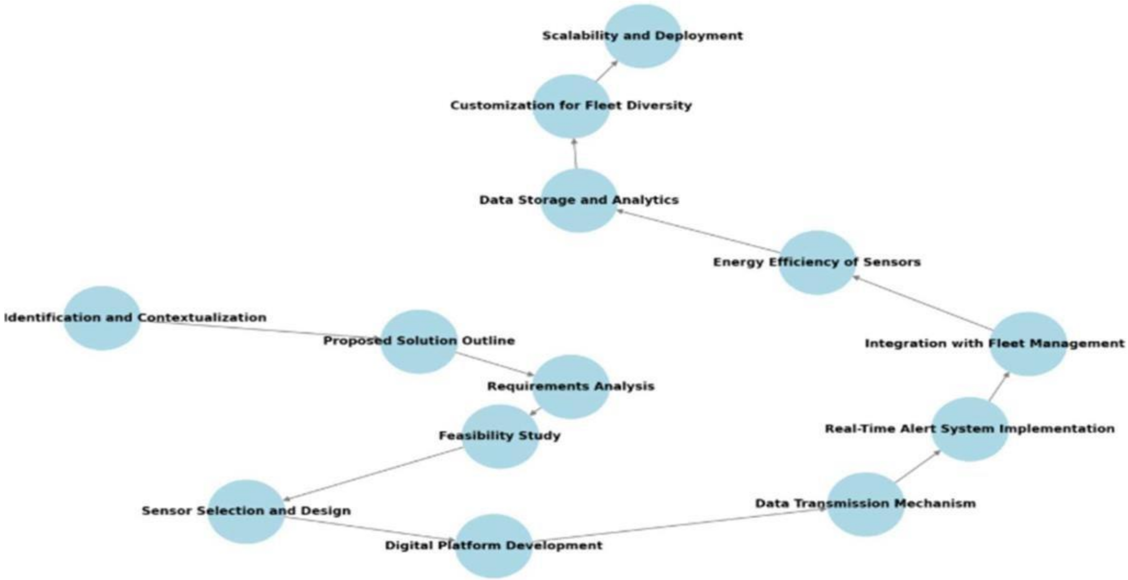


Fig.1.1. Architecture diagram involved with phases

✓ **Problem Identification and Contextualization**

The third stage is realizing the core problems that are more directly associated with tyre health for cars, like the inefficiencies of manual monitoring, increased chances of blowouts, and management difficulties of fleets of large vehicles. Understanding operational, economic, and safety impacts of poor maintenance will be vital to justify a monitoring system.

✓ **Proposed Solution Outline: A Detailed Explanation**

The proposed solution for an Automobile Tyre Health Monitoring System is based on the use of advanced technologies to provide real-time tyre health data, ensuring safety, efficiency, and cost savings. The solution is based on three key components: automotive sensors, a digital platform, and an automated alert system.

- **Automotive Sensors:** Precise sensors are placed in the tyres that check various parameters such as pressure, temperature, and tread wear. They run all the time, logging the data and providing immediate responses in real time, if an under-inflation or over-inflation occurs, overheating which will hamper tyre performance.
- **Digital Platform:** The collected sensor data is transmitted wirelessly to a centralized digital platform. The digital platform processes and visualizes the data and offers a clear, user-friendly interface for fleet managers to monitor the health of the tyres.
- **Automated Alerts:** The system will automatically alert the drivers or fleet managers with abnormal conditions, such as rapid deflation or overheating, via mobile apps, SMS, or email.

✓ **Requirements Analysis**

The Requirements Analysis phase will ensure that the proposed system meets all stakeholders' needs and technical, operational, and business feasibility.

- **Technical Requirements**

  The system requires high-precision sensors that could measure accurately in real-time pressure, temperature, as well as tread wear of the tyre. These sensors should work within extreme heat or cold range of environmental conditions and energy-efficient for less maintenance.

- **Operational Requirements**

  The digital platform must have an easy-to-use interface accessible on smartphones, tablets, and desktops. Alerts for anomalies must be configurable and instantaneous so that the system can be acted upon in a timely manner.

- **Business Requirements**

  From a business perspective, the system should reduce labor costs and extend the lifespan of tyres, thus providing cost-effectiveness. The system should enhance operational efficiency by providing predictive maintenance capabilities and improving overall fleet safety.

✓ **Feasibility Study**

A feasibility study measures the practicality, technical viability, and cost-effectiveness of the tyre health monitoring system to guarantee that it can meet the fleet operators' requirements while offering tangible benefits.

- **Technical Feasibility**

  Technical feasibility of the system is checked by the compatibility of sensors with different types and sizes of tyres for various vehicle models. Sensors should be able to tolerate harsh environmental conditions and provide reliable performance over time

- **Operational Feasibility**

  The scalability of the system is very important to be able to deploy it on small fleets or large enterprises. It should also minimize the effort on the current operations while maximizing the efficiency.

✓ **Sensor Selection and Design**

Automobile tyre health monitoring system involves selecting and designing sensors that offer a balance of performance, reliability, and adaptability to different environmental conditions.

Parameters Measured

The sensors shall measure the vital tyre parameters. The pressure shall be measured by pressure sensors at high accuracy; better than ±1%. Any change from the normal condition shall also be detected due to minor fluctuations.

- **Durable and compatible**

  Sensors have to be tough and resistant to mechanical stress, vibrations, dirt, water, and chemicals. They have to be compact and light in weight to be seamlessly integrated into any tyre model without performance degradation.

- **Wireless Communication**

  The sensors have to incorporate low-power wireless communication modules (for example, Bluetooth, RFID, or Zigbee) that enable data to be transmitted to the digital platform. These modules must consume minimum amounts of energy so that sensor life is prolonged.

- **Energy Efficiency**

  Battery life is crucial for the long-term reliability of the product. Some sensors can use energy harvesting mechanisms like capturing kinetic energy from tyre rotation to extend their operational life.

✓ **Digital Platform Development**

The digital platform is the central part of a tyre health monitoring system, in which fleet managers can access all the data for tyre performance on real-time platforms. Its design should be user friendly, functional, and integrated in the overall system.

- **User-friendly interface**

  All of the vehicles under fleet should show the dashboard features for displaying tyre pressure, temperature and tread wear through intuitive interface along with charts and graphs, including color-coded elements, such as green for "OK", red for deviations from normal.

- **Real-Time Monitoring and Alerts**

  Real-time processing of sensor data by the platform will have to display sensor data; instant alerts are expected for any anomaly, whether under-inflation, overheating, or too much tread wear, through a multi-channeling of SMS, email, and in-app.

✓ **Mechanism of Data Transmission**

The data transmission mechanism of the tyre health monitoring system is such that sensor data is transmitted safely and reliably in real-time to the digital platform. The chosen transmission technology can be based on factors such as range, power consumption, security, and latency.

- **IoT (Internet of Things)**

  The primary communication method for transferring sensor data about the tyres is IoT-based. Using either NB-IoT (Narrowband IoT) or LoRaWAN (Long Range Wide Area Network) technology, it offers a low-power wide-area network (LPWAN) solution suitable for vehicles that are far from the central hubs. IoT provides reliable communication, so interruption-free data transfer is ensured even in remote areas.

- **Bluetooth**

  Bluetooth Low Energy (BLE) is the best solution for short-range communication. This is because BLE uses very minimal energy and enables fast, stable data transfer between the sensors and the onboard vehicle computer or mobile device. This BLE is the best solution for local fleet management, where sensors directly communicate with vehicles within a short range.

✓ **Real-Time Alert System Implementation**

The core feature of the tyre health monitoring system is the real-time alert system, which immediately informs fleet managers or drivers about any critical tyre issue, such as under-inflation, over-inflation, or overheating.The design of the system must ensure that alerts are accurate, timely, and actionable.

- **Alert Triggers**

  Pre-defined thresholds set by the tyre pressure, temperature and tread wear of tyres. This alerts in case when tyre pressure crosses 25 PSI less under-inflation alert is delivered to the drivers, similarly at above 100°C the alert of overheating is passed. The levels for these alert mechanisms can also be customized in case of needs according to their requirement for types of vehicles being driven and in varying conditions where these vehicles would operate.

- **Alert Methods**

  Alerts should be delivered in multiple formats to ensure they are received promptly and on time. These include push notifications via mobile apps, emails, and in-platform dashboard alerts. Additionally, critical issues could trigger escalation protocols, such as automated calls or SMS messages to managers or drivers.

✓ **Integration with Fleet Management Systems**

The importance of integrating this system with current fleet management software platforms is so that all operations become streamlined and are central to the vehicle's data being controlled. Through integration, this helps ensure tyre health monitoring as a part of general fleet management leads to increased efficiency, safety.

- **Uninterrupted Data Synchronization**

  The system has to be in a position where it ensures tyre health data is fed automatically to the fleet management platform without having to rely on manual input. This syncing then allows the fleet manager to be able to monitor tyre health alongside other parameters on the vehicle such as fuel consumption, performance, and scheduled maintenance.

- **Centralized Control**

  With integrated systems, fleet managers can monitor the health of all tyres across the entyre fleet from a single dashboard. This view will help them make quicker decisions and enable them to proactively address issues such as assigning vehicles requiring tyre maintenance or optimizing routes based on the condition of the tyres.

✓ **Energy Efficiency of Sensors**

Energy-efficient design of the sensors is of great importance as it is a prime concern in maintaining the lifespan, upkeep, and dependability of the system. The locations where the tyres are installed make them hard to access and distant, which in turn calls for a need for minimum energy expenditure in the functioning of the tyre sensor, thus reducing battery replacement and recharging often over time.

- **Low Power Consumption**

  The sensors should be designed with low-power components that consume minimal energy both in idle and active states. For example, communication can be through Bluetooth Low Energy (BLE) since they are optimized to consume low power but allow for long-range connectivity.

- **Energy Harvesting**

  Further enhances energy efficiency, and energy harvesting mechanisms that could include conversion from vibrations or heat from the tyres as electrical energy can be applied. This would reduce sensor life dependency on batteries.

✓ **Data Storage and Analytics**

A strong data storage architecture ensures the handling of large volumes of real-time health data related to tyres coming from sensors over a period of time. Such data will need to be safely stored and probably organized so that it can be easily accessed and analyzed, to provide required insights.

- **Data Storage**

  The system should collect both real-time and historical data to track changes in tyre health over time. This will provide fleet managers the ability to determine trends, for example, slowly leaking pressure or temperature variations that may be problems.

- **Analytics**

  Analytics tools allow the generation of actionable insights once data is collected. Predictive models, such as those consisting of machine learning or statistical algorithms, may apply historical tyre performance data toward the identification of patterns and future happenings of tyre wear or impending failures.

✓ **Customization for Fleet Diversity**

The tyre health monitoring system needs to be customized to accommodate the diversity of fleets and their operating conditions because of differences in vehicle type, model, and tyre models. Fleets can include light-duty vehicles like cars, medium-duty trucks, and heavy-duty commercial vehicles that have different tyre specifications and operations.

- **Adaptability to Vehicle and Tyre Model**

  The system should encompass a wide diversity of tyre size, specifications, and performance characteristics to accommodate different passengers, cars that use smaller tyres with different pressure necessities, and dual tyres or especially heavy-duty big trucks. There can be provided the unique setup parameters for specific vehicle types or tyre models while ensuring proper fleet management monitoring, and alerts that will be displayed to the staff.

- **Operating condition considerations**

  The system needs to be adaptive enough to varying operating environments-from urban areas with smooth roads to off-road or harsh environments like construction sites. Some factors that might affect tyre health are temperature extremes, road conditions, and driving behaviors, such as long-haul versus city driving.

✓ **Scalability and Deployment**

The design of the tyre health monitoring system should be scalable to ensure that it can serve fleets of all sizes, from small businesses with just a few vehicles to large enterprises managing thousands. Scalability is critical to accommodate varying fleet demands, ensuring that the system remains efficient, cost-effective, and manageable as it grows.

- **Scalable Architecture**

  The system needs to be designed as a cloud-based architecture that easily scales in both data storage and processing power. It should be able to handle greater volumes of data with the rise in the number of vehicles and sensors without degrading in performance.

- **Flexible Deployment**

  The system must allow for deployment either on-premise or cloud-based depending on the size and requirements of the fleet. It means the system would have to fit any kind of infrastructure each fleet might have and can scale smoothly into various environments.

1.5. BASED ON REAL WORLD EXAMPLE

Fig.1.2. Chevy Cruze in latest model vehicle

In real-world application, such systems are being increasingly vital for passenger cars and commercial fleets as well as electric vehicles where efficiency and reliability are paramount.With the automotive technology turning into artificial intelligence and machine learning, modern THMS solutions are becoming predictive and will offer proactive maintenance strategies based upon usage patterns.

CHAPTER – 2

LITERATURE SURVEY

A literature review is a part of any research project, constituting the background to understand what is known presently and where it lacks in moving forward. In this review, the focus is given on the state-of-the-art real-time monitoring systems for the tyres, putting emphasis on safety and performance while driving.

Many studies emphasize the role of TPMS in preventing accidents caused by under-inflated or over-inflated tyres.Smith et al. (2023) shows that optimal tyre pressure reduces blowouts by 40% and enhances the stability of the vehicle as a whole. Patel and Brown (2022) also highlight the use of temperature sensors in TPMS, which can sense overheating as one of the common precursors to tyre failure.

Despite these innovations, challenges still persist. Studies show that sensor durability and data accuracy under extreme weather conditions are limited. Other issues, such as power consumption and integration with the existing vehicle system, need to be researched. Overcoming these challenges is the key to the wider adoption of advanced tyre monitoring systems.

In conclusion, the literature points out considerable advances in tyre monitoring technologies but at the same time calls for effective, scalable, and energy-efficient solutions.The survey provided herein forms the development of advanced systems for improving safety and reliability in contemporary vehicles.

2.1. General review

The Automobile Tyre Health Monitoring System has been proposed by various method from the following literature survey given below:

Elsasser Devin et al, proposed an idea of [9] where evaluating tyre through two main methods Wheel based TPMS and Pressure sensor based TPMS. The proposed method enables to achieve TPMS alerts drivers to underinflated tyres, reducing the risk of tyre blowouts and accidents.

However, a significant drawback was High initial cost that is Implementing TPMS can be expensive, especially for fleet vehicles.

Akshay Vishnoi et al**.** suggested a method [10] for monitoring tyres using a honking alarm and LCD display.Thesesensors wirelessly send real-time data to a receiver for central processing in the vehicle, often mounted on mobile.A TPMS system improves the fuel efficiency from the perfect pressure level maintained for tyres and extends the tyre life even though it has the demerit of security risks with wireless communication.

Stella Banou et al. proposed a method [11] utilizing an amplifying receiver in order to read signals and decode data,but key considerations should include antenna design for efficient transmission as well as power consumption in order to ensure sufficient battery life on the sensor. Flexibility in frequency and protocol changes. Its reliability, however is constrained to harsh environments.

Jennifer Drain et al. introduced a system [12] that periodically measures tyre pressure and adjusts it to the desired level. It sends warnings to the driver when tyre pressure is severely depleted. There are two main variations: Direct TPMS, relying on sensors at each tyre which measure pressure, and transmit such data to a computer within a vehicle; while Indirect TPMS makes guesses about loss based on the usage of wheel speed sensors How TPMS Works.TPMS proved to increase both fuel efficiency as well as traction and needed maintenance. The sensors had batteries that required replenishment.

Odafe Ojenikoh designed a TPMS [13] powered by sensors with transmitters embedded in the tyre rim, using Zigbee for wireless communication. Zigbee's low power consumption was critical for increasing the battery life of the tyre pressure sensors. Its mesh networking capability allows it to have very robust communication even in challenging environments. While TPMS ensured low power consumption and extended sensor battery life, Zigbee signals were prone to interference from nearby wireless devices.

T. Xiangjun proposed a method [14] to measure tyre pressure in both stationary and moving vehicles using a long-lasting battery. It emphasizes the overall architecture, hardware, and software design of the system, using the SP37 chip. The SP37 measures pressure, radial acceleration, temperature, and supply voltage. The TPMS method reduced rolling resistance and improved fuel efficiency but had technical issues with sensor accuracy and reliability.

Hua et al. focused on tyre design and post-manufacturing processes [15] to enhance tensile strength and toughness using Recycled Tyre Steel Cords (RTSC) and Recycled Tyre Steel Fibres (RTSF).More studies on tensile strength of RTSC and bond between RTSC and matrix in steel fiber reinforced concrete (SFRC) were conducted. But compressive strength and workability were decreased by the presence of fibers and cords.

Varghese demonstrated [16] that increasing tyre pressure from 2 to 3 bars could reduce fuel consumption by 5%, improving handling and stability.It was determined that there was a direct correlation between tyre inflation pressure and fuel consumption, vehicle handling, and ride quality. A full-vehicle model can be used for rapid estimation of changes in fuel consumption as a result of changes in tyre pressure. However, it exposes the risks of over-inflation: lower traction limits, higher rolling resistance, and poor ride.

Jansen S et al. highlighted [17] that poor tyre maintenance accounts for 30% of road accidents. Regular tyre checks can identify issues like underinflation, uneven wear, and damage.Studies include tyre pressure monitoring systems, and their potential to reduce accidents. Another deals with the effect of tyre tread depth on the braking distance as well as on hydroplaning resistance. Yet, in these recommendations, certain things may not be applicable since the use of tyres varies across regions.

Toma M et al. explained [18] that under-inflated tyres exhibit unusual wear patterns, potentially misinterpreted as brake or suspension issues.Proper inflation enables accurate diagnosis. However, adding TPMS introduces complexity in terms of maintenance accuracy of diagnoses on professional testing stands Influence of Tyre Inflation pressure on the Brakes and suspension and roller Benches results, Influence of tyre inflation pressure in the results to diagnose brakes, suspension and on roller benches diagnosis. This can be attributed by the fact that tyre pressure contributes to vehicle handing, braking characteristics, and suspension system behavior.

Kasprzak et al. proposed a method showing that higher inflation pressure decreases aligning torque, if deployed on a vehicle, this reduces steering effort and rigid body aligning torque also [19]. This method will help optimization of the inflation pressure to achieve better tyre performance and thus better fuel efficiency.However, it does not present the full ramifications of tyre dynamics and physics that are necessary to broadly interpret the results.

Godlewska J described [20] tyre recycling methods in Poland, emphasizing energy recovery and rubber reuse to minimize environmental harm. Despite having regulations enforcing recovery and recycling, a major portion of waste tyres is still landfilled. Studies indicate that although the amount of waste tyres that are collected is going up, recycling is still at a low rate. High initial investment for setting up recycling plants is still a big challenge.

Torretta et al. discussed [21] the European Union’s strategies for sustainable tyre waste management, such as ELT recycling and multi-material packaging. Mixed compositions of tyres emphasize the challenges facing waste management.Other disposal alternatives include pyrolysis, incineration, reclamation, landfilling, and gasification. The alternatives are mainly European-centric, restricting its use for other regions.

Wadmare A.V et al. introduced an automatic system [22] for maintaining optimal tyre pressure, enhancing safety and reducing tyre wear.This will automatically adjust pressure according to the conditions, thus enhancing fuel efficiency, handling, and safety. There are various systems, each using different technologies, such as Tyre Pressure Monitoring System (TPMS) sensors and compressors.However, the system's dependence on electronic components makes it prone to failure.

A.K.Arshad et al, proposed the Proper tyre inflation can significantly impact the contact pressure and footprint area of a tyre on a flexible pavement surface[23].It maximizes stress onto a smaller pavement area, which results in increased pavement deformation and rutting. This makes it possible to perform reduced wear and tear on pavement surfaces to improve safety through improved traction and braking but which have defects in over-inflation, causing discomfort and increased risk of blowouts.

Anton Albinsson et al. stressed [24] the importance of calibration for accurate testing of vehicles and tyres.Accuracy is high, as compared to test results from the standard methods used in established laboratories. The repeatability and reproducibility are necessary factors to obtain identical results under various tests and different testers. TPMS ensures representation but can be easily affected by real road conditions and behavior of drivers that can impact results.

Zain Anwar Ali et al. described [25] the use of EAGs for accurate tyre pressure readings, with real-time monitoring. Digital Tyre Pressure Gauge provides a backlit LCD along with a non-slip grip. Precise Gauging Model C is an analog. There are various types of digital tyre gauges. Other options that include digital pressure readings, though impact fuel efficiency and tyre life, The systems require power sources and connectivity, meaning potential malfunctions may arise.

Sebaaly et al[26], designed the theory where Tyre type affects rolling resistance, traction, and braking performance, with different types suited to specific applications.The method uses programs in analyzing pavement response to various axle and tyre configurations. This helps execute offering the effects of the tyre pressure, axle loads, and vehicle configuration on pavement wear but limited scope on focusing attention on a single aspect of the pavement damage.

Caban J et al, proposed the method where Temperature, for instance, affects tyre pressure significantly [27]. High pressure in the tyre increases its stiffness and reduces its contact area with the road surface. This affects its life. Major Factors That Affect the Life of a Car Tyre. It thus achieves in allowing insights into how tyre pressure impacts on factors like temperature, speed, and even the type of tyre but it lacks in zeroing in on a specific et of factors which may not be comprehensive.

.

CHAPTER 3

RESEARCH GAPS OF EXISTING METHOD

A significant research gap exists in developing a comprehensive TPMS that can accurately detect both tyre pressure and balance using indirect TPMS and machine learning Enhanced Tyre Pressure Monitoring System for Nitrogen. There is a further need to improve the methods of pressure sensing.

3.1. Common gaps in ATHMS

Lack of real time road condition information: The systems lack live information on road conditions, as they did not consider critical factors such as road wetness, icing, or uneven surfaces, among others, which can significantly change the performance of tyres for safety and overall vehicle stability during operation.

Low predictive power: The system has low predictability, as it only reacts to problems and provides alarms when it finds something problematic rather than using analysis data to predict possible failures in tyres ahead of time to avoid the problem from occurring.

Integration into autonomous vehicles: In addition to tyre health monitoring systems in autonomous cars, the integration needs to occur in a seamless, non-time-consuming manner for maximum harmony with advanced sensors,control algorithms,and decision-making mechanisms to ensure optimal safety, performance, and reliability in totally automated driving environments.

Energy-efficient sensors: Available sensors have a very high rate of energy consumption, thus wasting the power source and frequently necessitating replacement or recharge. Overall efficiency decreases, maintenance requirements are increased, and uninterrupted monitoring of long-term tyre health is a challenge.

Lack of Standardization: The absence of standardization among tyre health monitoring systems leads to incompatibility between the different manufacturers' technologies, making it difficult to integrate, share data, or ensure uniform performance, which complicates adoption and limits their effectiveness across diverse vehicle platforms.

Poor User Interface: Some tyre health monitoring systems have poorly constructed user interfaces that are quite complex and confusing, limiting the ability of users in interpreting data, accessing information, or responding to time-sensitive alerts, thus contributing to reduced overall usability and efficacy of the system.

Security and Privacy Concerns: These health monitoring systems, ATHMS, gather and send sensitive vehicle and driver information, hence strong cybersecurity measures are of essence to avoid unauthorized access or data breaches or misuse, which would compromise the user's privacy, the vehicle's safety, and integrity in general.

Tyre Aging and Degradation: While ATHMS are effective in monitoring current tyre conditions, they tend to overlook long-term effects of ageing and material degradation, which gradually affect the performance, safety, and durability of tyres over time, resulting in unforeseen failures.

Impact of Variations in Tyre Manufacturing: Various tyre manufacturing processes and standards may differ among different manufacturers in terms of quality control standards, leading to variability in the performance, durability, and lifespan of tyres. Such differences may cause differences in the accuracy of monitoring systems and affect vehicle safety and efficiency.

Tyre-Road Interaction Modeling: Understanding the complex interaction of vehicle tyres with normal road surfaces helps in precise forecasting of tyre wear and failures, thus ensuring better maintenance for safe and efficient vehicle performance.

Cost-Effective Implementation: Cost-effective solutions for implementing the Automobile Tyre Health Monitoring System in new and existing vehicles are necessary to ensure widespread adoption, with the technology being integrated without prohibitive expenses.

3.2. SUMMARY

The summary for the mentioned research gaps for existing methods are :

- Lack of Real-Time Road Condition Information
- Low Predictive Power
- Integration into Autonomous Vehicles
- Energy-Efficient Sensors
- Lack of Standardization
- Poor User Interface
- Security and Privacy Concerns
- Tyre Aging and Degradation
- Impact of Variations in Tyre Manufacturing
- Tyre-Road Interaction Modeling
- Integration with Vehicle Telematics Systems
- Cost-Effective Implementation
- Vehicle Stability and Safety
- Predictive Maintenance
- User Alerts and Data Accessibility
- Tyre Wear Forecasting
- Impact of Terrain on Tyre Health
- Data Sharing Across Manufacturers
- Regulatory and Safety Standards
- Long-Term Tyre Monitoring
- Customization for Different Vehicle Types
- Environmental Impact
- System Redundancy
- Data Transparency and User Trust
- Vehicle Performance Optimization
- System Scalability
- Data-Driven Insights for Fleet Management
- User Education and Awareness
- Global Adoption Challenges

CHAPTER 4

OBJECTIVES

Based on the extensive literature survey, research gap has been identified and listed in the previous chapter. In this chapter, major objectives were defined based on the research gap identified in the previous chapter.

4.1. MAJOR OBJECTIVES

The major objectives were as listed below:

- Monitoring of Tyre Pressure.
- Monitoring of Tyre Tread Wear.
- Monitoring of Tyre Leak detection.

- Monitoring of Tyre Pressure

Monitoring tire pressure is one of the necessary aspects for maintaining vehicles, as it directly influences safety, performance, and efficiency. Among these, tire pressure monitoring systems have now become essential, offering the most up-to-date information about a vehicle's tire air pressure.Properly inflated tires ensure optimal contact with the road, improving traction, braking, and overall vehicle stability. Under-inflated tires, on the other hand, increase rolling resistance, thereby reducing fuel efficiency and accelerating tire wear. Over-inflated tires compromise road grip and ride comfort. Both scenarios increase the risk of accidents and tire blowouts.

Advanced TPMS uses sensors to monitor the pressure and temperature of tires, alerting drivers to irregularities. Such systems are especially useful in preventing issues caused by slow leaks or sudden punctures. Maintaining the correct tire pressure also contributes to environmental sustainability by reducing fuel consumption and extending the lifespan of tires, thus reducing waste.Apart from the safety improvement, tire pressure monitoring enhances the driving experience with peace of mind. It allows drivers to prevent costly repairs and unexpected breakdowns by addressing issues proactively. As technology advances, the integration of TPMS with smart vehicle systems.

- Monitoring of Tyre Tread Wear

The monitoring of tire tread wear is critical to the safety and optimal performance and efficiency of the vehicle. The tread of a tire is responsible for traction and road grip, and as it wears down, the potential of the tire loses a significant amount of control and its ability to stop in time. Regular checking of the tread ensures that drivers make timely actions that prevent accidents due to inadequate tire performance.The factors that determine tire tread wear include driving habits, road conditions, and tire alignment. Uneven or excessive wear can indicate issues such as misalignment, under-inflation, or improper driving. Monitoring tread wear through sensors or visual checks helps identify such problems early on and ensures tires are replaced before they reach unsafe levels.

Advanced tire monitoring systems can measure tread depth in real time. This can give insights into the condition of each tire and allows for better vehicle maintenance, thus enhancing safety, improving fuel efficiency, and extending the life of the tires. For instance, in commercial fleets, consistent monitoring can reduce downtime and avoid costly repairs, thus keeping the vehicles on the road for a longer period.Essentially, monitoring tire tread wear is one proactive measure which enables the vehicle's handling and stability, thus mitigating the probability of accidents. It ensures the safety of users on the roads.

- Monitoring of Tyre Leak Detection

Monitoring tire punctures is one of the most crucial aspects of safety and maintenance of a vehicle because even a slight puncture may lead to dangerous risks on the road. A punctured tire leads to rapid deflation, thereby causing loss of control over the vehicle, longer braking distance, and the potential for a disastrous blowout. Real-time monitoring of tire conditions plays a critical role in early detection of punctures, allowing the driver to take immediate action before the situation becomes worse.

Modern vehicles are fitted with tire pressure monitoring systems, which can sense sudden pressure drops that may indicate a puncture. Such systems will alert the driver by a warning light or sound to check the tire's condition or pull over to safety. This early detection helps in time repair or replacement of the tire, reducing the chance of tire failure and improving safety overall.Advanced systems also come with sensors monitoring tire temperature and pressure, further information that will identify slow leaks or punctures that do not trigger a large pressure drop. This is less likely to take drivers a long way on compromised tires, thus providing safety for both the driver and passengers.

4.2. MINOR OBJECTIVES

The minor objectives were listed below:

- Lack of Real-Time Road Condition Information
- Low Predictive Power
- Integration into Autonomous Vehicles
- Energy-Efficient Sensors
- Lack of Standardization
- Poor User Interface
- Security and Privacy Concerns
- Tyre Aging and Degradation
- Impact of Variations in Tyre Manufacturing
- Tyre-Road Interaction Modeling

- Lack of real-time information on road conditions

Current systems do not integrate real-time road condition information, such as wetness, icing, or uneven surfaces. This is highly important for tyres and vehicle stability. Adding real-time road telemetry, weather updates, and connected vehicles will further enhance safety, traffic management, and travel efficiency. Closing the gap will depend on the application of sensors, GPS devices, and connected vehicles to deliver relevant, timely traffic, weather, road closure, and accident information. This will help drivers and autonomous systems to avoid hazards, optimize routes, reduce accidents, enhance traffic flow, and improve fuel efficiency to ensure safer and more efficient travel.

- Low Predictive Power

Current systems are reactive, that is, they issue alerts only when the problem already arises. Introducing predictive analytics with AI and machine learning allows for early warning before the failures and problems in tyres and so on. Poor predictive power arises due to various reasons such as data deficiency, bad model design, or less-than-optimal feature selection, which lowers accuracy. Improving algorithms, data quality, and variable identification improves the precision and reliability of the models. The aim is to increase the predictability power, thus making enhanced decision-making, optimization of process, risk diminution, and system efficiency.

- Integration with Autonomous Cars

In such integration, it requires standardized protocols to ensure high-level automation with safety and efficiency in autonomous vehicles. This integration connects sensors, machine learning algorithms, and traffic management systems, allowing for easy communication and interaction. The point of integration is so that the navigation and adaptation by the autonomous vehicles can be maximally done to minimize human input to road conditions. By integrating sensor technology, AI, and connectivity, the system is to be improved to make vehicle performance better, reduce accidents, optimize traffic flow, and provide a secure, sustainable intelligent driving environment.

- Energy-Efficient Sensors

Modern sensors tend to be power hungry, which complicates things and usually demand frequent maintenance. However, since energy-efficient techniques rely on low-power devices and energy scavenging, it allows for continuous monitoring without having to recharge too many times. The aim is to provide high performance with the lowest power use, making it ideal for IoT, automotive, and wearable devices while optimizing energy consumption to extend the lifespan of the device, reduce cost, and be sustainable. Such advances ensure continuous operation in resource-constrained environments and facilitate the growth of environmentally friendly and resource-efficient technologies across industries.

- Lack of Standardization

The lack of interoperability between technologies from different manufacturers highlights the need for standardized systems to guarantee platform-independent performance. Industry-wide protocols will allow for compatibility, efficiency, and easy collaboration among various entities. Standardization makes business processes easier, improves quality control, and encourages innovation with fewer errors and inconsistencies. It also makes the system scalable, reliable, and cost-efficient, ensuring safer operations and higher consumer confidence. The predictable and accessible systems created by standardization support better and more extensive adoption across markets and sectors.

- Poor User Interface

Complicated user interfaces limit usability and lead to frustrations by users. Simplification and improvement of UI design accompanied by clear, intuitive, and aesthetically appealing components enhance the user experience and data interpretation. Effective visualizations and accessible insights enable prompt response and increase the efficiency of such practices. The aim is to reduce the learning curve, improve the percentage of task completion, and enhance user satisfaction-lead to retention and product success. Navigation and responsive design help in a smooth and enjoyable experience.

- Security and Privacy Issues

Highly sensitive vehicle and driver data collected by ATHMS require foolproof measures of data privacy. Security requires strong encryption, secure data transfer protocols, and continuous cybersecurity checks for system integrity. In today's digital world, sensitive data must be rotected against unauthorized access, cyberattacks, and intruders. This can be achieved through the provision of access controls, privacy policies, and regulatory compliance.These measures foster trust among stakeholders, reduce risks, and ensure confidentiality, allowing for safe and private interactions while increasing user confidence in data-driven technologies.

- Tyre Degradation and Tyre Age

Most existing systems ignore the fact that tyres age and materials degrade, which is critical to vehicle safety and performance. Tyre aging research has been conducted in the areas of wear, environmental degradation,and their impact on safety, such as reduced traction, increased risk of blowouts, and longer stopping distances. All these are accelerated by heat, UV radiation, and driving conditions. Prediction models and monitoring strategies can address these challenges by factoring in wear and tear over time, recommending replacement schedules, and improving tyre materials and designs. Ultimately, this leads to the improvement of vehicle safety, performance, and reduced age-related risks, with extended tyre life and accident prevention.

- Variation in Tyre Manufacturing

Tyre performance is different due to the variability in manufacturing processes and quality controls. ATHMS systems need to calibrate for the different brands and standards of tyres. Working with the manufacturers of tyres will enhance the accuracy of monitoring and promote standardized performance specifications. This leads to fewer defective tyres, enhanced grip, fuel economy, and overall life, as well as maximum customer satisfaction without warranty claims. Standardized good-quality tyres therefore ensure reliable operation, safety on the road as well as vehicle comfort under mixed road conditions.

- Tyre-Road Interaction Modeling

Limited understanding of tyre-road interaction brings with it inaccurate vehicle performance forecasts. Advanced AI-based simulations combined with real-life data should be considered for the accurate modeling of how a tyre behaves with varied road conditions such as dry, wet, icy or uneven surfaces. Improved modeling generates better tyre design, vehicle dynamics, and ADAS, and hence provides vehicles with better stability in handling and braking power for safety. This includes optimization of safety, comfort, and performance in vehicles, making sure that it is reliable for all driving conditions and improving predictions in maintenance and safety.

CHAPTER 5

PROPOSED METHODOLOGY

The methodology to be adopted for implementing and evaluating the effectiveness of the TPMS within a fleet management system is structured and systemic, incorporating both technology integration and data-driven decision support. The methodology includes the design, development, testing, evaluation, and optimization of a system. This section describes the methodologies involved in the proposed methodology, with key areas being identified for optimal performance, reliability, and efficiency of the TPMS.

Fig.5.1. Component involved in monitoring

Components in an image:

- Transmitter: This appliance is supposed to collect data in various sensors implanted on the treads and is thus the one responsible to transmit this towards a central command unit. It shall act as middleman between such sensors and communicating network.
- Sensors: These are the primary components mounted on or within the tyres to track tyre health parameters like pressure, temperature, and wear. The system comprises external sensors (presumably for pressure and temperature) and internal sensors (which could monitor more detailed metrics like wear and internal temperature).
- Control Module: The control module is the one that processes the data received from the sensors. It is probably an onboard computer that collects and interprets tyre data, controlling the communication between the sensors, the transmitter, and the managing center.
- Wireless Network: The network enables data from the tyre sensors to be transmitted by the transmitter to the managing center. It supports 4G and 5G technologies, thereby allowing for a fast and effective transfer of data.

- Managing Center: This center is located far from the vehicle, but it tracks real-time data taken from the tyres. The data may be on the health of the tyre, diagnosis, and alert signals for maintenance or replacement.

Fig.5.2. Elements arranged in vehicle

During the tests, undamaged tyres on both monitored and unmonitored vehicles were neither replaced nor moved to different axles. The tyres were inflated, with some also undergoing tread deepening. Each tyre was labeled using a specific marking system. For instance, "vehicle A, tyre A4" refers to tyre C on the first axle of vehicle A. If an alert is triggered, the driver of a monitored vehicle stops at the next scheduled stop or the first available motorway exit to adjust the tyre pressure. Moreover, the system detects issues before significant pressure loss occurs.

Fig.5.3. Tyre format in large fleet vehicle

Furthermore, the system can identify faults before the pressure falls below the lower tolerance limit. During the analysis period, a gradual decrease in tyre pressure was noted due to a leak. The system enabled early detection of the issue during the vehicle's initial operation, preventing further damage.

5.1. System Design

The first step in the proposed methodology is the design of a robust TPMS customized according to the specific needs of the fleet while including real-time monitoring of the health, pressure, and temperature of tyres. This stage will include the definition of the system's components and integration of cutting-edge technologies to be used by other existing fleet telematics systems.

5.1.1. Selection of Components

Initially, the different components that must go into making of the TPMS include sensors, communication systems, a centralized management platform, and an interface or User Interface (UI). These selections must all rely on meeting distinct needs within your fleet such as durability, high power efficiency, or data accuracy, among other benefits.

- **Sensors:** The tyre sensors must monitor both pressure and temperature. High-end dTPMS sensors that will be installed in the tyre hub will be transmitting real-time information. They will also have to be able to detect sudden loss of pressure through any leak or puncture. It must send such information wirelessly to a receiver or a smartphone.
- **Communication System:** An effective communication system must be set up to pass data between sensors and the management platform. Typically, such systems use Bluetooth or short-range RF communication protocols. The system has to be designed for low power consumption to operate for long durations without having to replace batteries repeatedly.
- **Centralized Management Platform:** The central heart of the system is a centralized platform where data from the vehicle is collected, processed, and stored. It has to be real-time processable and analysis friendly. Data storage and analysis can be performed by using a cloud-based platform in case of several vehicles and, therefore, a global overview can be given to fleet managers on tyre health for the entyre fleet.
- **User Interface (UI):** It should be intuitive and easy to navigate so that both drivers and fleet managers are able to gain meaningful insights. It should provide clear, actionable tyre health information via the mobile app or in-vehicle display.

5.1.2. Integration with existing vehicle systems

Integration with the present vehicle system, therefore, ensures that there will be a seamless interface between TPMS and existing OBD-II or in-vehicle telematics in the system, allowing the platform to exchange and update information relating to data streams across all its fleet's variety of vehicles, for example relating tyre wear, fuel usage patterns, and actual engine performance by cross referencing derived insights of effects of the latter on general effectiveness of a car.

Data Flow Design: Define the data flow through the system. When sensors determine that a condition exists, then the data from the sensor should be sent to the mobile device or centralized management platform. This information is then analyzed and if an issue exists in the system like under-inflation or possible tyre damage, it will alert accordingly.

5.1.2. Use of Advanced Data Analytics

Machine learning algorithms and data analytics tools will be integrated into the design to improve efficiency in the system and predictive capacity. For instance, these tools can process huge volumes of data collected over time to allow identification of trends, predict potential failures in the system, and optimize maintenance activities for tyre health. For instance, data analytics can reflect recurrent problems experienced in certain tyres, thus it would project at what stage the tyres are going to have weaknesses before hitting the critical point.

5.2. System Installation and Setup

The installation and configuration of the TPMS in the fleet is the other major stage of this methodology, following the finalization of system design and architecture. This includes sensor calibration, system integration, and testing.

5.2.1. Sensor Calibration

Sensor calibration is part of the installation. Sensors have to be calibrated in order to achieve accurate measurements in terms of pressure and temperature readings of tyres. Any disparity in sensor calibration can lead to errors in the measurement and would reflect on the performance of the TPMS as a whole.

Step-by-Step Procedure in Calibration

- Sensors are fitted into the tyres of the vehicle.
- A base pressure and temperature is recorded for each tyre when the vehicle is stationary and operating under normal conditions.
- These recorded values are then compared to the given recommended specifications for each type of vehicle and each brand of tyre.
- Deviation from base values is adjusted, with the system checked to ensure accuracy in the results.

5.2.2. Integration with Fleet Management System

The TPMS needs to be integrated to the fleet management system to have smooth data exchange. This way of integration ensures the availability of tyre data to fleet managers in real-time so that informed decisions can be made in advance. For example, such integration may include configuring the centralized server, building up secure communication protocols, and ensuring compatibility with the current telematics adopted by the fleet.

5.2.3. Initial Testing and Troubleshooting

The initial testing must be carried out after installing the system. Once this is installed, normal operations on the running of the vehicle, with adequate tests for its working conditions, along with sensor data transfer, can be confirmed to have occurred normally.

The areas for testing would be:

- **Testing Validation of the reading taken from sensors-** Whether or not it's accurately calculating tyre pressure and temperature.
- **Check Data transmission:** confirmation that data transmits from sensors to mobile devices or platform within no time.
- **Alarm function:** Testing the system's alerting capability in case of abnormal tyre conditions, such as under-inflation or punctures.

5.3. Real-Time Monitoring and Data Collection

Real-time monitoring and data collection is the next stage of the methodology. The TPMS must be able to monitor the tyres continuously, both when the vehicle is stationary or in motion, and provide feedback constantly to the driver and fleet management system.

5.3.1. Continuous Data Monitoring

Data read from the sensors should be continuously monitored and sent in real-time. The TPMS will monitor tyre pressure and temperature for any variations or anomalies that may indicate a possible problem.

The information may be sent to the mobile device or central management system and should contain:

- **Tyre pressure:** Recorded in bars or psi
- **Tyre temperature:** Recorded in °C
- **Time stamped:** To contextualize pressure and temperature variations. This would make it possible to correlate the observed tyre performance to the operating conditions.

5.3.2. Early Warning System and Alerts

The real-time monitoring system needs to be developed in such a way that when the tyre conditions fall below predefined thresholds, an early warning can be given. For instance, the system will alert if the tyre pressure drops more than 10% of the recommended value or if the temperature exceeds the normal operating range.

Alerts will be sent to the driver and the fleet management center:

- **Driver Alerts:** These can be visual and/or audio alerts inside the vehicle, warning the driver to stop and resolve the problem.
- **Fleet Manager Alerts:** Notifications that are sent to the central fleet management system, so that fleet managers can monitor tyre health remotely and take necessary steps, such as scheduling maintenance or sending a repair team.

5.3.3. Data Logging and Analysis

In addition to the real-time analysis, this system must log historical data for later analysis. The data can be useful to identify long-term trends like repeatedly persistent tyre wear issues or predict the future failure of the tyre based on historical patterns. Predictive models are generated by the use of data analytics tools, which can foresee the estimated number of remaining life cycles and suggest times to replace the tyres.

5.4. Evaluation and Performance Assessment

Once the TPMS has been installed and is functional, the performance of the system over time must be measured. This would involve measuring how the system monitors tyre health effectively and provides alerts on time as well as the general impact it makes on fleet efficiency, safety, and cost savings.

5.4.1 Performance Metrics

To evaluate the efficacy of the TPMS, the following key performance metrics must be taken into consideration:

- **Accuracy of Data:** Evaluate how close the reading of the sensor is to the prevailing pressure and temperature of the tyres.
- **Alert Responsiveness:** The ability of the system to react to the changes of tyre condition with alacrity and provide alerts that reach the driver as well as fleet management in time.
- **Impact on Downtime:** Percentage difference of downtimes between vehicles with and without TPMS. Focus areas for downtime related to tyre failure and maintenance.
- **Cost Savings:** The savings in terms of damage to tyres, better fuel consumption, and life of the tyre.

5.4.2 Ongoing Optimization

Continuous performance assessments with periodical reviews are required to establish the areas where improvement is necessary. Based on the feedback received from drivers and fleet managers, the system may be adjusted in terms of performance. This might include:

- Refine the alert thresholds to minimize false alarms.
- Enhancing data processing algorithms to improve prediction accuracy.
- Hardware or software update to accommodate new tyre types or vehicle models.

5.5. Reporting and Documentation

A good reporting system to monitor the effectiveness and efficiency of the TPMS implementation should be developed. Such a reporting system will provide detailed reports to stakeholders about the system's performance and contribution to operational efficiency and cost savings.

Reports should contain:

- **Tyre health reports:** A summary of the condition of tyres across the fleet, including pressure, temperature, and wear data.
- **Alert reports:** Recording the number of alerts raised, actions taken, and whether any problems with a tyre are resolved.
- **Maintenance cost analysis:** Determination of the savings in maintenance costs resulting from proactive tyre management.

The methodology developed here embodies a holistic approach to the design, implementation, and evaluation of TPMS in a fleet management environment. It encompasses the whole lifecycle from design to installation, real-time monitoring, and evaluation cycles, optimizing the system. This methodology ensures that the TPMS operates effectively, generates reliable data, and leads to improved fleet performance, cost savings, and safety. Continuous refinement and optimization of the system by fleet operators can maximize the benefits of TPMS, which is a sustainable and efficient approach to fleet tyre management.

CHAPTER 6

SYSTEM DESIGN AND IMPLEMENTATION

Systems Design involves defining the architecture, components, modules, interfaces, and data for a system to satisfy requirements specified. Essentially, it deals with translating the user requirements into a detailed blue print to be used as guidelines in the implementation stage. It entails creating a clean, well-organized, efficient structure to fit the purpose envisioned while keeping other factors like scalability, maintainability, and performance in mind.

6.1. System Overview

The Tyre Health Monitoring System (THMS) aims to monitor and maintain the overall health of the tyres by continuously tracking important parameters that directly impact vehicle safety and performance. These parameters include:

- **Tyre Pressure (TPMS)**: Tyre pressure plays a crucial role in the stability, handling, and fuel efficiency of the vehicle. Under-inflated tyres can lead to blowouts, while over-inflated tyres increase wear and reduce grip.
- **Tyre Temperature**: Tyres generate heat due to friction with the road. Excessive temperature can cause the tyre to degrade or fail. Monitoring temperature helps prevent tyre blowouts, especially in high-speed driving conditions.
- **Tread Wear**: Tyre tread depth directly impacts vehicle traction, especially in wet conditions. Monitoring tread wear ensures that the tyres are replaced before they become dangerous.

6.2. System Components

6.2.a. Sensors

The system relies on a combination of sensors to gather data about tyre conditions in real-time. The sensors are designed to be durable and able to withstand the harsh conditions found inside the tyre.

- **Tyre Pressure Sensors (TPMS)**

✓ **Function**: Monitors the air pressure inside the tyre.

- ✓ **Technology**: Typically, TPMS sensors use either a **direct** or **indirect** measurement system. Direct systems measure actual air pressure with sensors inside the tyre. Indirect systems estimate pressure using wheel speed sensors in the vehicle's ABS system.
- ✓ **Placement**: Sensors are usually installed in the tyre valve stem or inside the tyre (on the rim).

- **Temperature Sensors**
- ✓ **Function**: Monitors the tyre's internal and external temperature.
- ✓ **Technology**: Temperature sensors like **thermistors** or **infrared sensors** detect the temperature. Thermistors change resistance with temperature, while infrared sensors measure surface heat without direct contact.
- ✓ **Placement**: These can be placed on the tyre's outer surface or near the internal part of the tyre.

- **Tread Wear Sensors**
    - **Function**: Measures the depth of the tyre's tread.
    - **Technology**: **Optical sensors**, **ultrasonic sensors**, or **laser scanners** can be used to measure the tread depth. These systems send a light signal to the tyre's surface and measure the reflection, which helps in estimating the tread depth.
    - **Placement**: Integrated into the tyre tread or placed on the vehicle near the wheel.

- **Accelerometer/Gyroscope (Optional)**
    - **Function**: Measures vibrations and abnormal behavior, which can indicate uneven wear or tyre defects.
    - **Technology**: These sensors detect changes in the vehicle's movement, which can be associated with issues such as imbalanced tyres or problems with the tyre's integrity.
    - **Placement**: Typically mounted in the vehicle chassis or near the wheel.

6.2.b. Microcontroller / Edge Device

A microcontroller or edge device acts as the processing unit that manages sensor data, performs preliminary analysis, and handles communication with the user interface.

- **Role**:

✓ Collects and processes data from the sensors.

✓ Performs basic data filtering (removes noise from sensor data).

✓ Compares sensor readings to predefined thresholds (for alerts).

✓ Sends the data to the cloud or mobile app via communication modules.

- **Popular Devices**:

✓ **Raspberry Pi**: Suitable for complex calculations and communication.

✓ **Arduino**: Lightweight, commonly used for simple sensor data collection.

✓ **ESP32**: Provides built-in Wi-Fi and Bluetooth, ideal for embedded IoT systems.

6.2.c. Communication Module

For remote monitoring, the data from the sensors and the microcontroller needs to be communicated wirelessly to an interface, such as a mobile app or central server.

- **Communication Protocols**:

✓ **Bluetooth**: Suitable for short-range communication between the vehicle and a mobile device (ideal for personal use).

✓ **LoRa (Long Range)**: Useful for long-range communication, especially in large fleets of vehicles or outdoor environments.

✓ **Wi-Fi**: For scenarios where the vehicle is within range of a known Wi-Fi network.

✓ **Cellular Networks (4G/5G)**: For real-time cloud communication in fleet management systems.

6.2. Power Supply

The system must be able to operate without requiring constant recharging. Possible solutions include:

✓ **Battery-powered** sensors, designed to last the lifetime of the tyre or vehicle battery.

✓ **Energy Harvesting** techniques, such as using the tyre's rotational energy or vehicle movement to power the sensors.

6.3. Data Flow and Communication

Data Flow Process:

- **Sensors Collect Data**: Each sensor (pressure, temperature, tread wear) continuously collects data from its respective tyre.
- **Microcontroller Processing**: The microcontroller (or edge device) receives the data from the sensors, filters it for noise, and compares the values to pre-configured threshold values (e.g., tyre pressure lower than 30 PSI triggers an alert).
- **Transmission to Mobile App/Cloud**: The processed data is transmitted to a cloud server or mobile app using wireless communication protocols (e.g., Bluetooth, LoRa, or Wi-Fi).
- **User Interface Displays Data**: The mobile app or web dashboard receives the tyre data and provides a user-friendly interface for the vehicle owner or fleet manager.Real-Time Monitoring and Alerts:
- **Tyre Pressure**: If the tyre pressure goes below or above the predefined safe range, an immediate alert is sent to the vehicle owner.
- **Tyre Temperature**: An alert is triggered if the tyre's temperature exceeds the safe limit, which may indicate overheating and the risk of failure.
- **Tread Wear**: As the tyre tread wears down, the system tracks the remaining tread depth and sends a warning when the tread reaches a minimum safety level.

6.4. Data Analytics and Predictive Maintenance

- **Threshold-Based Alerts**: Alerts are triggered when tyre conditions exceed safe operating limits. For example:

✓ **Pressure below 30 PSI** triggers a warning.

✓ **Temperature above 80°C** triggers an alert.

✓ **Tread depth below 2 mm** triggers an alert.

- **Predictive Maintenance**: Based on collected data and historical trends, predictive models can be built to forecast when a tyre might fail or need replacement. Machine learning techniques (e.g., regression, anomaly detection) can be applied to the data to predict:

✓ **Tyre life expectancy**: Predict the remaining lifespan of a tyre based on driving conditions and current wear patterns.

✓ **Failure Prediction**: Detect early signs of failure (e.g., temperature spikes, sudden pressure drops) and alert the user to take preventive action.

6.5. System Testing and Calibration

- **Field Testing**: Test the system in real-world conditions to validate sensor accuracy and ensure reliable communication.

✓ **Calibrate sensors** to account for environmental factors like humidity, temperature, and road conditions.

✓ **Test power consumption** to ensure battery life is sufficient for long-term operation.

- **Data Validation**: Ensure that the tyre pressure, temperature, and tread wear readings match known standards or calibrated test equipment.

6.6. Safety Features and Redundancy

- **Redundant Sensors**: To increase the reliability of the system, each tyre can have multiple sensors (e.g., two pressure sensors or temperature sensors per tyre).
- **Fail-Safe Mechanisms**: If the communication module or sensors fail, the system should have a backup mechanism, such as using vehicle CAN bus data or other safety monitoring systems.

6.7. Future Enhancements

- **Integration with Autonomous Vehicles**: Advanced integration with autonomous systems to allow the vehicle to automatically adjust settings (e.g., tyre pressure) for safety.
- **Fleet Management Integration**: For commercial vehicles, the system can be integrated with fleet management software to monitor tyre health across a fleet of vehicles, enabling proactive maintenance scheduling.
- **Data Logging and Historical Trends**: Store tyre health data over time to build a historical record for each tyre. This data can be used to analyze long-term trends and optimize tyre replacement schedules.

6.8. FLOWCHART FOR ANALOG TO DIGITAL CONVERSION

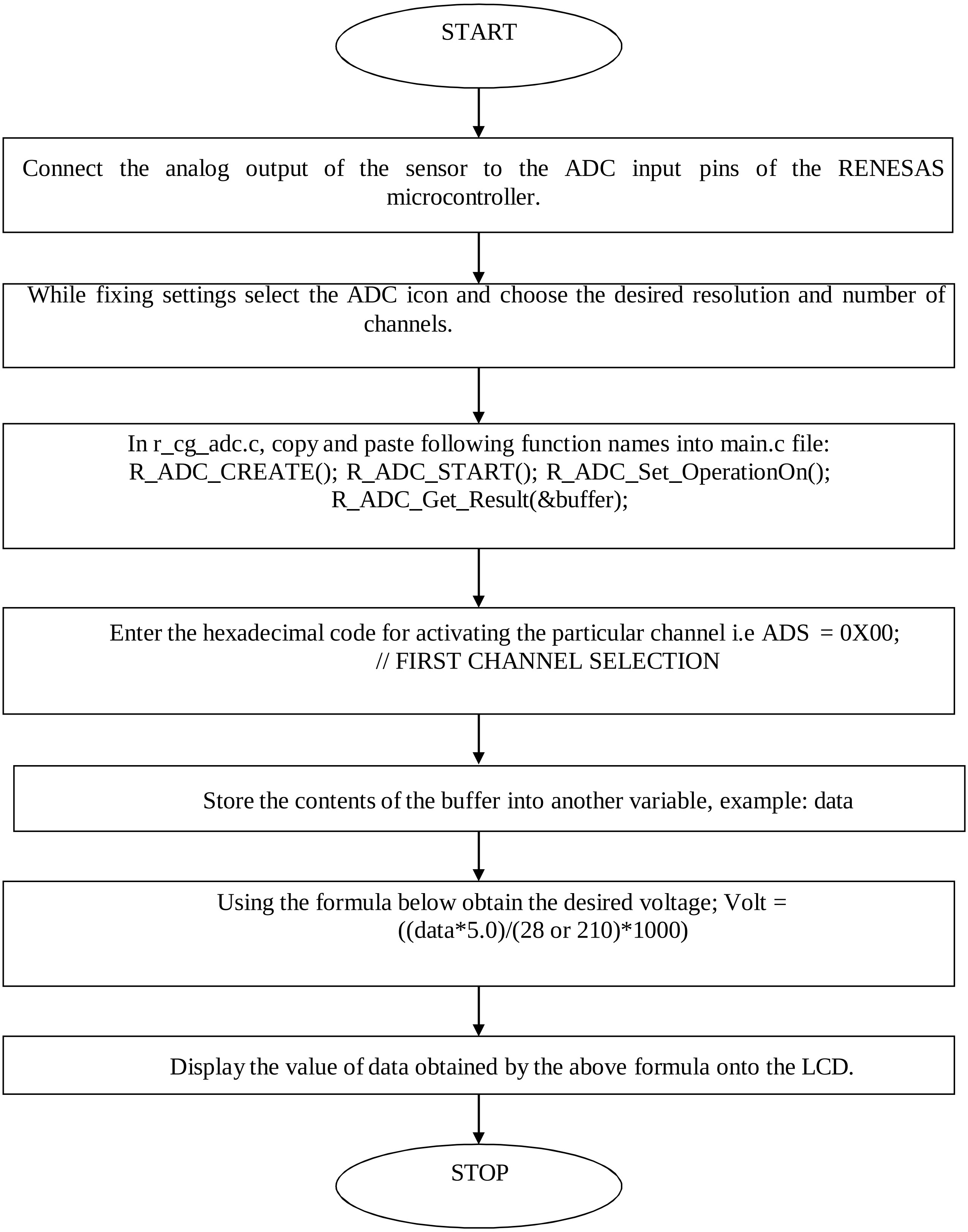


Fig.6.1. Flowchart Diagram from analog to digital

6.9. SYSTEM IMPLEMENTATION

To execute the following code :

Step-1 : Install Arduino ide application

```
#include <ESP8266WiFi.h>
#include <ThingSpeak.h>

// HX710B pins
#define DATA_PIN 12  // HX710B data pin (D6)
#define SCK_PIN 14   // HX710B clock pin (D5)

// LED pins
#define GREEN_LED_PIN 16 // Green LED (D0)
#define RED_LED_PIN 5    // Red LED (D1)

// Wi-Fi credentials
const char* ssid = "NESARA-JIO";      // Replace with your Wi-Fi SSID
const char* password = "dayarani1234"; // Replace with your Wi-Fi Password

// ThingSpeak setup
WiFiClient client;
unsigned long channelID = 1060859;        // Replace with your ThingSpeak channel ID
const char* writeAPIKey = "YV59QHJTUD3XTNM4";      // Replace with your ThingSpeak
Write API Key

// Pressure threshold
const float PRESSURE_THRESHOLD = 10.0; // Example threshold in PSI/kPa

// Function to read 24-bit data from HX710B
long readHX710B() {
  long result = 0;

  // Wait until DATA line goes low, indicating data is ready
```

```
  while (digitalRead(DATA_PIN));

  // Read 24 bits from HX710B
  for (int i = 0; i < 24; i++) {
    digitalWrite(SCK_PIN, HIGH);
    delayMicroseconds(1);
    result = (result << 1) | digitalRead(DATA_PIN);
    digitalWrite(SCK_PIN, LOW);
    delayMicroseconds(1);
  }

  // Optional: Read extra clock pulses to complete communication
  digitalWrite(SCK_PIN, HIGH);
  delayMicroseconds(1);
  digitalWrite(SCK_PIN, LOW);

  // Convert result to signed value
  if (result & 0x800000) {
    result |= 0xFF000000;  // Sign extension for 24-bit data
  }
  return result;
}

void setup() {
  // Initialize HX710B pins
  pinMode(DATA_PIN, INPUT);
  pinMode(SCK_PIN, OUTPUT);
  digitalWrite(SCK_PIN, LOW);

  // Initialize LED pins
  pinMode(GREEN_LED_PIN, OUTPUT);
  pinMode(RED_LED_PIN, OUTPUT);
```

```
  digitalWrite(GREEN_LED_PIN, LOW); // Turn off Green LED initially
  digitalWrite(RED_LED_PIN, LOW);  // Turn off Red LED initially

  // Initialize Serial Monitor
  Serial.begin(115200);

  // Initialize Wi-Fi
  Serial.println("Connecting to Wi-Fi...");
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    Serial.print(".");
    delay(1000);
  }
  Serial.println("\nConnected to Wi-Fi!");

  // Initialize ThingSpeak
  ThingSpeak.begin(client);

  Serial.println("HX710B Pressure Sensor Test");
}

void loop() {
  // Read pressure data from HX710B
  long adcValue = readHX710B();
  float pressure = (adcValue / 16777215.0) * 100.0; // Example conversion to pressure
  // Adjust scale factor based on calibration and sensor specifications

  Serial.print("Raw ADC Value: ");
  Serial.print(adcValue);
  Serial.print("\tPressure: ");
  Serial.print(pressure);
  Serial.println(" PSI / kPa");
```

```
  // Control LEDs based on pressure
  if (pressure > PRESSURE_THRESHOLD) {
    digitalWrite(GREEN_LED_PIN, HIGH); // Green LED ON
    digitalWrite(RED_LED_PIN, LOW);   // Red LED OFF
  } else {
    digitalWrite(GREEN_LED_PIN, LOW); // Green LED OFF
    digitalWrite(RED_LED_PIN, HIGH); // Red LED ON
  }
  // Send pressure data to ThingSpeak
  int responseCode = ThingSpeak.writeField(channelID, 1, pressure, writeAPIKey);
  if (responseCode == 200) {
    Serial.println("Data sent to ThingSpeak successfully!");
  } else {
    Serial.print("Failed to send data to ThingSpeak. Error code: ");
    Serial.println(responseCode);
  }
delay(20000); // Update ThingSpeak every 10 seconds
}
```

STEP-2 : Application

To run the device,the application used is ThingSpeak MathLab (R2014b through R2018b)

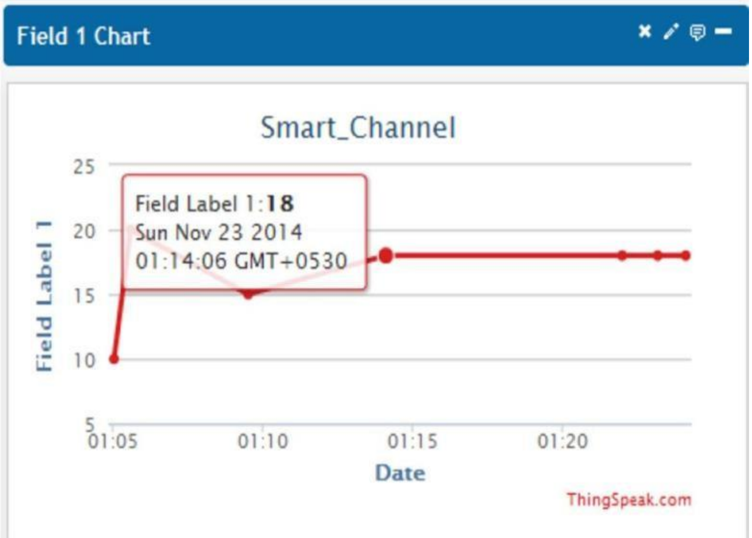


Fig.6.2 Sample output generated in ThingSpeak

Step-3: Developing a project

Fig.6.3. Overall Project

Fig.6.4. NodeMCU (ESP8266)

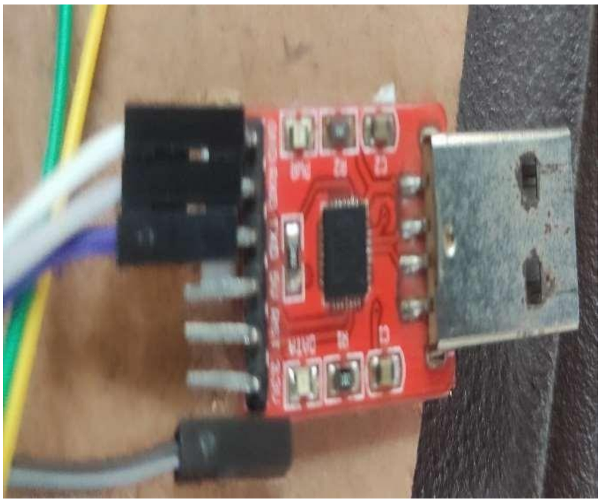


Fig.6.5. USB(arduino)

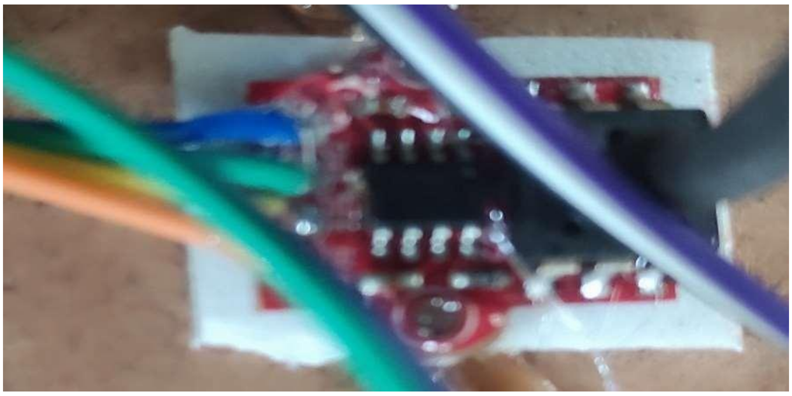


Fig.6.6 Pressure Sensor (HX710B)

CHAPTER 7
RESULT AND DISCUSION

The project is based on various methodology. The key factor of this project is listed below:

Enhanced-Safety: This real-time monitoring of tyre pressure, temperature, and tread wear reduces the risk of a blowout, accident, and vehicle instability to an insignificant level. A system will alert the drivers whether the tyre is under-inflated, over-heated, or immediately required change in tyre and make them safe on road

Improved Vehicle Performance: The direct impact of tyre health is on vehicle performance, fuel efficiency, braking, handling, and ride comfort. A monitoring system ensures tyres are always in top shape, enhancing responsiveness and control in the vehicle.

Predictive Maintenance: Continuous tracking of tyre health metrics by the system helps predict failures and alert the driver or service center about the potential failure before it occurs. This leads to proactive maintenance, reducing downtime and maintenance costs.

Environmental Impact Reduction: The system can reduce the consumption of fuel and carbon emission,thus contributing to environmental sustainability by optimizing tyre pressure and wear.

Real-Time Alerts: Drivers receive real-time alerts on the existing website if tyre pressure, temperature, or tread wear is out of the safe levels. This instant feedback will improve decision-making and encourage safer driving habits.

Increased Lifespan of Tyres: Tyre health that is closely monitored can ensure that tyres last up to 30% longer, replacing them less often and supporting sustainability.

Compatibility with Autonomous Cars: Tyre health monitoring is essential in an autonomous vehicle where the occurrence of any tyre issues would mean that a vehicle will not be able to travel safely. They can deliver real-time data for the software of an autonomous car to use in its decision-making, thereby enabling route changes.

Fleet Management Efficiency: For commercial vehicles such as delivery trucks or public transports, a tyre health monitoring system provides fleet managers with timely data to optimize vehicle schedules for maintenance and manage fleets in the most cost-efficient manner.

Better Ride Comfort: A well-maintained tyre provides a smoother ride with reduced vibrations.This, in turn, would increase the comfort of passengers.

Road Safety Features: The use of tyre health data along with other safety features such as anti-lock braking systems, electronic stability control, and collision warning systems would contribute to more effective crash avoidance and response.

Monitoring Across Several Vehicles: It can monitor tyre health across a number of vehicles for a car-sharing service or fleet of rentals, enabling the operators of a fleet to manage in real-time tyre health across all vehicles.

Integration with vehicle telematics: it can integrate tyre health data for a better overview of vehicle performance and the necessity for certain maintenance,hence improving service scheduling while reducing the possibility of vehicle breakdown.

Insurance Premium Benefits: Advanced tyre health monitoring systems can provide insurance companies with a good reason to offer lower premiums for cars equipped with these systems.

Integration with Driver Assistance Systems: The incorporation of tyre health into ADAS allows for even better prediction and reaction toward changes in road conditions through improved safety.

Better Fleet Safety Compliance: Tyre monitoring systems ensure compliance to safety regulations for commercial and transport fleets, thus preventing related violations in terms of tyre health and wear.

Data-Driven Decision Making: Collected data can be analyzed to find patterns of tyre wear and changes in pressure over time to inform decisions about the management of tyres and vehicle usage.

A simulation model for is a digital imitation of the system's behaviour, used to test and evaluate its performance. It allows us to simulate various scenarios, such as changing environmental conditions, irregular tyre pressure, and system failures, without physically exposing the system to the conditions.

A TPMS simulation model is typically built using C programming language, incorporating detailed tyre and atmospheric models, as well as sensor simulations.

Market evaluation suggests that ATHMS has improved road safety, reduced fuel consumption, and lowered maintenance costs. The target audience for Automobile Tyre Health monitoring sytem(ATHMS) in real life includes various individuals and groups. First and foremost, car owners are the primary users of ATHMS. It benefit from the system's warnings and alerts, ensuring Its safety while driving. Fleet managers, who oversee large vehicle fleets, also benefit from ATHMS to optimize tyre performance and prolong the lifespan of Its vehicles.

Accuracy of Automobile Tyre Health Monitoring System To illustrate the accuracy differences graphically, a comparative chart can be created that compares the accuracy of several popular TPMS brands, such as:

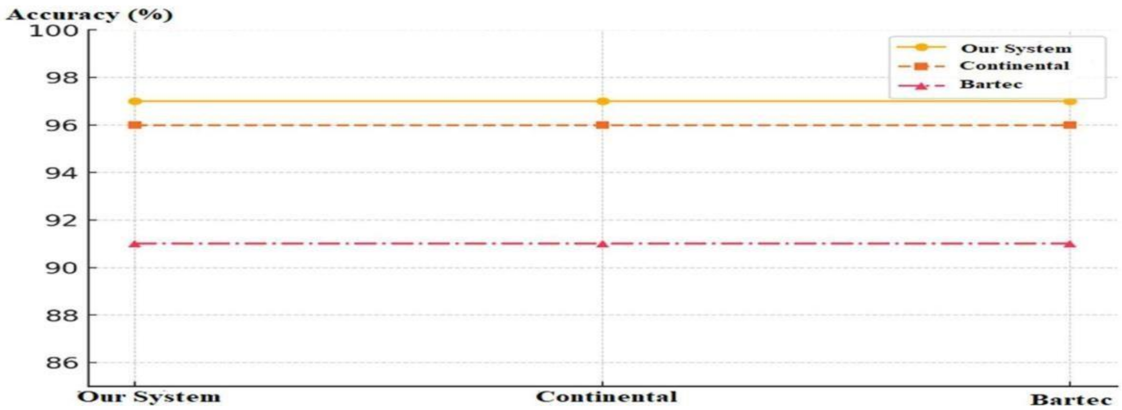


Fig.7.1.Comaprison

Tread wear after specific kilometer:

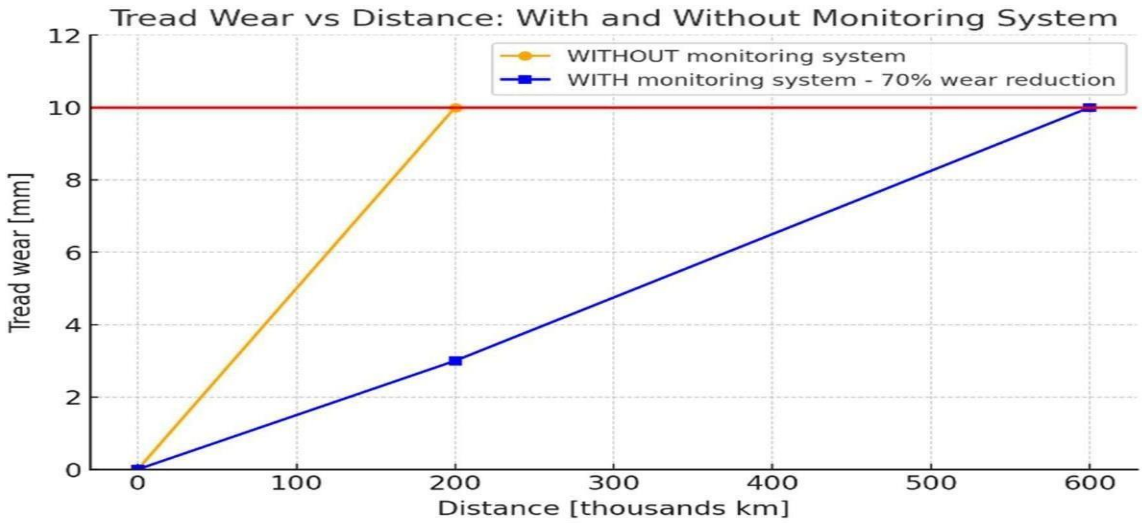


Fig.7.2 Tread wear after certain distance travelled

Here graph representing tread wear vs distance with and without a monitoring system. The orange line represents tread wear without a monitoring system, reaching the maximum tread wear (10 mm) much sooner, while the blue line shows a 70% reduction in wear with the monitoring system, extending the tyre's lifespan over more kilometres.

Confusion Matrix For a binary classification (Normal Pressure vs. Abnormal Pressure)

This confusion matrix comprises four elements: TRUE POSITIVE(TP), TRUE NEGATIVE(TN), FALSE NEGATIVE(FN), FALSE POSITIVE(FP)

To calculate the confusion matrix needs actual and predicted labels. Based on the sample data, ATHMS can calculate the confusion matrix together. With help of an example scenario:

Total tyres checked: 100

Actual normal pressure: 70

Actual abnormal pressure: 30

TP = 25 TN = 60

FP = 10 FN = 5

Let's calculate and visualize the confusion matrix:

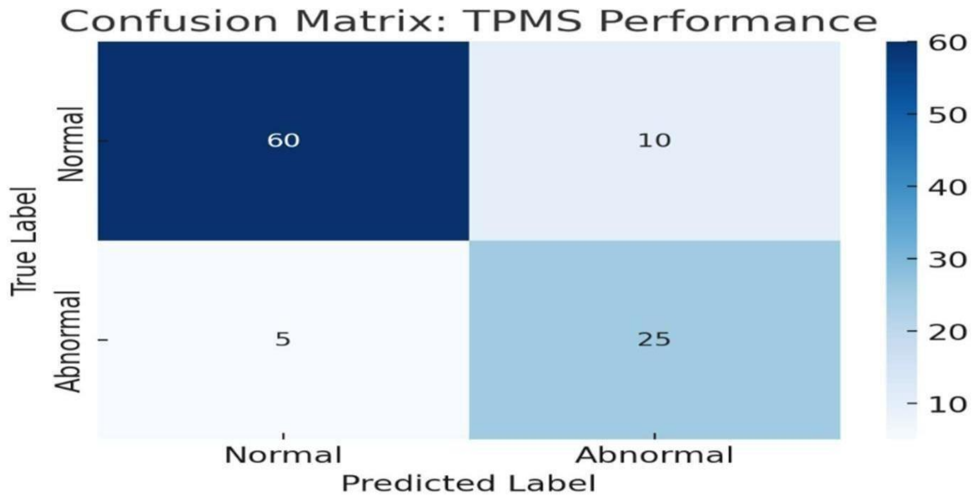


Fig.7.3. Confusion matrix for normal and abnormal pressure

Here is the confusion matrix for the Automobile Tyre Health Monitoring System (ATHMS) performance:

TP: 25

TN: 60

FP: 10

FN: 5

TPMS confusion matrix helps evaluate the system's ability to correctly identify tyre pressure issues and where it might need improvement.

The future of ATHMS will involve the integration with autonomous driving systems, in which tyre health monitoring becomes critical to ensure safety for the vehicle. It also has a good potential for ATHMS using AI and machine learning to predict more accurately when tyres will fail based on historical data and real-time monitoring.

Discussion on Cost-Effectiveness ATHMS is becoming increasingly less expensive with developments in sensor technology and manufacturing processes. Even though it is costly in the first place, ATHMS may save millions in the long run through a reduction in the rate of replacement of tyres and risk of accidents.

User Feedback and Acceptance: User feedback also shows that ATHMS drastically improves driver confidence, which in remote areas is always less because of limited car services. The adoption level is different in different places, but it is surely going up with the raising awareness of safety benefits.

Impact on Fleet Management ATHMS is also used in commercial and fleet vehicles. The tyre health of a large number of vehicles can be monitored by the fleet managers, which optimizes maintenance schedules, reduces downtime, and lowers overall operational costs.

Promising results have been reported for the reliability and accuracy of ATHMS through real-world testing. The systems are currently undergoing tests in different driving conditions, such as highways, urban areas, and rural roads. The data acquired from these tests are crucial in the development of more robust and effective ATHMS.

With a growing need for safety, technology, and consumer awareness toward improved vehicle safety, the ATHMS market is seeing an increase. Major companies are investing in ATHMS research and development to secure a larger market share.

The regulatory bodies are increasingly recognizing the role of ATHMS in the safety of vehicles and considering to make it a standard fit for new vehicles. The data that has been brought forth indicates a correlation between monitored tyre health and the reduction of road accidents.

ATHMS save money through fuel consumption reduction, reduced maintenance costs, and prolonged tyre life. These systems also contribute to the reduction of waste due to tyres, which supports environmental sustainability

ATHMS have the ability to monitor real-time and, therefore can intervene promptly in case of issues with tyres. This becomes very essential in long-distance journeys and at high speeds when the risks of tyre failure are high.

A designed user interface is fundamental when it comes to user friendlyness of the drivers at the wheels, coupled with safety. This alerts tyre problems to the attention of the drivers, preventing disturbances to drivers from performing safely on the roads.

Fig.7.4.TPMS protected tyre

ATHMS form a significant vehicle safety advancement. They present numerous advantages, from improving the performance of vehicles to accident prevention of tyre-related hazards. More than ever, technology will become more integral with ATHMs in the automotive sector as these vehicles become connected.

CONCLUSION

The TPMS is technological equipment that measures the air inside the tyres in real time, giving continuous data of the state of the tyre. They contribute much to a vehicle's safety and efficiency because they give direct feedback to drivers in real-time when the tyres' pressure changes from the usual rate, which can make it risky when experiencing a blowout or losing friction between the tyre and the ground.There are two main forms of TPMS. dTPMS utilizes sensors installed within the tyres to directly measure the pressure in the tyre and then relay that data back to the vehicle's onboard system. The other, TPMS, is estimated based on pressure changes determined through analysis of data acquired through the ABS on the vehicle. Both methods promote safer driving while at the same time ensuring users of more convenience without the burden of manual pressure checks, which can be a very cumbersome exercise.

It gives the driver real-time responses in case any of the tyres are underinflated that can cause deterioration of the tyre, reduced mileage, and could also pose significant safety risks when a tyre will blow out. There are two types of TPMS: the direct and the indirect. This direct system utilises sensors mounted at each tyre in order to make pressure measurements whereas the indirect relies on estimates created by data drawn from the car's ABS or wheel speed sensor.The advantages of TPMS go beyond safety. They ensure that tyres are always under the right pressure, which enhances fuel efficiency by reducing rolling resistance and thus lowering CO_2 emissions. Maintaining optimal pressure also prolongs the life of tyres, reducing waste and saving money for vehicle owners. However, TPMS adoption is hindered by factors such as high initial installation costs, integration complexities, limited consumer awareness, and varying regional regulations.

Future Enhancements

The future of TPMS looks promising, as it is expected to be in sync with innovations in autonomous vehicles, sensor technology, and environmental sustainability. One area of development would be the integration of TPMS with smart vehicles. The future TPMS will be equipped with AI and machine learning to predict tyre failures before they occur, providing a further layer of safety for drivers.Sensor technology is also ready for innovation. Future TPMS sensors will be capable of monitoring further parameters such as tyre temperature, tread depth, and road conditions in real-time. To cut down on the use of battery-operated systems, energy-harvesting techniques like piezoelectric or thermoelectric technologies can be used to drive sensors, hence making the system more energy efficient and environmentally friendly.

The regulation will also become simpler to adopt when the internationalization of TPMS regulations takes effect, forcing more manufacturers to create better and newer designs. Lastly, campaigns among consumers about the benefits of TPMS on safety, environment, and cost-effectiveness will encourage higher acceptance rates.Looking forward, TPMS systems would also cater to emerging markets through low-cost, modular solutions targeted toward budget-conscious consumers. Designs for such applications may be implemented as basic functions but can always add more advanced functionality as the needs arise. Indeed, vehicles continue to evolve toward safety and sustainability, with TPMS being the cornerstone that shall pave the way for smarter and greener transportationFuture TPMS would be integrated into ADAS so that it sends more advanced notifications and even self- correcting actions, including adjusting the car's speed to a safe rate or activating various safety features for the vehicle upon detecting low pressure in the tyres. Advanced TPMS could inform the onboard diagnostic system of a car or a mobile app with real-time tyre health data, helping drivers monitor tyre condition over time to better plan when maintenance is necessary.Research is on for the creation of battery-less sensors. Sensors can draw power from the vehicle motion or even other sources and therefore contribute more to ustainability. • In the future, TPMS will be much more accurate and therefore deliver much better data about the pressure in tyres, temperatures, and levels of wear so that potential tyre faults are identified in good time.

REFERENCES

1. Jersey, NJ, USA, 2005. "Federal Motor Vehicle Safety Standards; Tyre Pressure Monitoring Systems; Controls and Displays." National Highway Traffic Safety Administration (NHTSA-2005–20586).
2. Fleming, B., 2009. "Tyre Pressure-Monitoring Systems Rollout (Automotive Electronics)." IEEE Vehicular Technology Magazine, 4, pp. 6–10.
3. Manla, G., White, N.M., Tudor, J., 2009. "Harvesting Energy from Vehicle Wheels." Proceedings of the Solid-State Sensors, Actuators and Microsystems Conference, Denver, CO, USA, 21–25 June.
4. Onoda, T., 2009. "IEA Policies-G8 Recommendations and an Afterwards." Energy Policy, 37, p. 3823.
5. Rui, X.H., Jin, Y., Feng, X.Y., Zhang, L.C., Chen, C.H., 2010. "A Comparative Study on the Low-Temperature Performance of LiFePO4/C and Li3V2(PO4)3/C Cathodes for Lithium-Ion Batteries." Journal of Power Sources, 196, p. 2109.
6. Zhang, S.S., Xu, K., Jow, T.R., 2003. "The Low Temperature Performance of Li-ion Batteries." Journal of Power Sources, 115, p. 137.
7. Roundy, S., 2008. "Energy Harvesting for Tyre Pressure Monitoring Systems: Design Considerations." Proceedings of the Power MEMS + microMEMS, Sendai, Japan, 9–12 November.
8. Löhndorf, M., KvisterØy, T., Westby, E., Halvorsen, E., 2007. "Evaluation of Energy Harvesting Concepts for Tyre Pressure Monitoring Systems." Proceedings of the Technical Digest PowerMEMS, Freiburg, Germany, 28–29 November, pp. 331–334.
9. U.S. Department of Transportation, "An Evaluation of Existing Tyre Pressure Monitoring Systems."
10. Vishnoi, A., Rani, S., Singhal, D., Singh, A., Shinghal, K., "Tyre Pressure Monitoring System Using Wireless Communication." International Journal of Scientific Research and Management Studies (IJSRMS), 2(2), ISSN: 23493771.
11. Banou, S., Gabriel, F., Reyes, A., Hussain, S.S., "Designing a Pseudo Tyre Pressure Monitoring System Transmitter Using Software Defined Radios." Worcester Polytechnic Institute, Major Qualifying Project.
12. Drain, J., Hall, R., Pentland, C., Snedeker, M., Thurber, A., "Tyre Pressure Management System." University of Arizona.

13. Ojenikho, O., "Wireless Tyre Pressure Monitoring System Using Zigbee." University of Kent, Canterbury.
14. Xiangjun, T., 2016. "The Design and Research of Tyre Pressure Monitoring System." 2016 International Conference on Intelligent Transportation, Big Data & Smart City (ICITBS), Changsha, pp. 479–481.
15. Hua, H., Papastergiou, P., Angelakopoulos, H., Guadagninia, M., Pilakoutas, K., 2018. "Mechanical Properties of SFRC Using Blended Recycled Tyre Steel Cords (RTSC) and Recycled Tyre Steel Fibres (RTSF)." Construction and Building Materials, 187, pp. 553–564.
16. Varghese, A., 2013. "Influence of Tyre Inflation Pressure on Fuel Consumption, Vehicle Handling and Ride Quality Modelling and Simulation." Master’s Thesis, Chalmers University Of Technology, Gothenburg, Sweden.
17. Jansen, S., Schmeitz, A., 2014. "Study on Some Safety-Related Aspects of Tyre Use." Stakeholder Information and Discussion Document MOVE/C4/2013-270-1, Brussels.
18. Toma, M., Andreescu, C., Stan, C., 2017. "Influence of Tyre Inflation Pressure on the Results of Diagnosing Brakes and Suspension." 11th International Conference Interdisciplinarity in Engineering (INTER-ENG), Tirgu-Mures, Romania, 5–6 October.
19. Kasprzak, E., Lewis, K., Milliken, D., 2006. "Inflation Pressure Effects in the Nondimensional Tyre Model." SAE Technical Paper 2006-01-3607. https://doi.org/10.4271/2006-01-3607.
20. Godlewska, J., 2017. "Recovery and Recycling of Waste Tyres in Poland." Procedia Engineering, 182, pp. 229–234.
21. Torretta, V., Rada, E.C., Ragazzi, M., Trulli, E., Istrate, I.A., Cioca, L.I., 2015. "Treatment and Disposal of Tyres: Two EU Approaches. A Review." Waste Management, 45, pp. 152–160.
22. Wadmare, A.V., Pandure, P.S., 2017. "Automatic Tyre Pressure Controlling and Self Inflating System: A Review." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 6th National Conference RDME, 17–18 March, pp. 1–5.
23. Arshad, A.K., Harun, M.S., Jasmi, N., Yaacob, S., Haron, H.A., 2018. "Effect of Heavy Vehicles’ Tyre Pressure on Flexible Pavements." International Journal of Civil Engineering and Technology, 9(9), pp. 1161–1170.
24. Albinsson, A., Bruzelius, F., Jacobson, B., Bakker, E., 2018. "Evaluation of Vehicle-Based Tyre Testing Methods." Published March 27.
25. Ali, Z.A., Shahid, U., Wasi, S., Farid, F., Farooq, F., 2011. "Electronic Air Gauge." 6th IEEE Joint International Information Technology and Artificial Intelligence Conference.

26. Sebaaly, P.E., 1992. "Pavement Damage as Related to Tyres, Pressure, Axle Loads, and Configurations." Vehicle, Tyre, Pavement Interface, ASTM STP 1164, Philadelphia, pp. 54–68.
27. Caban, J., Turski, A., Nieoczym, A., Tarkowski, S., Jereb, B., 2019. "Impact of Specific Factors on the State of the Tyre Pressure Value." The Archives of Automotive Engineering, 85(3), pp. 137–148. https://doi.org/10.14669/AM.VOL85.ART10.
28. Gonzalez, R.C., Woods, R.E., Eddins, S.L., 2020. "Digital Image Processing Using MATLAB, 3rd Edition." Gatesmark Publishing.
29. Anandha, R.A., Ilakkiya, K., Ebinesar, P., Deni, J.S., 2019. "Automatic Jacking and Puncture Detection System for Four Wheeler Vehicle (CAR)." 5th International Conference on Advanced Computing & Communication Systems (ICACCS).
30. "Sensor Analysis for the Internet of Things." Publisher: Morgan & Claypool, 2018, Edition: 1, ISBN: 9781681732886.
31. Kruthi, S., Kamalakannan, J., 2018. "Implementation of Moving Object Detection and Categorization from HEVC Compressed Surveillance Video." International Journal of Mechanical Engineering and Technology, 9(4), pp. 35–42.
32. Kaur, K., Kaur, M., 2015. "Case Study of Colour Model of Image Processing." International Journal of Computer Engineering and Technology, 6(12), pp. 60–64.
33. Fryza, T., 2007. "International Workshop on Systems, Signals and Image Processing and 6th EURASIP Conference Focused on Speech and Image Processing, Multimedia Communications and Services." Brno University of Technology, Brno, Czech Republic.
34. Chimakurthi, V.N.S.S., 2020. "Digital Asset Management in the Communication of Product Promotional Activities." Asian Business Review, 10(3), pp. 177–186.
35. Chimakurthi, V.N.S.S., 2020. "The Challenge of Achieving Zero Trust Remote Access in Multi-Cloud Environment." ABC Journal of Advanced Research, 9(2), pp. 89–102.
36. Chimakurthi, V.N.S.S., 2020. "Application of Convolution Neural Network for Digital Image Processing." Engineering International, 8(2), pp. 149–158.
37. Chimakurthi, V.N.S.S., 2021. "An Optimal Cloud-Based Electric Vehicle Charging System." Asia Pacific Journal of Energy and Environment, 8(2), pp. 29–38.

APPENDIX-A

PSUEDOCODE

```
#include <ESP8266WiFi.h>
#include <ThingSpeak.h>

// HX710B pins
#define DATA_PIN 12  // HX710B data pin (D6)
#define SCK_PIN 14   // HX710B clock pin (D5)

// LED pins
#define GREEN_LED_PIN 16 // Green LED (D0)
#define RED_LED_PIN 5    // Red LED (D1)

// Wi-Fi credentials
const char* ssid = "NESARA-JIO";      // Replace with your Wi-Fi SSID
const char* password = "dayarani1234"; // Replace with your Wi-Fi Password

// ThingSpeak setup
WiFiClient client;
unsigned long channelID = 1060859;        // Replace with your ThingSpeak channel ID
const char* writeAPIKey = "YV59QHJTUD3XTNM4";      // Replace with your ThingSpeak
Write API Key

// Pressure threshold
const float PRESSURE_THRESHOLD = 10.0; // Example threshold in PSI/kPa

// Function to read 24-bit data from HX710B
long readHX710B() {
  long result = 0;

  // Wait until DATA line goes low, indicating data is ready
  while (digitalRead(DATA_PIN));
```

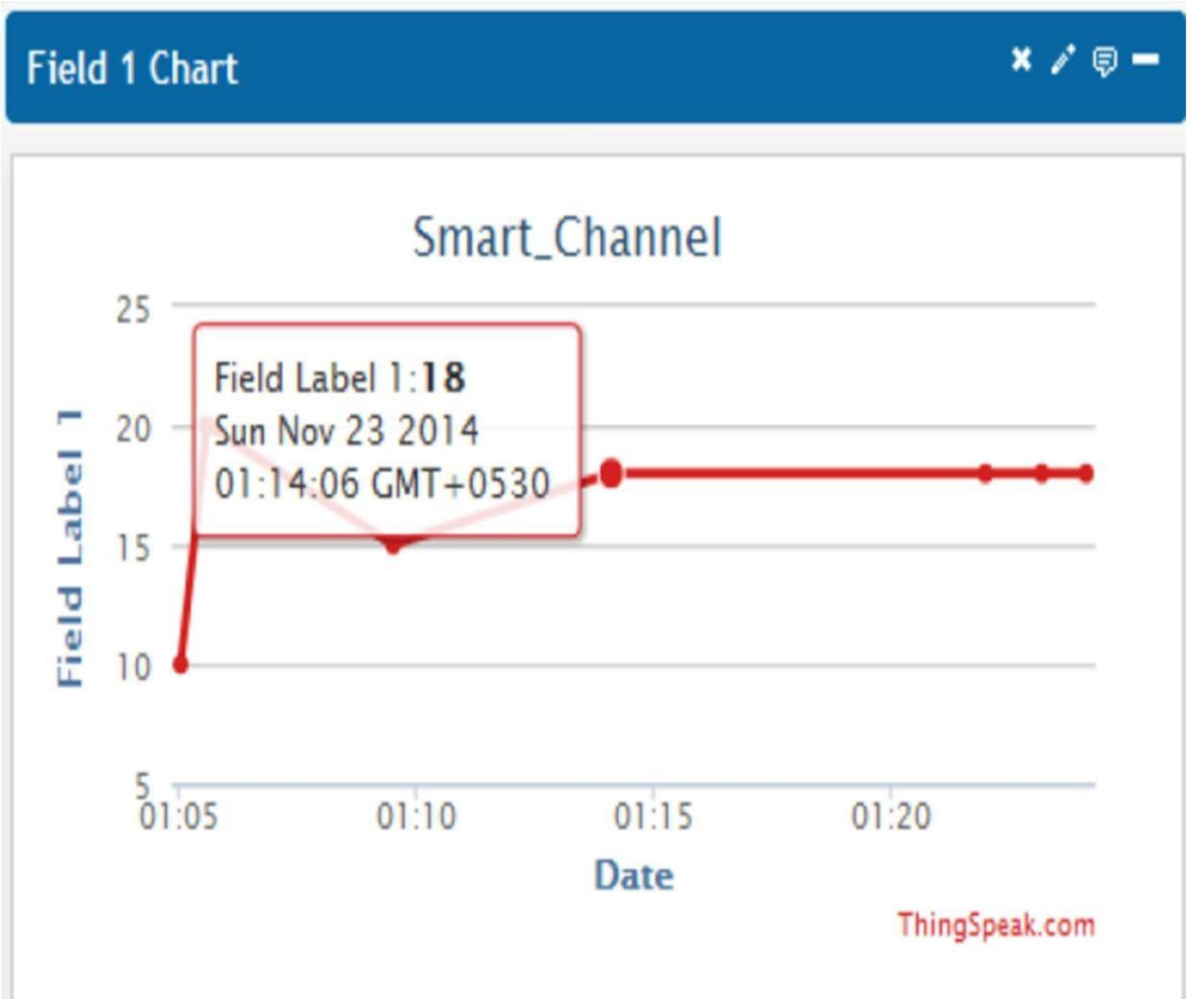
```
  // Read 24 bits from HX710B
  for (int i = 0; i < 24; i++) {
    digitalWrite(SCK_PIN, HIGH);
    delayMicroseconds(1);
    result = (result << 1) | digitalRead(DATA_PIN);
    digitalWrite(SCK_PIN, LOW);
    delayMicroseconds(1);
  }

  // Optional: Read extra clock pulses to complete communication
  digitalWrite(SCK_PIN, HIGH);
  delayMicroseconds(1);
  digitalWrite(SCK_PIN, LOW);

  // Convert result to signed value
  if (result & 0x800000) {
    result |= 0xFF000000;  // Sign extension for 24-bit data
  }
  return result;
}

void setup() {
  // Initialize HX710B pins
  pinMode(DATA_PIN, INPUT);
  pinMode(SCK_PIN, OUTPUT);
  digitalWrite(SCK_PIN, LOW);

  // Initialize LED pins
  pinMode(GREEN_LED_PIN, OUTPUT);
  pinMode(RED_LED_PIN, OUTPUT);
  digitalWrite(GREEN_LED_PIN, LOW); // Turn off Green LED initially
```

```
  digitalWrite(RED_LED_PIN, LOW);  // Turn off Red LED initially

  // Initialize Serial Monitor
  Serial.begin(115200);

  // Initialize Wi-Fi
  Serial.println("Connecting to Wi-Fi...");
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    Serial.print(".");
    delay(1000);
  }
  Serial.println("\nConnected to Wi-Fi!");

  // Initialize ThingSpeak
  ThingSpeak.begin(client);

  Serial.println("HX710B Pressure Sensor Test");
}

void loop() {
  // Read pressure data from HX710B
  long adcValue = readHX710B();
  float pressure = (adcValue / 16777215.0) * 100.0; // Example conversion to pressure
  // Adjust scale factor based on calibration and sensor specifications

  Serial.print("Raw ADC Value: ");
  Serial.print(adcValue);
  Serial.print("\tPressure: ");
  Serial.print(pressure);
  Serial.println(" PSI / kPa");
```

```
  // Control LEDs based on pressure
  if (pressure > PRESSURE_THRESHOLD) {
    digitalWrite(GREEN_LED_PIN, HIGH); // Green LED ON
    digitalWrite(RED_LED_PIN, LOW);   // Red LED OFF
  } else {
    digitalWrite(GREEN_LED_PIN, LOW); // Green LED OFF
    digitalWrite(RED_LED_PIN, HIGH); // Red LED ON
  }

  // Send pressure data to ThingSpeak
  int responseCode = ThingSpeak.writeField(channelID, 1, pressure, writeAPIKey);
  if (responseCode == 200) {
    Serial.println("Data sent to ThingSpeak successfully!");
  } else {
    Serial.print("Failed to send data to ThingSpeak. Error code: ");
    Serial.println(responseCode);
  }
delay(20000); // Update ThingSpeak every 10 seconds
}
```

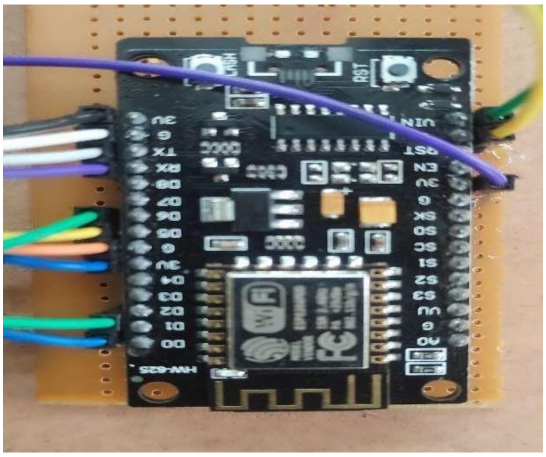
APPENDIX-B

SCREENSHOTS

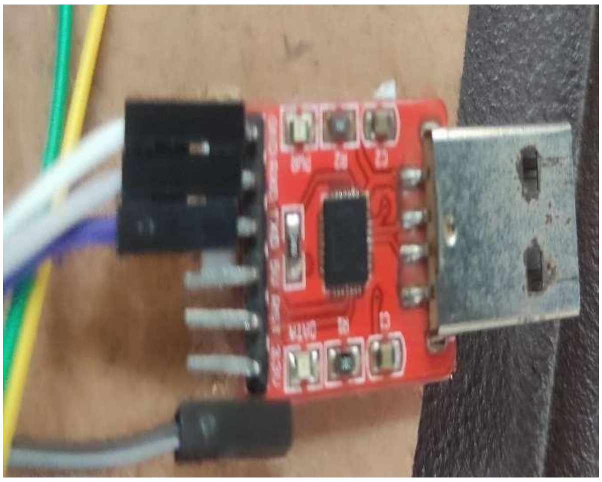


Screenshot.1. Sample output generated in ThingSpeak

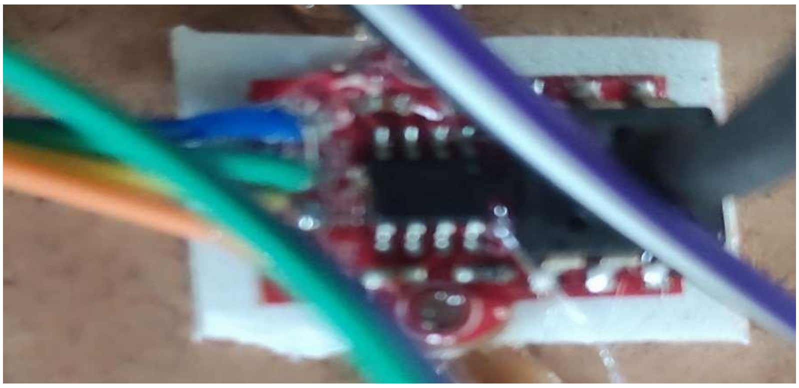
Screenshot.2. Overall Project



Screenshot.3. NodeMCU (ESP8266)



Screenshot.4.USB(arduino)



Screenshot.5. Pressure Sensor (HX710B)

APPENDIX-C

ENCLOSURES

1. Journal publication/Conference Paper Presented Certificates of all students.

AUTHOR-1 : Dr.Madhusudhan MV

IJFMR

International Journal For Multidisciplinary Research

An International Open Access Peer Reviewed Journal • Impact Factor: 9.24 • E-ISSN: 2582-2160

Certificate of Publication

The editorial board of IJFMR is hereby awarding the certificate of publication to

Madhusudhan MV

in recognition of publication of the paper titled

Automobile Tyre Health Monitoring System

Co-Authors: Dinakar S, Adarsha SG, Rahul Ashok, Diwakar S

Published In: Volume 6, Issue 6 (November-December 2024)

Paper Id: 33381

Editor / Publisher

IJFMR

www.ijfmr.com • editor@ijfmr.com

AUTHOR-2 : Mr.Adarsha SG

IJFMR

International Journal For Multidisciplinary Research

An International Open Access Peer Reviewed Journal • Impact Factor: 9.24 • E-ISSN: 2582-2160

Certificate of Publication

The editorial board of IJFMR is hereby awarding the certificate of publication to

Adarsha SG

in recognition of publication of the paper titled

Automobile Tyre Health Monitoring System

Co-Authors: Dinakar S, Rahul Ashok, Diwakar S, Madhusudhan MV

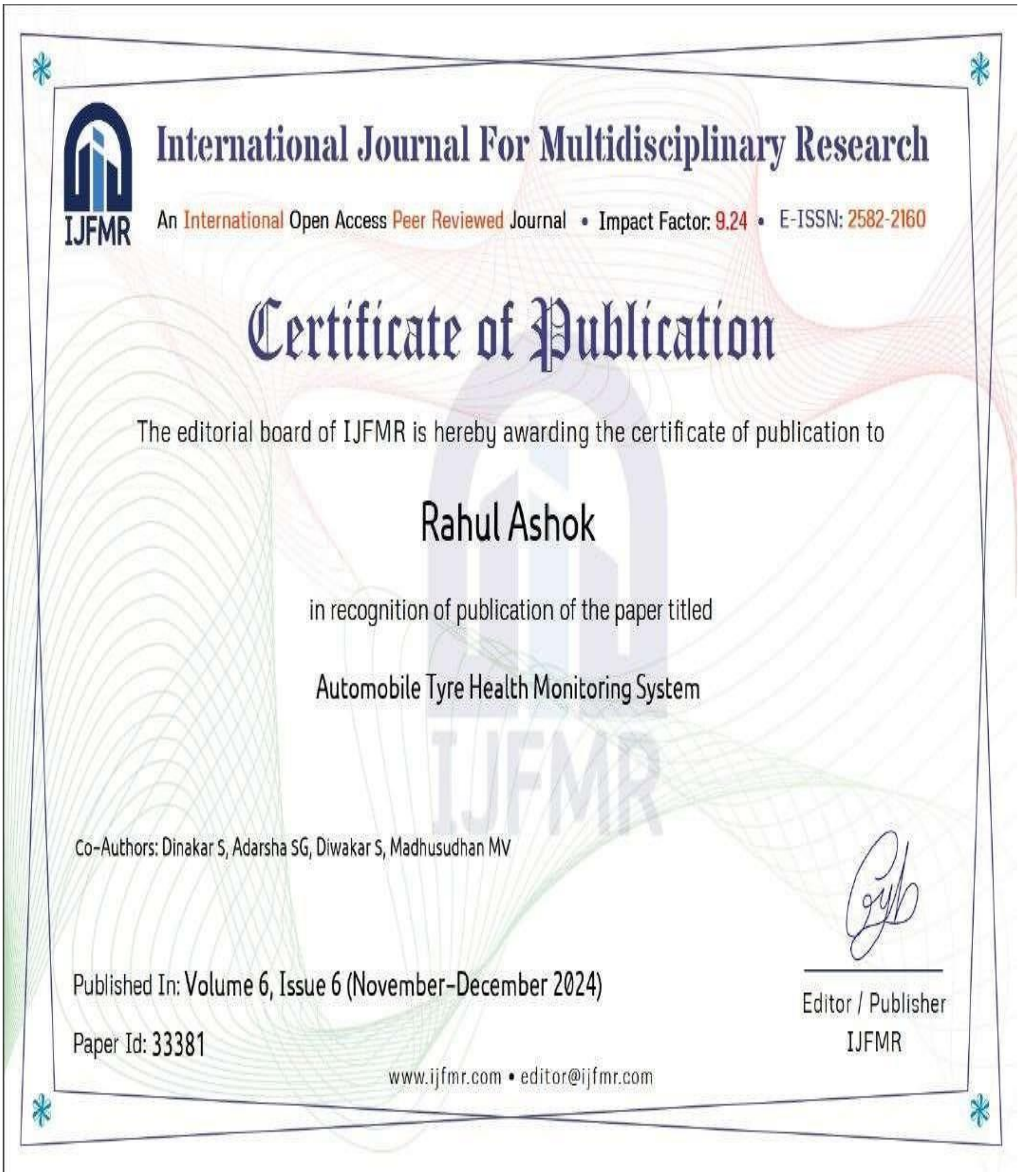
Published In: Volume 6, Issue 6 (November-December 2024)

Paper Id: 33381

Editor / Publisher
IJFMR

www.ijfmr.com • editor@ijfmr.com

AUTHOR-3: Mr.Rahul Ashok



International Journal For Multidisciplinary Research

IJFMR

An International Open Access Peer Reviewed Journal • Impact Factor: 9.24 • E-ISSN: 2582-2160

Certificate of Publication

The editorial board of IJFMR is hereby awarding the certificate of publication to

Rahul Ashok

in recognition of publication of the paper titled

Automobile Tyre Health Monitoring System

Co-Authors: Dinakar S, Adarsha SG, Diwakar S, Madhusudhan MV

Published In: Volume 6, Issue 6 (November-December 2024)

Paper Id: 33381

Editor / Publisher

IJFMR

www.ijfmr.com • editor@ijfmr.com

AUTHOR-4: Mr.Dinakar S

International Journal For Multidisciplinary Research

IJFMR

An International Open Access Peer Reviewed Journal • Impact Factor: 9.24 • E-ISSN: 2582-2160

Certificate of Publication

The editorial board of IJFMR is hereby awarding the certificate of publication to

Dinakar S

in recognition of publication of the paper titled

Automobile Tyre Health Monitoring System

Co-Authors: Adarsha SG, Rahul Ashok, Diwakar S, Madhusudhan MV

Published In: Volume 6, Issue 6 (November-December 2024)

Paper Id: 33381

Editor / Publisher

IJFMR

www.ijfmr.com • editor@ijfmr.com

AUTHOR-5: Mr.Diwakar S

IJFMR

International Journal For Multidisciplinary Research

An International Open Access Peer Reviewed Journal • Impact Factor: 9.24 • E-ISSN: 2582-2160

Certificate of Publication

The editorial board of IJFMR is hereby awarding the certificate of publication to

Diwakar S

in recognition of publication of the paper titled

Automobile Tyre Health Monitoring System

Co-Authors: Dinakar S, Adarsha SG, Rahul Ashok, Madhusudhan MV

Published In: Volume 6, Issue 6 (November-December 2024)

Paper Id: 33381

Editor / Publisher
IJFMR

www.ijfmr.com • editor@ijfmr.com

2. Similarity Index / Plagiarism Check report clearly showing the Percentage (%). No need for a page-wise explanation.

AUTOMOBILE TYRE HEALTH MONITORING SYSTEM

ORIGINALITY REPORT

9%	8%	6%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	hrcak.srce.hr Internet Source	3%
2	www.ijirset.com Internet Source	1%
3	Submitted to Presidency University Student Paper	1%
4	www.idtechex.com Internet Source	<1%
5	wokwi.com Internet Source	<1%
6	vbook.pub Internet Source	<1%
7	Matheen Fathima G, Shakkeera L. "Efficient Task Scheduling and Computational Offloading Optimization with Federated Learning and Blockchain in Mobile Cloud Computing", Results in Control and Optimization, 2025 Publication	<1%

3. Details of mapping the project with the Sustainable Development Goals (SDGs).

SDG 3: Good Health and Well-being

ATHMS contributes directly to reducing road accidents and minimizing the injuries and fatalities caused due to tyre failures. Since it optimizes the tyre conditions, it prevents the blowouts and tyre-related accidents that enhance the road safety level in general.

Tyre pressure, temperature, and tread wear can be monitored in real time, and issues are detected early.This enables timely intervention to prevent accidents. It can also aid emergency response services by giving accurate information about the vehicles involved in accidents.

SDG 9: Industry, Innovation, and Infrastructure

ATHMS is a significant innovation in the safety of vehicles. The system integrates sensors, AI, and wireless communication technologies and plays a role in the development of smart infrastructure and smart vehicles.The ATHMS can be integrated with smart road infrastructure to provide V2I communication, which is a facilitator of the intelligent transport system. This interaction could lead to better traffic management, reduced congestion, and enhanced efficiency in transportation networks.

SDG 11: Sustainable Cities and Communities

ATHMS can contribute to making the urban transportation environment safer and more efficient. The system contributes to reducing pollution and emissions caused by tyre wear and tear through monitoring tyre health.The real time data generated by ATHMS would provide the city planners and policy makers with information on the condition of roads and how their vehicles are performing so that urban roads can be planned and maintained while promoting sustainable mobility.

SDG 12: Responsible Consumption and Production

ATHMS promotes sustainable vehicle behavior by increasing tyre life, saving waste, and enhancing fuel economy. This is in line with the objective of reducing the vehicle's environmental footprint.The reduction of waste through tyre wastage and prevention of premature wear with the subsequent replacement requirements by ATHMS contributes to this effect. Additionally, through tyre pressure and temperature monitoring, the system contributes to improving fuel efficiency, thereby promoting responsible consumption.

SDG 13 Climate Action

ATHMS reduces climate change in that it encourages the use of energy-efficient cars and decreases the greenhouse gases that are related to the wear of tyres.ATHMS reduces rolling resistance by ensuring that tyres are properly inflated and maintained. This helps in lowering fuel consumption and CO_2 emissions, thereby contributing to climate action through improve vehicle energy efficiency.

SDG 17: Partnerships for the Goals

The successful deployment and maintenance of ATHMS require a collaboration between government, private sector, and technology providers.

Public-private partnerships could also quicken the development and application of ATHMS, raising money, conducting research, and employing expertise. Such partnerships might also be extended to devising standardized safety protocols and regulations for tyre health monitoring.