INTEGRATED VEHICLE HEALTH MANAGEMENT, MONITORING AND MAINTENANCE SYSTEM

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How does a person say “thank you” when there are so many people to thank? Obviously, this work is the result of our parents’ efforts who always supported us spiritually throughout our lives.

We would also like to thank our all teachers who made efforts and made us deliver this work which would not be possible without them.

ABSTRACT

The present study contributes to the modern computer-based technologies embedded in the automobiles for their better understanding and development of their better performance.

By upgrading this available technology on hand to next higher level, an objective of achieving better health of automobiles along with no compromise on better to best performance at the lowest cost incurred can be achieved.

Integrated vehicle monitoring, maintenance and management system (IV3MS) is a collection of data relevant to the present and future performance of a vehicle system and its transformation into information can be used to support operational decisions. This design and operation concept embraces, an integration of sensors, communication technologies, and artificial intelligence to provide vehicle-wide abilities to diagnose problems and recommend solutions.

IV3MS is a platform that is implemented for predictive or Condition-Based Maintenance (CBM) of automobiles whose main aim is to provide safe operation of automobiles with no delays at the time when required and enhance the reliability of vehicles by providing maintenance strategies that requires less amount of both time and cost. Hence this platform brings the solution to the problems that are associated with preventive and corrective maintenance strategies.

This model not only can forecast the faults but also can be able to prevent their occurrence in near future by better understanding the automobiles health.

This work also focusses particularly on Fuel Management System (FMS) of automobiles which has become one of the most critical tasks to the auto-manufacturers in recent years due to sudden hike in prices of fuel and customers demand for best performance of vehicle at the lowest cost.

Experiments were performed on **Honda Civic 2005** Model in order to achieve Fuel Management of the car by real time monitoring of the car back to back on the server which receives the data sent to it accordingly.

The server is developed with algorithms that implies with the international standards of the vehicle health and fuel management laws that are devised by manufacturing firms and Auto Service Industry.

The results of this study have clearly approved that the implementation of IV3MS in automobiles service firms will significantly reduce the maintenance cost by maintaining the vehicle only when required and repairing the parts only when needed.

This results in increasing the operational hours of automobiles and also enhances the performance of the vehicles hence increasing the reliability and durability both at the lowest cost and minimum time spent.

Further limitations and futuristic approaches are discussed accordingly in the study.

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CHAPTER 1

INTRODUCTION

1.1. INTRODUCTION

In present high technological and diversified era automobiles and machinery are second to human and the most reliable and durable source for human transportation and daily life chores.

As the human health is critical to human society so as the vehicle health to the production industries mainly transportation firms which is the concern field of study here.

Maintenance is an ever-green field which is subjected to the upgradation. At the same time in the present era it is a major concern to industries like transportation, Manufacturing and so on.

With the rapid growth of automobiles in the market and its dire need for human logistics and transportation within the allowable framework of time. Maintenance of vehicles is a great issue, as with the rapid growth of technology the customary maintenance has to be changed.

The adaptation of integrated vehicle Monitoring, Maintenance and Management (IV3MS) in the auto industry promises to provide significant new capabilities to enhance the overall customer ownership experience with their vehicles. In essence, it provides a means to essentially redefine "reliability" by being able to proactively deal with future problems before they actually inconvenience the customer and, thus, largely mitigate the negative impact of those problems.

IV3MS provides an important building block upon which these innovative new features can be implemented. In addition, IV3MS provides an improved framework to better manage the life cycle of maintenance for such vehicles which in turn provides an immediate saving opportunity for all vehicles. Traditional maintenance schedules in automotive industry have typically been time or mileage based but this can lead to negative consequences in multiple ways. The maintenance intervals can be too conservative for some operating conditions and therefore potentially waste the owner's time and money as well as wasting valuable natural resources. On the other extreme, under certain operating conditions, the time or mileage-based approach may signal a maintenance action too late to avoid a service issue of some kind. By tracking actual usage patterns, system can dynamically adapt the maintenance intervals to more appropriate periods based on the actual needs.

1.2. ENGINE MANAGEMENT SYSTEM

Engine Management system is the brain of the engine. It monitors and controls all the key functions of the engine. The control system also acts as interface to the vehicle automation system. The (EMS) ensures low emissions and high-power output. It also ensures a low fuel consumption over the entire vehicle life. Engine Management System consist of wide range of electronics and electrical components such as sensors, actuators, relays, and Engine Control Unit. They all work together to provide the Engine Management System with the vital parameters that are essential for governing various engine functions effectively.

The modern-day cars already come with an engine management system which takes all the decisions and acts as a brain of the system. The data from the sensors is taken as input and makes decisions about the performance of car and how the various parameters are to be controlled in order to keep the engine at an optimum level of performance [1].

1.2.1. Engine Control Unit

The Engine Control Unit is the central part of Engine Management System. It plays an important role in collecting, analyzing, processing and executing the data it receives from the various sub-systems of the vehicle. Furthermore, an ECU also comprises a computer which uses a microchip to process the inputs from engine sensors in real time.

The Electronic Control Unit consist of hardware and software. The printed circuit board (PCB) of ECU consist of a micro-controller chip which is also known as Central Processing Unit (CPU). The software is stored on the micro-controller or chips on PCB. It is possible to re-program the ECU by updating the software or by replacing chips.

All the engine sensors send the data to the ECU by the way of electrical signals. The ECU in turns controls various actuators, ignition timing, variable valve timing.

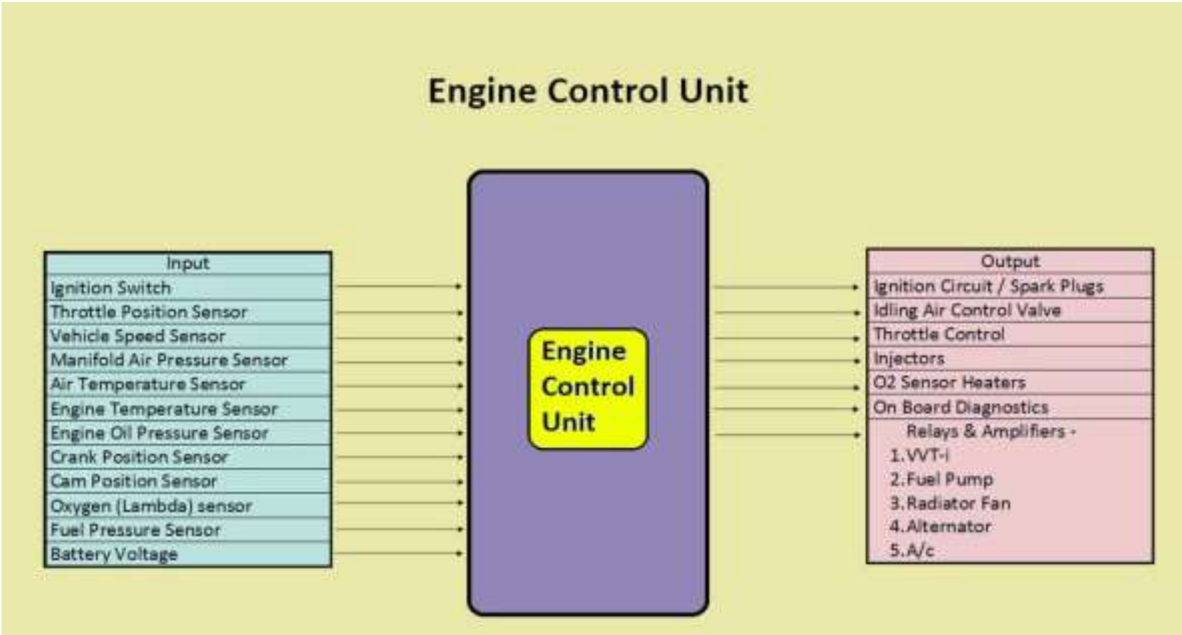

Figure 1.1 Engine Management System *[1]*

From the above figure it can be clearly seen that how the ECU receives data from the sensors and processes that data and sends an output signal to the actuators.

Based on this input data ECU precisely calculates and delivers the ideal air-fuel mixture. It also regulates the ideal speed of the engine and limits the top speed of the vehicle.

The Modern-day ECU can also be customized to meet the customer demands. In addition, some cars have an individual "Control Module" for all major systems. A modern car has following individual Control Modules which control the respective systems [2].

Table 1. 1 Various Control Modules in a car.

S.NO	Acronyms	Terminology
01	ECM	Engine Control Module.
02	PCM	Powertrain Control Module.
03	TCM	Transmission Control Module.
04	EBCM	Electronic Brake Control Module.
05	CCM	Central Control Module.
06	CTM	Central Timing Module.
07	GEM	General Electronic Module.
08	BCM	Body Control Module.
09	SCM	Suspension Control Module.
10	SCU	Speed Control Module.
11	TCU	Tele-Matic Control Module.

1.3. VEHICLE HEALTH

Vehicle health determines the performance of a vehicle. There are many factors which contribute towards the health of a vehicle. Increase in the carbon dioxide emissions or decrease in fuel economy are indications of bad vehicle health. Most of the problems arise in the engine of a vehicle. The engine is controlled by a management system that comprises of an ECU and sensors, the sensors and ECU work in collaboration to keep the engine in a healthy operating condition. Due to the presence of this management system the vehicles are able to monitor the health of their own systems.

For certain values of input that are sensed by the sensors the output by ECU is determined by the maps that are put in ECU by the company. The ECU manipulates the data and sends output to the actuators, these maps have certain correction criteria of their own, larger variation in the data cannot be compensated by it. The variation in the data or input is due to environmental changes landscape and variation in load. It is because these maps are made in controlled environments so when the vehicle is working in extreme conditions so because of lack of information in the maps the health suffers [1].

1.4. INTEGRATED VEHICLE MONITORING, MAINTENANCE & MANAGEMENT SYSTEM

(IV3MS) Provides us with the capability to work on the system/automobile to prevent its transition to the failed state or to recover the system back to its operational state from its earliest possible failed state within minimum time frame work utilization & reduced cost.

With the advent of higher and higher levels of electronics in today’s products, there has been an increasing emphasis on On-board diagnosis to quickly detect faults and isolate their root causes. The new technology frontier is clearly prognosis which adds the predictive element to what has gone before. This seeks to be able to identify problems before they happen so that corrective action can be taken prior to loss of service. A primary focus is on improved fuel economy and safety and emission control. These kinds of systems are specifically targeted because of their obvious importance and because their successful implementation is typically dependent upon heavy use of electronics, controls technology and software, to achieve the required levels of performance. IV3MS can offer greater challenges in terms of both diagnostics and Health Management prognostics.

- IV3MS is the transformation of the system data on a complex vehicle (cars, airplanes etc.) into the information to support operational decisions & optimize maintenance.
- IV3MS is a capability comprising a number of technologies that can be used across number of sectors for business benefits.
- IV3MS Provides us with the opportunity to carry out the preventive & Condition Based Maintenance.

1.5. MAINTENANCE AND ITS TYPES

1.5.1. Maintenance

Maintenance is the administrative and financial measures to keep the system/service at its maximum optimum level. These measures include testing, inspection servicing, repair, and replacing.

1.5.2 Types of Maintenance

Maintenance is basically of three types:

1. Preventive Maintenance/Periodic Maintenance/Scheduled Maintenance.
2. Corrective Maintenance.
3. Predictive Maintenance/Condition-based Maintenance.

1.5.2.1. Preventive Maintenance

It is a routine "check-up" on periodic basis whose main goal is to inspect the overall parts of machinery and repair the worn-out parts so that nothing major problem like machinery break-down occurs in future.

Preventive Maintenance activities include partial or complete overhauls at specified periods, oil changes, lubrication, minor adjustments, and so on.

Preventive maintenance contracts are generally a fixed cost, whereas improper maintenance introduces a variable cost: replacement of major equipments.

1.5.2.2. Corrective Maintenance

It is a type of maintenance that is carried out once the machinery is breakdown or malfunctioned.

The main disadvantage of this type of maintenance is that it is very costly due to complete damage of parts and other one is that along with damaged parts other components of the machinery are also affected due to compact system and interdependency on each other.

It is also very time consuming. The major activities under this strategy are rebuilding of equipment.

1.5.2.3. Predictive/Condition-Based Maintenance

Predictive maintenance is maintenance that monitors the performance and condition of equipment during normal operation to reduce the likelihood of failures. Also known as condition-based maintenance.

This maintenance strategy uses sensors to monitor key parameters within a machine or system, and uses this data in conjunction with analyzed historical trends to continuously evaluate the system health and predict a breakdown before it happens.

The major benefits of this strategy are:

1. Maintenance is performed more efficiently.
2. Less time is consumed as compare to other two.
3. Cost effective as only those areas of machinery are analyzed which needs to be.

1.6. FUEL MANAGEMENT SYSTEM (FMS)

Fleet Management System (FMS) is a highly applicable system which gets more and more attention among Transportation field. Recent years, fuel consumption has become one of the most concerned topics, hence, establishment of a fuel consumption monitoring system is required.

Fuel-management systems are designed to effectively measure and manage the use of fuel within vehicles and aircraft, as well as any vehicle that requires fuel to operate. They employ various methods and technologies to monitor and track fuel inventories, fuel purchases and fuel dispensed. This information can be then stored in computerized systems and reports generated with data to inform management practices. Online fuel management is provided through the use of web portals to provide detailed fueling data, usually vis-à-vis the back end of an automated fuel-management system. This enables consumption control, cost analysis and tax accounting for fuel purchases for govt. Officials.

Fuel-management systems are used to maintain, control and monitor the fuel consumption and fuel stock in any type of industry that uses transport, including air, water and road as a means of business.

There are several types of fuel-management systems. Card-based fuel-management systems typically track fuel transactions based on a fueling credit card and the associated driver PIN. Reports can then be generated based on fuel consumption by driver, and data can be directly downloaded. On-site fuel-management systems may employ fleet refueling services or bulk fuel tanks at the site. Fuel is tracked as it is pumped into vehicles, and on-site storage levels can be managed.

This Study focuses on the new type of generation of fuel management system which has its own up & downs [3].

1.6.1. Fourth generation

The fuel-island controller is fully connected directly to a central internet-based server which is updated in real time. All fleet information and transactions are held on the central server. Connection is made from the fuel island to the server using GPRS, or can use the operators own network using WIFI or Cabled Network Link [4].

1.7. ON BOARD DIAGNOSTIC DEVICE (OBD-II)

OBD-II is an On-board computer that monitors emissions, mileage, speed, and other data about vehicle. It is connected to the Check Engine light, which illuminates when the computer detects a problem.

This port is mandated to be installed in every car that is manufactured after 1996 for the purpose of inspection of emission control and many other information relevant to the maintenance.

The OBD-II on-board computer features a 16-pin port located under the driver’s side dash. It allows reader to read the error code using a special scan tool.

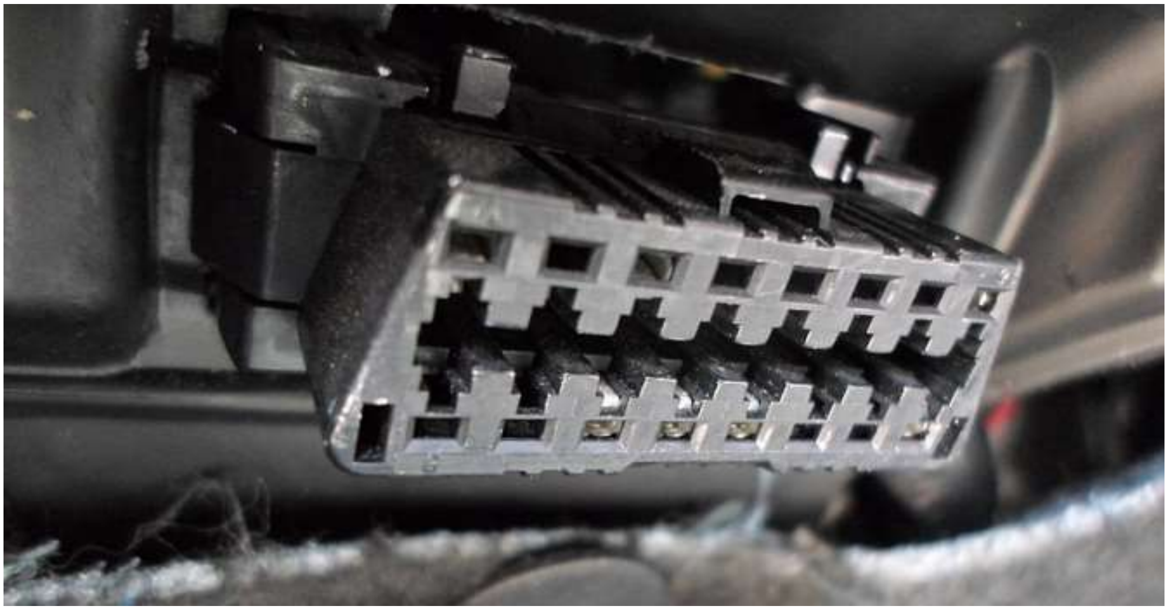

Figure 1. 2 OBD-2 Port in Vehicle.

Before OBD-I, each manufacturer had their own set of standards for OBD, meaning that mechanics had to buy expensive scan tools for each manufacturer. OBD-I was first introduced in 1987, and started the standardization of onboard diagnostics.

It had sensors that detected emissions and was able to minimize them through emissions-controlling valves. However, it had many problems and shortfalls.

As a result, in 1996 car manufacturers started to equip cars and trucks with an OBD-II port. Every system is mostly the same, but there are slight variations. These are known as protocols, and are specific to vehicle manufacturers.

Once the computer senses a problem with the engine or any other component of the car it is monitoring, it will trigger the Check Engine light. Some vehicles also blink the engine light if the problem is a very serious one [5].

1.7.1. Working Of OBD-II

Diagnostic Trouble Codes (DTC) are stored in the computer system. Codes can vary from one manufacturer to another. However, anyone with an OBD-II scan tool can connect to the port and read the diagnostic trouble codes from the computer.

The reason any OBD-II scan tool can read these codes is because of the standardized pinout. Scan tools can read from any of the protocols.

The standardized pinout is as follows:

1. **Pin 1**: Used by manufacturer.
2. **Pin 2**: Used by SAE J1850 PWM and VPW.
3. **Pin 3**: Used by manufacturer.
4. **Pin 4**: Ground.
5. **Pin 5**: Ground.
6. **Pin 6**: Used by ISO 15765-4 CAN.
7. **Pin 7**: The K-Line of ISO 9141-2 and ISO 14230-4.
8. **Pin 10**: Used only by SAE J1850 PWM.
9. **Pin 14**: Used by ISO 15765-4 CAN.
10. **Pin 15**: The K-Line of ISO 9141-2 and ISO 14230-4.
11. **Pin 16**: Power from the car battery.

OBD-II scanners can connect to these ports and identify the trouble code from any manufacturer that uses one of the OBD-II protocols [5].

Figure 1. 3 OBD-2 Dongle Device.

1.8. SYSTEM WORKABILITY

For IV3MS to Operate for concerned tasks, the setup must possess the following:

I. OBD- II.
II. Internet Connection.
III. Motor Car Model (1996 & Recent).
IV. Web Server.
V. Interfacing Application.
VI. Wireless Transfer of Data.
VII. Data Storage Facility.

1.9. AIMS & OBJECTIVES

The basic Aims & objectives of this study is:

I. To reduce the unscheduled maintenance by real time monitoring.
II. To reduce the cost of maintenance by analyzing only the problematic part/area.
III. To enhance the efficiency of the fuel management system. (Fuel Economy, Fuel Theft Alarms).
IV. The principal advantages of a real-time system are that site operation can be monitored in real time, and with integrated tank gauging, fuel theft from tanks and short deliveries can be identified immediately.

1.10. SUMMARY

Vehicle Monitoring System is a system which makes sure that your engine gives you its maximum life possible, in other words increasing its efficiency.

It accesses the engine sensors, collects the data from the sensors, displays it to the operator on the screen, detects the problem or adjusts the faulty parameters in order to remedy the faults then checks whether what remedial action taken is sufficient or not if yes than ok and if not than it adjusts some other parameters or remaps the whole data on which the engine is running and continues testing unless and until the engine is brought to its best working safe condition.

Fuel management system helps in best and economic utilization of fuel and reduce the risks of fuel theft or fuel leakage if there is any, as the fuel is being consistently monitored.

CHAPTER 02

LITERATURE REVIEW: 01

Integrated Vehicle Monitoring, Maintenance and Management System (IV3MS)

2.1 INTRODUCTON

Integrated Vehicle Monitoring, Maintenance and Management System (IV3MS) is the unified capability of systems to access the current or future state of the member system health and integrate that picture of system health within a frame of available resources and operational demand.

As sensors are improved and the understanding of the systems concerned grew it became possible not only to detect failure but also to predict it.

Understanding IV3MS requires arriving at a common definition, one that captures all the facets of the system. IV3MS should not be treated as a standalone subsystem, added on the vehicle. Nor should a group of sensors and related instrumentation be considered IV3MS. From a software perspective, IV3MS is more than just fault models, algorithms and sensor processing software. While IV3MS utilizes these components to perform its intended function, a true IV3MS incorporates a philosophy, methodology and process that focuses on design and development for safety, operability, maintainability, reliability and testability.

To be most effective, IV3MS must be "designed in" to the target system (i.e, the vehicle and its supporting infrastructure) from the beginning of the program and not "added on" along the way.IV3MS must be elevated to the status of a system engineering discipline [1].

Integrated vehicle Monitoring, Maintenance and Management (IV3MS) is a collection of data relevant to the present and future performance of a vehicle system and its transformation into information that can be used to support operational decisions. The basic idea is that the vehicle should be capable of monitoring the health of its own systems, and play an active role in scheduling its own maintenance. This reduces the chances of experiencing an unexpected failure and increases the reliability and useful life of the vehicle. So before going into the details of IV3MS lets first discuss a system which is on-board in a vehicle, this system sets the tone for IV3MS, Engine management system [1].

2.2. COMPONENTS OF IV3MS

A method and apparatus for detecting abnormal behavior in a vehicle with an engine having engine control module includes providing a database, and a vehicle analyzer having a communication device and an interface that links the communication device to the vehicle. Engine parameters that are retrieved through the interface during driving experience are uploaded to the database using the communication device. The database analyzes the engine parameters from the multiple driving experiences to establish historical data and determine normal operation of the particular retrieved engine parameters based on the historical data.

IV3MS is concerned not just with the current condition of the vehicle but also with health across its whole life cycle. IV3MS examines the vehicle health against the vehicle usage data and within the context of similar information for other vehicles within the fleet. In use vehicles display unique usage characteristics and also some characteristics common across the fleet. Where usage data and system health data are available, these can be analyzed to identify the characteristics. This is useful in the Identification of problems unique to one vehicle as well as identifying trends in vehicle degradation across the entire fleet.

IV3MS is a concept for the complete maintenance life cycle of a vehicle. It makes extensive use of embedded sensors and self-monitoring equipment combined with prognostics and diagnostic reasoning. In the case of vehicles, it is typical for them to possess a data acquisition module on-board and a diagnostic unit. Some vehicles can transfer selected data back to base while in use through various systems. Whenever the vehicle is at base the data is also transferred to a set of maintenance computers that also process that data for a deeper understanding of the true health of the vehicle. The usage of the vehicle can also be matched to the degradation of parts and improve the prognostics prediction accuracy [1].

Various components of Integrated Vehicle Health Management System are:

1. Vehicle Health Monitoring System.
2. Communication.
3. Central Data Base.
4. Tech Center.

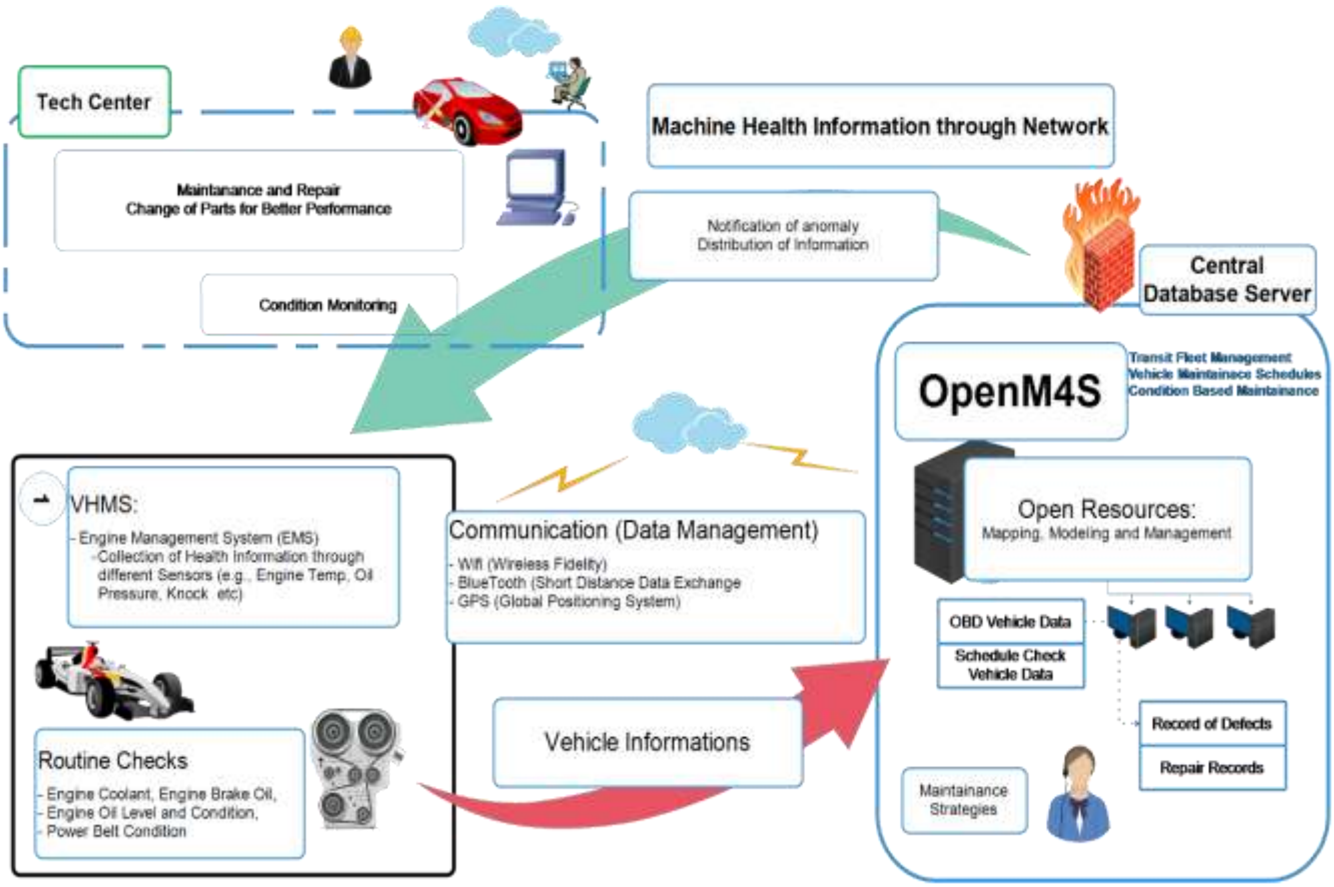

Figure 2. 1 IV3MS Flow Diagram *[1]*.

2.2.1. VEHICLE HEALTH MONITORING SYSTEM (VHMS)

The VHMS Controller is an onboard processor for collecting data and connected via a data communication network with the existing controllers for the engine, transmission gear, etc. There are cases in which other sensors are linked to the computer. Since there is no need to make any modifications to the existing controllers, the VHMS Controller can be installed even to an existing vehicle.

The VHMS Controller receives signals from other controllers and sensors as required to perform various types of processing, such as giving the date, stratifying data according to the degree of importance, totaling, averaging, and maximization/minimization of data, preparing frequency distribution, and performing the flight data recorder function (saving time-serial data before and after some trouble), and stores processed data in its internal memory.

The introduction of Electronic Control System (ECS) and sensors in vehicles has made it possible of the vehicles to monitor its own systems without relying on diagnosis based on the experience and institution of skilled mechanics [1].

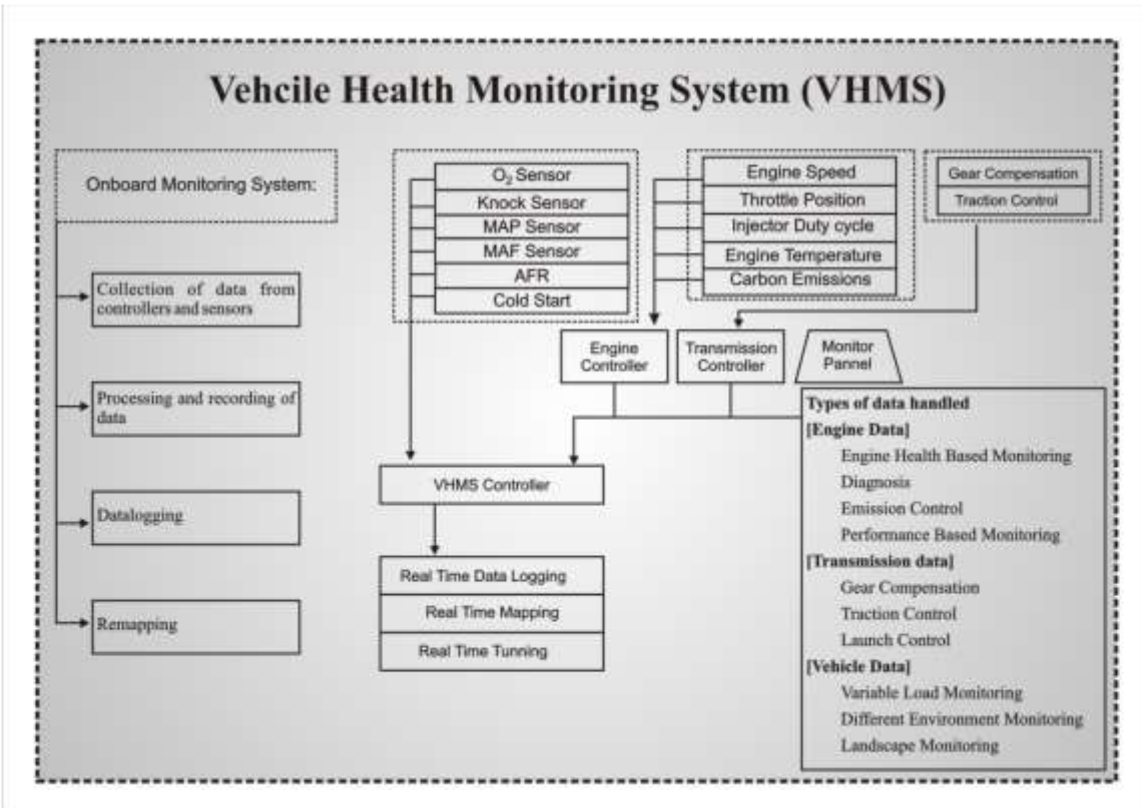

Figure 2. 2 Vehicle Health Monitoring System *[1]*.

VHMS is made of the combination of an Engine Management System (EMS) and sensors present in an engine. As discussed earlier that EMS sets the tone for IV3MS, and is proven as EMS is required in the very first component of IV3MS. The introduction of EMS and sensors in vehicles has made it possible for the vehicles to monitor its own systems without relying on diagnosis based on the experience and institution of skilled mechanics.

In VHMS data of different parameters can be collected from the sensors present in the vehicle. The sensors are a part of the EMS, information of various health parameters such as engine temperature, air-fuel ratio, throttle position, etc. are collected, which can further be used to analyze the vehicle’s health.

What the VHMS Controller monitors is limited to the main components which take much time and cost if they break down. Thus, the design concept is that the Controller leaves out unnecessary information as far as possible.

2.2.2. DATA TRANSFER

In modern vehicles the Electronic Control System (ECU), in Electronic Management System (EMS) controls most of the functions, such as calculating the amount of fuel required, the Air-Fuel Ratio etc. Due to this reason various sensors must be able to communicate their data with the ECU/EMS. A Controller Area Network (CAN bus) was devised to fulfill this need.

A CAN bus is a vehicle bus, (A vehicle bus is a specialized internal communications network that interconnects components inside a vehicle), standard designed to allow microcontrollers and devices to communicate with each other in applications without a host computer. Data from the sensors is sent to the ECU via the CAN bus.

The EMS utilizes the Controller Area Network (CAN) that links computers for electronic control of engine to acquire the sensor data. The data acquired in this way was automatically transmitted through a communication terminal to the dedicated server data base via the ground station at the optimum timing [1].

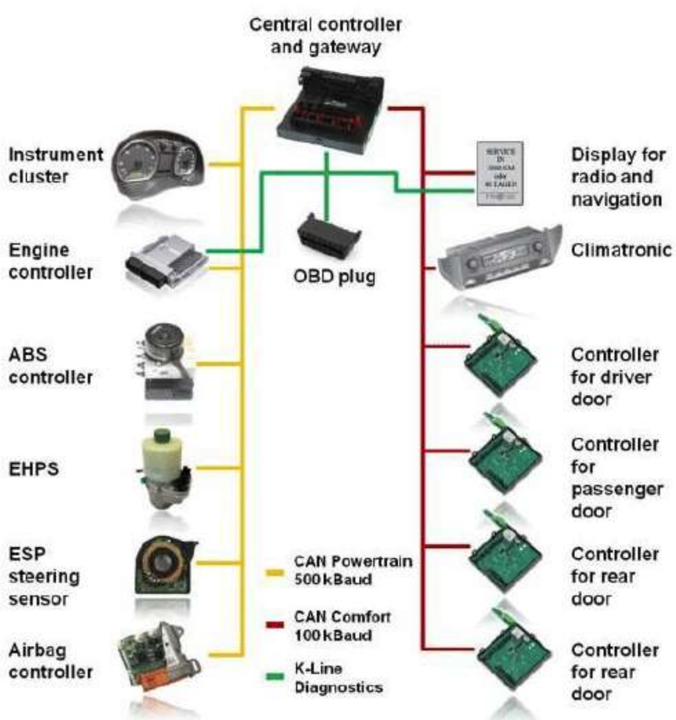

Figure 2. 3 CAN Bus *[1]*.

Communication is important because the data sent to the ECU by the sensors should be available to us in a compiled form in order to analyze it to predict the performance of the vehicle. The data sent to the ECU can be read from the OBD II port.

OBD II also known as On-Board Diagnostics is referring to a vehicle's self-diagnostic and reporting capability. OBD II systems give us access to the status of various vehicle subsystems. OBD II port is a sixteen-pin port present under the steering wheel of a vehicle; the vehicle's diagnostic data can be viewed connecting a scan tool to it. The scan tool used was ELM327.

The ELM327 is a programmed microcontroller for translating the On-Board Diagnostics (OBD II) interface found in most vehicles. It can be connected to a Smartphone via Bluetooth.

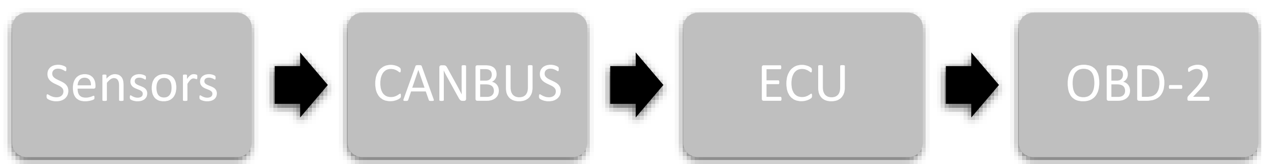

Figure 2. 4 Communication

2.2.3. CENTRAL DATA BASE (obdmechanicalproject.com.pk)

Formerly, the conditions of a vehicle were determined by periodical health examination using various diagnostic tools, oil analysis, maintenance and repair records, etc. By utilizing IV3MS it is possible to free the service personnel from the burdensome examination. As the monitored data is digitized and stored in data bases provided for the individual models and machine numbers, the service personnel can always monitor the latest data on the server. The web screen can display detail data by, for example, frequency of speed change, and error codes from the vehicle. In the central data-base the data is displayed and it is characterized for the ease of the service personal [1].

2.2.4. TECH CENTER

Once the data is analyzed and scheduled, the schedule is sent to the Tech Center. The Tech Center keeps all the previous records of the vehicle and should maintain an optimum level of spare part inventory in-order to prevent time loss whenever parts are required.

The repairs in a vehicle take place in the Tech center, after the repairs the vehicle is tested to ensure that the repaired parts work properly.

The condition of the vehicle is also monitored by the Tech Center. Condition monitoring is a process of monitoring a parameter of condition in machinery such as vibration or temperature, in order to identify a significant change which is indicative of a developing fault. Condition monitoring also helps in devising a maintenance schedule or other action in order to prevent failure. Condition monitoring benefits in conditions that would shorten normal lifespan can be addressed before they develop into major failure.

Once the data was analyzed it was scheduled, the schedule was sent to the Tech Center. Here the problems in the vehicle are isolated; the faulty parts are repaired or replaced. After the repairs the repair data was sent back to the Central Data Base, where it is stored so that the record is available if needed in the future [1].

2.3. SUMMARY

- Integrated Vehicle Monitoring, Maintenance and Management System (IV3MS) is the unified capability of systems to access the current or future state of the member system health and integrate that picture of system health within a frame of available resources and operational demands.
- Electronic control unit controls a series of actuators on an internal combustion engine to ensure optimal engine performance.
- Various components of Integrated Vehicle Health Management System are: Vehicle Health Monitoring System, (ii) Communication, (iii) Central Data Base, and (iv) Tech Center.
- The VHMS Controller is an onboard processor for collecting data and connected via a data communication network with the existing controllers for the engine, transmission gear, etc.
- In Communication the data sent to the ECU by the sensors should be available in a compiled form in order to analyze it to predict the performance of the vehicle. And from ECU it is communicated to central data base.
- In Central data base, the received data is displayed, analyzed, schedule and stored. The result of the analysis is shared with the tech center to take corrective actions.
- Tech center is workshop where along with specified task, routine check-ups are also carried out [1].

CHAPTER 03

LITERATURE REVIEW: 02

3.1. INTRODUCTION

The advent of vehicle management system (IV3MS) in the auto industry promises to provide significant new capabilities to enhance the overall customer ownership experience with their vehicles. In essence, it provides a means to essentially redefine "reliability" by being able to proactively deal with future problems before they actually inconvenience the customer and thus largely mitigate the negative impact of those problems. IV3MS provides an important building block upon which these innovative new features can be implemented. In addition, IV3MS provides an improved framework to better manage the life cycle maintenance for such vehicles which in turn provides an immediate saving opportunity for all vehicles. Traditional maintenance schedules in automotive use have typically been time or mileage based but this can lead to negative consequences in multiple ways. The maintenance intervals can be too conservative for some operating conditions and therefore potentially waste the owner's time and money as well as wasting valuable natural resources. On the other extreme, under certain operating conditions, the time or mileage-based approach may signal a maintenance action too late to avoid a service issue of some kind. By tracking actual usage patterns, the system can dynamically adapt the maintenance intervals to more appropriate periods based on the actual needs.

IVHM is all about active management of the automotive vehicle's health, as it relates to the performance of key vehicle functions, to meet the customer's need for reliable transportation. It is instructive to consider the broad ramifications of IVHM in the context of the new paradigm the auto industry has entered. This is important because the assumptions and limitations implicit in today's designs will simply no longer apply as this new paradigm takes hold [6].

Finally, areas including safety systems, fuel economy systems, emissions systems, or ones with sophisticated computer control are the target for advanced prognostics.

3.2. FUEL MONITORING SYSTEM VIA OBD-II

The fuel consumption of an automobile has to be improved in order to avoid global warming and to resolve energy resource issues. Therefore, various technologies related to an internal combustion engine have been researched, and are applied to series production automobiles. In today's world, the actual record of fuel filled and fuel consumption in vehicles is not maintained. It results in a financial loss.

OBD-II systems monitor the vehicle's electrical, mechanical, and emissions Systems and generate data that are processed by a vehicle's engine control unit (ECU) to detect malfunctions or deterioration in the vehicle's performance. Most ECU'S transmit status and diagnostic information over a shared, Standardized electronic buss in the vehicle. The buss effectively functions as an On-board computer network with many processors, each of which transmits and receives data [3].

Sensors that monitor the vehicle's engine functions (e.g., Spark controller, fuel controller) and power train (e.g. engine, transmission Systems) generate data that pass across the buss. Such data are typically stored in random-access memory in the ECU and include parameters, Such as vehicle speed (VSS), engine speed (RPM), engine load (LOAD), and mass air flow (MAF). Nearly all OBD compliant vehicles, however, report VSS, RPM, and LOAD.

3.3. METHODOLOGIES ALREADY IMPLEMENTED

1. Shut-Down Monitoring through using compatible computers connected through port to the ECU (Electronic Control Unit).
2. General Motors used On-Star Telematics System to monitor automobile performance in real time [7].
3. Boeing Adapted an Airplane health management (AHM) that uses remote analysis of real time airplane data to provide airlines and operators with the customized maintenance support [8].
4. US Navy have installed an ICAS (Integrated condition assessment system) on their ships that integrates with remote support to provide system level monitoring and performance trending for Condition Based Maintenance (CBM) [9].
5. Microcontroller Arduino is used by various other organizations around the globe to develop monitoring system related to fuel consumption for fuel economy optimization of vehicles and lessen the amount of carbon emission [3].

3.3.1. OVERALL DRAWBACKS OF THE MENTIONED METHODOLOGIES

1. All the methods other than Arduino are very expensive to be implemented on automobiles and brought to the use of normal Non-Tech customers.
2. They are also very complex and requires high level of expertise even for a common utility.
3. Apart from that they have not been tested on a common utility automobile.
4. In case of Arduino we have to provide an external circuit to Electronic Control Unit (ECU) which is not always suitable as it may burns sometime due shortage in wiring and to keep it in compact form is very difficult for person with little or no knowledge of Arduino.

3.3.2. BENEFITS OF USING OBD-II DEVICE

1. The device used for monitoring is very easy, simple “plug & play”.
2. It is very affordable for an average car user.
3. Nothing to be worried about the working chemistry of this device and no special configuration is to be remembered.
4. The end user will get the final result about the vehicle which will guide end user to decide whether further action needs to be taken or not and if yes then which sort of actions.

3.4. SCOPE OF OUR PROJECT

3.4.1. FUEL THEFT

Almost all of the public have their own vehicle. Now-a-days fuel theft is happening in the parking and vehicle security becomes a challenging thing. In practice by today no record of data is being maintained for fuel filled and its consumption value. To overcome this challenging problem a fuel monitoring system is being implemented. This task is being carried out by the use of embedded system based on Global System along with mobile communication technology. A system has been developed in which if fuel theft occurs, the system reports automatically via GSM module by sending message to server and from there this message is forwarded to the owner [3].

Another sector that is in dire need of embedded system like this is government sector where there is no fuel monitoring system and fuel theft is very easy in these organizations, so in order to keep an eye on the fuel consumption of the vehicles that are daily utilized by their officials this set-up is very helpful.

Same goes with the fleet management problems. The owners of the transportation companies need to know the fuel consumption of their vehicles to make sure that they are not being deceived by their employees/drivers.

3.5. AIMS AND OBJECTIVES

1. Here main focus is on the fuel consumption of the car, its efficiency and mileage it will cover with its present volume in the car tank.
2. Fuel theft can be detected if by any means it is carried out by any unauthorized person.
3. With the increasing duplicity day by day we can also verify the amount of the fuel added by the fuel station worker by cross-checking it with installed embedded system which is the combination of hardware and software.
4. For this purpose, OBD- II will be utilized which will send data to its interfacing application and from there, the data will be sent to the central server and so the values will be recorded and decision will be made by the analyst of the server.
5. With the receiving data to the server from the car through interfacing application of OBD-II, it will also help analyst be able to make operational decisions for the car’s maintenance strategies which will minimize the total cost and will take less time as compare to the preventive maintenance.

Chapter 04

METHODOLOGY

4.1. INTRODUCTION

Along with successful interface of the software/hardware IV3MS is equipped with more sophisticated and reliable sources to monitor the health of vehicle.

Such advances facilitate end user with the ability of remote monitoring, diagnosis and condition-based maintenance of automotive systems.

This invention discloses a system for measuring and monitoring the fuel consumption of an automobile in real time. The system comprises On-board equipment, roadside equipment and a monitoring center, wherein the On-board equipment is arranged in the automobile, is connected with an On-board self-diagnosis system by an On-board diagnosis (OBD) interface module to read fuel consumption information and automobile information, and calculates the total fuel consumption of an engine by a master control unit; and the roadside equipment reads the total fuel consumption of the automobile by wireless communication and transmits super-standard automobile information to the monitoring center. In the system and the method, data is read from the On-board self-diagnosis system, so the technology is simple and reliable and the detection accuracy is high; and the system and the method are applied to the fuel consumption detection of the automobile in any state to integrate the fuel consumption detection, maintenance and management of the automobile [10].

In this chapter the approach that have been opted for the fuel management system of automobile shall be discussed in detail.

Discussions like how data was acquired and analyzed in order to achieve vehicle health management and also to manage fuel system shall be disclosed.

Data acquisition system consist of sensors, data acquisition measurement hardware and a computer with the programmable software.

Analysis of data is the transforming of the acquired variables with the goal of digging useful information, suggesting conclusions, and supporting decision-making.

In short, the reader shall come to know at the end of this chapter that how goal was achieved and what methods have been applied in order to manage fuel system and also to maintain the health of vehicle properly by not allowing it to fall-down through proper monitoring and making rational decisions.

4.2. CAUSE AND EFFECT DIAGRAM

In a vehicle there are a number of parameters which contribute towards the health of a vehicle. The most common parameters are specified in the cause and effect diagram below.

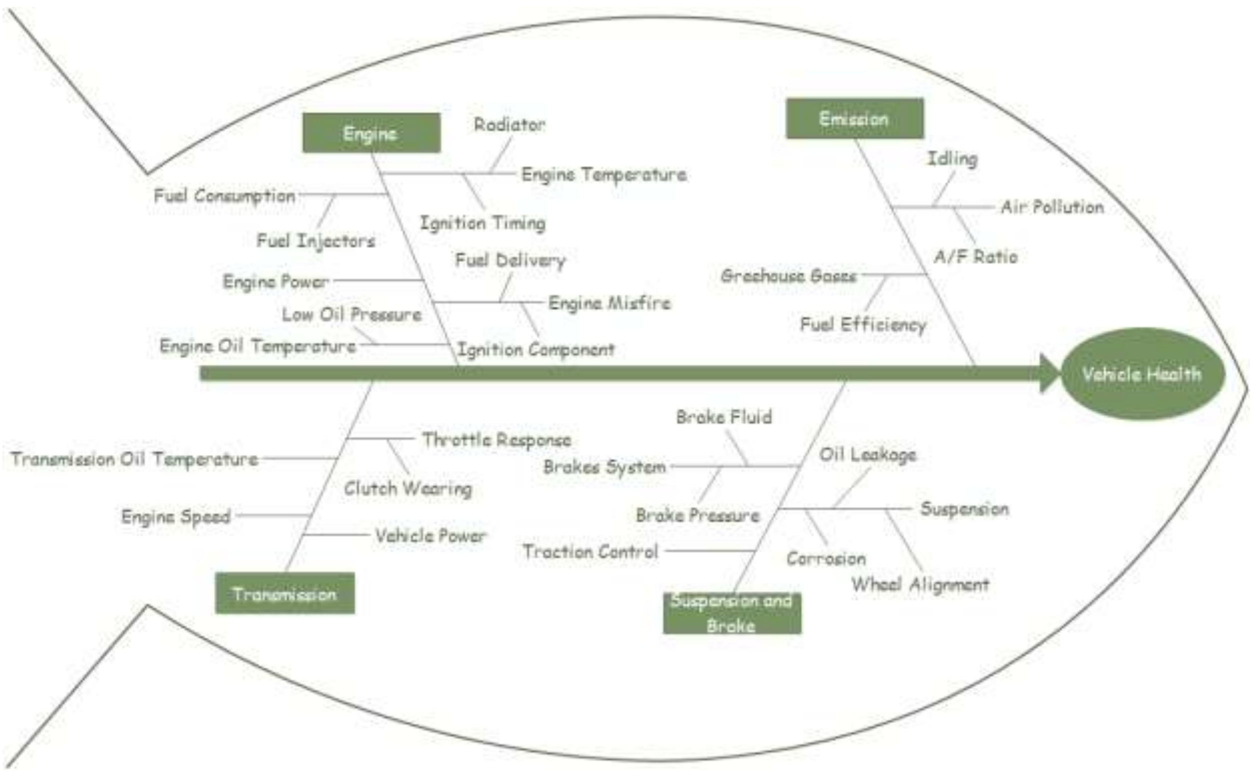

Figure 4. 1 Fishbone Diagram.

The health parameters are divided into four different class as seen in the diagram but the causes related to the engine health are the most crucial so they are given the most importance [1].

4.3. DATA ACQUISITION

Various sensors are installed in the vehicle that send data to the Electronic Control Unit (ECU) of the vehicle and so the ECU makes its decisions accordingly such as adjusting Air Fuel Ratio (AFR) of the vehicle according to speed and throttle position of the vehicle and so on.

Now in order to study these parameters and other parameters related to the fuel management such as remaining fuel, fuel efficiency, volumetric efficiency, distance covered in the trip the data is be send to the server where it can be monitored in the real time in order to make rational decisions regarding fuel management and vehicle health parameters.

The very basic overall look of the whole process can be graphically summarized as:

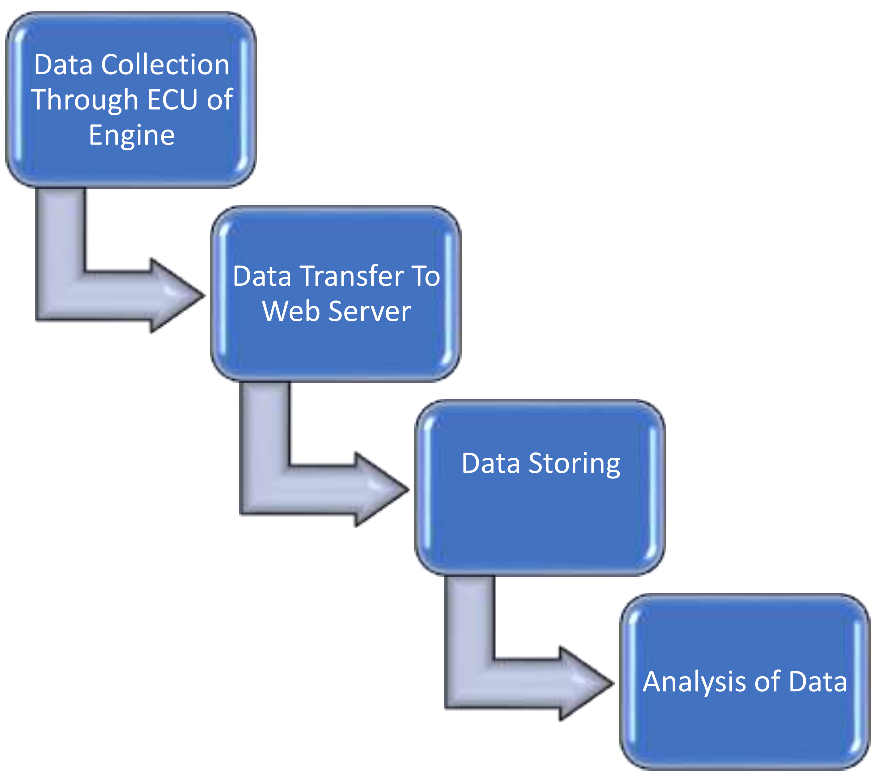

Figure 4. 2 Data Acquisition and Real time Monitoring.

Methods are explained in the chronological order.

4.3.1. DEVELOPMENT OF WEB SERVER

A web server was developed for this purpose in php language (Personal Home Page) that now stands for (Hyper Text Pre-Processor) in order to make the server dynamic in nature so to make it suitable for real time monitoring.

Dial-gauges of concern were embedded in that page through proper design and along with that different other parameters and primary design of the pages were achieved.

It was personalized as consumer friendly and with personal security login interface so that the data do not fall to wrong hands.

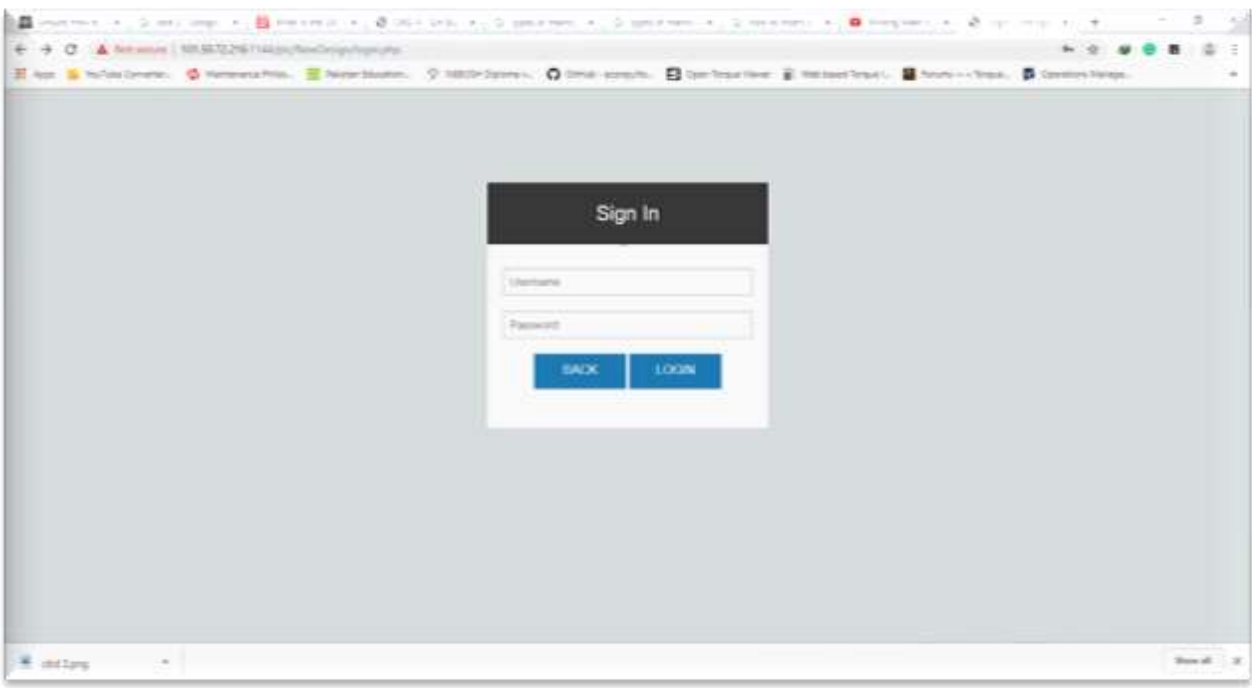

Figure 4. 3 Web server Login page.

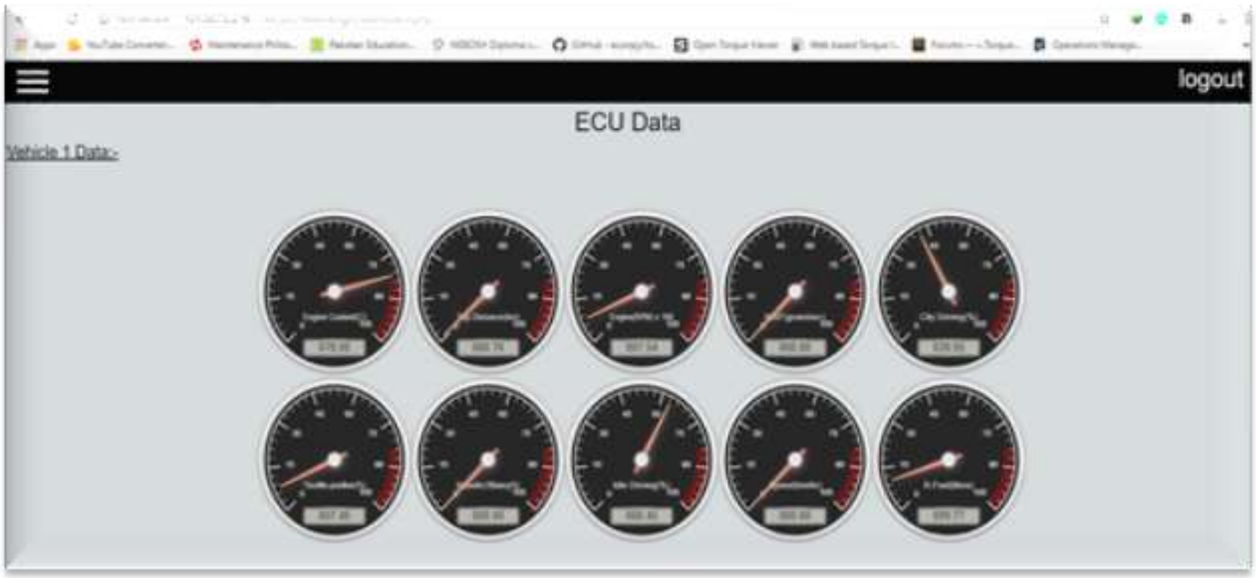

Figure 4. 4 Page 1st of Server showing different parameters.

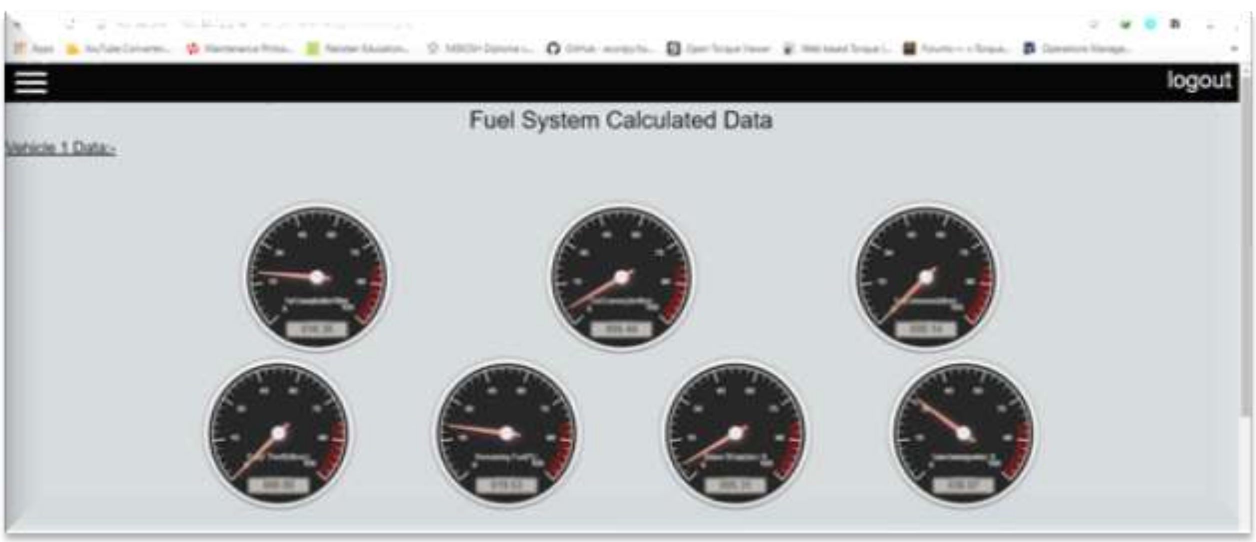

Figure 4. 5 Page 2nd of server with fuel parameters.

4.3.2. INTERFACE THE WEB SERVER WITH MOBILE APPLICATION (TORQUE)

Once the server is fully developed and the design of gauges and other parameters of concern is achieved, now it is time to interface the server with the torque application by providing the link of the server to the torque application so that the data could be sent to the server directly and shortly after the torque is connected to the Electronic Control Unit (ECU).

4.3.3. TRANSFER OF DATA FROM MOBILE APPLICATION (TORQUE) TO THE SERVER

Once the torque application is connected to the Electronic Control Unit (ECU) of the vehicle now the data is sent to the server through fast means of internet (3G or WIFI) and only the data of those parameters are sent which are of primary concern here.

The parameters include:

4.3.3.1. Basic Engine Parameters

1. Engine Revolution per Minute (RPM).
2. Engine Coolant Temperature (Degree Celsius, °C).
3. Trip Distance (Km's).
4. Mass Air Flow (MAF, g/s).
5. Throttle Position.
6. Idle Position.

4.3.3.2. Fuel Management Parameters

1. Fuel Consumption (liters/100km).
2. Fuel Economy (km's/liters).
3. Fuel Consumed (Liters)/Trip.
4. Fuel Theft (Liters).
5. Remaining Fuel (Percentage, %).
6. Distance till Empty (Km's).
7. Carbon Emission (gm/km).

4.3.4. CONNECTION OF TORQUE TO THE ENGINE ECU

The torque application is connected to the engine ECU through OBD device via Bluetooth. Once the OBD device is plugged in the vehicle and it starts blinking which means that it has started extracting data from the ECU, only then it can be connected with the torque application via Bluetooth connection. Once the connection is built up then data starts coming to the torque application and all the basic parameters can be monetized in real time on this application.

4.4. DATA ANALYSIS

Data analysis is the process of evaluating data using analytical and logical reasoning to examine each component of the data provided, in order to discover useful information that helps us in decision making and suggesting corrective actions.

Here in this case study the data of fuel related parameters were analyzed and decisions were made on the spot by using different algorithms and formulas related to the fuel from the standard automotive fuel management book whose reference is provided in the end.

The derivation of formulas and the establishment of standards for objective was achieved as follows:

4.4.1. CALCULATION OF FUEL CONSUMTION

1. The first step is that we obtain the Mass Air Flow (MAF) value from the ECU of Engine which is given in (gm/sec) units.

2. Convert the units to liters/hour, As:

$$1\ \frac{gm}{sec} = 3.60\ \frac{liters}{hr} \tag{1}$$

3. Then we convert the obtained RPM into m/s, As:

$$\frac{2\pi N}{60} * \frac{m}{s} = \frac{2\pi N}{60} * \frac{3600}{1000} * \frac{km}{hr} \tag{2}$$

$$= 0.37699 \text{ N} * \frac{km}{hr}$$

Where N = Vehicle Speed.

4. Once both the values are obtained then fuel consumption can be calculated as:

$$\text{Fuel Consumption} = \frac{fuel\ consumed\ (liters)}{Distance\ Travelled\ (km)} \tag{3}$$

$$= \frac{3.60\ liters/hr}{0.37699N * km/hr}$$

$$= \frac{9.55\ liters}{km} * \frac{MAF}{N}$$

5. For an Instant Fuel Consumption

$$\text{Instant fuel consumption} = 9.55 * 100 * \frac{MAF}{N} * \frac{liters}{100\ km's} \tag{4}$$

$$= 955 * \frac{MAF}{N} * \frac{Liters}{100\ km's}$$

6. For an Average Fuel Consumption

$$\text{Average fuel consumption} = \frac{Fuel\ Consumed\ (liters)}{Trip\ Distance\ (km's)} * 100 \tag{5}$$

4.4.2. CALCULATION OF FUEL ECONOMY

1. The obtained MAF value from the torque app via ECU of the vehicle is converted as

$$1\ \frac{gm}{sec} = 3.60\ \frac{liters}{hr} \tag{6}$$

2. Similarly, the obtained RPM value obtained is converted as

$$\frac{2\pi \mathrm{N}}{60} * \frac{3600}{1000} * \frac{km}{hr} \tag{7}$$

3. Now we can calculate the fuel Economy as

$$\text{Fuel Economy Instant} = \frac{\text{How much Km's travelled}}{How\ much\ Fuel\ is\ consumed\ (Liters)} \tag{8}$$

$$= \frac{0.3768 * N * \frac{km}{hr}}{3.60 * MAF * \frac{liters}{hr}}$$

$$= 0.104666 * \frac{N}{MAF} * \frac{km}{liter}$$

4. For an average economy

$$\text{Fuel Economy Average} = \frac{Trip\ Distance\ Covered\ (km's)}{\text{Fuel Consumed during Trip (liters)}} \tag{9}$$

4.4.3. DISTANCE TILL EMPTY

It is Calculated by Utilizing Fuel Economy Value and Trip Distance:

$$\text{Fuel Economy} = \frac{\text{Distance Covered (km's)}}{\text{Fuel Consumed (liters)}} \tag{10}$$

So,

$$\text{Fuel Economy} = \frac{\text{Remaining Distance (km's)}}{\text{Remaining Fuel (liters)}} \tag{11}$$

Eq-11 can be re-arranged as

$$\text{Remaining Distance} = \text{Fuel economy} * \text{Remaining Fuel} \tag{12}$$

$$= \frac{\text{km's}}{\text{liters}} * \text{Liters}$$

Remaining Distance = (kilometers)

4.4.4. CALCULATION OF FUEL THEFT

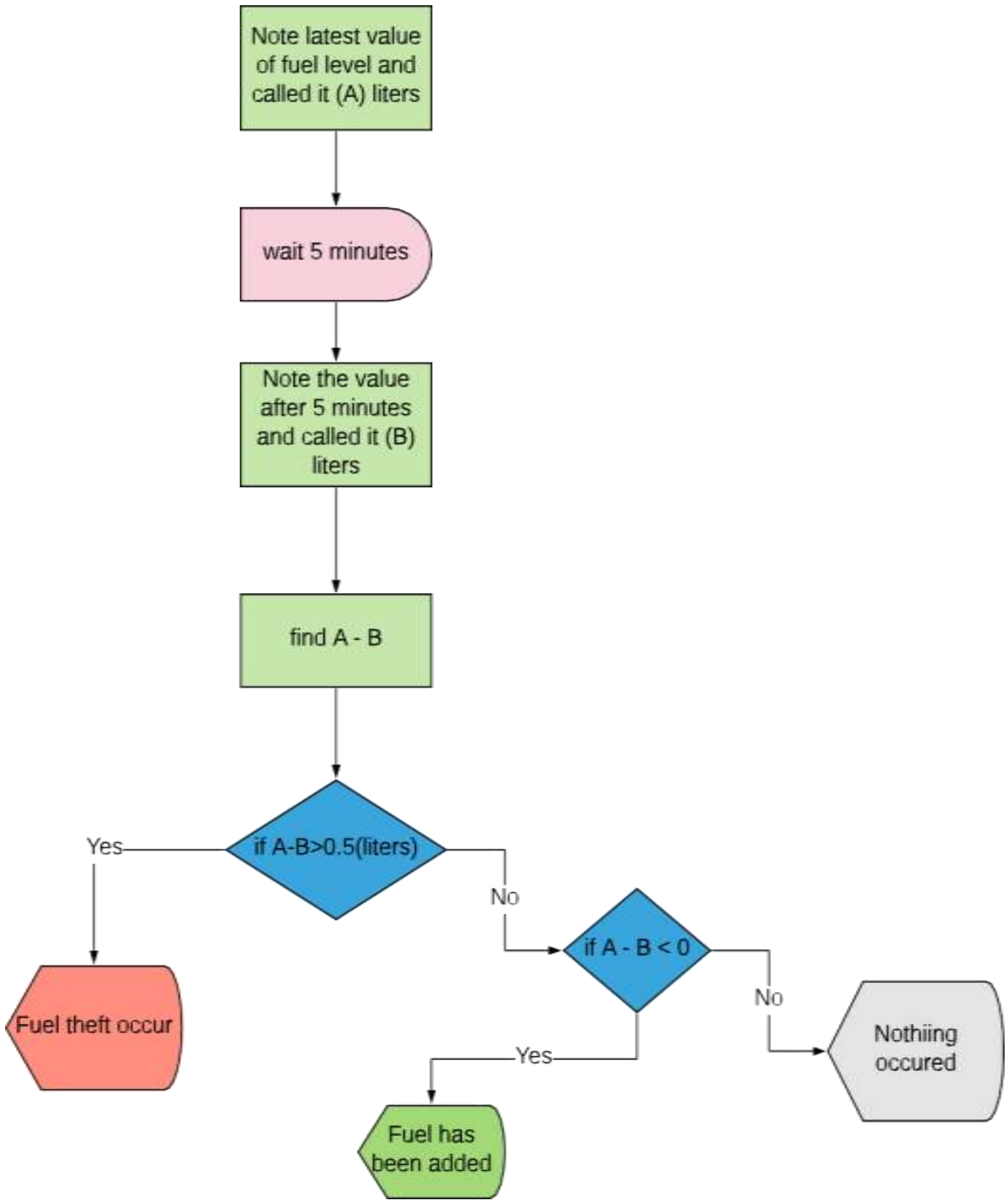

Figure 4. 6 Flow Chart for Fuel Theft.

4.5. DE-CODING OF PID VALUES FROM TORQUE APPLICATION AND THEIR RELEVANT PARAMETERS FOR DATABASE

Table 4. 1 PID Codes Decoded.

S.NO	PID CODE	PARAMETER (PID DE-CODED TO PARAMETER NAME)
01	K5	Engine Coolant temperature.
02	Kff1204	Trip Distance Covered.
03	KC	Engine RPM.
04	K10	MAF (Mass Air Flow).
05	Kff1269	Volumetric Efficiency.
06	Kff1269	% City Driving.
07	Kff126b	Remaining Fuel.
08	Kff1258	Carbon Emission (gm/km).
09	Kff126a	Distance till Empty (Km's).
10	e7c701	Remaining Fuel. (liters).

4.6. ENGINE SPECIFICATIONS

Subject Car **Honda Civic (VTI).**

Model **2005.**

Table 4. 2 Engine Specifications.

01	Cylinder Configuration	In-Line
02	Displacement	1493 cc
03	Engine Power	115hp@ 6200 RPM
04	Fuel System	EFI
05	Fuel Type	Petrol
06	No. of Cylinders	4
07	Torque	142 Nm@ 4200 RPM
08	Valves per Cylinder	4
09	Compression Ratio	9.3

CHAPTER 5

CASE STUDY DESCRIPTION AND THEIR RESULTS

5.1. INTRODUCTION

Once the entire set-up for test/objective is built and all the parameters of vehicle's concern are calculated through proper formulation. Now is the time that proper experimental test on setup shall be carried out in order to verify its validity, reliability and durability and to check whether it fulfills the required purpose or not.

5.2. CASE STUDY DESCRIPTION

As soon as all the parameters are received in real time on the server when connected to the vehicle via internet protocol, now we develop a case model for ourselves in order to verify the functionality of our project and to make management system of the vehicle possible by taking decisive decisions after receiving values from the vehicle and studying their relations and drawing results from them.

Case Models have been developed for this purpose and then on the basis of those case models the main objectives of this study were achieved i.e, Monitoring of the vehicle in real time and fuel management system of the vehicle.

5.2.1. STUDY MODELS

Limits for the parameters of concern are defined here and then whenever the values of parameters go below those limits, system will be notified as accordingly which is the result of different algorithms that have been embedded in the server.

The standards of limits are taken from published book which is universal to all vehicles and is accepted throughout the world. This book provides us with the standard limits of the fuel economy and fuel consumption which helps us in defining the goal of fuel management task.

Most of the Algorithms of fuel parameters has been developed previously in methodology chapter.

5.2.2. REMAINING FUEL MONITORING

Algorithm is developed for 8 liters still remaining in the tank as reservoir.

So, with (**IF**) statements:

- If the remaining fuel in tank is equal to or greater than 8 liters then display the value in **Green**.
- If the remaining fuel in tank is less than 8 by 2 liters then display the value in **Yellow**.
- If the remaining fuel in tank is less than 8 by 4 liters then display the value in **Red**.

In our case study upon monitoring and analyzing the amount of fuel in the fuel of subject comes out to be 14.5 liters which is greater than the set value of 8 Liters so, according to algorithm the value must be in **Green** mark. As it can be clearly verified from the result attached below that the value is marked in green color.

Numbers of vehicles	***VEHICLE HEALTH PARAMETERS***						
	Fuel Consumption		***Fuel economy***		***Remaining fuel***	***Fuel***	
	City	**Idle**	***City***	**Idle**		**Status**	**Amount**
Vehicle 1	13.7552liters/100km		7.63km/liter		14.5 liters	Nothing occurred	0 liters
	51.54%	48.53%	51.56%	48.50%			
Vehicle 2							

Figure 5. 1 Monitoring On server which shows the amount of fuel remaining.

5.2.3. Fuel Economy

So, up till now as its clear that the fuel economy shows simply the mileage of the vehicle i.e, how much kilometers is driven per liter of fuel.

For this Purpose, the standard limits for our subject car were calculated from fuel consumption guide.

Another Algorithm was developed in order to achieve the desired result:

The standard limit of fuel economy in combined (Highway and City Drive) from fuel guides available in markets for the subject car was

$$13\ \frac{km's}{liters} \tag{13}$$

So, again using (**<u>IF</u>**) conditions:

- If the value read by the OBD was greater (>) than 13 $\frac{km's}{liter}$, then Display the value on the server in **Green** color.
- If the value read by OBD was Less (<) than 13 $\frac{km's}{liter}$, then Display the Value on the Server in **Red** color.

The results were acquired upon having short trip distance of about 1 kilometer on subject car and the results are displayed accordingly.

So, upon testing it was analyzed that the value (Fuel Economy) displayed was about 7.63 $\frac{km's}{liter}$ that was less than the standard value for the subject car so, it was marked in **Red** color which ultimately leads us to the result that the subject car was inefficient in fuel consumption and needed some engine tune-up.

Numbers of vehicles	VEHICLE HEALTH PARAMETERS							
	Fuel Consumption		Fuel economy		Remaining fuel	Fuel		
	City	Idle	City	Idle		Status	Amount	
Vehicle 1	13.7552liters/100km		7.63km/liter		14.5 liters	Nothing occurred	0 liters	
	51.54%	48.53%	51.56%	48.50%				
Vehicle 2								

Figure 5. 2 The value (Fuel Economy) is marked in Red as it is less than the standard.

5.2.4. Fuel Consumption

The value of fuel consumption in combined (Highway and City Drive) of subject car from fuel guides came to be

$$7.1 \quad \frac{liters}{100\ km's} \tag{14}$$

So, again using (**IF**) conditions:

- If the value read by OBD is less (<) than 7.1 $\frac{liters}{100\ km's}$, then display the value on server in **Green** color.
- If the value read by OBD is greater (>) than 7.1 $\frac{liters}{100\ km's}$, then Display the value on server in **Red** color.

Upon receiving of the value to the server from the ECU of the car through OBD upon having a short trip of about 1 kilometer on the subject car, it was greater than 7.1 $\frac{liters}{100\ km's}$, i.e: 17.75 $\frac{liters}{100\ km's}$ So, the value was marked in **Red** color.

Numbers of vehicles	VEHICLE HEALTH PARAMETERS						
	Fuel Consumption		Fuel economy		Remaining fuel	Fuel	
	City	*Idle*	*City*	Idle		Status	Amount
Vehicle 1	17.7552liters/100km		5.63km/liter		24.5 liters	fuel theft occurred	-2.8179 liters
	51.54%	48.53%	51.56%	48.50%			
Vehicle 2							

Figure 5. 3 Fuel Consumption is marked Red.

Which also Leads us to the conclusion that the subject car needs engine tune-up immediately as the fuel economy was very low the fuel cost was raised much.

5.2.5. Fuel Theft

As we have already developed the algorithm for fuel theft in the previous chapter So, no is time to verify the algorithm by practical experimentations.

We in this regard have stopped the subject car and turned the engine Off which in turn ceased the connection of OBD and the server, So, the server stored the last value of Fuel Tank level that was sent by the OBD.

Now 2 Bottles of 1.5 liter each of fuel was extracted from the tank through fuel suction pipe and waited for approximately 10 minutes and after that turned the on the engine and let the OBD connection build up with the server.

As the server received the latest value of the fuel from the OBD, it showed the amount of fuel that was reduced from the last value stored in the server before turning engine off.

That amount was marked in **Red** Color. And the value was approximately 2.817 liters which is very close to what was extracted.

Numbers of vehicles	VEHICLE HEALTH PARAMETERS							
	Fuel Consumption		Fuel economy		Remaining fuel	Fuel		
	City	*Idle*	*City*	Idle		Status	Amount	
Vehicle 1	17.7552liters/100km		5.63km/liter		24.5 liters	fuel theft occurred	-2.8179 liters	
	51.54%	48.53%	51.56%	48.50%				
Vehicle 2								

Figure 5. 4 Fuel Theft is marked in red.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1. CONCLUSION

All the activities that are performed in order to predict the state of vehicle and if there is any error in the vehicle system IV3MS is designed to take the decisive steps in order to restore the vehicle system back to its normal functioning mode with the least amount of time consumed and with the less possible cost incurred upon.

The main objective was to enhance the vehicle fuel efficiency viewing to such raise in fuel prices these days and to stop any activities that could lead to fuel theft scenario which is very common in parking lots and lot of government sectors.

This system is designed to answer such questions and to provide better fuel economy to the vehicle by continuously monitoring the state of the vehicle back to back on server in real time.

IV3MS is potentially valuable strategy for the manufacture and management of vehicle platforms as currently there is a deep financial burden on the commercial and military markets to reduce the cost of the operation of vehicles and to make the operation safety priority so, to avoid any negative consequences in the time of operation of the vehicle.

Additionally, due to constant monitoring we can easily detect any problem in system before it becomes unbearable and costly and can easily take right steps in order to restore the system back to its functional mode.

IV3MS is seen to provide value in many things as with the help of this platform we can reduce unnecessary maintenance, unscheduled maintenance, and requires less need of routine inspection as it is constantly being monitored and above all the input of human is reduced due to artificial intelligence hence increases reliability, durability and maintainability of the system at lowest possible cost which is an important factor in market of such competition.

IV3MS is an important step towards the successful operation of vehicle throughout its life cycle and towards the ergonomics which has become the ultimate goal of every technology firm in such a diverse and advance era.

6.2. FUTURE WORK

- Integrated Vehicle Monitoring, Maintenance and Management (IV3MS) is an end to end capability that transforms system data into operational support information to help enable maintenance actions and also to enhance the fuel efficiency of the vehicle.
- The future endeavors of this project may be extended to ultimate monitoring of the total vehicle system and can easily be implemented on fleet system which will help the fleet owners to continuously monitor their assets/vehicles and hence increases the reliability of vehicles to owners.
- Tomorrow is the age of hybridization and high technology dependency. In this age every person is dependent on the technology and without the technology the world will be a place where living will be difficult.
- This system could also incorporate an automated text or mail delivery system for the owner of vehicle so that owner can be updated well in time and also periodically and thus enables the person to manage the health of the vehicle in proper time.

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