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# Integration of Internet of Things in Conventional Vehicle Technology and its Synergy with Vehicle Telematics Systems and Fleet Management Sequence

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## Abstract

The integration of the Internet of Things in conventional vehicle technology poses several challenges and the need for standardised communication protocols; as such, the synergy between IoT and vehicle telematics systems raises questions about data privacy, ownership and control. On the other hand, the traditional approach to fleet management often involves manual processes and limited real-time data, leading to inefficiencies and increased operational costs. However, the implementation of IoT in fleet management systems poses technical, security and privacy concerns that need to be addressed. This study employed a qualitative research approach, utilising a literature review and case studies to analyse the integration of IoT in conventional vehicle technology and its synergy with VTS and fleet management sequence. The analysis focused on identifying the benefits and challenges of IoT integration and exploring best practices for optimising FMS. The findings revealed that the integration of IoT in vehicle technology offers several solutions, such as enabling real-time monitoring, predictive maintenance and data-driven decision-making. This has resulted in significant improvements in fleet management, including enhanced vehicle tracking, predictive maintenance and fuel efficiency. Real-time data analytics and remote monitoring capabilities have also enabled fleet managers to make informed decisions and optimise operational processes. However, it was observed that challenges such as data security, interoperability, and integration complexity remain barriers to the widespread adoption of IoT in fleet management. Similarly, the integration of IoT in VTS offers numerous benefits, including real-time monitoring, predictive maintenance, and enhanced driver assistance systems. However, challenges such as data security, interoperability, and privacy concerns must be addressed to realise the potential of this integration fully. The findings suggest that while IoT integration in conventional vehicle technology has the potential to revolutionise VTS and FMS by improving vehicle performance and efficiency in the automotive industry, careful consideration must be given to address the associated challenges while developing robust data governance policies and standardised protocols for proper regulation.

**Keywords:** Internet of things, Vehicle telematics systems, Fleet management sequence, Vehicle technology, Automotive industry.

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# 1|Introduction

Integration of Internet of Things (IoT) technology into conventional vehicle technology has become a topic of interest in recent years. This integration has the potential to revolutionise the automotive industry by enhancing safety, efficiency, and convenience for both drivers and passengers [1]. IoT is a revolutionary technology that is transforming conventional vehicle technology. It refers to the network of physical devices, vehicles, and other objects embedded with sensors, software, and connectivity that enables them to collect and exchange data [2].

In the context of conventional vehicles, IoT is being used to enhance safety, efficiency, and overall performance. In conventional vehicle technology, IoT is being utilised to connect vehicles to the internet and other devices, allowing for real-time monitoring and control [3]. This connectivity enables vehicles to communicate with each other, with infrastructure, and with other devices, creating a seamless and integrated system. For example, IoT sensors can monitor vehicle performance, track location, and provide alerts for maintenance or potential issues. The operation principles of IoT in conventional vehicle technology are based on the collection, analysis, and utilisation of data [4].

IoT sensors collect data from various sources, such as vehicle components, road conditions, and driver behaviour. This data is then analysed to identify patterns, trends, and potential problems. Based on this analysis, IoT systems can make real-time decisions, such as adjusting vehicle settings, alerting drivers to hazards, or even autonomously controlling the vehicle [5].

One of the key ways in which IoT fits into conventional vehicle technology is through the concept of connected cars. Connected cars are vehicles that are equipped with internet connectivity and the ability to communicate with other devices, such as smartphones, traffic lights, and other vehicles on the road. This connectivity allows for real-time data exchange, enabling vehicles to communicate with each other to avoid accidents, optimise traffic flow, and improve the overall driving experience [6], [7]. Another way in which IoT technology is integrated into conventional vehicles is through the use of sensors and data analytics. Sensors embedded in vehicles can collect data on various aspects of vehicle performance, such as engine temperature, tire pressure, and fuel efficiency [8].

This data can then be analysed in real-time to identify potential issues and optimise vehicle performance. For example, sensors can alert drivers to low tire pressure or engine malfunctions, allowing them to address these issues before they become more serious. Furthermore, IoT technology can also enhance the overall driving experience for consumers. For example, connected cars can provide drivers with real-time traffic updates, weather forecasts, and navigation assistance. Additionally, IoT technology can enable vehicles to connect with smart home devices, allowing drivers to control their home appliances, such as thermostats and security systems, from their vehicles [9], [10].

The integration of IoT technology into conventional vehicle technology has the potential to revolutionise the automotive industry by enhancing safety, efficiency, and convenience for drivers and passengers. By leveraging the power of connectivity, sensors, and data analytics, IoT technology can improve vehicle performance, optimise traffic flow, and enhance the overall driving experience. As the automotive industry continues to evolve, it is clear that IoT technology will play a crucial role in shaping the future of transportation.

# 2|Vehicle Telematic Systems and the IoT

Vehicle telematic systems and the IoT have revolutionised the way vehicles operate and communicate with each other and the surrounding environment. These technologies have become essential components in modern vehicle technology, enabling vehicles to become smarter, safer, and more efficient, ultimately enhancing the overall driving experience for consumers [11].

Vehicle telematics can be defined as the integration of telecommunications and informatics in vehicles to enable real-time monitoring and communication (see *Fig. 1*). This technology allows vehicles to collect and transmit data on various parameters such as location, speed, fuel consumption, and engine performance. On the other hand, IoT, in this context, refers to the network of interconnected devices and sensors that communicate with each other to exchange data and perform tasks without human intervention. The operation principles of vehicle telematic systems and IoT in vehicle technology involve the use of sensors, communication networks, and data processing algorithms [12].

Sensors installed in vehicles collect data on various parameters, which is then transmitted through communication networks to a central server for processing. The processed data is then used to provide real-time information to drivers, fleet managers, and other stakeholders. The applications of vehicle telematic systems and IoT in vehicle technology are vast and diverse. One of the key applications is fleet management, where these technologies are used to monitor vehicle performance, track vehicle location, and optimise route planning [13].

This helps fleet operators to improve efficiency, reduce fuel consumption, and enhance overall productivity. Another important application of vehicle telematics and IoT is in vehicle safety and security. These technologies enable vehicles to communicate with each other and with infrastructure systems to prevent accidents, detect vehicle malfunctions, and provide emergency assistance in case of an accident. This can help reduce the number of road accidents and save lives. One of the key benefits of vehicle telematic systems and IoT is the ability to collect and analyse real-time data from vehicles [14]. This data can be used to monitor vehicle performance, track maintenance schedules, and even predict potential issues before they occur. For example, telematic systems can alert drivers when their vehicle is due for an oil change or when a tire is low on air pressure. This proactive approach to vehicle maintenance can help prevent costly repairs and improve overall vehicle reliability [15].

Furthermore, vehicle telematic systems and IoT can also enhance vehicle safety by providing real-time monitoring of driver behaviour and road conditions. For instance, telematic systems can track a driver's speed, acceleration, and braking patterns to identify risky driving behaviours. In the event of an accident, these systems can also automatically alert emergency services and provide critical information about the location and severity of the crash [16]. By leveraging IoT technology, vehicles can communicate with each other and with infrastructure to improve traffic flow and reduce the likelihood of accidents. Despite the numerous benefits of vehicle telematic systems and IoT, some challenges must be addressed. One of the main concerns is data privacy and security. As vehicles become increasingly connected, there is a risk that sensitive information could be compromised or misused [17].

Manufacturers and regulators must work together to establish robust cybersecurity measures to protect consumer data and ensure the integrity of vehicle systems. Another challenge is the interoperability of telematic systems and IoT devices. As more manufacturers develop their own proprietary systems, there is a risk of fragmentation and compatibility issues. Standardisation efforts are underway to address this issue and ensure that vehicles can communicate effectively with each other and with external systems.

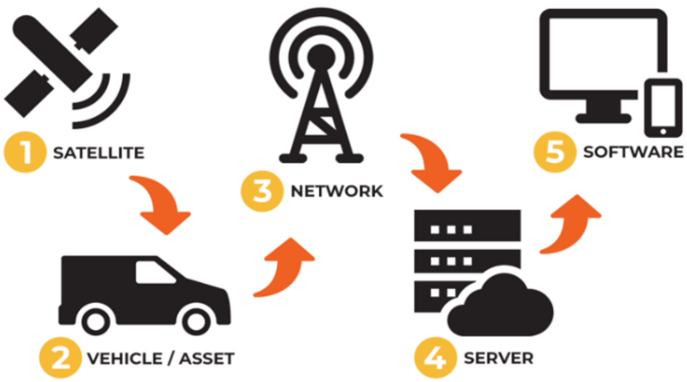


**Fig.1. Vehicle telematics systems [18].**

## 3|Implementation of Vehicle Telematics Using IoT

VTS has become an integral part of modern vehicles, providing a wide range of benefits such as real-time tracking, remote diagnostics, and driver behaviour monitoring. With the advent of the IoT, these systems have become even more advanced and efficient. The step-by-step procedure for implementing vehicle telematics using IoT technology is outlined as follows:

I. The first step in implementing vehicle telematics using IoT is to select the appropriate hardware and software components. This includes choosing the right sensors, communication modules, and data processing units that are compatible with IoT technology. It is important to ensure that these components are reliable, secure, and capable of handling the data transmission and processing requirements of the telematics system [19].

II. Once the hardware and software components have been selected, the next step is to install and configure them in the vehicle. This involves mounting the sensors in strategic locations within the vehicle, connecting them to the communication modules, and setting up the data processing units to collect, analyse, and transmit the data to the cloud-based IoT platform. It is crucial to follow the manufacturer's instructions and guidelines during the installation and configuration process to ensure the proper functioning of the telematics system [19].

III. After the hardware and software components have been installed and configured, the next step is to integrate the telematics system with the IoT platform. This involves setting up the necessary communication protocols, data formats, and security measures to ensure seamless data transmission between the vehicle and the cloud-based platform. It is important to test the integration thoroughly to identify and resolve any compatibility issues or communication errors that may arise [20].

IV. Once the telematics system has been successfully integrated with the IoT platform, the next step is to configure the system settings and parameters according to the specific requirements of the vehicle and the FMS. This includes setting up geofencing zones, defining driver behaviour metrics, and configuring alerts and notifications for critical events such as accidents or unauthorised vehicle usage. It is essential to customise the system settings to meet the unique needs and preferences of the fleet operators and managers [21].

V. Finally, monitor and evaluate the system performance on a regular basis. This involves analysing the data collected by the sensors, reviewing the reports generated by the data processing units, and assessing the overall effectiveness of the telematics system in achieving the desired objectives. It is important to continuously monitor and optimise the system to ensure maximum efficiency, accuracy, and reliability in tracking and managing the vehicles [22].

Implementing a vehicle telematics system using IoT technology requires a systematic and well-planned approach. By following the step-by-step procedure outlined in this study, fleet operators and managers can successfully deploy and manage advanced telematics systems that leverage the power of IoT to enhance vehicle tracking, monitoring, and management capabilities.

## 4|Vehicle Telematics Hardware

Vehicle telematics technology has revolutionised the way vehicles are monitored and managed. Telematics hardware plays a crucial role in collecting and transmitting data from vehicles to a central system for analysis and decision-making. There are various types of telematics hardware available in the market, each with its own unique features and capabilities. The list of various vehicle telematics hardware in-vehicle technology is outlined as follows:

I. Global Positioning System (GPS) tracking devices: GPS tracking devices are one of the most common types of telematics hardware used in vehicles. These devices use GPS technology to track the location of vehicles in real-time. GPS tracking devices can provide information on vehicle speed, location, and route history [23].

II. OBD-II devices: On-Board Diagnostics (OBD-II) devices are another popular type of telematics hardware used in vehicles. These devices plug into the OBD-II port of a vehicle and can monitor various parameters such as engine performance, fuel efficiency, and emissions. OBD-II devices can also provide diagnostic information in case of vehicle malfunctions [24].

III. Controller Area Network (CAN) bus adapters: CAN bus adapters are telematics hardware devices that connect to the vehicle's CAN bus system to collect data on various vehicle parameters. CAN bus adapters can monitor engine performance, vehicle speed, fuel consumption, and other critical data points [25].

IV. In-vehicle cameras: in-vehicle cameras are telematics hardware devices that capture video footage inside and outside the vehicle. These cameras can provide valuable information on driver behaviour, road conditions, and incidents such as accidents or theft. In-vehicle cameras are often used for fleet management and driver safety purposes [26].

V. Radio Frequency Identification (RFID) tags: RFID tags are telematics hardware devices that use radio waves to track vehicles and assets. RFID tags can be attached to vehicles to monitor their location and movement in real-time. RFID tags are commonly used for vehicle tracking, inventory management, and security purposes Munoz [27].

VI. Accelerometers: accelerometers are telematics hardware devices that measure acceleration forces on vehicles. These devices can provide information on vehicle speed, acceleration, braking, and cornering forces. Accelerometers are often used in vehicle performance monitoring and driver behaviour analysis [28].

VII. Tire Pressure Monitoring Systems (TPMS): TPMS are telematics hardware devices that monitor the air pressure in vehicle tires. TPMS can alert drivers to low tire pressure, which can help prevent accidents and improve fuel efficiency. TPMS are mandatory in many countries to ensure vehicle safety [29].

There are various types of telematics hardware available in vehicle technology, each serving a specific purpose in monitoring and managing vehicles. GPS tracking devices, OBD-II devices, CAN bus adapters, in-vehicle cameras, RFID tags, accelerometers, and TPMS are just a few examples of telematics hardware used in vehicles. These devices play a crucial role in improving vehicle safety, efficiency, and performance. As technology continues to advance, we can expect to see more innovative telematics hardware solutions in the future. The list of various vehicle telematics software is presented under subheading No. 7 in this study.

# 5 | Fleet Management and the IoT

Fleet management is a crucial aspect of any organisation that relies on a fleet of vehicles to carry out its operations. It involves the coordination and supervision of all activities related to the management of a company's fleet of vehicles. This includes vehicle maintenance, fuel management, driver management, route planning, and compliance with regulations [30]. The definition of fleet management can vary depending on the industry and the size of the fleet. However, in general terms, fleet management can be defined as the process of managing a company's fleet of vehicles in order to maximise efficiency, minimise costs, and ensure compliance with regulations. The operation principles of fleet management are based on the efficient use of resources, effective communication, and the use of technology to streamline operations. By implementing best practices in fleet management, organisations can improve their operational efficiency, reduce costs, and enhance customer satisfaction. One of the key advantages of fleet management is the ability to track and monitor the performance of vehicles in real-time. This allows organisations to identify areas for improvement, optimise routes, and reduce fuel consumption [31].

Additionally, fleet management can help organisations comply with regulations and ensure the safety of their drivers and vehicles. Fleet management has a wide range of applications across various industries, including transportation, logistics, construction, and delivery services. By implementing fleet management solutions, organisations can improve their operational efficiency, reduce costs, and enhance customer satisfaction. The bottom line is that fleet management systems have become an essential tool for businesses that rely on a fleet of vehicles to operate efficiently. These systems help companies track and manage their vehicles, monitor driver behaviour, and optimise routes to reduce costs and improve productivity. With the advancement of technology, fleet management systems are now incorporating the IoT to enhance their capabilities further. In the context of FMS, IoT technology allows vehicles to be equipped with sensors and other devices that can collect and transmit data in real-time [32].

This data can include information on vehicle location, speed, fuel consumption, engine performance, and more. By integrating IoT technology into FMS, companies can gain valuable insights into their operations and make more informed decisions. For example, real-time data on vehicle performance can help identify maintenance issues before they become major problems, reducing downtime and costly repairs. Additionally, IoT-enabled FMS can provide companies with the ability to track driver behaviour, such as speeding or harsh braking, and implement measures to improve safety and efficiency. One of the key benefits of IoT technology in fleet management is the ability to automate processes and streamline operations [33]. For example, IoT-enabled systems can automatically generate optimised routes based on real-time traffic data, saving time and fuel costs.

Additionally, IoT technology can enable remote monitoring and control of vehicles, allowing companies to track their fleet's performance and make adjustments as needed. Despite the numerous advantages of IoT technology in fleet management, there are also challenges that companies must address. These include concerns about data security and privacy, as well as the need for robust infrastructure to support the increased data transmission and processing requirements of IoT-enabled systems.

# 6 | Procedures for FMS Implementation Using IoT

With the advancement of technology, the IoT has emerged as a powerful tool to streamline and optimise fleet management processes. The step-by-step procedures for the implementation of fleet management using IoT are as follows:

I. Define objectives and requirements: the first step in implementing fleet management using IoT is to define the objectives and requirements of the organisation clearly. This includes identifying Key Performance Indicators (KPIs) such as fuel efficiency, vehicle utilisation, maintenance costs, and driver behaviour. It is important to involve all stakeholders in this process to ensure that the objectives are aligned with the overall goals of the organisation [34].

II. Select IoT devices and sensors: the next step is to select the appropriate IoT devices and sensors that will be used to collect data from the fleet vehicles. These devices can include GPS trackers, fuel sensors, temperature sensors, and cameras. It is important to choose devices that are compatible with the existing fleet vehicles and can provide real-time data to the fleet management systems [35].

III. Install IoT devices and sensors: once the devices and sensors have been selected, the next step is to install them on the fleet vehicles. This may require the assistance of a professional installer to ensure that the devices are properly installed and configured. It is important to test the devices to ensure that they are functioning correctly and are able to transmit data to the fleet management system [36].

IV. Implement fleet management software: the next step is to implement fleet management software that will collect, analyse, and visualise the data collected from the IoT devices. This software should be able to provide real-time insights into the performance of the fleet vehicles and drivers, as well as generate reports and alerts for any issues that may arise. It is important to train the fleet managers and drivers on how to use the software effectively [1].

V. Monitor and analyse data: once the fleet management system is up and running, the next step is to monitor and analyse the data collected from the IoT devices. This includes tracking vehicle locations, monitoring fuel consumption, analysing driver behaviour, and identifying any maintenance issues. It is important to regularly review the data to identify areas for improvement and take corrective actions as needed [37].

VI. Optimise fleet operations: the final step in the implementation of fleet management using IoT is to optimise fleet operations based on the insights gained from the data analysis. This may include adjusting routes to reduce fuel consumption, implementing driver training programs to improve safety, and scheduling maintenance tasks to prevent breakdowns. It is important to continuously monitor and evaluate the performance of the fleet management system to ensure that it is meeting the objectives of the organisation [38].

The implementation of fleet management using IoT can provide organisations with valuable insights into their fleet operations and help them optimise performance and reduce costs. By following the step-by-step procedure outlined in this study, organisations can successfully implement IoT technology to improve their fleet management processes.

## 7 | Vehicle Telematics and Fleet Management Software

Vehicle telematics and fleet management software play a crucial role in modern vehicle technology, providing a wide range of functionalities that enhance the overall driving experience, improve safety, and optimise fleet management. The list of various vehicle telematics and fleet management software available in the market is enlisted as follows:

I. Geotab: Geotab is a leading provider of telematics solutions for fleet management, offering a wide range of features such as real-time tracking, driver behaviour monitoring, and vehicle diagnostics [39].

II. Verizon Connect: Verizon Connect offers a comprehensive suite of telematics software solutions for fleet management, including GPS tracking, route optimisation, and maintenance scheduling [40].

III. Fleet Complete: Fleet Complete provides telematics software that helps fleet managers monitor vehicle performance, track fuel consumption, and improve driver safety [41].

IV. Teletrac Navman: Teletrac Navman offers telematics software that enables fleet managers to track vehicle location, monitor driver behaviour, and optimise route planning.

V. Samsara: Samsara provides telematics software that combines real-time GPS tracking with advanced analytics to help fleet managers improve operational efficiency and reduce costs.

VI. Omnitracs: Omnitracs offers telematics software solutions for fleet management, including route optimisation, driver safety monitoring, and compliance management.

VII. TomTom Telematics: TomTom Telematics provides telematics software that helps fleet managers track vehicle location, monitor driver performance, and optimise fuel consumption [42].

VIII. Fleetmatics: Fleetmatics offers telematics software solutions for fleet management, including vehicle tracking, driver behavior monitoring, and maintenance scheduling [43].

IX. Fleetio: Fleetio is a cloud-based fleet management software that offers features such as maintenance tracking, fuel management, and driver management. The software is user-friendly and provides real-time data to help fleet managers optimise operations.

X. CalAmp: CalAmp provides telematics software that enables fleet managers to track vehicle location, monitor engine performance, and improve driver safety.

XI. GPS insight: GPS insight offers telematics software solutions for fleet management, including real-time tracking, route optimisation, and maintenance scheduling [44].

The aforementioned list provides a comprehensive overview of various vehicle telematics software available in the market. Each software solution offers unique features and functionalities that cater to the specific needs of fleet managers and drivers. By leveraging the power of telematics software, organisations can improve operational efficiency, enhance safety, and reduce costs in their fleet management operations.

## 8 | Fleet Management Hardware

Fleet management hardware in vehicle technology plays a crucial role in optimising the efficiency and safety of fleet operations. With advancements in technology, there is a wide range of hardware options available to fleet managers to monitor and manage their vehicles effectively. The list of fleet management hardware and its key features are highlighted as follows:

I. GPS tracking devices: GPS tracking devices are essential for fleet management as they provide real-time location data of vehicles (see *Fig. 2*). This allows fleet managers to track the movement of their vehicles, optimise routes, and improve overall efficiency [45].


**Fig. 2. GPS tracking devices [46].**

II. Telematics systems: telematics systems combine GPS technology with OBD-II to provide detailed information about vehicle performance. This includes data on fuel consumption, engine health, and driver behaviour, allowing fleet managers to make informed decisions to improve fleet operations [47].

III. Dash cameras: dash cameras are becoming increasingly popular in fleet management as they provide video evidence of accidents, theft, and other incidents (see *Fig. 3*). This can help fleet managers protect their assets and ensure the safety of their drivers [48].


**Fig. 3. Dash cameras [49].**

IV. Electronic Logging Devices (ELDs): ELDs are mandatory for commercial vehicles to track driver hours of service and ensure compliance with regulations. These devices help fleet managers to monitor driver behaviour and prevent fatigue-related accidents.

V. TPMS: TPMS help fleet managers to monitor tire pressure in real-time, reducing the risk of blowouts and improving fuel efficiency. This can lead to cost savings and increased safety for fleet operations.

VI. Remote diagnostics systems: remote diagnostics systems allow fleet managers to monitor vehicle health and performance remotely. This can help to identify potential issues before they become major problems, reducing downtime and maintenance costs [50].

VII. Asset tracking devices: asset tracking devices are used to monitor the location and status of valuable assets, such as trailers and equipment. This can help fleet managers to prevent theft and improve asset utilisation.

Fleet management hardware in vehicle technology plays a crucial role in optimising fleet operations. By utilising a combination of GPS tracking devices, telematics systems, dash cameras, ELDs, TPMS, remote diagnostics systems, and asset tracking devices, fleet managers can improve efficiency, safety, and compliance.

Investing in the right hardware can lead to cost savings, increased productivity, and a competitive edge in the industry [51].

## 9|Advances in IoT Integration in Vehicle Technology

The integration of IoT technology in conventional vehicle technology has seen significant advancements in recent years, leading to notable improvements in the automotive industry. The various advances in IoT integration in vehicles and its applications in the automotive sector are highlighted as follows:

I. One of the key advancements in IoT integration in vehicles is the development of connected car technology. This technology allows vehicles to communicate with each other and with external infrastructure, such as traffic lights and road signs, to improve safety and efficiency on the road. Connected car technology also enables features such as remote vehicle diagnostics, predictive maintenance, and real-time traffic updates, enhancing the overall driving experience for consumers [52].

II. Another important advancement in IoT integration in vehicles is the development of autonomous driving technology. This technology uses IoT sensors and data analytics to enable vehicles to navigate and operate without human intervention. In other words, IoT-integrated vehicles use IoT technology to collect and analyse data from sensors, cameras, and other devices to navigate roads, detect obstacles, and make decisions without human intervention. Autonomous driving technology has the potential to revolutionise the automotive industry by reducing accidents, improving traffic flow, increasing mobility for individuals with disabilities and increasing fuel efficiency [53].

III. Furthermore, IoT integration in vehicles has led to advancements in Vehicle to Everything (V2X) communication technology. V2X communication allows vehicles to communicate with each other, with infrastructure, and with pedestrians to improve safety and efficiency on the road. V2X communication also enables features such as collision avoidance, traffic signal optimisation, and pedestrian detection, making driving safer and more convenient for consumers [54].

The integration of IoT technology in conventional vehicle technology has seen significant advancements in recent years, leading to notable improvements in the automotive industry. Connected car technology, autonomous driving technology, and V2X communication technology are just a few examples of the advancements in IoT integration in vehicles that are shaping the future of the automotive sector. As technology continues to evolve, we can expect to see even more innovations in IoT integration in vehicles that will further enhance safety, efficiency, and convenience for consumers.

## 10|Classification of IoT in Vehicle Technology

The IoT has revolutionised the way we interact with technology, and its impact on the automotive industry is no exception. In conventional vehicle technology, IoT can be classified into the following categories: vehicle-to-vehicle communication, vehicle-to-infrastructure communication, vehicle-to-cloud communication, vehicle-to-device communication, vehicle-to-grid communication, and vehicle-to-home communication:

I. Vehicle-to-vehicle communication involves the exchange of data between vehicles on the road, allowing them to communicate with each other and share information such as speed, location, and road conditions (see *Fig. 4*). This technology can help improve road safety by enabling vehicles to warn each other of potential hazards and avoid collisions [55].

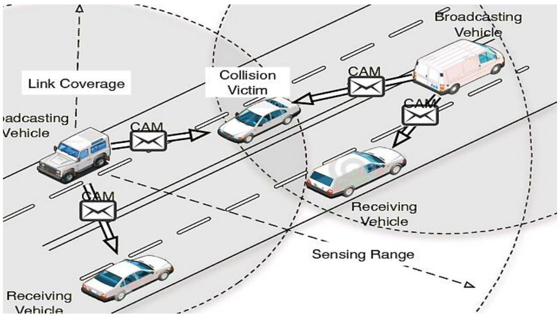


**Fig. 4. Vehicle-to-vehicle communication [56].**

II. Vehicle-to-infrastructure communication, on the other hand, involves the exchange of data between vehicles and the surrounding infrastructure, such as traffic lights, road signs, and parking meters (see *Fig. 5*). This technology can help optimise traffic flow, reduce congestion, and improve overall transportation efficiency [57].

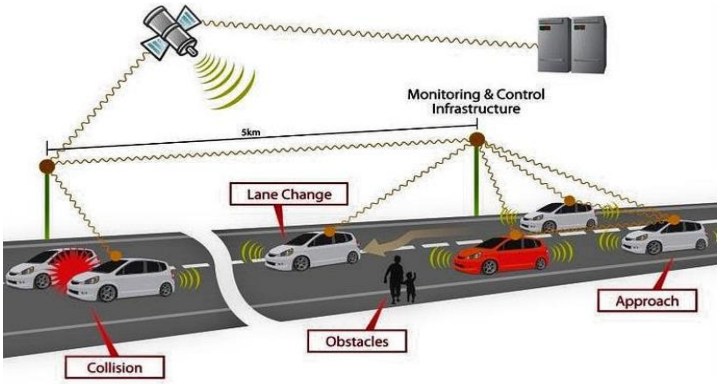


**Fig. 5. Vehicle-to-infrastructure communication [58].**

III. Vehicle-to-cloud communication involves the exchange of data between vehicles and cloud-based services, allowing for remote monitoring, diagnostics, and software updates (see *Fig. 6*). This technology can help improve vehicle performance, enhance driver experience, and enable new business models such as subscription-based services and predictive maintenance [59].

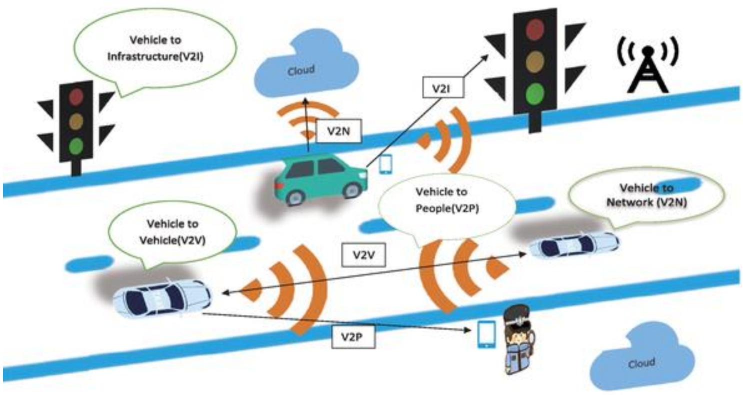


**Fig. 6. Vehicle-to-cloud communication [60].**

IV. Vehicle-to-device communication refers to the ability of vehicles to communicate with other devices, such as smartphones, tablets, and wearable technology. This type of communication allows for seamless integration between the vehicle and other devices, enabling features such as remote vehicle monitoring, control, and diagnostics [61].

V. Vehicle-to-grid communication involves the interaction between vehicles and the electrical grid. This type of communication enables vehicles to communicate with the grid in order to optimise charging and discharging schedules, as well as to participate in demand response programs. By leveraging vehicle to grid communication, vehicles can help to balance the grid and support the integration of renewable energy sources [62].

VI. Vehicle-to-home communication allows vehicles to communicate with smart home devices and systems. This type of communication enables vehicles to interact with home automation systems, such as smart thermostats, lighting, and security systems. By integrating vehicle-to-home communication, users can automate tasks such as opening garage doors, adjusting home temperatures, and turning on lights upon arrival [63].

The classifications of IoT in conventional vehicle technology have a wide range of applications in the automotive industry. These highlight the diverse range of communication capabilities that are available to vehicles. By leveraging these communication technologies, vehicles can enhance their functionality, improve efficiency, and provide a more seamless and integrated user experience. In addition, automotive companies can improve road safety, optimise traffic flow, enhance vehicle performance, and create new business opportunities. As IoT continues to evolve, its impact on the automotive industry is only expected to grow, making it an essential technology for the future of transportation.

# 11 | Collection of Real-Time Data from Vehicle Components Using Sensors

Sensors play a crucial role in monitoring the performance and health of the vehicle, as well as providing valuable insights for maintenance and optimisation. One of the key aspects of IoT in vehicles is the use of sensors to collect real-time data from various components of the vehicle. These processes are as follows:

I. The first step in utilising IoT in vehicles is the installation of sensors in key components such as the engine, brakes, tires, and suspension. These sensors are equipped with various technologies, such as accelerometers, gyroscopes, and temperature sensors, to measure different parameters. For example, an accelerometer can detect changes in speed and direction, while a temperature sensor can monitor the heat generated by the engine [64].

II. Once the sensors are installed, they continuously collect data from the components they are monitoring. This data is then transmitted wirelessly to a central processing unit, which analyses and interprets the information in real-time. For example, if a sensor detects a sudden increase in temperature in the engine, it can alert the driver or the maintenance team to take immediate action. Furthermore, IoT in vehicles allows for predictive maintenance, where the sensors can predict when a component is likely to fail based on the data collected. This proactive approach helps prevent costly breakdowns and ensures the vehicle is always in optimal condition [65].

In addition to monitoring the performance of the vehicle, IoT sensors can also collect data on driving behaviour and environmental conditions. For example, sensors can track the speed, acceleration, and braking patterns of the driver, providing valuable insights for improving fuel efficiency and safety. Moreover, sensors can also monitor external factors such as road conditions, weather, and traffic congestion, allowing for better navigation and route optimisation. The use of sensors in IoT-enabled vehicles is a game-changer in the automotive industry. By collecting real-time data from various components of the vehicle, these sensors provide valuable insights for maintenance, optimisation, and safety.

# 12 | Iot-Enabled Sensors in Vehicle Technology

IoT-enabled sensors play a crucial role in enhancing the functionality and safety of vehicles, providing real-time data and insights that can improve performance and efficiency. The different types of IoT-enabled sensors used in vehicle technological applications and their functions are as follows:

I. One of the most common types of IoT-enabled sensors found in vehicles is the GPS sensor. This sensor uses satellite technology to track the location of the vehicle in real-time, allowing for accurate navigation and location-based services. GPS sensors are essential for applications such as fleet management, stolen vehicle recovery, and emergency services [66].

II. Another important type of sensor is the accelerometer, which measures the acceleration and deceleration of the vehicle. Accelerometers are used in applications such as stability control systems, rollover detection, and impact detection in the event of a crash. By providing real-time data on the vehicle's movement, accelerometers help improve safety and performance [67].

III. Temperature sensors are also commonly used in vehicles to monitor the temperature of the engine, transmission, and other critical components. These sensors help prevent overheating and ensure optimal performance of the vehicle. In addition, temperature sensors can also be used to monitor the temperature inside the vehicle, providing a comfortable and safe environment for passengers [68].

IV. Pressure sensors are another type of IoT-enabled sensor that is used in vehicles to monitor tire pressure, oil pressure, and other fluid levels. By providing real-time data on pressure levels, these sensors help prevent mechanical failures and optimise performance. Pressure sensors are essential for maintaining the safety and efficiency of the vehicle [69].

IoT-enabled sensors play a crucial role in enhancing the functionality and safety of vehicles in technological applications. GPS sensors, accelerometers, temperature sensors, and pressure sensors are just a few examples of the types of sensors used in vehicles to provide real-time data and insights. By leveraging the power of IoT technology, automotive manufacturers can improve performance, efficiency, and safety for drivers and passengers alike.

## 13 | Factors that Affect the Performance of IoT in Vehicle Technology

In the automotive industry, IoT has the potential to enhance the performance of conventional vehicle technologies greatly. However, the following factors can affect the performance of IoT in this context.

I. One of the key factors that can impact the performance of IoT in conventional vehicle technologies is connectivity. In order for IoT devices to communicate effectively with each other and with external systems, a reliable and fast internet connection is essential. Poor connectivity can lead to delays in data transmission, which can, in turn, affect the performance of IoT applications in vehicles [70].

II. Another factor that can affect the performance of IoT in conventional vehicle technologies is security. With the increasing amount of data being collected and transmitted by IoT devices in vehicles, there is a growing concern about the security of this data. Hackers could potentially access sensitive information, such as location data or vehicle diagnostics if proper security measures are not in place. This can not only compromise the safety and privacy of vehicle occupants but also affect the overall performance of IoT in vehicles [71].

III. Interoperability is another factor that can impact the performance of IoT in conventional vehicle technologies. As IoT devices in vehicles come from different manufacturers and operate on different platforms, ensuring that they can communicate effectively with each other can be a challenge. Lack of interoperability can lead to compatibility issues and hinder the seamless integration of IoT applications in vehicles [72].

IV. The complexity of IoT systems in vehicles can also affect their performance. As more and more IoT devices are integrated into vehicles, the complexity of the system increases, making it more difficult to manage and troubleshoot issues. This can lead to performance issues and downtime, affecting the overall efficiency of IoT in conventional vehicle technologies [73].

Several factors can affect the performance of IoT in conventional vehicle technologies, including connectivity, security, interoperability, and complexity. By addressing these factors and implementing proper measures to mitigate their impact, the automotive industry can fully harness the potential of IoT to enhance the performance of conventional vehicle technologies.

# 14 | Considerations for Selecting IoT-Enabled Sensors in Vehicle Technology

IoT-enabled sensors have become an integral part of conventional vehicle technology, providing valuable data and insights that can improve safety, efficiency, and overall performance. However, with the plethora of options available in the market, it is crucial for automotive manufacturers and engineers to carefully consider the following factors when selecting IoT-enabled sensors for their vehicles.

I. One of the key considerations when choosing IoT-enabled sensors for conventional vehicle technology is the accuracy and reliability of the data they provide. Sensors that are not accurate or reliable can lead to incorrect readings and potentially dangerous situations on the road. It is important to thoroughly test and evaluate the sensors before integrating them into the vehicle to ensure that they meet the necessary standards for accuracy and reliability [74].

II. Another important factor to consider is the compatibility of the sensors with existing vehicle systems and infrastructure. IoT-enabled sensors should be able to seamlessly integrate with the vehicle's on-board computer systems and communicate effectively with other sensors and devices. Compatibility issues can lead to malfunctions and breakdowns in the vehicle, so it is essential to choose sensors that are designed to work well with the existing technology in the vehicle [75].

III. Cost is also a significant consideration when selecting IoT-enabled sensors for conventional vehicle technology. While it is important to invest in high-quality sensors that provide accurate and reliable data, it is also important to consider the overall cost of integrating these sensors into the vehicle. Manufacturers and engineers should carefully weigh the cost of the sensors against the potential benefits they will provide in terms of improved performance and safety [76].

IV. In addition to accuracy, reliability, compatibility, and cost, it is also important to consider the security and privacy implications of IoT-enabled sensors in conventional vehicle technology. With the increasing connectivity of vehicles to the internet, there is a growing concern about the potential for cyber-attacks and data breaches. Manufacturers and engineers should prioritise security measures to protect the data collected by IoT-enabled sensors and ensure the privacy of vehicle owners and users [3].

Selecting IoT-enabled sensors for conventional vehicle technology requires careful consideration of a number of factors, including accuracy, reliability, compatibility, cost, security, and privacy. By taking these factors into account, automotive manufacturers and engineers can ensure that they choose sensors that will enhance the performance and safety of their vehicles while also protecting the data and privacy of their customers.

# 15 | Establishing IoT Connections and Communication in Vehicle Technology

Conventional vehicles are now being equipped with IoT capabilities to enhance communication and connectivity, providing a range of benefits such as improved safety, efficiency, and convenience. In this context, the procedure for establishing IoT connections and communication in conventional vehicle technology is as follows:

I. Hardware installation: the first step in implementing IoT connections in conventional vehicles is to install the necessary hardware. This typically involves the installation of sensors, actuators, and communication modules that enable the vehicle to collect and transmit data. These components are essential for establishing a network of connected devices within the vehicle [77].

II. Data collection and processing: once the hardware is in place, the next step is to collect and process data from various sources within the vehicle. This includes data from sensors that monitor vehicle performance, environmental conditions, and driver behaviour. The data is then processed and analysed to extract meaningful insights that can be used to improve vehicle performance and safety.

III. Connectivity setup: after data collection and processing, the next step is to establish connectivity between the vehicle and external networks. This typically involves setting up a secure connection to the internet or a dedicated IoT platform. This connection allows the vehicle to communicate with other devices, services, and applications, enabling a range of IoT functionalities such as remote monitoring, diagnostics, and software updates [78].

IV. Communication protocols: to ensure seamless communication between the vehicle and external networks, it is essential to implement robust communication protocols. These protocols define the rules and standards for data exchange, ensuring that information is transmitted securely and efficiently. Common communication protocols used in IoT applications include MQTT, CoAP, and HTTP.

V. Data transmission and analysis: once the vehicle is connected to external networks, data can be transmitted in real-time to cloud-based servers or analytics platforms for further analysis. This data can be used to generate insights, detect anomalies, and trigger automated actions such as maintenance alerts or emergency notifications. Advanced analytics techniques such as machine learning and artificial intelligence can also be applied to optimise vehicle performance and predict potential issues.

The integration of IoT technology in conventional vehicles offers a range of benefits for both drivers and manufacturers. By following the step-by-step procedure outlined in this study, automotive companies can effectively implement IoT connections and communication in their vehicles, paving the way for a more connected and intelligent transportation system.

## 16 | Implementation of IoT Assisted Driving Vehicles Technology

The IoT technology in conventional vehicle systems has revolutionised the patterns of driving. IoT-assisted driving sequences have significantly enhanced the safety, efficiency, and overall driving experience for motorists. The procedure for implementing IoT-assisted driving in conventional vehicles is as follows:

I. Sensor installation: the first step in implementing IoT-assisted driving is the installation of sensors in the vehicle. These sensors can include cameras, radars, lidars, and ultrasonic sensors. These sensors collect data on the vehicle's surroundings, including other vehicles, pedestrians, and road conditions [79].

II. Data collection and processing: once the sensors are installed, the data collected by these sensors is processed in real-time using IoT technology. This data includes information on the vehicle's speed, acceleration, braking, and steering inputs, as well as the surrounding environment. This data is then analysed to make informed decisions about the vehicle's driving behaviour.

III. Communication with cloud servers: the processed data is then transmitted to cloud servers using IoT technology. This allows for real-time communication between the vehicle and external servers, enabling the vehicle to access up-to-date information on traffic conditions, weather, and road hazards [80].

IV. Decision-making and control: based on the data collected and processed, the vehicle's on-board computer makes decisions about the vehicle's driving behaviour. This can include adjusting the vehicle's speed, changing lanes, or applying the brakes to avoid collisions. The vehicle's control systems are then activated to execute these decisions.

V. Feedback and monitoring: throughout the driving sequence, the vehicle's IoT system continuously monitors the vehicle's performance and surroundings. Any deviations from the desired driving behaviour are immediately detected, and corrective actions are taken to ensure the safety of the vehicle and its occupants [81].

IoT-assisted driving sequences in conventional vehicles have the potential to improve road safety and efficiency greatly. By following the step-by-step procedure outlined in this study, manufacturers and developers can successfully implement IoT technology in vehicles to enhance the driving experience for motorists.

## 17 | IoT Assisted Troubleshooting in Vehicle Technology

With IoT-assisted troubleshooting, conventional vehicle technology can be diagnosed and repaired more efficiently than ever before. The process for utilising IoT in troubleshooting vehicle issues is highlighted as follows:

I. The first step in IoT-assisted troubleshooting is to install IoT devices in the vehicle. These devices can be connected to various components of the vehicle, such as the engine, transmission, and brakes, to collect real-time data on their performance. This data is then transmitted to a central server, where it can be analysed by technicians to identify any potential issues.

II. Once the IoT devices are installed and data is being collected, the next step is to monitor the data for any anomalies. Technicians can set up alerts to notify them of any unusual readings, such as a sudden increase in engine temperature or a drop in oil pressure. By monitoring the data in real-time, technicians can quickly identify and address any issues before they escalate into more serious problems [82].

III. After identifying a potential issue, the next step is to diagnose the problem using the data collected by the IoT devices. Technicians can analyse the data to pinpoint the root cause of the issue, whether it be a faulty sensor, a malfunctioning component, or a software glitch. This data-driven approach to diagnosis allows technicians to make more informed decisions about how to proceed with repairs.

IV. Once the problem has been diagnosed, the next step is to repair the issue. IoT devices can be used to remotely access the vehicle's systems, allowing technicians to make adjustments or repairs without having to be present physically. This can save time and money, as technicians can troubleshoot and repair issues more quickly and efficiently [83].

IoT-assisted troubleshooting offers a number of benefits for conventional vehicle technology, including real-time monitoring, data-driven diagnosis, and remote access for repairs. However, there are also challenges to implementing IoT in the automotive industry, such as data security and privacy concerns. By following the process outlined in this study, technicians can harness the power of IoT to troubleshoot and repair vehicle issues more effectively than ever before.

## 18 | Applications of IoT in Conventional Vehicle Technology

In the automotive sector, IoT has been integrated into vehicles to enhance safety, efficiency, and overall driving experience. In this context, the applications of IoT in conventional vehicle technology are enlisted as follows:

I. One of the primary applications of IoT in vehicles is remote monitoring and diagnostics. Through IoT sensors installed in vehicles, manufacturers and drivers can remotely monitor the performance of various components such as engines, brakes, and tires. This real-time data allows for proactive maintenance and timely repairs, ultimately improving vehicle reliability and reducing downtime [84].

II. Another significant application of IoT in vehicles is predictive maintenance. By analysing data collected from IoT sensors, manufacturers can predict potential issues before they occur. This proactive approach to maintenance helps prevent costly breakdowns and extends the lifespan of vehicle components. Additionally, IoT-enabled vehicles can automatically schedule maintenance appointments based on real-time data, ensuring optimal performance at all times.

III. IoT has also been instrumental in enhancing driver safety through features such as collision avoidance systems and driver assistance technologies. IoT sensors can detect potential hazards on the road and alert drivers in real-time, helping to prevent accidents. Furthermore, IoT-enabled vehicles can communicate with each other to improve traffic flow and reduce congestion, ultimately making roads safer for everyone [85].

IV. IoT technology is also being used in fleet management systems to monitor and track vehicles, optimise routes, and improve fuel efficiency. By integrating IoT devices in commercial vehicles, companies can reduce operating costs, increase productivity, and enhance customer service.

V. IoT technology is being utilised in VTS to provide drivers with real-time information on traffic conditions, weather forecasts, and vehicle performance. This data can help drivers make informed decisions, avoid accidents, and optimise their driving habits to reduce fuel consumption and emissions.

VI. IoT has also transformed the driving experience through features such as connected infotainment systems and personalised settings. IoT-enabled vehicles can connect to the internet to access real-time traffic updates, weather forecasts, and entertainment options. Drivers can also customise their driving experience by adjusting settings such as seat position, climate control, and music preferences, all through IoT-enabled interfaces.

IoT has significantly impacted conventional vehicle technology by enhancing safety, efficiency, and overall driving experience. Through remote monitoring, predictive maintenance, driver assistance technologies, and connected infotainment systems, IoT has revolutionised the automotive sector. As technology continues to evolve, the integration of IoT in vehicles will only continue to advance, ultimately shaping the future of transportation.

# 19 | Advantages of IoT in Conventional Vehicle Technology

Conventional vehicle technology has greatly benefited from the integration of IoT, leading to the following advantages:

I. First, IoT has enhanced vehicle safety. With the implementation of IoT devices such as sensors and cameras, vehicles are now equipped with advanced safety features such as collision detection, lane departure warnings, and automatic emergency braking. These features help prevent accidents and save lives on the road [86].

II. Furthermore, IoT has improved vehicle maintenance and diagnostics. Through IoT-enabled systems, vehicles can now monitor their own performance and detect potential issues before they escalate. This proactive approach to maintenance not only saves time and money for vehicle owners but also ensures that vehicles are always in optimal condition.

III. In addition, IoT has enhanced the overall driving experience. With the integration of IoT devices, vehicles can now offer personalised services such as in-car entertainment, navigation assistance, and real-time traffic updates. This level of connectivity and convenience has transformed the way people interact with their vehicles, making driving more enjoyable and efficient [87].

IV. Moreover, IoT has contributed to the development of autonomous vehicles. By leveraging IoT technology, vehicles can now communicate with each other and with the surrounding infrastructure, enabling them to navigate and operate autonomously. This advancement in vehicle technology has the potential to revolutionise transportation systems and improve road safety.

The advantages of IoT in conventional vehicle technology are undeniable. From enhanced safety features to improved maintenance and diagnostics, IoT has significantly transformed the automotive sector. As technology continues to evolve, the integration of IoT in vehicles will only continue to enhance the driving experience and pave the way for a more connected and efficient transportation system.

# 20 | Limitations of IoT in Conventional Vehicle Technology

Despite its numerous advantages, there are several key disadvantages of IoT in conventional vehicle technology, which are considered as follows:

I. One major disadvantage of IoT in vehicles is the potential for security breaches. With the increasing connectivity of vehicles to the internet, there is a greater risk of hackers gaining access to critical systems, such as the engine or brakes. This could lead to serious safety concerns for drivers and passengers. In fact, a study by the University of Michigan found that many popular vehicles are vulnerable to cyber-attacks, highlighting the need for improved security measures in IoT-enabled vehicles [88].

II. Another disadvantage of IoT in vehicles is the potential for data privacy issues. As vehicles become more connected, they are able to collect and transmit a vast amount of data about their drivers and passengers.

This data could be used for targeted advertising or even sold to third parties without the consent of the individuals involved. This raises serious concerns about privacy and the protection of personal information in IoT-enabled vehicles [89].

III. Furthermore, the reliance on IoT in vehicles could lead to increased complexity and cost. As vehicles become more connected, they require more sophisticated technology and components, which can drive up the cost of manufacturing and maintenance. This could make it more difficult for consumers to afford and repair IoT-enabled vehicles, potentially widening the gap between those who can afford the latest technology and those who cannot [90].

While IoT has the potential to revolutionise the automotive industry, several key disadvantages must be addressed. From security breaches to data privacy issues to increased complexity and cost, there are significant challenges that must be overcome in order to realise the benefits of IoT in conventional vehicle technology fully. Manufacturers, regulators, and consumers need to work together to address these issues and ensure that IoT-enabled vehicles are safe, secure, and affordable for all.

# 21|Conclusion

The integration of IoT in conventional vehicle technology has shown immense potential for revolutionising the automotive industry. Through various studies and research, it has been established that IoT can enhance vehicle performance, safety, and efficiency by enabling real-time data monitoring, predictive maintenance, and autonomous driving capabilities. The applications of IoT in automotive industries are vast and diverse, ranging from fleet management and telematics to connected car services and smart infrastructure. These advancements not only improve the overall driving experience for consumers but also have the potential to reduce accidents, lower emissions, and optimise traffic flow.

Despite the numerous benefits of IoT integration in vehicles, there are still challenges that need to be addressed, such as data security, privacy concerns, and interoperability issues. However, with ongoing research and development in this field, these obstacles can be overcome to realise the potential of IoT in the automotive sector fully. The integration of IoT in conventional vehicle technology is a game-changer for the automotive industry, offering endless possibilities for innovation and improvement. As technology continues to evolve, manufacturers, policymakers, and stakeholders must collaborate and invest in IoT solutions to drive the industry forward and create a safer, more efficient, and sustainable transportation system. Based on the findings obtained from this study, the following recommendations are suggested to improve the integration of IoT in vehicle technology and its applications in the automotive industry.

I. One of the key recommendations based on the findings of this study is the need for increased collaboration between automotive manufacturers and IoT technology providers. This collaboration is essential to ensure that IoT technology is seamlessly integrated into vehicle systems, allowing for improved connectivity and communication between vehicles and external devices. By working together, automotive manufacturers and IoT technology providers can develop innovative solutions that enhance the overall driving experience and improve vehicle performance.

II. Another important recommendation is the need for standardisation in IoT technology for vehicles. Standardisation is crucial to ensure interoperability between different IoT devices and systems, allowing for seamless communication and data exchange. By establishing common standards for IoT technology in vehicles, automotive manufacturers can ensure that their vehicles are compatible with a wide range of IoT devices and services, ultimately enhancing the user experience and driving efficiency.

III. This study has highlighted the importance of data security and privacy in IoT-enabled vehicles. As vehicles become increasingly connected to the internet and external devices, there is a growing concern about the security of personal and sensitive data. Automotive manufacturers must prioritise data security and privacy in the design and implementation of IoT technology in vehicles, implementing robust encryption and authentication measures to protect user information.

The integration of IoT technology in conventional vehicle technology has the potential to revolutionise the automotive industry, offering new opportunities for innovation and efficiency. By following the recommendations outlined in this study, automotive manufacturers can successfully integrate IoT technology into their vehicles, enhancing connectivity, communication, and performance. Collaboration with IoT technology providers, standardisation of IoT technology, and prioritisation of data security and privacy are key factors in ensuring the successful integration of IoT in vehicle technology and its applications in the automotive industry.

## Author Contributions

Aniekan Essienubong Ikpe contributed to conceptualization, methodology, and data collection. Imoh Ime Ekanem was responsible for formal analysis, visualization, and writing – original draft preparation. Jephtar Uviefovwe Ohwoekevwo handled supervision, review, and editing.

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## Data Availability

Data supporting the findings of this study are available within the article and upon reasonable request from the corresponding author.

## Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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