Charles Sturt University

Internet of Things

Assessment No.3

Research Report: IoT in Intelligent transportation systems

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1. Abstract

An important area of interest in the solution to road safety, traffic efficiency and carbon emission problem, many cities increase their traffic every year, leading to delays, traffic jams, increase fuel costs, rise in CO2 emissions, accidents, emergencies, and society's quality of life. The objective of an intelligent transportation system (ITS) is to enable users to use transportation networks in a safer, more organised, and "smarter" way by offering cutting-edge services related to various modes of transportation and traffic management. Today, the most mature methodology is using in-road sensors to provide assistance, monitoring, control and comfort to the driver, but the cities are growing faster, and extra measures are required to keep the ITS services. In terms of traffic collisions, human error and infractions account for approximately 90% of collisions. Furthermore, this study is focused to explore alternative solutions that can be integrated into ITSs. Technologies that are currently investigated such as Driving behaviour analysis using smartphones, driver support in In-built vehicles, monitoring driver state using external devices, services provide and improvements to in road sensors, and services support using UAV in transportation are reviewed. Then, it is determined advantages and disadvantages, and discover challenges and limitations. This work is envisaged to explore current alternatives to be implemented and encourage governments to establish policies around them in a pro to their benefits and posteriors integration into ITSs. It is advised that future research should tackle the challenges and limitations found. Driving behaviour Analysis using smartphones is the most possible alternative due most of the world while population have access to these devices. Therefore, it has the potential to shape the future of intelligent transportation systems and redefine how we see traffic today.

2. Introduction

Road safety and driving-related concerns are currently getting international attention. According to a study by the World Health Organization (WHO) on the state of road safety worldwide in 2018, there are 1.35 million traffic-related fatalities worldwide annually, making it the top cause of death for those aged 5 to 29. (Organization, 2019). Road safety has significantly increased since the WHO's "Decade of Action in Road Safety (2011-2021)" initiative was introduced. Road safety incidents have been reduced via the use of driver assistance and safety awareness programmes. The new decade programme 2021-2030 targets a minimum 50% reduction in traffic-related deaths and injuries. To guarantee a safe usage of the roadways, it is suggested to use competency-based testing for driver licencing and to adopt graduated driver licencing for new drivers.

The goal of the study is to analyse the pertinent research on IoT devices used in transportation as well as approaches that support the notion of enhancing traffic efficiency, reducing CO2 emissions, and improving road safety as a component of intelligent transportation systems. The technology that supports tasks for regulating, monitoring, and automation is all around us these days and is now appearing in the shape of sensors. Cars are built with around 60-100 sensors and this number is increasing, smartphones have around 18 sensors, fitness bands and smartwatches have around 16 sensors, Commercial drones around 10 with the possibility to adapt more, and there are around 11 powerful sensors used on the roads today. This raises the idea of using the information gathered by the sensors to address transportation issues using ITS. Therefore, the current technology brings advantages that may help to face these issues with the methodologies found, However, extracting this information is not an easy task and is surrounded by several problems that include connectivity, privacy, policies, raw data extraction, environment, security, data storage, data processing and data opening. Then, this report will explore five methods that are current investigated: Monitoring using smartphones, Monitoring using In-build vehicle sensors, Monitoring with External devices, Monitoring In road sensors and Monitoring with UAV.

3. Literature Review

A literature review was conducted addressing methods to monitor the transportation networks that can be integrated into ITSs. Particular methodologies were found and explored to find more information about challenges and limitations.

(Rahim et al., 2021) investigates the evolution of technology enabling connectivity and applications. The author explored the advantages and difficulties of installing IoT applications and presents a framework. Additionally, this study also focuses on evaluating various connectivity types integrated into the sensor node and linking them with related applications. Finally, this effort is intended to influence the creation of IoT platforms by the automotive industry community and shape future perspectives for IoT technology in the automobile sector.

(Guerrero-Ibáñez et al., 2018) examines the current sensors and methodologies used for data collection and processing in Intelligent Transportation. The author identifies the most used sensors in-build vehicles as part of the methodology for Real-time monitoring and classified them into 6 categories: safety, Diagnostic, traffic, assistance, environment, and user. On the other hand, the in-Road sensors and separated into two categories intrusive and non-intrusive were identified. Additionally, they discussed the key sensors and techniques to access the data that is provided by the sensors. Finally, they discussed the challenges and opportunities in this area.

(Zhu et al., 2018) investigates big data in Intelligent transport systems. The author's research focuses on the history and characteristics of big data ITS. Then, it is review a framework for big data analysis in ITS, and the types of big data analytics applications, data sources, and collection techniques. Moreover, numerous case studies of big data analytics applications in intelligent transportation systems are presented, including analyses of traffic accidents, forecasts of traffic flow, plans for personal travel and public transit, administration and control of rail transportation, and asset maintenance. Finally, this study examines several unresolved issues with big data analytics in ITS.

(Menouar et al., 2017) describes the possibility of using UAVs as part of an Intelligent Transport System. The authors explore the idea that due to UAVs' mobility, autonomy, and communication/processing capacities; UAVs are envisioned in several ITS application domains. Moreover, This article discusses the potential ITS uses for UAVs and underlines the benefits and drawbacks of UAV-enabled ITS for the next generation of smart cities. Finally, they discussed the Deployment Issues and Challenges.

(Li et al., 2020) present a method for data collection using UAV to support the tasks from ITS. The author provided a fair data collection method based on UAV speed control that considers network and energy consumption models. In addition, they demonstrate the problems of data collection which include two factors, one multi-hop transmission and the size of the clusters. Finally, they analysed and compared other schemas with the proposed one concluding that the method can reduce energy consumption and increase fly time and data collection.

(Kanarachos et al., 2018) researched the usage of driver behaviour monitoring using smartphone sensor data, notably as a crucial component of intelligent transportation systems. The author reviewed Aggressiveness Driving as part of DBA tasks in ITS, which is one of the key areas for research and applications in ITS. Moreover, the author indicated that the most used metric techniques for this purpose include acceleration, speed, speed variance, GPS position, map information, gyroscope, and magnetometer. Finally, The author concluded by saying that, while deep learning techniques are more appropriate for this task and machine learning algorithms were employed to uncover knowledge.

(Fan et al., 2021) proposed a mechanism to detect abnormal behaviours in real-time, collecting data from electromyography (EMG) sensors. The author used a wearable EMG sensor that can classify actions such as pulling up, picking up, abruptly turning the wheel, spinning around, and tapping the sunroof. Then, they used a convolutional neural network (CNN), long short-term memory (LSTM), and gated recurrent unit (GRU) to effectively classified the abnormal driving behaviour actions.

(Sun et al., 2021) examines distracted driving detection using a wearable device to read (IMU) to detect common gestures while driving. The authors developed a progressive classification model for gesture recognition that includes a Hidden Markov Model and two significant time-based sequencing components (HMM). The model accuracy for identifying disruptions was 95.52%, according to the results. Moreover, the author demonstrates the classification of different signals and shows the model benefits of using perceptions of motion that effectively resolved the issue of a fall-off in recognition performance caused by excessive disturbances in motion samples.

(Azadani & Boukerche, 2021) examines applications, difficulties, and the field's future directions for DBA approaches, key current and emerging trends, and an analysis of various data sources. The authors' research concentrated on compiling all the approaches for driving behaviour analysis (DBA) that are currently in use and declared that there are no established guidelines for approaching this field correctly. The author specifically characterized each component of DBA, which is further divided into tasks, models, and data sources. They identified the following data sources: CAN-bus, GPS, Smartphone sensors, Lidar and radar, multimedia, and driving simulators. They also identified the tasks that are considered in DBA: driving style detection, driver identification, driver inattention detection, drunk driver detection, and driving events prediction.

(Muthuramalingam et al., 2019) investigates and explains the whole implementation of a typical IoT-ITS system for a scenario including smart cities. The author investigates a few system-related hardware and software components. Then, They emphasised how concepts like multiple regression analysis, multiple discriminant analysis, and logistic regression, as well as conjoint analysis, cluster analysis, and other big data analytics methodologies, can work with IoT and help the development of IoT-ITS. At last, it presents some findings from big data analytics and illustrates how they are used to smart transportation systems.

The next section is dedicated to exploring with more detail the methods found and may encourage future research. The methodologies were compared with specific parameters that can be relevant for research and implementation, Finally, Challenges and limitations were found and they also were discussed in the next section with a suggested solution.

4. Proposed Methodologies

4.1 Methodology 1 – Monitoring using smartphones

The idea to use smartphones to monitor driving behaviour has not been more than 10 years, around 2014 the operating systems started to evolve quickly and improve significantly energy efficiency, connectivity, and increased sensors and quality as shown (Kanarachos et al., 2018). Nowadays, open the possibility of many applications in several areas including Transportation systems. (Kanarachos et al., 2018) show the evolution of sensors to the most recent ones in terms of sensors see Table 1. the author reviewed the capacity that the smartphones have to determine driving behaviour styles using the most common in-build sensors for this task such as accelerometer, magnetometer, gyroscope, GPS, camera, and microphone. This is done with different techniques to process the raw data to feed an algorithm or machine learning mechanism or/and deep learning mechanism to determine de driving behaviour that requires to classify.

Embedded sensors in a modern smartphone per Android version. In brackets the release date of the Android platform.

Sensor	Android 1.5 [04/2009]	Android 2.3 [12/2010]	Android 4.0 [10/2011]	Android 4.3 [7/2012]	Android 5.0 [11/2014]	Android 6.0 [10/2015]	Android 7.0 [08/2016]
Temperature	☺	☺	☺	☺	☺	☺	☺
Camera	☺	☺	☺	☺	☺	☺	☺
GPS	☺	☺	☺	☺	☺	☺	☺
Microphone	☺	☺	☺	☺	☺	☺	☺
Accelerometer	☺	☺	☺	☺	☺	☺	☺
Ambient temperature	–	–	☺	☺	☺	☺	☺
Gravity	–	☺	☺	☺	☺	☺	☺
Gyroscope	–	☺	☺	☺	☺	☺	☺
Light	☺	☺	☺	☺	☺	☺	☺
Linear acceleration	–	☺	☺	☺	☺	☺	☺
Orientation	☺	☺	☺	☺	☺	☺	☺
Pressure	–	☺	☺	☺	☺	☺	☺
Proximity	☺	☺	☺	☺	☺	☺	☺
Relative humidity	–	–	☺	☺	☺	☺	☺
Rotation vector	–	☺	☺	☺	☺	☺	☺
Game rotation vector	–	–	–	☺	☺	☺	☺
Tilt detector	–	–	–	–	☺	☺	☺
Gesture sensor	–	–	–	–	☺	☺	☺

Table 1. Evolution of embedded sensors in Android (Kanarachos et al., 2018)

The most common driving behaviour, driver state, and applications that can be detected in real-time monitoring are Transportation mode classification, Aggressive driving, eco-friendliness Driving, driving Style Detection, Drunk driving behaviour, Driving event detection, Drowsiness detection, and Distracted Detection. (Kanarachos et al., 2018), (Chan et al., 2019), (Azadani & Boukerche, 2021), most of these applications use motion sensors and location sensors such as accelerometers, magnetometers, gyroscopes and GPS. The concept behind is to determine the g-force changes and location changes, this can indicate actions like harsh acceleration, harsh deacceleration, change lane, cornering and speed. this is used for abnormal driving detection such as aggressive or drunk to simplify. On the other hand, this technique can be combined with another sensor like a microphone to define if the driver is using the indicator to change the lane or turn on a corner. Drowsiness and distracted behaviour can be supported by using the front camera to a pointing the driver's face monitoring their eyes using a method called PERCLOS to detect drowsiness (Chan et al., 2019), and distracted combine de with different methods using the camera pointing the wheel, microphone to detect environment sounds and classify them, software to determine if the driver is using the smartphone(Chan et al., 2019). Algorithms, Machine learning or deep learning techniques are used here to classify the actions, it can be during the trip or after the trip.

Driving behaviour analysis (DBA) is the process of characterising how people drive to achieve a particular goal. Due to its potential for use in cutting-edge automated driving innovations, intelligent transportation systems, and advanced driver-assistance systems, DBA has recently drawn a lot of interest from academia(Azadani & Boukerche, 2021), the detection of such events opens the possibility to prevent and predict accidents base in behaviour, reduce traffic congestion, and reduce pollution, It has been found that human factors are the primary cause of traffic accidents.

4.2 Methodology 2 - Monitoring using In-build vehicle sensors

Sensor Technology in cars has been increasing in recent years, making more and more sensors mandatory to install in cars such as sensors and actuators, Rear-view sight systems and tyre pressure monitors. Vehicle manufacture and the adoption of intelligent transportation systems are geared towards offering services that will enhance passenger and driver satisfaction, enhance road safety, and lessen traffic congestion, Moreover, Manufacturers offer the option of installing additional sensors to track the functionality and status of the car, increase efficiency, and help drivers. (Guerrero-Ibáñez et al., 2018) mentioned that the number of vehicle sensors probably reach 200 sensors.

(Guerrero-Ibáñez et al., 2018) research classifies the in-built vehicle sensors by purpose into 6 categories as Safety, diagnostic, traffic, assistance, environment, and user showed in Table 2. According to the author, it is essential to identify the kinds of sensors that can be used to develop applications that help address problems like traffic congestion and parking difficulties, longer commute times, higher levels of CO2 emissions, and an increase in the number of traffic accidents, among other things, in order to improve a vehicle's performance and the driving experience.

Category of Sensors	Description	Example
Safety	Form the basis of safety systems and focus on recognizing accident hazards and events almost in real-time.	Micro-mechanical oscillators, speed sensors, cameras, radars and laser beams, inertial sensors, ultrasonic sensors, proximity sensors, night vision sensors, haptic.
Diagnostic	Focus on gathering data for providing real-time information about status and performance of the vehicle for detecting any malfunction of the vehicle.	Position sensor, chemical sensors, temperature sensors, gas composition sensors, pressure sensor, airbag sensor.
Traffic	Monitor the traffic conditions in specific zones, gathering data that improves the traffic management.	Cameras, radars, ultrasonic, proximity.
Assistance	Responsible for gathering data that provide support for comfort and convenience applications.	Gas composition sensor, humidity sensors, temperature sensors, position sensors, torque sensors, image sensors, rain sensors, fogging prevention sensors, distance sensors.
Environment	Monitor the environment conditions, offering drivers and passengers alert and warning services that are used to enhance their trips.	Pressure sensors, temperature sensors, distance sensors, cameras, weather conditions.
User	Focus on gathering data that support the detection of abnormal health conditions and behavior of the driver that can deteriorate the driver's performance.	Cameras, thermistors, Electrocardiogram (ECG) sensors, Electroencephalogram (EEG). sensors, heart rate sensor.

Table 2. Classification of a vehicle's sensors (Guerrero-Ibáñez et al., 2018)

(Guerrero-Ibáñez et al., 2018) concluded that implementing assistance systems in automobiles doesn't have a special solution. The integration of multiple sensor systems is the key to the new generation of vehicles. Radar systems (placed in the front and back of the car to monitor traffic) are integrating camera systems to increase the accuracy of measuring speed and distance as well as the detection of the shapes of barriers and moving objects. Although Radar and LIDAR are both promising technologies that work well together, Radar does not always deliver the level of granularity that LIDAR does, V2I communications are used to exchange data with the traffic management system.

4.3 Methodology 3 – Monitoring with External devices

Nowadays hundreds of devices are developed with several sensors including smartwatches or fitness bands, it is possible to find around 16 sensors, able to sense the environment, obtain the location, monitor the user state and more, and they continue evolving to bring more services, (Sun et al., 2021) propose a technique to capture data for driver Distraction and abnormal classification, the author refers to wearable sensors as devices that can collect information such as electrodermal activity, skin temperature, and heart rate (HR). The potential for integrating different driving states is then open for evaluation and development in this area. For instance, it mentions driver motions inside the automobile, hand locations, and safety belt use is studied and detected by the technique.

On the other hand (Halin et al., 2021) proposes a methodology to detect Driver states such as drunk. Pupil size, breathing rate, body temperature, and several physiological indicators, such as heart rate, are used to monitor those. Alcohol is known to speed up respiration and heart rate. It is well known that cannabis makes breathing more challenging and speeds up pulse rate. Alcohol makes arteries and other blood vessels more active, which boosts how warm a drunk person's face feels. Wearable EMG sensors have been created and proposed by (Fan et al., 2021) as a way to detect abnormal driving behaviour. EMG signals record the distinctive patterns of the five typical deviant driving behaviours depicted in the image. The effective detection of driver activities included turning the wheel smoothly and slowly TSW, moving to the front FF, picking up objects from the floor PU, opening the sunroof TS, and turning back to get objects TB.

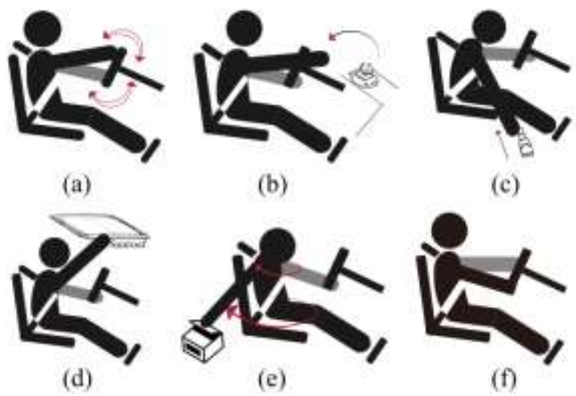

Figure 1. Driving behaviours that are Normal and abnormal. (a)TSW. (b)FF. (c) PU. (d) TS. (e)TB. (f) Normal Driving(Fan et al., 2021)

Alternatively, (Rahim et al., 2021) found that exists another option that can be incorporated into a vehicle is called IoT-enabled black box. Recorder of event data Black Box is set up as an electronic footage gathering tool to capture various data while in an operation mode for future research. IoT-enabled black box installed in the automobile for in-depth investigation in the future. The system can take pictures, record videos, gather coordinates, and process data using analysis tools with the use of IoT technology. The necessary data is subsequently sent to the cloud server and shared via clever transmission systems. Additionally, an event data recorder is a cutting-edge device with exceptional characteristics designed for data storage and transmission through IoT technology during the accident, which aids in uncovering the truth about unexpected accidents (EDR). EDR installation within the car has become required in recent years to record incidental information for post-accident forensic reports due to its obvious benefits.

4.4 Methodology 4 – Monitoring In road sensors

Nowadays, Roads already count on a variety of sensors and actuators to monitor and control traffic. Vehicles can benefit from new services like smart parking, which matches drivers with available parking spaces. To strengthen and increase the resilience of transportation networks, sensors continuously collect environmental data which is helpful to support the driver. (Guerrero-Ibáñez et al., 2018) divided transportation networks into two categories: intrusive and non-intrusive. Pavement surfaces are equipped with intrusive sensors. Despite their excellent precision, they are expensive to instal and maintain. Generally, there are three categories into which intrusive sensors can be placed: Magnetic passive sensors, Pneumatic tube sensors, and inductive loops. Most sensors in traffic control systems belong to this group.

On the other hand, The transit of a vehicle as well as other elements like vehicle speed and lane coverage are detected by non-intrusive sensors that are placed at various points along the routes. They may be impacted by environmental factors and are costly. Typically, non-intrusive sensors are used in the development of applications that provide information on a particular region, such as the detection of a line at a stoplight, the flow of traffic, and the state of the pavement and the weather. Some sensors are mounted on a tower and are used to monitor a certain coverage area.

Category	Sensor Type	Application and Use
Intrusive	Pneumatic road tube.	Used for keeping track of the number of vehicles, vehicle classification and vehicle count.
	Inductive Loop Detector (ILD).	Used for detection vehicle's movement, presence, count and occupancy. The signals generated are recorded in a device at the roadside.
	Magnetic sensors.	Used for detection of presence of vehicle, identifying stopped and moving vehicles.
	Piezoelectric.	Classification of vehicles, count vehicles and measuring vehicle's weight and speed.
Non-intrusive	Video cameras.	Detection of vehicles across several lanes and can classify vehicles by their length and report vehicle presence, flow rate, occupancy, and speed for each class.
	Radar sensors.	Vehicular volume and speed measurement, detection of direction of motion of vehicle and used by applications for managing traffic lights.
	Infrared.	Application for speed measurement, vehicle length, volume, and lane occupancy.
	Ultrasonic.	Tracking the number of vehicles, vehicle's presence, and occupancy.

Table 3. Categories of sensors currently used for traffic control (Guerrero-Ibáñez et al., 2018).

4.5 Methodology 5 – Monitoring with UAV

UAV applications in smart cities have a strong potential to support many autonomous tasks. Automated UAVs might enable a variety of ITS applications to support improved traffic, improved safety and security, or increased driver comfort. (Menouar et al., 2017) suggested some applications that support some of the tasks given on roads today. The author proposes Flying Accident Report Agent as an additional strategy to aid the rescue squad in getting to the accident location as quickly as possible. The rescue team also can obtain real-time information such as their profiles, which can be supported by photos and videos, this prepares the team before arriving at the accident scene. In addition, it may be utilised to deliver a first aid package to the accident scene while the rescue crew arrive.

(Menouar et al., 2017) also proposed Flying Roadside Unit and indicates that the cars will be integrated with DSRC technology to enable communication between the cars and nearby road infrastructure through a DSRC channel (similar to WiFi). The author indicates that the road will be equipped with physical Roadside Units for communication between vehicles and ITS if required, Flying Roadside units are meant to fill the areas where there are no RSUs available to enable communications and warning other drivers is necessary. Finally, the author mentioned another application called flying Police Eye enables the police the option to monitor roads with a drone. These applications support the idea to enforce traffic rules such as speed limits with this technology.

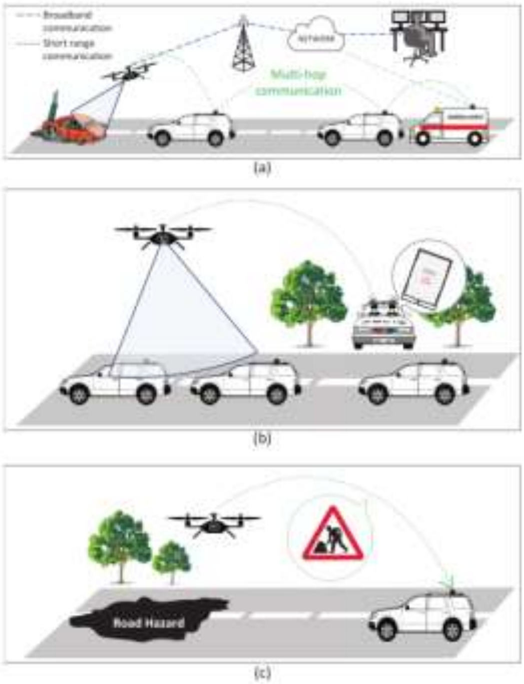

Figure 2. Examples of UAV applications in ITS (Menouar et al., 2017).

This application is proposed to require deployment, data traffic control and face security and privacy issues. In addition, the UAV itself sum issues such as limited energy, processing capabilities, and signal transmission range. However, (Li et al., 2020) proposed some solutions to some of these issues. The author offered a method for gathering fairness data that accounts for network and energy consumption models and is based on UAV speed control.

5. Comparison of Methodologies

	Parameter 1 – Sensors	Parameter 2 - Communication	Parameter 3- Implementation Complexity	Parameter 4 - Usage	Parameter 5 - Purpose
Methodology 1 - Smartphone	Accelerometer, magnetometer, gyroscope, camera, and microphone are the most used sensors	The smartphones already can connect through the internet or V2I communications	Extract data, calibrate, and process before classifying using machine learning, and deep learning, for implementation requires government policies and standard records	Driving detection styles, driver states such a drowsy, fuel consuming	Road safety, accident detection, accident prevention and prediction, road notification, traffic control
Methodology 2 – In-build vehicle sensors	Proximity, ultrasonic, and electromagnetic, RADAR, gyroscope and accelerometer, GPS, camera, and LIDAR	V2I communications	Implementation is complex because today's cars are not standardized with a methodology	Driver prevention and support while driving	traffic congestion, parking challenges, Pollution, and reduced accidents
Methodology 3 – External Devices	Optical heart rate, SpO2 monitor, Bioimpedance Sensor, compass, ECG, GPS, Gyroscope, EMG	V2I communications, internet access with smartphone	The challenge for implementation requires the user to compromise	electrodermal activity, skin temperature, and heart rate (HR). determine distraction and abnormal behaviour	Monitoring Drivers and their state to determine actions such as prevention or prediction of an event
Methodology 4 – In-Road Sensors	Pneumatic Road tube, Inductive loop detector, magnetic Sensors, Piezoelectric, Video Cameras, Radar Sensors, Infrared, Ultrasonic.	Physical cable or wireless	It is a mature system that is already implemented that now is looking to improve installation and maintenance costs	to monitor and control traffic. smart parking	Traffic control, driver support, Monitoring
Methodology 5 - UAV Monitoring	Camera, Speed Sensor, obstacle avoidance sensor	Roadside Unit, Wireless, DSRC technology, RSU	It is still in its start and needs to tackle many issues to become a reliable application.	Supporting accident activities, Support police monitoring activities, and support communication along the road	Reduce and increase the effectiveness of rescue services during an accident, enforce traffic laws, and keep continuing communication to support drivers along the road

Table 4. Comparison of Methodologies

6. Challenges, Limitations and Solution

Challenges and limitations for each methodology are met to suggest solutions and future work. Some of them are mature methods and others are early research.

Driving behaviour analysis using smartphones seen at the start of this study is still a trend. Challenges are still open, and they are related to acceptance and encouragement from the government of its use, Statista estimates that there are presently 6.648 billion smartphone users globally or 83.37% of the world's population, and that number is expected to rise in the future (O'Dea, 2022). Therefore, this opens the possibility of implementation. Limitations found are associated with the policies on data manipulation, privacy, and security scales such as systems and users. Challenges for data collection and data storage are still open until standards and protocols are promoted. Finally, It is found that the use of a framework is not yet established for DBA tasks, then, makes it difficult for wide implementation. However, is a viable methodology.

On the other hand, the implementations using In-build sensors can be integrated into ITS to increase the road services in relation directly to the drivers. However, it is not possible to be implemented in relation to ITS in the short term. The rate at which a vehicle is changed is very low, and the vehicle growth rate is faster than the time it takes to change from one generation to another, approximately the depreciation of a vehicle increases faster after 8 years of use, and today we still see vehicles on the road with more than 20 years of being manufactured. The global economy is not moving faster as the population has grown and other industries require more attention.

The challenges and limitations found by external devices used to support to detect Driver states required two important aspects to be integrated into ITSs, Connectivity and data storage, V2I communication supports the majority of IoT devices to connect to the internet, the use of these devices can be integrated into a system where the smartphone works as a host for application, storage and connectivity and create a sensor environment to feed the DBA tasks on ITS or serve basic application such EDR to track accident records. A limitation found is there is no established framework for these activities or even to develop an application.

In-road sensors' cutting-edge technological status is their main advantage. They have a wide range of applications and are very effective at identifying cars. The biggest drawbacks of road sensors are high installation and maintenance costs and the necessity to interrupt traffic while they are being installed, maintained, or repaired. The use of wireless battery-powered sensor nodes that are installed over the pavement in place of the intrusive sensors is one option that has been used to alleviate the installation and maintenance costs. With less expensive than existing options, this technology is intended to increase the quality, quantity, accuracy, and dependability of the data gathered from highways and avenues (Guerrero-Ibáñez et al., 2018).

UAV solution presents difficulties associated with data collecting which are caused by two variables: one multi-hop transmission and cluster size. Another challenge found is the fly time, which is directly proportional to energy consumption. Therefore, (Li et al., 2020) examined the possibility to improve its functionality, the author compare current schemas with theirs and found a strategy that might save energy consumption and increase fly time and data collection.

It presented challenges and limitations to the methodologies proposed, current and exploring methodologies are independent of each other but have some similarities that can apport to each other in terms of data collection, data storage, quality and connectivity. They provide different ways to contribute to mobility problems, road safety and the pollution produced by cars. However, the adoptions of those technologies require societal development and several changes that how we see transportation today. Society needs to understand the benefits of sharing the data collected for these methodologies with ITS to see real changes in transportation.

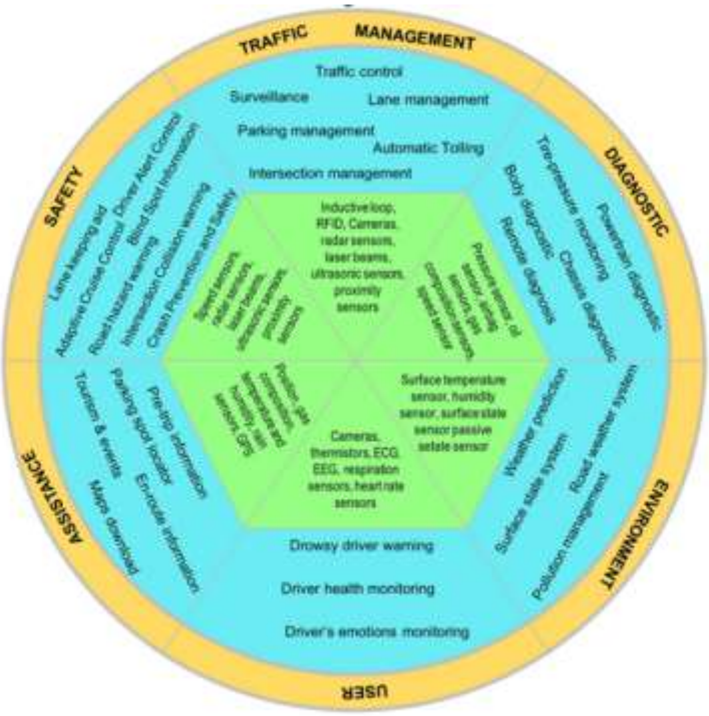

Figure 3. Taxonomy for ITS applications (Guerrero-Ibáñez et al., 2018)

7. Conclusion

In the future, sensors will be key to ITS. Their use enables the creation of several applications for driver assistance, traffic control entertainment, and traffic safety. Sensors provide a method for gathering information about the vehicular context, which can be used to address some of the problems that both previous and current transportation systems have encountered such as road conditions, traffic conditions, and vehicle conditions. (Guerrero-Ibáñez et al., 2018) indicates that the potential of integrating sensors with ITS is clearly shown by the application of analytical and statistical approaches. The development of numerous cutting-edge smart applications aimed at improving the traffic management and safety of present and future transportation systems will be made possible by this integration, which is a potential research topic.

An important advantage is found that new technologies such as smartphones, wearable devices, new vehicles and UAVs, and new sensor generation, improve with every release, improve in terms of quantity and quality, this enables new possibilities to obtain the data required, and quality of the data extracted to enhance manipulation and processing. However, the disadvantages are their intrusive methods to access the data, this requires a lot of work in policies, security and data privacy. This study was focused on bringing methodologies to face the traffic and road safety issues, future research should focus to tackle the challenges and limitations found, and how to integrate those methodologies into ITS. Therefore, one option is using DSRC and RSU technology this can boost the transformation of transportation in the future.

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