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Real-Time Performance Analysis of Multiple Parameters of Automotive Sensor's CAN Data to Predict Vehicle Driving Efficiency

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Abstract: Car crashes typically lead to extreme human setbacks and enormous monetary misfortunes in genuine world situations. A convenient exact forecast of car crashes can possibly secure public wellbeing and lessen monetary misfortunes. Driving is a complicated movement whose wellbeing is impacted by a wide scope of variables like driver conduct, vehicle plan and the street climate. Albeit many empowering accomplishments have been made to further develop street wellbeing, yearly 1.35 million individuals bite the dust and upwards of 50 million are harmed and experience long haul inability from street car accidents ("World Health Organization report, 2018,"). The following outskirts of crash anticipation is in the innovation space with an expanding presence of dynamic wellbeing advances like Advanced Driver Assistance Systems (ADAS). A reasonable comprehension of various boundaries affecting driver association with street climate to settle on choices to control their vehicle can give another plan way to deal with a more powerful driver help framework. To investigate the most powerful contributing variables, the proposed work driving style can be analyzed with some safety features and driver-assist features to include, Antilock Braking System (ABS), Traction Control System (TCS), Electronic Stability Control (ESC), Hill Start Assist (HSA) and clutch actuation technique. In the present work, experimental analysis is conducted to evaluate the driver efficiency by using multiple vehicle safety features by acquiring corresponding multiple CAN data wirelessly using Raspberry pi with the ThingSpeak platform. The developed Wireless HMI interface will report vehicle driving patterns and fuel efficiency by giving warning notifications with safety standards to improve the driver's driving style following the road environment.

Keywords: Real-time CAN data, Safety assistance, Prediction, Driving Efficiency

1. Introduction

Notwithstanding huge upgrades, in-vehicle innovation and street design throughout the most recent 40 years, on overall scale street mishaps are as yet one of the principal unintentional reasons for death and injury (WHO, 2004). The appraisal of the event of street mishaps and the administration of a foundation to manage this danger is along these lines of research spaces of significant interest. Various examinations have been performed to recognize the main danger showing factors that add to the event of street mishaps. The most widely recognized methodology applied in early works is to display the communication between street calculation, traffic qualities and mishap frequencies utilizing traditional (various) straight relapse models. In such investigations, univariate counting models for just one single model reaction variable are utilized, inferring, for instance, that the quantity of mishaps relating to various levels of injury seriousness is displayed independently without considering the conditions that exist between them. Such conditions are considered in later investigations where the diverse reaction factors are displayed mutually utilizing multivariate demonstrating procedures. Multivariate information investigation dependent on multivariate ordinary disseminations has regularly been utilized to examine consistent information.

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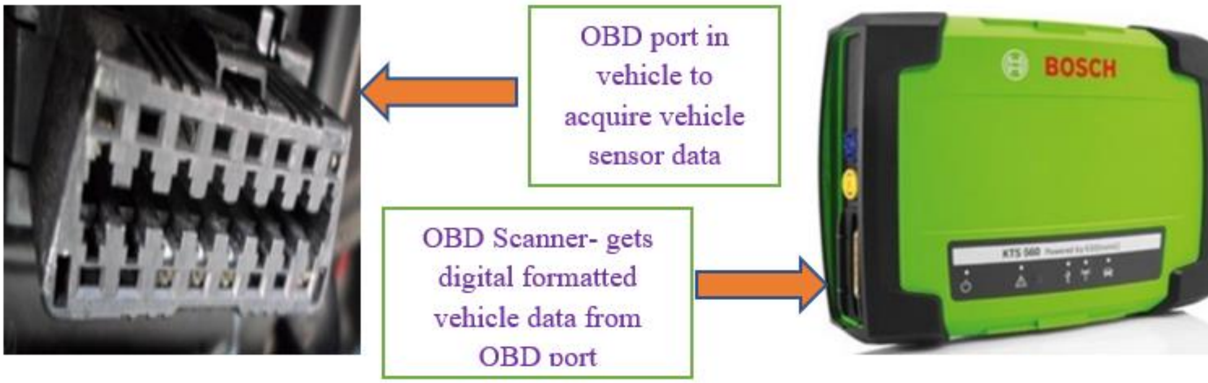

Figure 1. OBD Port with scanner for CAN data processing

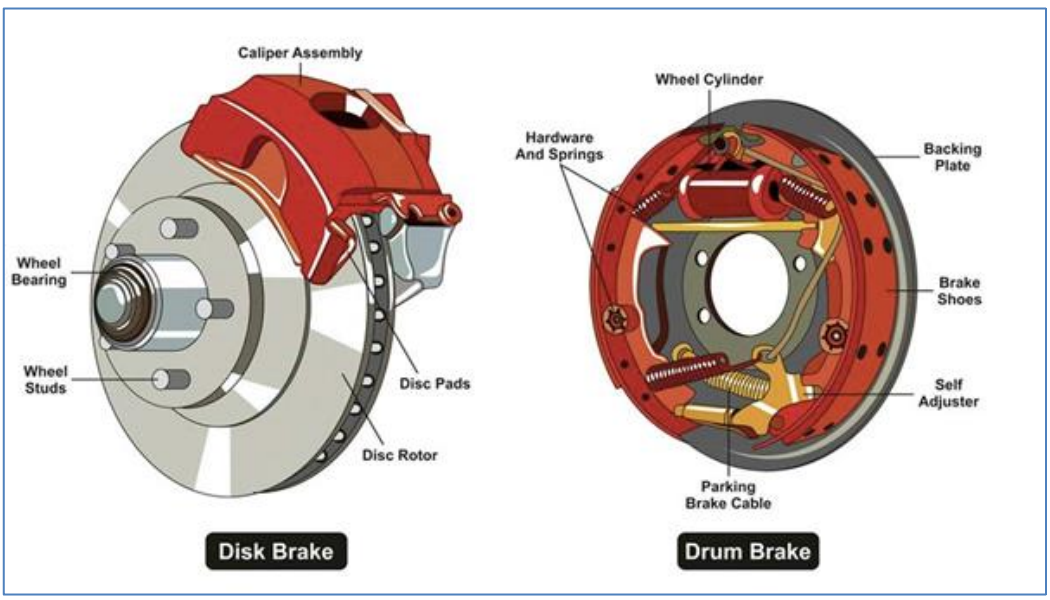

Figure 2. Disc and Drum Brakes

Nonetheless, when just discrete multivariate information on mishap numbers is accessible, the presumption of multivariate ordinary disseminations might be misdirected since mishap information is regularly described by little-noticed mean qualities and an enormous number of zero counts prompting the expectation of the normal number of reactions variable occasions, for example, the normal number of injury mishaps. Despite huge advancements in technology, drivers are still struggling to drive their vehicles efficiently. Global Positioning Systems (GPS) are playing a major role these days for travelers. 360-degree sensors around the blind spots of the car have led to the invention of self-driving cars to provide maximum comfort to the driver. Even though drivers are unable to understand their mistakes while driving, this system has been developed to provide feedback for the driver to improve their driving. The technology will be used in the cars of the future.

Controller Area Network (CAN) is a serial communication bus designed for robust and flexible performance in harsh environments. Bosch company came up with the CAN protocol and Intel developed the first CAN controller. The CAN communication can send data at a rate of 1 Mbps when the cable length is about 40 meters. CAN communication is well known for High speed, noise immunity, and offers more reliability in a noise critical environment. The can bus cannot be used to send large blocks of data like USB, it is meant to send small data with a size around 8-bytes containing information like temperature, rpm, etc. Through OBD automotive electronic system that provides information on the vehicle in case of any repairs. The service technicians can access all the ECU (Electronic control unit) through OBD. The major revolution in onboard diagnostics takes place from the 1970s to the 1990s. After the introduction of OBD II, it has become mandatory for all the vehicles manufactured in The United States. The EOBD was mandated for all gasoline vehicles since 2001 and all diesel vehicles in 2003 within the European Union (EU) Starting from 2008, all vehicles in the United States were required to implement OBDII through a CAN as specified by ISO 15765-4. OBD is internally connected to the communication interface of the vehicle such as CAN, Flex Ray, LIN bus. The OBD interface is usually located somewhere on the dashboard of the car shown in Figure 1.

Auto collisions lead to fatalities, wounds, and other roundabout effects on the people in question, for example post-mishap injuries, property harm, and wastage of assets. Past investigates uncover that passings in car crashes are second most noteworthy after cardiovascular infections. Mishaps happen by vehicle(s) slamming on a street client or vehicle(s) or a static apparatus like a post or tree or street divider. Vehicles in a street mishap are classified as the affected vehicle or casualty vehicle and affecting vehicle or blamed vehicle. By and large, subtleties of the vehicle(s) associated with mishaps are accessible. In any case, there are situations where one doesn't have the foggiest idea about the affecting vehicle as the driver runs away from the mishap area. These sorts of mishaps are quick in and out mishaps. Quick in and out mishap types, where affecting vehicles are not known, become a more concerning issue to address. Absence of data in a mishap is a test as this missing data has a huge effect. A braking system should be perfect enough to stop the car at the shortest distance safely while maintaining the passenger's ease. Mechanical brakes are used in Hand brakes. Mechanical braking is connected to brakes at the rear of the vehicle by steel wire connections. Air or pneumatic braking is used in Air brakes. A brake that is too strong will expose us to the dangers of a sudden brake operation in a bus or vehicle. Brakes are one of the most important components of any car, without which it is almost impossible to travel. A disc brake system is made up of a rotor or piston mounted on the wheel and a caliper with pads on both sides as given in Figure 2. The size of the pads or the area of contact of the pads with the disc determines the bite of the calipers on the disc.

The prime aim of this research work is to analyze the performance of the driver to provide maximum comfort of the vehicle by enhancing safety and warning notification to the passengers. To analyze vehicle performance especially in running mode, it is planned to consider the Clutch usage ass fuel economy metrics, some driver assistant and safety features include ABS, TCS, DTC, HSA. After proper data acquisition from multiple sensors CAN data through OBD kit, every data will be encrypted and compared with safety standard value predefined by the manufacturer to define the characteristics of the driving style in report format through high-level engineering Front end interface in online mode using Raspberry Pi by incorporating with ThingSpeak Platform for analyzing the data.

2. LITERATURE ANALYSIS

With an enormous number of street transportation clients, wellbeing stays an indispensable worry as street mishaps are a main source of fatalities and wounds. According to the Global Burden of Diseases (2020), street mishaps fatalities are the twelfth driving reason for death in the USA, India, Germany and numerous different nations despite the fact that numerous mishaps go unreported. An unpredictable driving style mishap involves worldwide worry for the wellbeing of street clients. According to the National Highway Traffic Safety Administration, India (NHTSA, 2020), fatalities brought about by quick in and out crashes expanded by 14.32 %, from 2547 out of 2017 to 3857 out of 2020. In India, 57089 sporadic driving examples with high velocity street mishaps were accounted for in 2019 and the figure rose to 72000 out of 2018 with a 32 % expansion in fatalities from 31452 to 35972 out of 2019 and 2020 individually (MoRTH Accident Trends, 2020). The increase shows the vulnerability of road accidents confirms the violating of traffic rules, improper clutch usage with high speed by not considering the road environment. A detailed road accident contributing factors in India reported by the highway authority service is shown in Figure 3.

To analysis, the analysis of road accident monitoring and control techniques, numerous researchers conducted experiments using both wired and wireless methodology to make smart and safety warning systems in the automotive field. Table 1 enumerates the clear schematic view of both wired and wireless methodology with the vehicle parameters undertaken to predict the road accident in the proper zone is survey properly to take the merits and demerits of the experimentation. A Fugiglando et al., (2017) explains that CAN will collect several hundred data and a new real time analysis of driving behavior can be found by using a selected subset of CAN bus signals like specifically velocity, brake pad pressure, RPM, longitudinal and lateral accelerations.

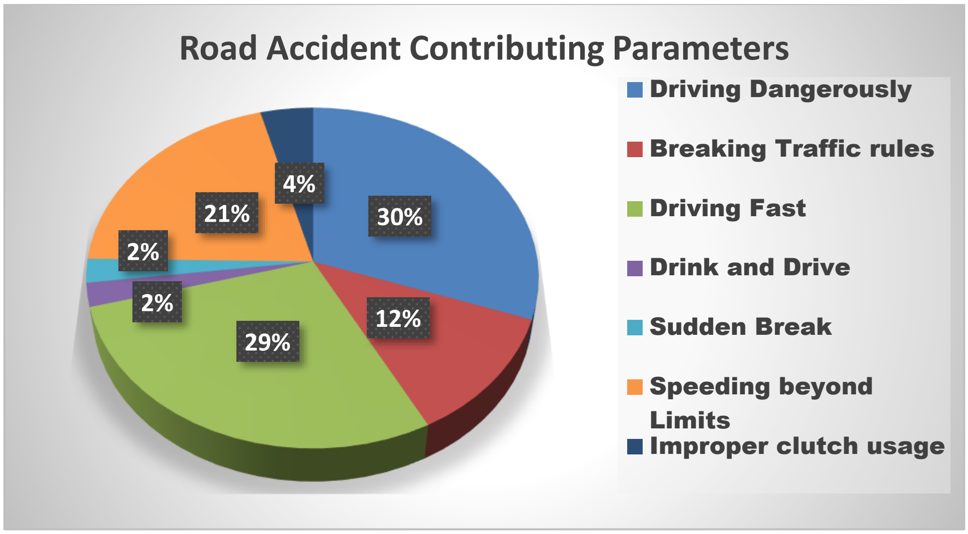

Figure 3. Factors contributing to road accidents in India

TABLE 1. LITERATURE SURVEY OF VEHICLE PERFORMANCE ANALYSIS THROUGH DATA ACQUISITION

Sl. No.	Title	Authors	Method of Analysis	Data monitored	Method of Data Collection
1	Driving Behaviour Analysis through CAN Bus Data in an Uncontrolled Environment	Fugiglando, Umberto et al.	Unsupervised learning technique	Brake Pedal Pressure, Gas pedal Position, RPM, Speed, Steering Wheel angle, Steering Wheel momentum, Frontal Acceleration, Lateral acceleration	Vehicle Data Logger available in Market
2	Analysis and Classification of Driver Behavior using In-Vehicle CAN-Bus Information	Choi, SangJo, et al	Hidden Markov Model, Gaussian Mixture Model	Steering wheel angle, Brake status, Acceleration status, Vehicle speed	UT Drive Corpus
3	A Deep Learning Framework for Driving Behavior Identification on In-Vehicle CAN-BUS Sensor Data	Zhang, Jun, et al.	Deep Learning Method	Intake air pressure, Accelerator Position, Fuel consumption, Friction torque, Engine torque, load value, Coolant temperature, Transmission oil temperature, Wheel speed, Torque converter speed	OBD-II scanner (Ocslab driving dataset)
4	Vehicle data recording method for vehicle service	Radhakrishnan et al.,		Engine Sensors like (temperature, timing, oxygen, Manifold sensors), Transmission Sensors, Final Drive sensors, Exhaust Sensors (oxygen, Nox)	Diagnostics data acquired from obd port through the mini computer
5	Mathematical Modelling & Analysis of Brake Pad for Wear Characteristics	Kakad & Kamble	Developed mathematical equation method	Brake power, Linear sliding wear (uniform Wear condition & uniform pressure condition), Force system for car model, Braking distance, Thermal modal,	

				Ansys software	
6	Accident prevention and prescription by analysis of vehicle and driver behavior	Peter. M and Vasudevan S. K		Deceleration value, Latitude, Longitude	External Sensors
7	Aggressive driver monitoring and reporting system	John & Donna		Vehicle speed data, Rear vehicle Images, Range	Camera
8	Vehicle performance detection and recording apparatus	Ronald & William		Speed, Acceleration or deceleration, Braking, Steering, Turn signals and lighting	Using External transducers individually
9	Experimental Investigation of the Influence of Tire Design Parameters on Anti-Lock Braking System (ABS) Performance	Srikanth Sivaramakrishnan.	Mathematical model	Tire data - Braking skid trailer, Vehicle ABS braking data, Instrumented high-performance vehicle, Instrumented mid-tier passenger sedan	IMC data logger
10	Improving the braking performance of a vehicle with (ABS) and a semi-active suspension system on rough roads	Herman Hamersma, Schalk Els Kanwar & Bharat Singh	Experimentally validated full vehicle model, co-simulation with MATLAB and Simulink	Anti-lock braking systems (ABS), Stopping distance, Spring and damper characteristics	Matlab and Simulink
11	A Control System for Hill Start Assistance for Commercial Vehicles	Diego Delvecchio , Sergio M. Savaresi, et al		Hill Start Assist, Anti-Lock Braking System, Electronic Parking Brake system, Pressure sensor	CAN bus module
12	Performance evaluation of traction control systems (TCS) using a vehicle dynamic model	Jeonghoon Song & Kwangsuck Boo		TCS (traction control system), Steering system yaw rate, Split m road, Oversteer, Understeer	data acquired from OBD II port
13	Performance analysis of the vehicle electronic stability control (ESC) in emergency maneuvers at low-adhesion surfaces	Kulikov & Bickel	Mathematical model	Simulating the actual road test in associate with ESC and without ESC	Yaw stability controller
14	Research on the Hill Start Assist of Commercial Vehicles Based on Electronic Parking Brake System	Xianhui Wang; Weihua Wang	A logic threshold control method	Hill Start Assist, Anti-Lock Braking System, Electronic Parking Brake system, Pressure sensor	CAN Bus Module
15	Fuel Economy and Performance Potential of a Five-Speed 4T60-E Starting Clutch Automatic Transmission Vehicle	Chi-Kuan Kao & Anthony L. Smith		Starting clutch, Two-speed simple planetary gearset, Torque converter	
16	Onboard vehicle data mining, social networking, advertisement	Hillol Kargupta	Onboard and remote data stream mining method	Determining the health condition of the vehicle, Computing fuel economy, Monitoring emissions and Driver behavior	OBD-II/CAN, J1708/J1939,
17	Smart Traction Control Systems (TCS) for Electric Vehicles Using Acoustic Road	Daghan Dogan & Pinar Boyraz.		Camera, Optical Sensor/Laser, Pressure sensor, Accelerometer, Infrared, Temperature sensor.	ARTE unit (ACOUSTIC ROAD TYPE ESTIMATION)
18	Improved hill start aid system for commercial vehicles equipped with automated transmission	Carlos Abílio, Luis Fernando, et al		Hill Start Assist, Anti-Lock Braking System, Electronic Parking Brake system, Brake pressure	Data from OBD II scanner

19	Mathematical modeling and performance prediction of a clutch actuator for heavy-duty automatic transmission vehicles	Tiancheng Ouyang et al.	Mathematical model, CFD simulation of the clutch actuator	Pressure reducing valve, Clutch actuator, Bode plots.	
20	Two-layer mass-adaptive hill start assist control method for commercial vehicles	Pai Peng & Hongliang Wang	A logic threshold control method	Anti-Lock Braking System, Pressure sensor & Hill Start Assist.	CAN Bus Module
21	Influence of Clutch Output Shaft Inertia and Stiffness on the Performance of the Wet Clutch	Nowshir Fatima & Par Marklund	Topographical analysis	Frictional induced vibration, Torsional stiffness, Inertia	A wet clutch test rig
22	Vehicle gear shifting strategy optimization for performance and fuel consumption	Fernanda, Fabio Mazzariol, et al	A genetic algorithm technique	Vehicle gear shifting, Acceleration performance and Fuel consumption	

The author collects data in a completely uncontrolled experiment including 54 people and around 2000 trips have been recorded without any predetermined arrangements on a wide variety of road scenarios. Among these only a few works have been analyzed the driving performances of more than 50 drivers using CAN bus data. Thus, the author proposed an unsupervised learning technique that predicts driving performance in an uncontrolled environment.[1] Choi et al., (2007) analyzed and classified the driving performance using in-vehicle CAN bus information and employed data obtained from UT drive corpus to develop a driving model and to detect distraction in CAN bus information, he develops three distinct distraction classifications action classification, distraction detection and driver identification.[2] Zhang et al., (2019) proposed a deep learning framework for driving performance identification on in-vehicle CAN bus sensor data. The data from the vehicle's sensors were collected using the OBD II scanners available in the market. The data monitored includes Long term fuel trim bank, Intake air pressure, Accelerator pedal value, Fuel consumption, Friction torque, Maximum indicated engine torque, Engine torque, etc.[3]

Radhakrishnan et al., (2010) developed an onboard computer module to record the vehicle data. The data of multiple sensors were recorded to diagnose more than one problem in the vehicle. The data were stored in a portable memory stick as well as in the cloud storage through wireless communication.[4] Peter and Vasudevan (2017) studied accident prevention and prescription by analysis of vehicles and their driving performance. The author analyses vehicle accelerations against location when there are more sudden accelerations, decelerations and lateral accelerations of vehicle, when analysing, it reveals that the driver performance is rash or not. Set of algorithms are proposed in this paper by identifying acceleration and location data for predicting the accidents.[5, 6] John and Donna (2017) studied on Aggressive driver monitoring and reporting system, and creates an system called "Auto risky condition recorder" which is furnished with car condition sensors coupled to the contribution of a clock outfitted with processor which invigorates in light of a sign level from the sensor demonstrating the presence of a foreordained dangerous working condition. It sends information about the dangerous situation to a storage facility, which stores the information for further inspection. This system also includes a monitor that will notify a driver of a dangerous driving situation and report the incident for further reference if the problem is not resolved in a fair amount of time.[7] Ronald and William (2012) developed a system that can detect and monitor different operating and performance characteristics of automobiles and other equipment. The unit contains a series of transducers that are tightly attached to the vehicle's various mechanical functions in order to sense their physical features in relation to one another. After capturing information over a selected time period, the recording is immediately discarded while new information is sent to the recorder to provide a current timeline over short time periods, such as 30 minutes, which is particularly helpful in accident investigation.[8]

Sivaramakrishnan et al., (2015) conducted an exploratory Investigation of the Influence of Tire Design Parameters on Anti-Lock Braking System (ABS) Performance. They said that consistent state, transient properties of the tire influence the activity of the vehicle's ABS framework, additionally subsequently influences the exhibition proficiency. The significant target of this review is to investigate how tire configuration changes impact the association with the ABS and furthermore impact on halting distance. Finally, he explored in tire ID routine to observe the tire slip point an incentive for ABS regulator to augment the tire slowing down force.[9] Dogan and Boyraz (2019) concentrates on The Smart Traction Control Systems for Ev's on Acoustic Road. He assessed the control framework which requires street tire erosion and slip-proportion esteems and in this manner work on tending to a brilliant TCS plan which incorporated with acoustic street type assessment (ARTE) unit. Here, ARTE unit utilizes AI and planning acoustic component inputs into street type yield. He analyzed TCS for EVs with and without ARTE unit and in this way, results show huge improvement in execution with ARTE, by decreasing slip proportion by 75% and saving energy through diminishing applied force and power of TCS is increased. [10, 11]

Kulikov and Bickel (2019) investigated execution examination of the vehicle electronic security control (ESC) while crisis moves at low-grip surfaces. The creator dissected the fundamental standards of vehicle ESC activity and arrives at a resolution by examining the reproduction results which permitted revealing changes of vehicle guiding execution, just as steadiness misfortune factors. Varieties in regulator's boundaries permits to characterizing conditions in ESC which intercedes to forestall vehicle slipping. [12, 13] Peng et al., (2019) assessed the powerful execution of the slope start aid different slant points. They fostered a model called rationale edge outline work to build the nature of the slope start help with the electronic slowing mechanisms. They developed the pulse width module and the pulse frequency module for the effective activation of the HAS in the slope regions. [14,15] Peng et al., (2020) studied the need of the adaptive control frame work for the improvement of the HSA with the EPS installed in it. Their developed model is effective while changing loads and also, they developed the two-layer system for effective usage. They showed the importance of precise actuation of HSA is the sloped with variable conditions.[16]

Zhang et al., (2016) complex working of the HSA has been discussed in that the actuation of HSA valve has been discussed elaborately that the actuation is happens with the help of two position three-way solenoid valve. The difficulties faced due to the inaccurate actuation of HSA in slopes.[17] Ouyang et al., (2020) developed a mathematical model to combine the wet clutch with the pulse width module to analyze the performance. The fast response and a precise control of a clutch is analyzed in term of performance.[18-21] Fatima et al., (2013) conducted an experiment that shows the performance of a clutch can be influenced with the damping system, springs, masses which are complex to handle are experimentally evaluated. They showed that the variation in the performance when the numerous numbers of clutch engagement and disengagement happens frequently. They also evaluated the overall clutch life and the performance based on the friction in the clutch.[22] Eckert et al., (2016) generated a genetic algorithm technique to increase the performance of a vehicle without any changes in the fuel consumption. They analysed the acceleration performance and the fuel consumption while changing the gears with the using the clutch. They evaluated the fuel efficiency while shifting the gears.[23] From the literature survey, it is clear that for collecting data from CAN both the wired and wireless methods can be utilized but the wired method of data collection is more reliable. Many of the papers proposed to introduce new sensors for performance measurement and wear prediction but introducing sensors enhancement platform increases vehicle cost and complexity. The CAN data from the vehicle's sensors were mostly collected using OBD scanners available in the market. Most of the researchers concentrated on the parameters are Brake pedal pressure, acceleration, speed, steering angle, yaw rate, fuel consumption for evaluating the performance of the driver. But accordance with automotive theory, the other features like ABS, TCS, ESC, HSA also plays a vital role in evaluating the Driver's performance which not only predicts the driving pattern but is also useful to evaluate the fuel consumption and efficiency of the vehicle by properly following the driving standards to save both human life and automotive vehicles. Hence the proposed work concentrates on wireless communication for receiving data from the OBD port through Raspberry Pi enabled with Bluetooth to send data to the cloud server for data analysis for driving patterns and fuel efficiency of the automotive vehicles.

3. PROPOSED METHODOLOGY

The data required for the driver performance analysis is available in CAN bus. To obtain the data from the CAN bus, a module that supports the CAN protocol is needed. Firstly, a physical connection between the CAN bus and the module should be established. OBD II (Onboard diagnostics) port serves as the communication medium between a module and CAN bus. OBD II PORT have 16 pins. These pins are used for various purpose. Separate pins support various protocols. The module used for data collection may consist of a CAN controller and a CAN transceiver. The CAN transceiver converts the raw electrical pulses from the OBD II port and sends the data to the CAN controller. The CAN controller is used to transmit the received the data from transceiver to the main module processor. Usually, the CAN bus module has an input of two lines from the OBD II port (CAN H & CAN L).

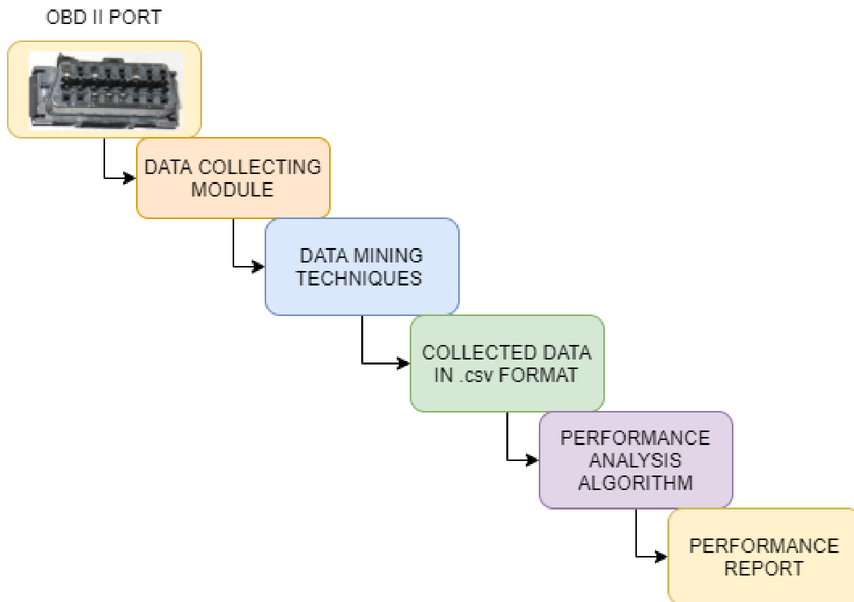

Figure 4. Proposed Flow chart of the step sequence utilized in proposed analysis

These pins produce differential signals so that the signal will be void of noises and data loss will be eliminated. The data obtained at the CAN controller can be transmitted to the main processor module using serial communication. The data from the CAN controller is in the hexadecimal format (E.g.: 0x3c).

Once the Hex data from the CAN bus is gained, the data has to be mined for the required data. The data speed of the CAN bus is about 1500 data lines per second. This results in a huge accumulation of data in the processor memory. This leads to an unnecessary increase in the processing time. To solve this issue, the filtering process is employed to reduce the number of data output. For this filtering process to work, the required CAN id (identifier) can be compared with the CAN id in the data line. The collected data can be converted into meaning full data using certain protocols. These are the protocols defined by the manufacturers to encode the raw data. After decoding the data, it can be stored in .csv format. This type of data storage format is useful in retrieving a large amount of data.

After the storage of data, these data can be processed through an algorithm. This algorithm takes ESC, TCS, ABS, half-clutch duration data into consideration and computes the overall driving performance score as well as the individual percentage of events. This report also indicates the measure to be taken to improve the driving score. As parameters like clutch usage, braking duration are taken into consideration, the performance score can be directly related to the vehicle performance and time for vehicle maintenance can also be estimated using these data. These data can be represented in pdf format so that a common user/driver could easily track their performance. All the data are represented in bar, line and circle charts and plots. This facilitates the user for a better understanding of his/her driving pattern.

4. Events Monitored

A. TCS

When running on slick surfaces, the Traction Control System (TCS) acts in the background to help accelerate and avoid wheel slippage (or "over-spinning"). If the vehicle is equipped with a drive by wire throttle, TCS operation can involve applying braking force to one or more wheels, reducing or suppressing the spark series to one or more cylinders, and reducing the fuel supply to one or more cylinders. When your engine is switched off, you will find that it handles differently than normal when driving on slick surfaces. This is why you can still keep your traction control on. To take advantage of this essential protection option, keep your traction control on at all times. Figure. 5 shows the TCS working block diagram.

When driving in a climate where chains are required and your vehicle's foothold control is meddling with your capacity to drive, or when your vehicle is caught in extremely profound snow, mud, or any state from which it can't get out all alone, you might have to briefly incapacitate foothold control. Winding down foothold control while shaking your vehicle can help you in driving out more rapidly. When people drive with the TCS turned off in their vehicle while driving on normal freeways, they are likely to experience skidding while there might be needs suddenly. Hence, unless the car is driven on irregular terrains, it is strictly advised to have the TCS on at all times for the safety of both the passengers and the vehicle.

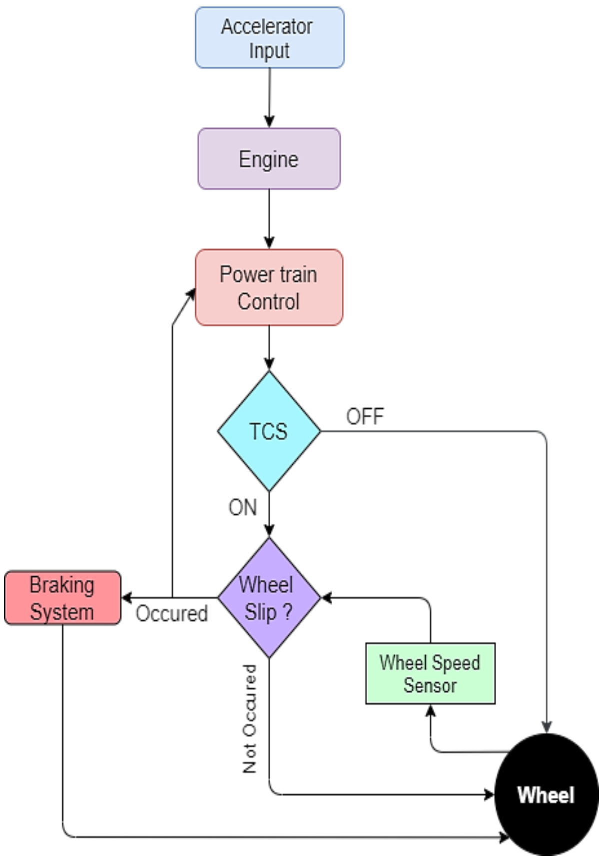

Figure. 5. Traction Control System (TCS)

During heavy acceleration from a standstill or when merging with traffic wheels can lose traction. we've juicing the drivers control of the vehicle traction control prevents this wheel slip. The traction control module monitors data from the wheel speed sensors and the powertrain control module it samples this data continually comparing the rotational speed of each wheel. If one or more wheels is rotating faster than the others indicating traction loss. The system instructs the powertrain control module to reduce torque and the braking system to apply braking pressure to the slipping wheel until it regains traction. Traction control allows drivers to safely apply heavy acceleration when merging with fast-moving traffic and on slippery or loose surfaces. In the block diagram given, the working of TCS is given in detail. When the accelerator is pressed, it's input passively takes the engine on. The powertrain of the vehicle is connected with the TCS system. When the control is in the OFF condition, the wheel does not get any information from the system. It performs as usual. But when the TCS is switched on, the wheel speed sensors from every wheel sends data to the TCS, to infer if all the data from all 4 sensors are same. If yes, the wheel again runs smoothly without any issue. Now, when wheel speed sensors data differ with one wheel faster than the others indicating a slippage, the TCS kicks in and sends data to the braking system to clutch that slipping wheel till the data from the wheel are same. This is how the TCS works.

B. ESC

Electronic Stability Control (ESC), is one of the advanced security highlights in the present vehicles. It is a modernized innovation that works on a vehicle's solidness by distinguishing and diminishing loss of footing (I. e.) while the vehicle is sliding. Some ESC frameworks additionally decrease motor power until control is recaptured. The manner in which your vehicle is voyaging, the direction of your guiding wheel, and the slowing down on your tires are totally perused by a bunch of sensors. This feature helps correct the car back on-route if they sense that it isn't heading in the direction you expected it to go by changing your pace and selectively braking one or more wheels. You can lose control of your vehicle or crash if you don't have ESC. When the car's anti-lock braking mechanism is functioning well, electronic stability control is most reliable. If there were some issues with ABS, ESC could not work properly or at all. Wearing brake linings and air or gravel in the brake fluid are two typical causes of 4-wheel ABS malfunctions. When the tyres are fully inflated and in good shape, both ESC and ABS perform best. Figure 6.3 shows the ESC working block diagram. As, Electronic Stability control is an integrated part of the Traction Control System, this provides a safety similar to that of the TCS, but the main difference is that it controls the vehicle's yaw control movement, (i. e). when the vehicle skids, ESC kicks-in and tries to restore the vehicle's original position before the skidding action occurred. This is the main advantage of ESC.

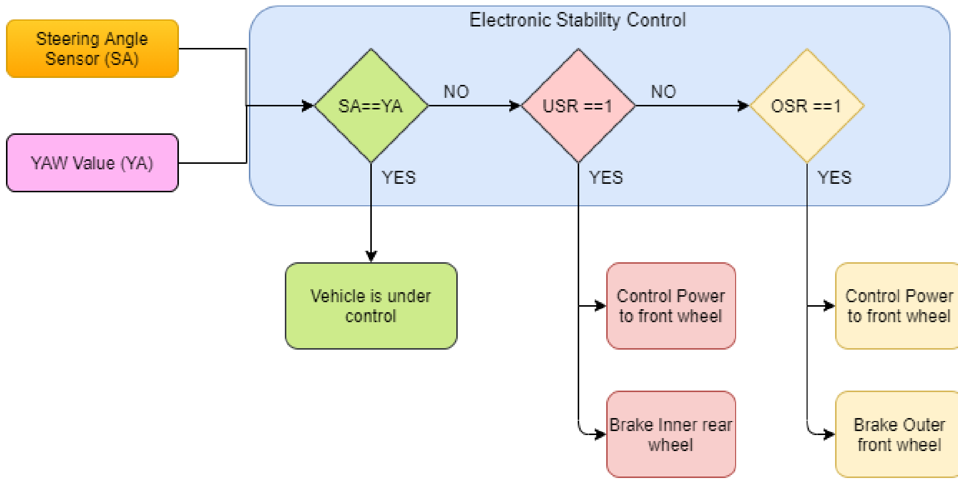

Figure 6. Electronic Stability Control (ESC)

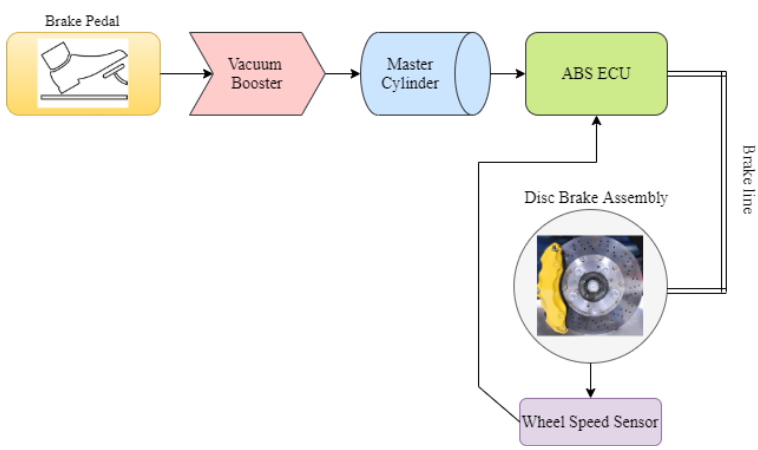

Figure 7. Anti-lock Braking System

During cornering or evasive manoeuvres, a vehicle can lose traction resulting in understeer or oversteer understeer. Understeer occurs when the front wheels lose traction while turning and the vehicle drives straight ahead instead of into the turn. Oversteer occurs when the rear wheels lose traction while turning and the vehicle's rear end slides out instead of following the front wheels into the turn. Electronic Stability control or ESC sensors and corrects understeer and oversteer. The Sensors measure the drivers intended cause the actual direction of the vehicle and the vehicle's traction with the road. The ESC control module samples this data continually if variation between the drivers intended course and the actual direction of the vehicle is detected the control module takes action. In an understeer situation the vehicles momentum continues straight ahead, instead of into the turn because the front wheels have lost traction. To correct this the control module reduces engine power to the front wheels until traction returns at the same time it applies brake to the inner rear wheel. This creates group anchor or pivot point that assists the vehicle into the turn. In an oversteer situation the momentum in the rear of the vehicle is directed straight ahead instead of into the turn because the rear wheels have lost traction. To correct this the control module reduces engine power to the front wheels at the same time it applies brake to the outer front wheel this creates an anchor or pivot point that counteracts the rear-end sliding out so it straightens up and follows the steering line.

C. ABS

One of the significant securities includes in slowing down is the Anti-lock Braking System (ABS). It forestalls the wheels from securing and assists them with keeping up with grasp with the street beneath. ABS frameworks generally have a focal electronic control unit (ECU), four-wheel speed sensors, and somewhere around two water powered valves inside the brake hydrodynamics. If the

ECU identifies a wheel turning possibly slower than the vehicle's speed, it opens valves to diminish water driven protection from the brake at the impacted wheel, bringing down the halting power and permitting the wheel to pivot quicker. If the ECU sees a wheel turning somewhat quicker than the others, the brake water driven protection from that wheel is raised, reapplying the slowing down power and dialing the wheel back. Figure. 7 shows the ABS working block diagram. Since, ABS is the basic safety feature of a car, all TCS and ESC systems are incorporated with the ABS only.

During emergency braking or on slippery surfaces a driver may apply braking force that is greater than the tires capacity for grip if this happens the wheels can lock up causing the vehicle to skid out of control. By forestalling this lock up the vehicle stops sooner and stays under the driver's influence. The stopping automation or ABS gives this help. The sensors on each wheel continually measure their rotational speed the ABS control module tests this information constantly contrasting the rotational speed of each wheel on the off chance that at least one wheels is pivoting slower than the others a condition that will carry the wheel to lock. The framework teaches the brake ace chamber to coordinate brake power away from the locking wheel. Along these lines, it delivers and recaptures foothold as the wheel turns once more. The slowing down power is immediately reapplied and this cycle is rehashed up to 20 times each second and causes the trademark beating feel through the brake pedal. Subsequently, the drivers planned brake power is applied without securing and slipping. Allowing the driver to maintain steering control while braking and stopping distances may also be reduced.

D. Fuel Economy Metrics

Clutch actuation is one of the best methods to improve a driver’s driving style and one can easily analyze someone’s driving with their clutch actuation. Clutch is supposed to be pressed only when the vehicle comes to a stop or when there is a need to change gears. While some drivers drive pressing the clutch unnecessarily and some have their clutch actuated partially at all times, they notice mileage drop drastically than the others who drive without actuating the clutch unnecessarily. When the clutch is pressed partially as shown in Figure 8, the flywheel does not mesh perfectly with the engine and this leads to the lag in power transmission. There are possibilities for parts to get damaged too. Hence, half-clutching is not advised while driving except when driven in terrains.

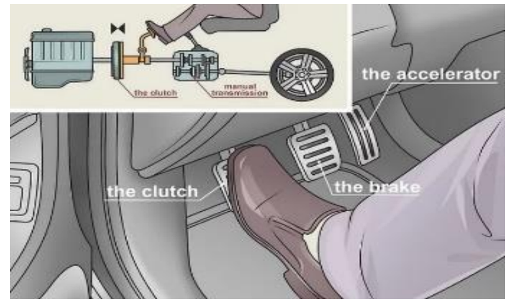

Figure 8. Half Clutch Usage

E. Driver assist events

By retaining the brakes when switching between the brake and acceleration pedals, the Hill Start Assist (HSA) feature will avoid rollback on an incline. Other models will also stop the vehicle from rolling over on a downhill slope. When a car is on an incline, sensors in the vehicle detect it. When you turn from the brakes to the gas pedal, the hill start assist retains brake pressure for a fixed amount of time. When you hit the accelerator, the brake is released. The hill start assist feature in cars with manual transmissions will also retain brake pressure before the driver releases the clutch. Fig. 9 shows the working of the HSA Control in vehicles.

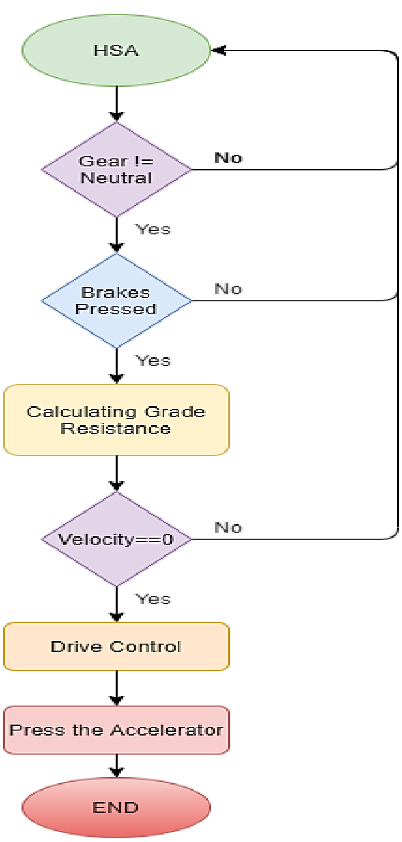

Figure 9. Hill Start Block Diagram

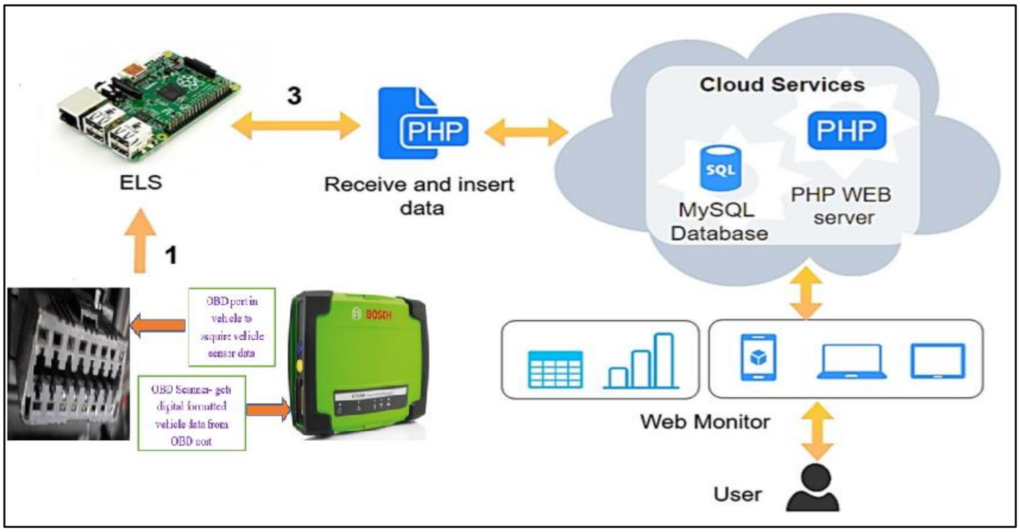

Figure 10. Wireless remote monitoring and control architecture for automotive vehicle pattern analysis

The working of the hill start assist is shown in the Fig. 9. First the HSA vehicle is travelling uphill and negative when it is travelling downhill. According to these parameters, the velocity of the vehicle is checked. When the vehicle is in a moving condition, the loop travels back to the sensor and indicated to it. So, the vehicle moves smoothly. Suppose if the vehicle is static and the grade resistance is not '0', HSA moves to the drive control and engages the brake even after the driver has taken his leg from the brake pedal for a shorter duration to prevent the rollback of the vehicle till the accelerator is pressed and the vehicle starts to move. The brakes are released once the vehicle is accelerated.

F. Rash braking

Normally, application of brakes in the vehicle causes deceleration and eventually the vehicle stops. This deceleration value should be in an optimal level so that the vehicle should have a minimum stopping distance as well as the driver should have a comfortable drive. The deceleration value is expressed in terms of m/s2 but in terms of vehicle deceleration it is expressed in terms of g (i.e.) no of time with respect to the gravity (9.81 m/s2). The term rash braking is considered when the braking deceleration of the vehicle is greater than 0.6g or 5.886 m/s2. Whenever the deceleration value exceeds the 0.6g, the braking force will be high enough to cause discomfort to the driver. If the passengers are not wearing seat, they would have a high chance of getting hurt. This rash braking event will occur due to various reasons like animals crossing the road, the unanticipated stopping of the vehicle in front, sudden lane changes which will require harsh braking, etc. One of the main effects of rash braking is brake pad wear. The crucial places where harsh braking is required cannot be determined but the possible places where rash braking is needed can be estimated. This estimation can be visualized by continuously plotting the location of rash braking event.

5. DEVELOPMENT AND INTEGRATION OF CLOUD CENTRIC BASED VEHICLE PATTERN ANALYSIS

In view of the IoT based general design, a remote observing and data framework has been produced for checking and control of Antilock Braking System (ABS), Traction Control System (TCS), Electronic Stability Control (ESC), Hill Start Assist (HSA) and grip incitation of the auto vehicle. Inserted framework interfaced with Things Speak improvement device is outlined in Figure 10 unruffled of gadgets used for IoT remote web observing of vehicle CAN information with PIC18F458 upheld by USB interface. This instrument is compelling in the improvement of adventures in light of the fact that there is no compelling reason to seize the microcontroller for the firmware update, differentiating to ongoing arising frameworks which usually utilize unequivocal c consuming modules and unite by means of link. Besides, Raspberry Pi is multiplatform, working on Python, Windows and Mac OSX which is fitting and play was unavoidably famous by support working frameworks denied of the establishment of driver programming. Consequently, this apparatus works with the aggregating, recording, and impersonation of a program finished quickly and capably. Continuous sensor information (tension and temperature) are given to the ADC of PIC microcontroller and changed over advanced information is sent by means of sequential correspondence module into RPi.

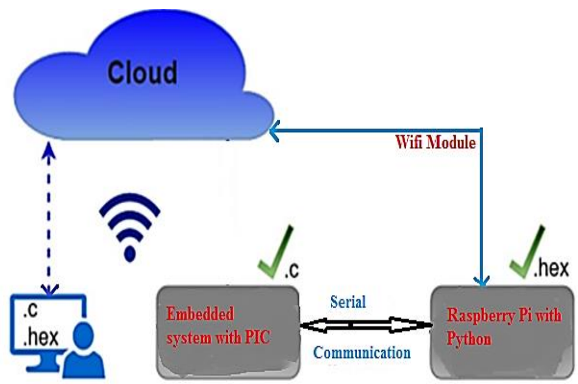

Figure11. Remote firmware and scripts updating

By enabling ground (GND), GPIO 14 (TX) and GPIO 15 (RX) pins the presentation of sequential correspondence between the RPi and a PIC microcontroller is refined. Since RISC engineering based implanted framework is interfaced with the IoT stage, programmed firmware module revamping from the Cloud is done deliberately as displayed in Figure 11. Records (.c and .hex documents) from the principle server are unloaded to the implanted framework firmware as (.hex documents) and it is sequentially communicated to RPi which processes its contents as (.c documents) to oversee online web observing and distributed storage of continuous modern sensors information. The installed framework is refreshed through a fitting wire association between RPi pin 10 and ES pin 15 alongside Bluetooth. To face segregated refreshing at any moment the indication of this wire association is crucial on getting programming orders which corruptly affect framework circuit authorization.

6. RESULTS AND DISCUSSION

The Driver's performance analysis helps the driver to improve the driving as well as improving the efficiency of the vehicle. In the performance analysis, we have considered Fuel economy metrics, safety or emergency events and Driver assist events.

A. Clutch usage

The clutch is used to disengage the crank while changing the gears. The clutch usage plays a crucial role in maintaining the efficiency of the engine. The clutch should be disengaged once the gear shift is completed. Otherwise, more power transmission loss will occur. Some people may tend to drive the vehicle in half clutch condition which is not a good driving practice. This kind of action tends to affect the Fuel economy directly. Figure 12 shows Clutch usage in a trip of 20 Km.

The nominal clutch usage time for good driving should be less than 2 Seconds. In Figure 13, the clutch is engaged for more than 2 seconds in many gear shifts. This is considered to be the half clutch duration and it affects the fuel economy.

Figure 14 is data of clutch usage during a trip of 35 kilometers. In this trip the clutch engaged duration is mostly around 2 seconds and so the fuel economy is much better. Comparing with trip 1, the clutch usage in trip 2 is much better. In the sense that, the duration of usage is minimized and power transmission will much more efficient than trip 1. This results in increased fuel economy. The duration of trip 2 is about 42 mins and the total clutch usage duration is 11.42 mins. The clutch is engaged about 27.19 % of the total duration shown in Figure 15.

The increased clutch usage leads to increased loss of transmission which means that the power produced from the engine is not transmitted completely to the wheels. The half engage clutch leads to reduced economy and also increased clutch pad wear. The Fuel economy depends on numerous parameters among those we have taken clutch usage as the major factor. The transmission loss will be directly proportional to the half clutch duration. Figure 16 shows the graph drawn between half clutch usage and economy loss.

B. Safety events

In the performance analysis of the vehicle, the occurrence of safety events should also be considered because it may be an indication of driver lost control over the vehicle. Braking system is the crucial one in the vehicles and it should be in perfect condition to ensure the safety of the passengers. The ABS kicks in when any of the wheels gets locked during braking. Normally ABS, most likely to kick in when brakes are applied in slippery surfaces. Without ABS, the rash braking in slippery surface may lead to skidding of the vehicle and may results in accidents. The Brake duration is monitored during the trip 2 of 35 kilometre and is shown in Figure 17. Around 75 times brakes were applied during the trip 2.

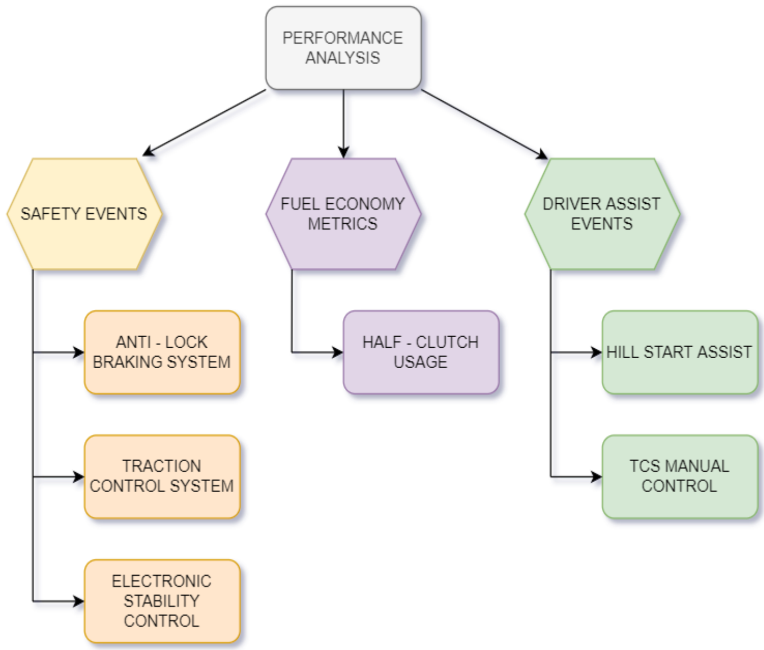

Figure 12. Performance analysis

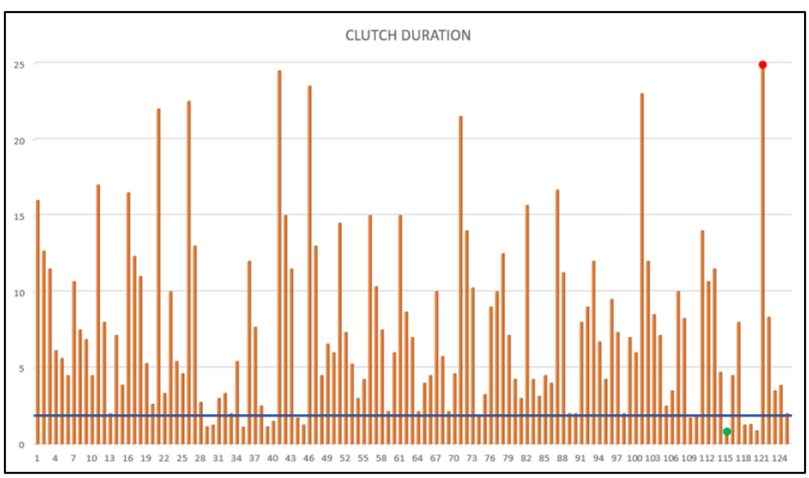

Figure 13. Clutch Usage in trip 1 (20Km)

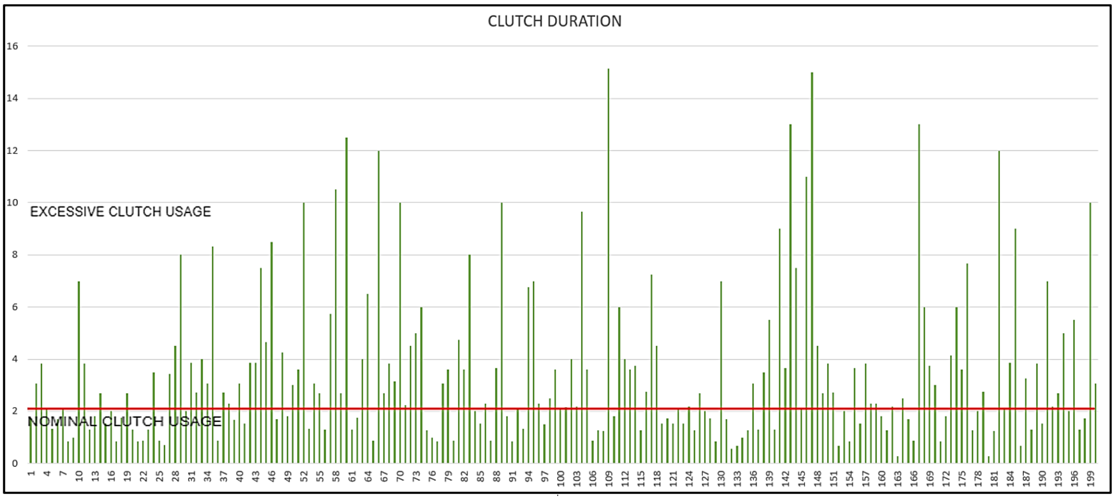

Figure 14. Clutch Usage during trip 2 (35 Km)

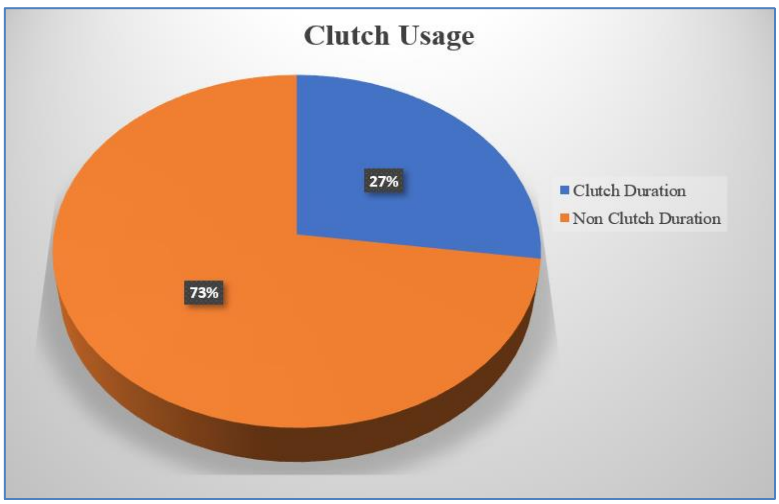

Figure 15. Clutch usage Duration vs Total Duration

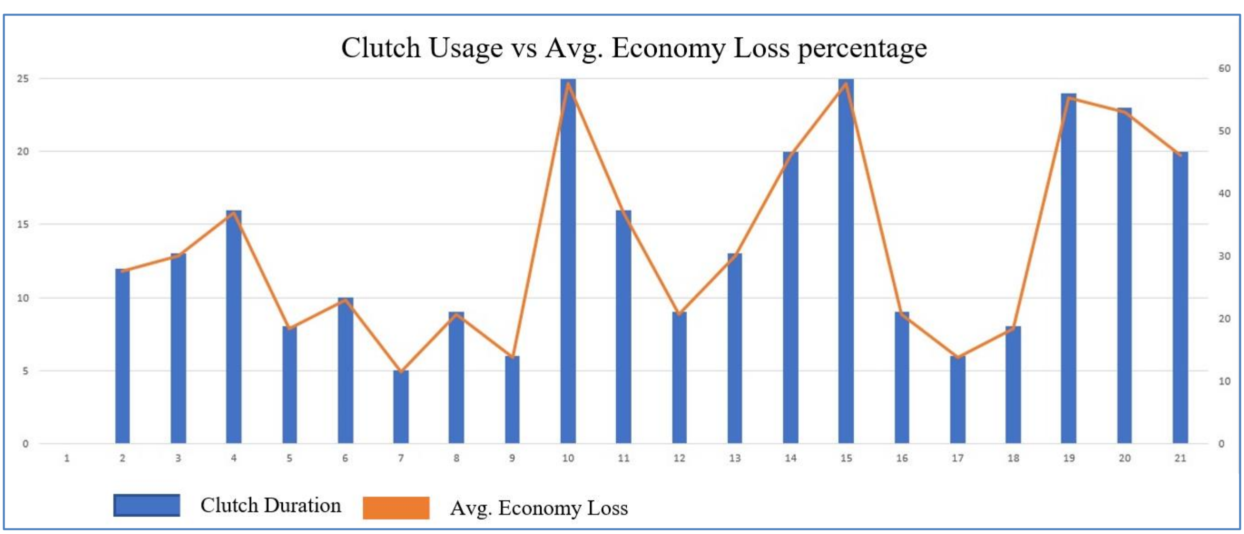

Figure 16. Half Clutch usage vs Economy Loss

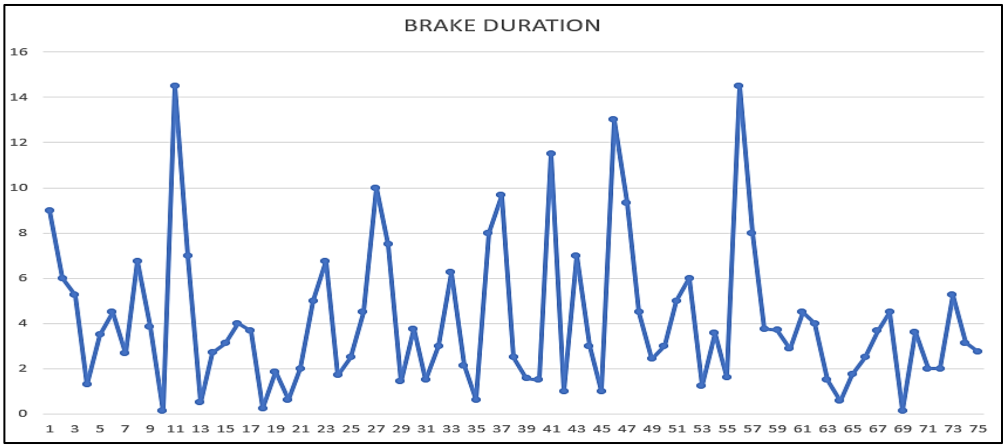

Figure 17. Duration of Braking Events

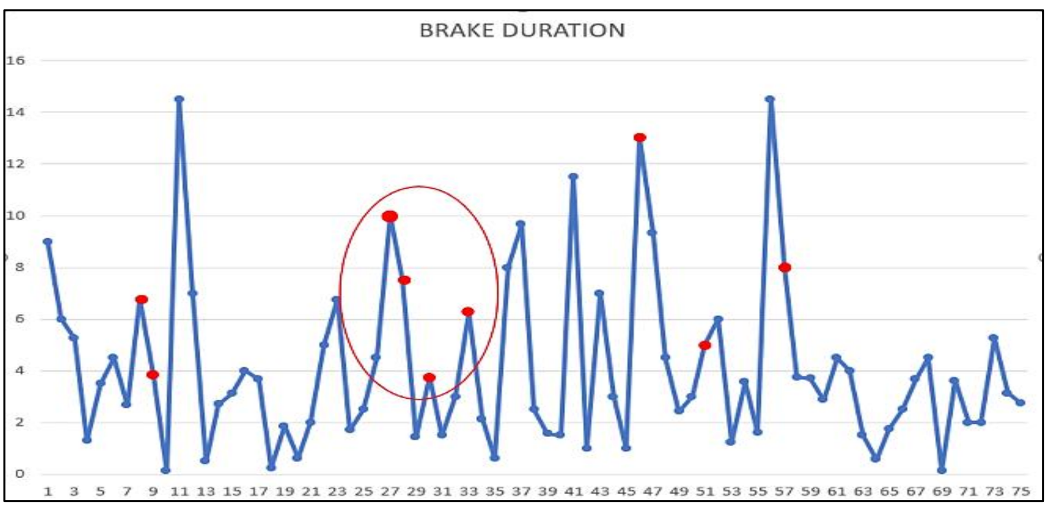

Figure 18. ABS occurrence in total set of braking events

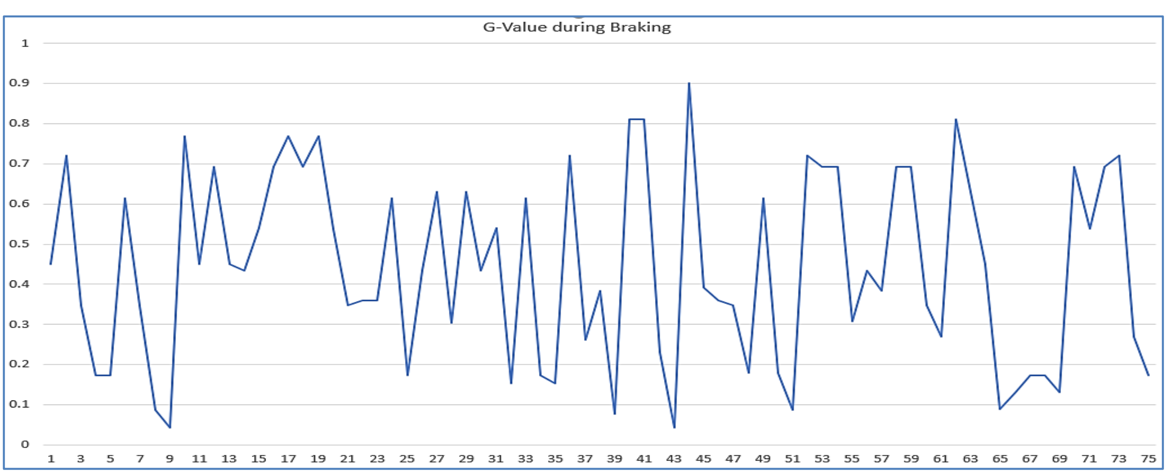

Figure 19 G-Value vs Braking

In the trip 2, the ABS kicked in about 9 times which can be interpreted as 9 rash braking events/ braking in slippery surfaces occurred during the trip 2. The points at which ABS kicked were marked as red dots in figure 18. In the overall trip most no. of ABS occurrence is between brakes numbered as 25 and 33. The braking events were also monitored manually during the trip 2 and it was observed that braking events marked with in red circle shown in fig. occurred during the drive over the slippery surface (Road was covered with mud due to rain).

Figure 19 shows the g values of respective braking events. The g-values are monitored using an external accelerometer kit fitted to the front panel of the vehicle. The x-axis of the accelerometer is aligned with that of the vehicle's axis. The g-values exceeding 0.6 are significantly hard braking events. In trip 2 about 26 hard brakes were applied but out of these only 9 times, ABS kick in. This clearly shows that the ABS need not to be kicked in all rash braking events. The occurrence of the other safety events like TCS, ESC and DTC were about 10, 5 and 8 times respectively. These events occur to maintain the stability of the vehicle when the manual control over the vehicle will not be enough to keep up the stability as shown in Figure 20.

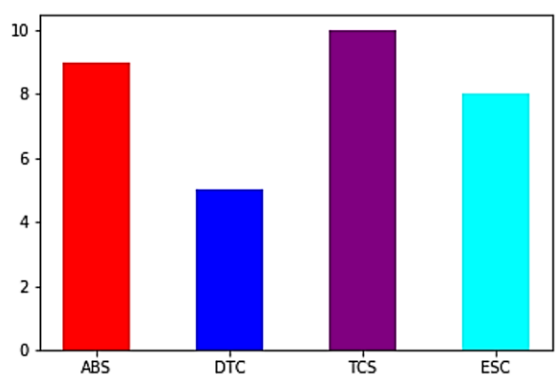

Figure 20. Number of occurrences of Safety events

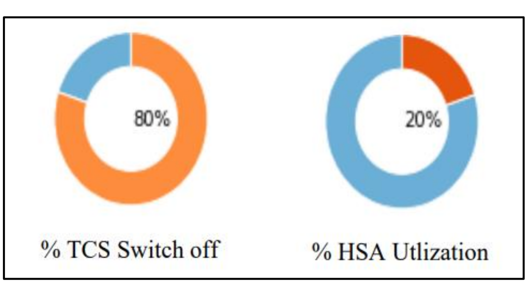

Figure 22. Driver Assist events

C. Driver assist events:

The Driver assist event HSA helps the driver to prevent the vehicle moving due to gravity while starting to drive in uphill or downhill. The TCS control switch is used to turn on/off the TCS activation manually. When driving through the slippery surface like mud/snow, its mandatory to turn off TCS activation in order to move the vehicle otherwise the vehicle may get stuck. Figure 21 shows the TCS switch status during static and intentional switching. The TCS control switch will be provided near the AC control in Ford Ecosport. The TCS on/off indication will be available in the cluster of the car. TCS manual control will not be used frequently during driving. It is used only when driving on slippery surfaces as shown in Figure 22.

6. COMPUTERIZED REAL-TIME DRIVER'S PERFORMANCE ANALYSIS USING MULTIPLE ONBOARD SENSOR'S CAN DATA

This driver's performance report informs the driver about their driving style, whether it is good or not. This analysis is important to improve the driving style and passively it improves the condition of the vehicle as well. Every time after a trip, inside the application, a report as shown in Figure 23 is generated to let the driver know how they have driven throughout the trip. When the vehicle moves in for the service, a driver's report is generated for the whole previous service period consolidated into a single report. The drivers can correct their driving style if needed, with the help of this report. In the first column of this chart, all the personal details about the owner/driver like name, age, driving license number, the vehicle details such as the make and model, year of manufacturing, it's unique Vehicle Identification Number (VIN), country the vehicle was supplied to, fuel type and engine power, vehicle fuel tank capacity, transmission details, the trip information indicating the start and end times, total duration drove, idling duration and the average speed in which the vehicle was driven.

In the second column, the fuel economy metrics and the driver assist events details will be provided. Fuel economy metrics represent the clutch actuation period. When the clutch is pressed for a long time, the fuel economy rate decreases. It is indicated with percentages to let know the details to the driver. In the driver-assist features, the traction control system and the hill start assist features are shown.

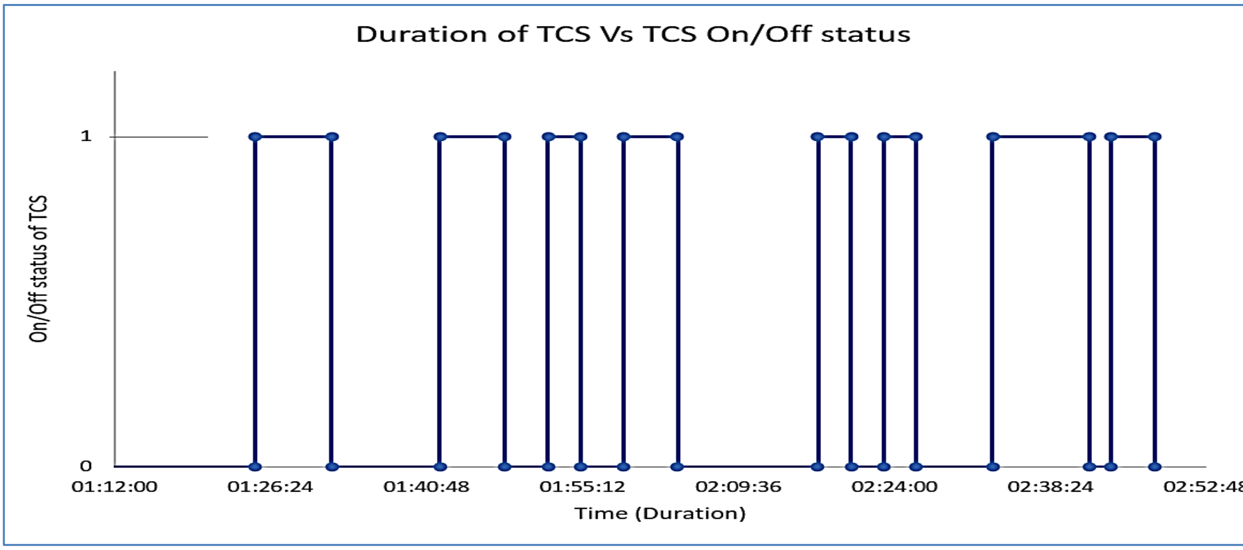

Figure 21. TCS switch status

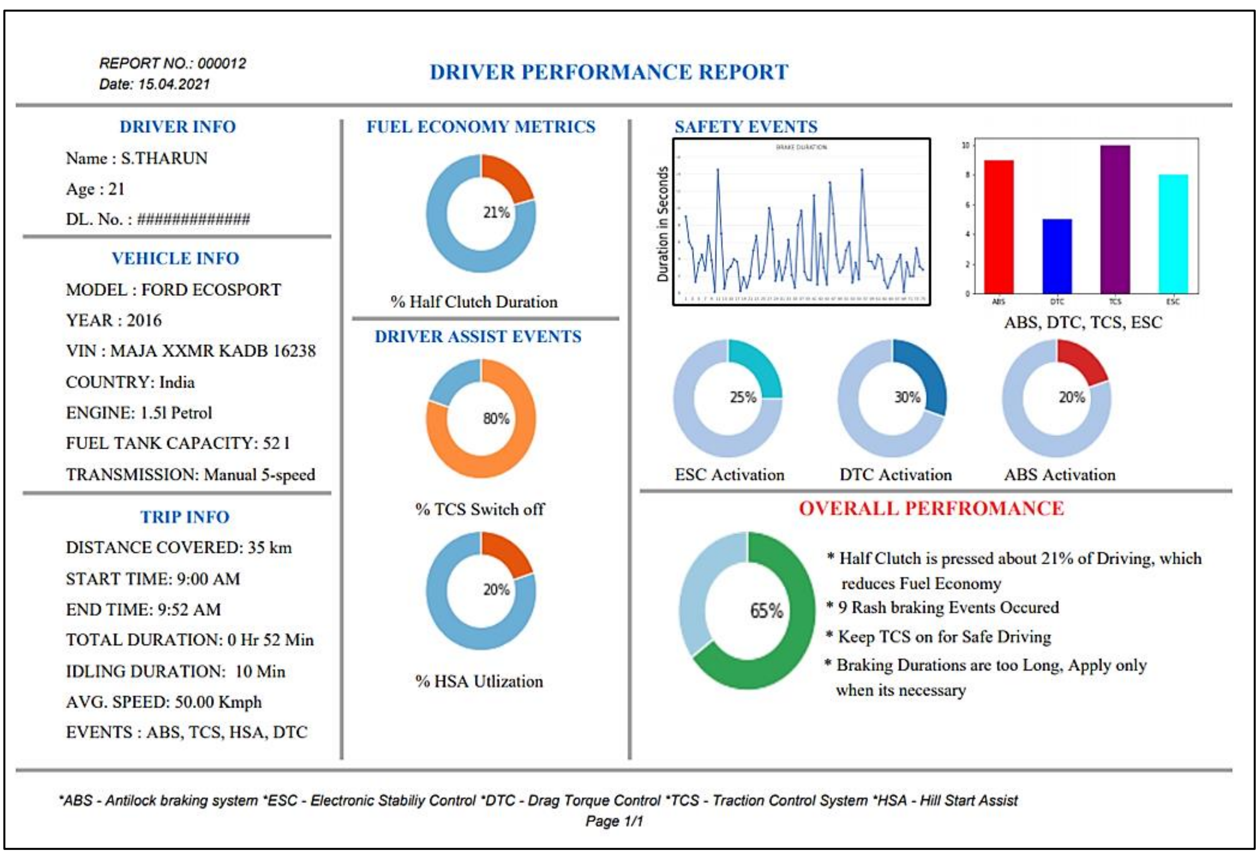

Figure 23. Performance Analysis Report

Except on terrains or slippery roads, the TCS is expected to be turned on for safety purposes. Hill-start assist helps the vehicle from rolling back on a steep hill road. Their utilization is also shown in percentages. The main part in this column represents the fuel economy percentage using the duration of the half clutching. In this case, the clutching duration is 70%. This will definitely have an effect in the fuel economy. This much clutching reduces the mileage and might damage the transmission system too. This is an example of really not an advisable style of driving except hill stations. These hilly road issues can also be solved using the HSA, with a utilization of 20% without having to roll back while on steep roads.

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The third column depicts all the safety features kicked-in in the vehicle while driving. It shows the number of braking counts done in the trip and their durations. Whenever rapid accelerations or decelerations occur, the safety features like ABS, TCS, ESC, DTC kick in to bring the vehicle to a stable condition to restore driving. The actions are recorded each time when they kick in and the report shows the details for the driver to know. For an instance, when a driver is driving a vehicle at around 100 kmph and there suddenly appears an obstacle where is a sudden need to brake hard, without ABS, the vehicle does not turn the way it should respond at that point. It either skids accidentally without any control or hits the obstacle. But when the ABS kicks in, the brake pressure is distributed accordingly that the vehicle stops with the driver's control over it and creates only minimal injuries where the injuries could be fatal without ABS. In the report given, in the total trip, the ABS had kicked itself in by nearly 20%. This is not likely a small amount and hence the ABS is required when traveling at a good speed.

In the same instance, the traction control and the stability programming kicks in when the braking is done are too severe. Even with the help of ABS, there could be some instances where the vehicle is expected to return to its original condition without the need to skid. This is the place where these two come under action. TCS is supposed to keep the tire from slipping from the surface and ESC control is used to bring the vehicle stable again after the hard braking. Thus, the performance chart shows all the necessary features that a driver needs to know to improve his/her driving techniques.

7. CONCLUSION

From the experimental analysis, the data taken from the automotive sensors CAN data are encrypted by proper channel id and are stored in the cloud where data analysis is performed to generate the vehicle-driven report. The data acquisition rate is around 1500 Messages per second which from the vehicle CAN bus line. In the cloud-stored messages, the filtering process is executed which is a comparison of acquired data with predefined values fixed by the manufacturer for the final report generation. This report explains the completed trip driver driving style and how it impacts vehicle efficiency. By using this report on the HMI screen of the vehicle display, the driver may change their style of driving adversely for the well-being and safety of both the passengers and the vehicle. The experimental report given in the present work was generated for the real-time trip of about 35 Km distance with a duration of 52 minutes engine run time. During the undertaken 52 minutes time slot, the vehicle was in idle condition for about 10 minutes. The top speed achieved during the trip was 125 Kmph and the average speed of the vehicle throughout the trip was 50 Kmph. The proposed analysis and performance report focused on the fuel economy, occurrence of safety events and driver-assist events. As mentioned, clutch usage is vital in fuel economy, the evaluated half clutch usage duration was 21% of the total duration of the evaluation period. The quite long clutch usage results in a 7.67% drop in the car's rated mileage. The triggering of the safety events are indications of the situations where the driver lost control over the vehicle. During the trip, it was observed that the ABS was triggered about 9 times and it mostly occurred during braking on slippery surfaces. The G-Values of each braking action were also monitored and it depicted that not all braking events above 0.6 g triggered the ABS events. The given real time-onboard performance analysis helps the driver to improve both the style of driving and vehicle efficiency.

In the future aspects, the collected sensor data can be manipulated by the company later to develop numerical model systems comparing different driving styles of drivers.

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