An

Industrial Internship Report

on

Telematics, Connected Vehicles, and Electric Vehicles

Submitted to

Symbiosis University of Applied Sciences (SUAS), Indore

Bachelor of Technology

in

Mechatronics Engineering

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India's First Skill University

DECLARATION

I hereby declare that the work, which is being presented in this industrial internship report entitled "**Telematics, Connected Vehicles and Electric Vehicles**" is an authentic record of work carried out by me.

The matter embodied in this report has not been submitted by us for the award of any other degree.

Abhishek Joshi

2019BTMT001

Symbiosis University of Applied Sciences, Indore
India's First Skill University

CERTIFICATE

This is to certify that the industrial internship report entitled "**Telematics, Connected Vehicles and Electric Vehicles**" was submitted to the School of Mechatronics Engineering, Symbiosis University of Applied Sciences, Indore by Mr **Abhishek Joshi** Enrolment number **2019BTMT001**, Bachelor of Technology in Mechatronics during the academic year 2019-23.

Supervisor **Head of the School**

Symbiosis University of Applied Sciences, Indore
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APPROVAL CERTIFICATE

This is to certify that the industrial internship report entitled "**Telematics, Connected Vehicles and Electric Vehicles**" was submitted to the School of Mechatronics Engineering, Symbiosis University of Applied Sciences, Indore by Mr **Abhishek Joshi** Enrolment number **2019BTMT001,** Bachelor of Technology in Mechatronics during the academic year 2019-23.

Signature of Internal Examiner **Signature of External Examiner**

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ACKNOWLEDGEMENT

The industrial internship at VE Commercial Vehicles Ltd. has been a life-changing experience. This incredible opportunity greatly helped me in expanding my knowledge and getting to know how to industrial world works. It helped me set new standards for myself and motivated me to achieve them with consistency and determination.

This internship provided me with the steppingstone toward working with highly skilled and experienced industry professionals and thriving under their unprecedented guidance. I would like to extend my sincere gratitude to my industry mentor, Mr Pramod Jagtap, for sharing his valuable ideas and enabling me to use the concepts that I learned in college in the real world. I also appreciated industrial exposure and everlasting practical experience under his guidance. I would also like to than, Mr Rakesh Mahali, Mr Shrikant Hiwase and Mr Dinesh Krishna who always helped me solve any challenge that I faced and considered me an integral part of their team.

I would also like to acknowledge the constant backing and guidance of all the Professors and staff of Symbiosis University of Applied Sciences for inspiring students to go through comprehensive internship training to get first-hand experience about how the industry works outside the books. I would particularly like to thank Dr Mamta Thakur and Dr Akshay Jain for their continuous support throughout this internship.

Lastly, I would like to show my appreciation to my internship colleagues for their frequent support and team spirit during the entire course of this training which made this internship an unforgettable experience.

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ABSTRACT

The internship report titled "Telematics, Connected Vehicles and Electric Vehicles" presents the experience and skills gained during my 6 months of training undertaken at VE Commercial Vehicles, India.

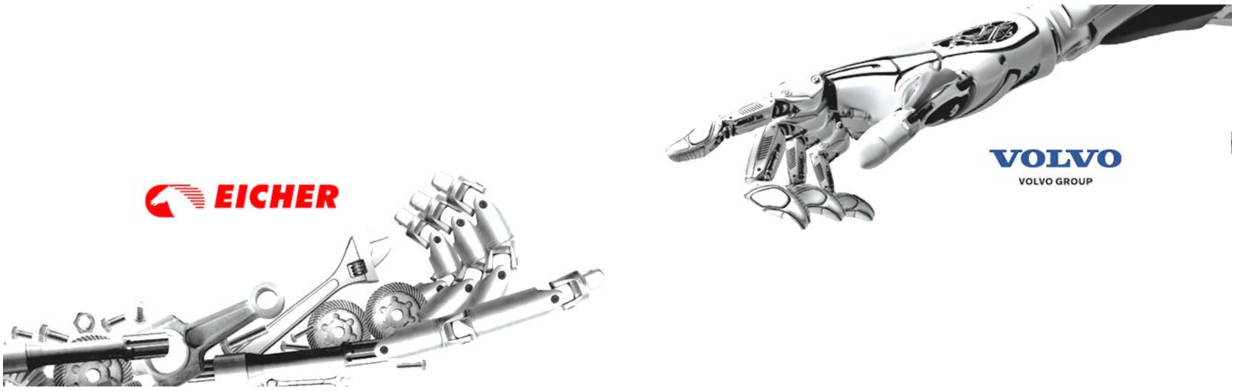
In VECV, I got the opportunity to work in the Sustainable Mobility and Advance Technology (SMAAT) department, which has given me a brief experience in Connected Vehicles, Telematics, Data Analytics, and the upcoming trends in Electric Vehicle technology.

During this period, I acquired practical knowledge, technical and research skills along with programming experience and engineering approach. I received tasks in data analytics for predictive maintenance and data validation. In addition to that, I worked on projects to automate these data analytics techniques using Python. I also got the opportunity to learn about the electric vehicle (EV) architecture, performance monitoring and telematics in EVs.

This report discusses the skills nurtured and experience enhanced during the internship, justifying the relevance of the scheme in equipping students with needed technical and interpersonal competence to thrive in the real world.

1. INTRODUCTION

VE Commercial Vehicles Limited (VECV) is a joint venture between the Volvo Group and Eicher Motors Limited. In operation since July 2008, VECV is a multi-brand, multi-division company comprising a complete range of Eicher Trucks and Buses, Volvo Buses, exclusive distribution of Volvo Trucks in India, engine manufacturing and export hub for Volvo Group, non-automotive engines and Eicher component business. VECV is also constantly introducing innovative technologies & services, through 9 manufacturing facilities spread across India, supported by a strong dealership network of over 500 outlets. The company is exporting to over 34 countries and is being recognized as an industry leader in driving modernization in commercial transportation in India and the developing world.



In 2008, two leading players, Volvo Group and Eicher Motors, in the commercial vehicle business joined hands with a common vision of driving modernization in the commercial transport business in India. Volvo Group comes with global expertise, leadership in product technology, well-defined processes, and a brand that is respected all over the world. Eicher Motors is a leader in the Light and Medium Vehicle segment and brings to the table frugal engineering, considerable after-sales infrastructure, and cost-effective operations. Together they complement each other and combine their strengths to deliver effective solutions that favourably impact the eco-system. This partnership has helped modernize and evolve the industry in India and many other countries with emerging markets.

The company includes the complete range of Eicher branded trucks and buses, Volvo buses, exclusive distribution of Volvo Trucks in India, engine manufacturing and exports for Volvo Group, non-automotive engines and Eicher component business. A multi-brand, multi-division company, backed by innovative products & services, VECV today, is recognized as an industry leader in the CV industry.

VECV offers a range of ultra-modern trucks across 4.9-55T, along with a wide range of safe and efficient buses with a seating capacity of 12- 72 across light, medium, and heavy-duty applications.

The world of commercial vehicles is always on the move, be it new emerging markets, state-of-the-art infrastructure, new policies, and the aspirations of customers. And VECV is always ahead with a continuous transformation of a holistic ecosystem that is based on progressive thinking, advanced technology, and unshakable values. This keeps VECV miles ahead of the rest.

Eicher Trucks and Buses completed 34 years of operations in India in June 2020. The first Eicher truck was rolled out from its manufacturing plant in Pithampur, Madhya Pradesh in 1986, and over the past years, the products have got endorsement from hundreds of thousands of happy customers. The plant is spread over 87 acres of land with a current installed capacity of 90,000 vehicles per annum, producing over 1000 vehicles per acre.

- Highly flexible, lean, and agile environment delivering high-quality trucks, Engines, and bus Chassis
- Smart factory with the right blend of automation, produces 1000 vehicles per acre.
- Certified for Integrated Management System – encompassing Quality, Health & Safety, Environment, and Energy Management system
- Volvo Production System as a base for Manufacturing Operation
- The plant has a fully equipped vehicle and engine development centre with fatigue lab, complete virtual vehicle integration capability and Simulation Lab.

1.1 PRODUCTS

Eicher Trucks and Buses have the lineage of three decades of operations in India. Adopting the most professional and holistic approach to modernize the Indian trucking industry, Eicher promises to deliver best-in-class fuel efficiency, higher loading capacity, superior uptime, and overall vehicle lifetime profitability. Eicher Trucks and Buses (ETB) is present in the LMD range with a strong presence in the 4.9T-16T truck segment, an ever-increasing market share in the 19T-55T heavy duty trucks segment and market leadership in the school bus segment. In 2020, Eicher unveiled its entire BS-VI range of trucks and buses across 4.9- 55T tagged with Eicher's innovative BS VI solution - EUTECH6 and also became the first CV player to offer 100% connected product range.

- **SUB-5 TON (LIGHT AND MEDIUM DUTY: LMD)**

The iconic sub-5T mini truck is here to rule the Indian truck industry for years to come with its best-in-class mileage and revolutionary driver comfort. With Eicher's EUTECH6 technology and the shortest TCD in the segment, it is miles ahead of its competition and truly a 'last mile delivery ka Badshah.

- **LIGHT DUTY (LMD)**

Eicher's light duty trucks with EUTECH6 technology are truly the 'profit ka Badshah' with their best-in-class mileage and highest payload carrying capacity. Ranging from 5.4 t to 11.1 t GVW, its revolutionary driver comfort puts it miles ahead of the curve for the years to come. The new Badshah of the roads, the series of trucks promises to make you the Badshah of your business.

- **MEDIUM DUTY (LMD)**

Eicher's medium-duty trucks with EUTECH6 technology is a revolutionary range of trucks with the Pro 2000 series and Pro 3000 series. Equipped with the next-gen engine and 7-speed gearbox, they are truly the most advanced series of trucks. Ranging from 12 t to 16 t GVW, its revolutionary driver comfort puts it miles ahead of the curve for the years to come.

- **TIPPER (LMD)**

Eicher's LMD tippers with EUTECH6 technology are the most advanced series, keeping in mind both owner and driver needs. Pro 2000 series tippers ranging from 6.9 t to 13 t GVW, are suitable for all tipper applications with 2.8 Cu M to 6.5 Cu M capacity and a high-grade ability. With sturdy and rugged aggregates and a rigid canopy, they are truly a 'business ka Badshah.

- **HAULAGE (HEAVY DUTY: HD)**

The new range of BS VI Eicher Pro Heavy Duty rigid trucks, available from 18.5-47.5 t GVW, is designed and developed to provide an unparalleled business advantage by maximizing product performance right through the life cycle of the vehicles and minimizing the cost of operations making these trucks Profitable for Life.

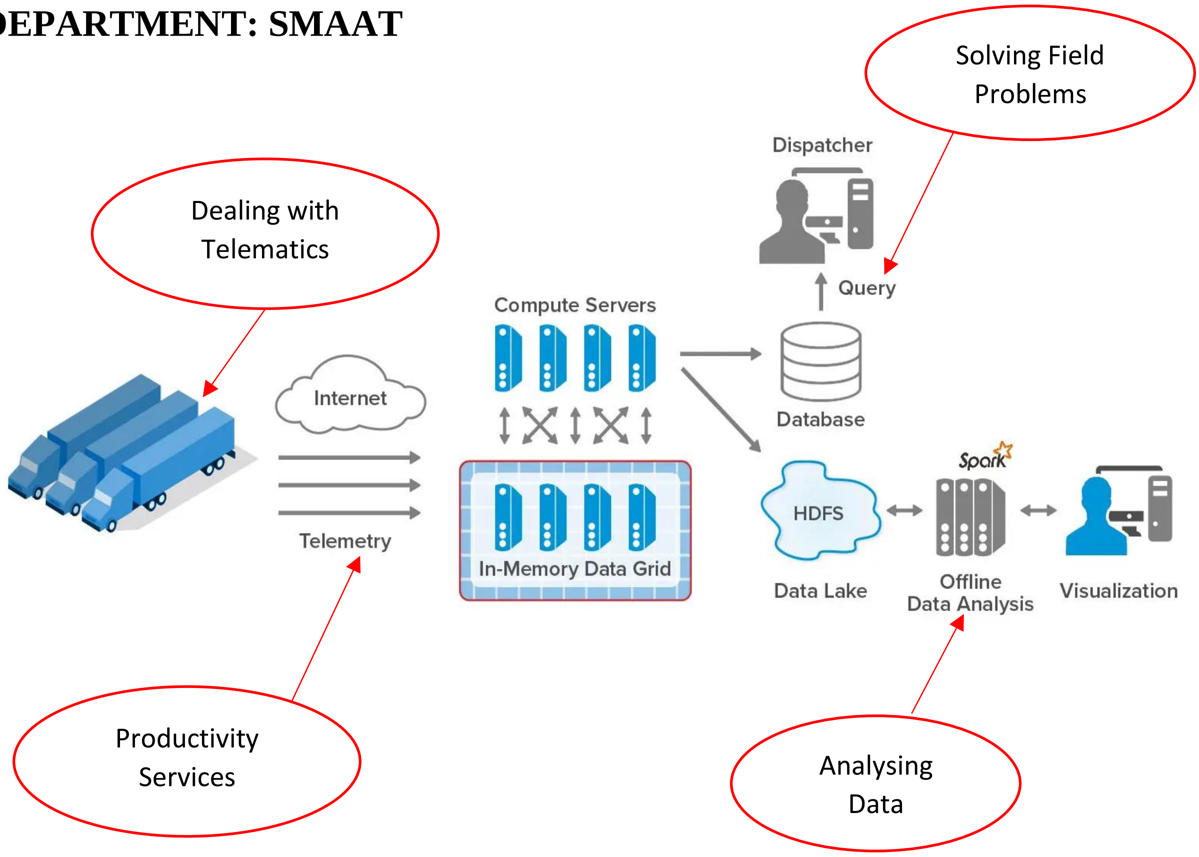
- **TIPPER (HD)**

The new Eicher Pro Range of BS-VI Tipper series is the next-gen range of construction and mining tippers from 18.5 T to 35 T GVW set to create benchmarks for performance, reliability, and higher productivity redefining the trucking experience with its overall lifetime profitability.

- **TRACTOR TRAILERS (HD)**

The new range of BS VI Eicher Pro Heavy Duty tractor trailers, available from 39.5-55 t GCW, is designed and developed to provide an unparalleled business advantage by maximizing product performance right through the life cycle of the vehicles and minimizing the cost of operations making these trucks *Profitable for life.*

2. DEPARTMENT: SMAAT



SMAAT (Sustainable Mobility and Advance Technology) department is an essential part of the Product Design and Development (PDD) Department which deals with research, development, and implementation of advanced technology in VECV vehicles to achieve the goal of improved quality, customer satisfaction as well as abiding government norms.

SMAAT department primarily deals with advanced technology (Electromobility and Connected Vehicles) which helps in connecting the vehicle to the customer as well as Eicher IT teams for exchange of valuable information 24x7. The telematics devices directly send us data which helps in analysis based on real-world conditions for resulting in better outcomes for predictive maintenance, etc.

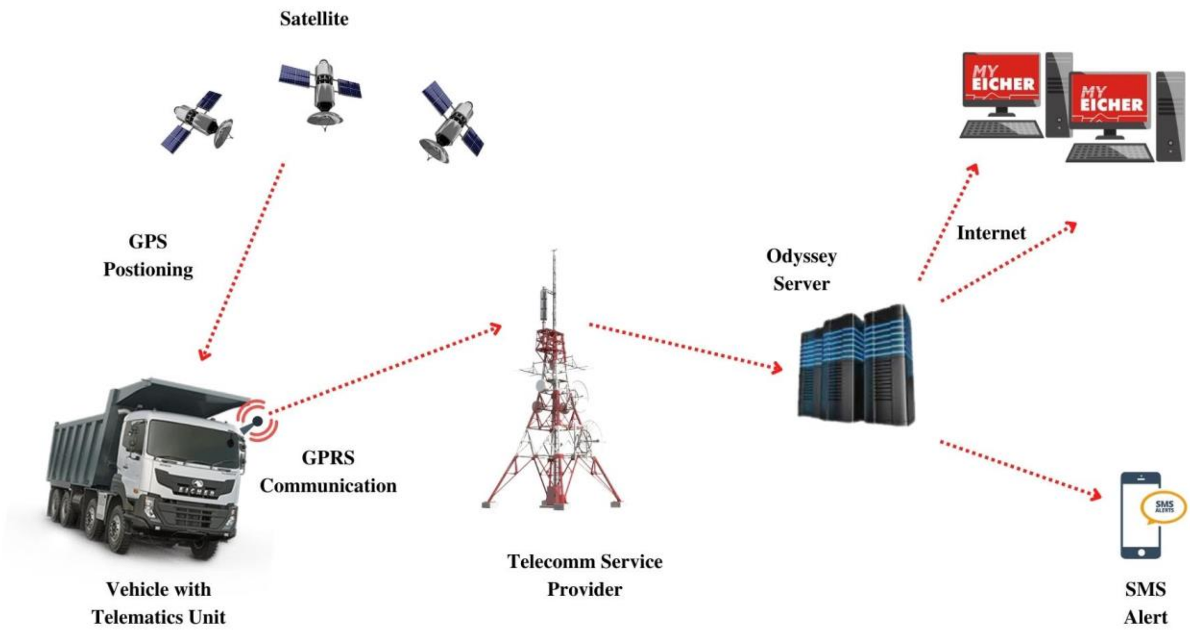
With the introduction of Eicher live, our team is constantly working to make our telematics system more reliable and informative day by day.

Besides telematics, our team is also working on several other projects which include ADAS (Advance Driver Assistance System), Electromobility, FOTA (Firmware Over the Air), Digital Twin, TLS (Transport Layer Security) Devices, and many more.

3. VEHICLE TELEMATICS SYSTEM

A vehicle telematics system includes vehicle telematics devices, which are tracking devices installed into vehicles that facilitate the transmission and storage of telemetry data via wireless networks and the vehicle's own onboard modem and diagnostics (ODBII). Telecommunications companies manage the transmission of information from the vehicle and telematics provider to computers or mobile devices that can be accessed by drivers and fleet telematics managers.

Vehicle telematics providers typically offer a combination of IoT vehicle telematics solutions, cloud, hardware, and software solutions, including GPS tracking, cloud-based platforms with easy integration for multiple partners, telematics sensors, fleet management software, a streamlined and accessible dashboard with visualizations, reporting capabilities, automated and configurable notifications and alarms, compliance parameters, and real-time Artificial Intelligence integration for early warnings and instant insights.



Telematics devices collect and then transmit GPS and vehicle-specific data via General Packet Radio Service (GPRS), 4G and cellular networks, or satellite communication to a centralized server, where the data is categorized, interpreted, and optimized for consumer user interfaces.

Modern commercial vehicle manufacturers typically embed automotive telematics technology directly into fleet vehicles. Aftermarket GPS devices are also available for installation.

Telematics data typically includes such factors as fuel consumption, idling time, location, speed, sharp acceleration or braking, and vehicle faults. Benefits of vehicle telematics analytics include decreased fuel costs, improved driver safety, increased productivity, improved vehicle visibility through precise tracking, data-driven vehicle maintenance schedules, maintaining ELD (Electronic Logging Device) compliance, and more precise payroll management.

3.1 NEED FOR VEHICLE TELEMATICS SYSTEM

- **Reducing operational costs**—Telematics software can help keep drivers updated on upcoming traffic concerns or road hazards, offer rerouting options and locate preferred gas stations—all of which can contribute to maximum fuel efficiency and lowered operational costs.

- **Encouraging safe driving**—Because telematics software detects driving behavior, employees will be even more motivated to follow safe driving practices and meet organizational standards. In addition, this technology allows employees to better monitor their individual driving habits and detect flaws that they might not have realized otherwise. In some cases, employers can send immediate in-cab alerts to correct dangerous behaviours in real-time. What's more, fleet managers can use the data that telematics collects to personalize driver coaching, helping employees actively address potentially dangerous driving behaviour.

- **Fostering employee engagement**—Drivers spend much of their workday confined to a vehicle with minimal communication opportunities, which can be harmful to both their physical and mental health. By implementing telematics software in your fleet, drivers will have an increased ability to digitally communicate and interact with others (e.g., their supervisor, co-workers, and dispatchers) regarding travel progress, road conditions, delivery requests, or vehicle concerns.

- **Bolstering fleet security**—Due to advanced tracking and communication features, telematics software can also help keep your fleet safe and secure in an emergency. For example, you can utilize telematics tracking to detect the location and route of any stolen vehicles—thus simplifying the vehicle recovery process. What's more, many forms of telematics software allow you to implement advanced security features in each vehicle, such as requiring the driver to enter a passcode before driving to reduce the risk of theft altogether. Apart from preventing theft, telematics software can also help drivers quickly alert the proper authorities and share their exact location in the event of an accident on the road.

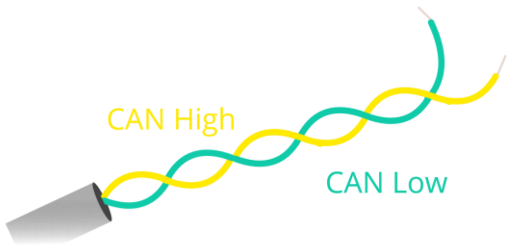
- **Ensuring vehicle maintenance**—Telematics software can detect a wide range of vehicle breakdown or maintenance problems, such as engine issues or diagnostic concerns. From there, this technology can inform the driver of the problem and locate the nearest repair centre or garage. Also, telematics software can be programmed to inform drivers of routine maintenance requirements, such as an oil change or tire pressure check. Many employers pair telematics with a preventive maintenance program to streamline the upkeep of the fleet.

- **Reducing administrative costs—**Telematics allows employers to digitize records that would otherwise have to be maintained manually, which can be a time-consuming process. Specifically, through telematics, employers can generate reports regarding expenses, driver performance, maintenance, and fuel expenses, thus simplifying a business's recordkeeping practices overall.

Thus, the telematics gateway enables remote monitoring of on-vehicle equipment. It can set alarms and send alerts via email or text to enable immediate action. This includes alarms for over-temperature, low fuel, low oil pressure, and other vehicle data. These parameters are received via the integrated CAN Bus interface.

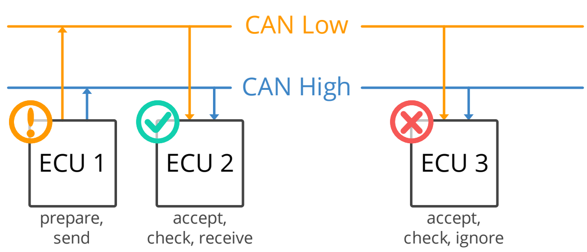
3.2 INTRODUCTION TO CONTROLLER AREA NETWORK (CAN)

Controller Area Network (CAN) is a serial network technology that was originally designed for the automotive industry, especially for European cars, but has also become a popular bus in industrial automation as well as other applications. The CAN bus is the **nervous system**, enabling communication. The CAN bus is primarily used in embedded systems, and as it is a network technology that provides fast communication among microcontrollers up to real-time requirements, eliminating the need for the much more expensive and complex technology of a Dual-Ported RAM.



CAN is a two-wire, half duplex, high-speed network system, that is far superior to conventional serial technologies such as RS232 regarding functionality and reliability, and yet CAN implementations are more cost-effective.

The CAN bus system enables each ECU to communicate with all other ECUs - without complex dedicated wiring. Specifically, an ECU can prepare and broadcast information (e.g. sensor data) via the CAN bus (consisting of two wires, CAN low and CAN high). The broadcasted data is accepted by all other ECUs on the CAN network - and each ECU can then check the data and decide whether to receive or ignore it.

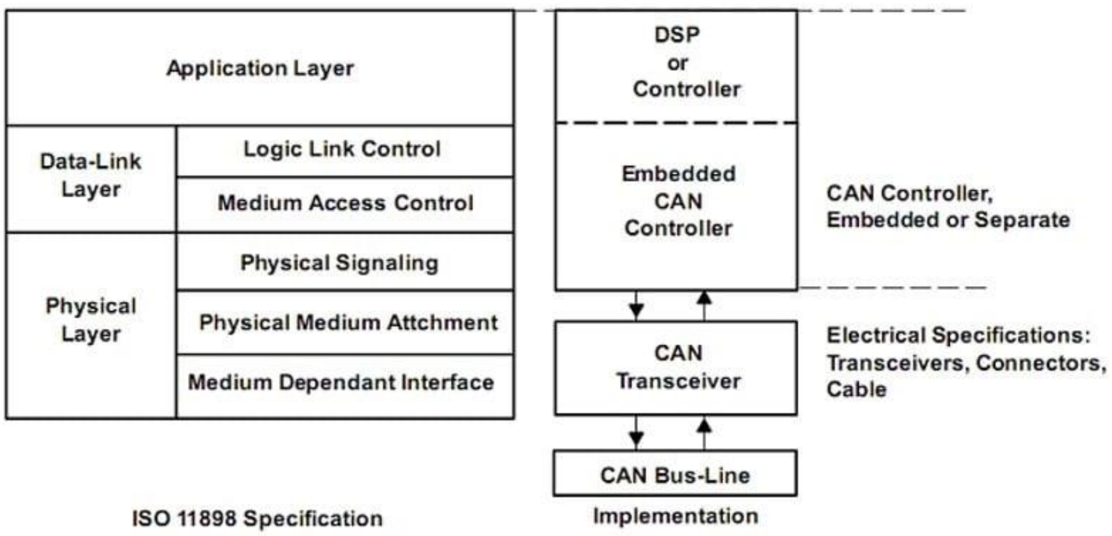


CAN is based on a broadcast communication mechanism. CAN is a peer-to-peer network. This means that there is no master that controls when individual nodes have access to read and write data on the CAN bus. When a CAN node is ready to transmit data, it checks to see if the bus is busy and then simply writes a CAN frame onto the network. The CAN frames that are transmitted do not contain addresses of either the transmitting node or any of the intended receiving node(s). Instead, an arbitration ID that is unique throughout the network labels the frame. All nodes on the CAN network receive the CAN frame, and, depending on the arbitration ID of that transmitted frame, each CAN node on the network decides whether to accept the frame.

If multiple nodes try to transmit a message onto the CAN bus at the same time, the node with the highest priority (lowest arbitration ID) automatically gets bus access. Lower-priority nodes must wait until the bus becomes available before trying to transmit again. In this way, you can implement CAN networks to ensure deterministic communication among CAN nodes.

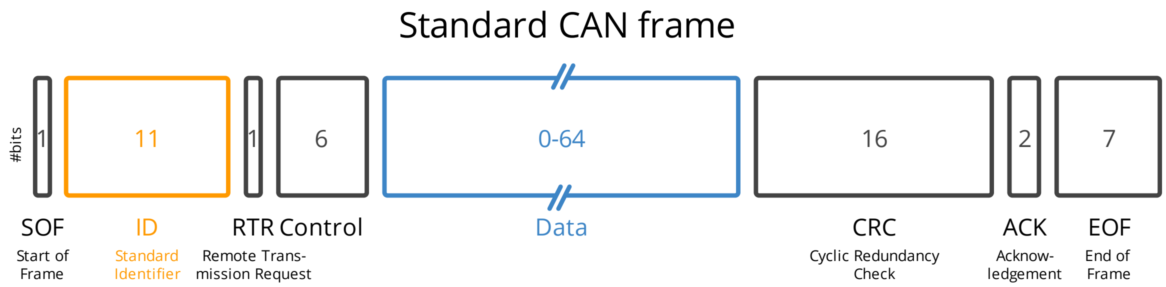
The layered architecture consists of three layers

- **Application Layer**: It interacts with the operating system or the application of the CAN device.
- **Data Link Layer**: It connects the actual data to the protocol in terms of sending, receiving, and validating data.
- **Physical Layer**: It represents the actual hardware.



3.2.1 CAN FRAMES

A CAN network can be configured to work with two different messages (or "frame") formats: the standard or base frame format (described in CAN 2.0 A and CAN 2.0 B), and the extended frame format (described only by CAN 2.0 B). The only difference between the two formats is that the "CAN base frame" supports a length of 11 bits for the identifier, and the "CAN extended frame" supports a length of 29 bits for the identifier, made up of the 11-bit identifier ("base identifier") and an 18-bit extension ("identifier extension"). The distinction between CAN base frame format and CAN extended frame format is made by using the IDE bit, which is transmitted as dominant in case of an 11-bit frame and transmitted as recessive in case of a 29-bit frame. CAN controllers that support extended frame format messages are also able to send and receive messages in CAN base frame format.

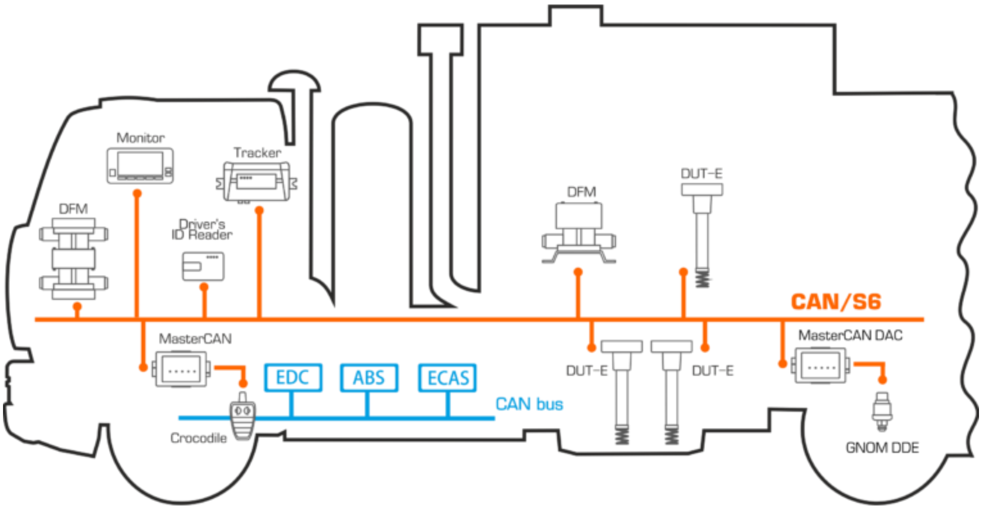


The 8 CAN BUS protocol message fields

- SOF: The Start of Frame is a 'dominant 0' to tell the other nodes that a CAN node intends to talk
- ID: The ID is the frame identifier - lower values have higher priority
- RTR: The Remote Transmission Request indicates whether a node sends data or requests dedicated data from another node
- Control: The Control contains the Identifier Extension Bit (IDE) which is a 'dominant 0' for 11-bit. It also contains the 4-bit Data Length Code (DLC) that specifies the length of the data bytes to be transmitted (0 to 8 bytes)
- Data: The Data contains the data bytes aka payload, which includes CAN signals that can be extracted and decoded for information
- CRC: The Cyclic Redundancy Check is used to ensure data integrity
- ACK: The ACK slot indicates if the node has acknowledged and received the data correctly
- EOF: The EOF marks the end of the CAN frame

3.2.2 SAE J1939

The SAE J1939 communications network is developed for use in heavy-duty environments and is suitable for horizontally integrated vehicle industries. The SAE J1939 communications network is applicable for light-duty, medium-duty, and heavy-duty vehicles used on-road or offroad, and for appropriate stationary applications which use vehicle-derived components (e.g., generator sets). In short, SAE J1939 is a set of standards that define how ECUs communicate via the CAN bus in heavy-duty vehicles.



The architecture of CAN J1939 telematics interface is based on the idea of single cabling system, physical interfaces, and protocols:

- physical interface CAN 2.0B is used for data transfer between on-board units
- data transfer sequence is defined by Data Link Layer in accordance with the requirements of SAE J1939/21 standard
- parameters, structure, and content of transferred data are defined by Vehicle Application Layer per SAE J1939/71

3.2.3 PARAMETER GROUP NUMBERS (PGN)

SAE J1939 is a very ingeniously designed protocol that takes a resourceful advantage of the CAN 29-Bit message identifier. Rather than relying on a myriad of protocol functions, SAE J1939 uses predefined parameter tables, which keep the actual protocol on a comprehensible level.

Parameters groups are, for instance, engine temperature, which includes coolant temperature, fuel temperature, oil temperature, etc. Parameter Groups and their numbers (PGN) are listed in SAE J1939 (roughly 300 pages) and defined in SAE J1939/71, a document containing roughly 800 pages filled with parameter group definitions plus suspect parameter numbers (SPN). In addition, it is possible to use manufacturer-specific parameter groups.

Parameter Groups

Parameter Groups contain information on parameter assignments within the 8-byte CAN data field of each message as well as repetition rate and priority.

The following is an example of a parameter group definition as listed in SAE J1939/71:

- PGN 65262 - Engine Temperature
    - Transmission Rate: 1 sec
    - Data Length: 8 bytes
    - Default Priority: 6
    - PG Number: 65262 (FEEEhex)

- Description of Data
    - Byte 1: Engine Coolant Temperature – SPN 110
    - Byte 2: Fuel Temperature – SPN 174
    - Byte 3, 4: Engine Oil Temperature – SPN 175
    - Byte 5, 6: Turbocharger Oil Temperature- SPN 176
    - Byte 7: Engine Intercooler Temperature - SPN 52
    - Byte 8: Engine Intercooler Thermostat Opening - SPN 1134

PGN Range

Program Parameter Numbers (PGNs) are in a range of:

- 0x0000 – 0xEEFF: 239 Peer-to-Peer messages defined by SAE
- 0xEF00 – 0xEFFF: 1 Peer-to-Peer message for proprietary use
- 0xF000 – 0xFEFF: 3840 Broadcast messages defined by SAE
- 0xFF00 – 0xFFFF: 256 Broadcast messages for proprietary use

3.2.4 SUSPECT PARAMETER NUMBERS (SPN)

A Suspect Parameter Number (SPN) is a number assigned by the SAE to a specific parameter within a parameter group. It describes the parameter in detail by providing the following information:

- Data Length in bytes
- Data Type
- Resolution
- Offset
- Range
- Reference Tag (Label)

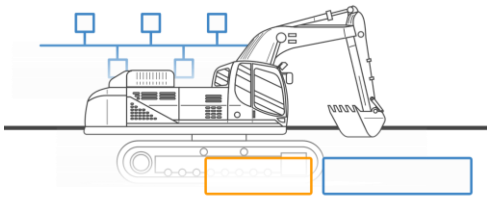
SPNs that share common characteristics are grouped into Parameter Groups (PG) and they will be transmitted throughout the network using the Parameter Group Number (PGN).

To follow up on the previous example (PGN 65262), the parameter Engine Coolant Temperature is described by SPN 110 in the following way:

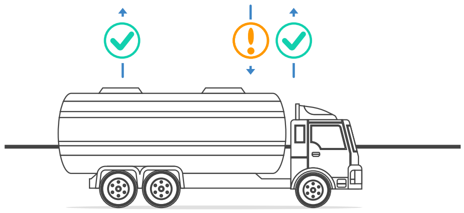
i. Data Length: 1 Byte
ii. Resolution: 1 deg C / Bit
iii. Offset: -40 deg C
iv. Data Range: -40 to 210 deg C
v. Type: Measured
vi. Reference: PGN 65262

The J1939 protocol has a set of defining characteristics outlined below:

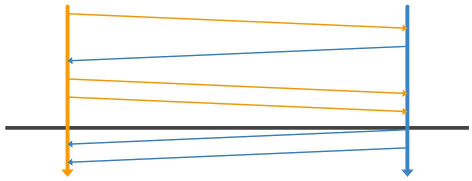
- **250K baud rate & 29-bit extended ID:** The J1939 baud rate is typically 250K (though recently with support for 500K) - and the identifier is extended 29-bit (CAN 2.0B).



- **Broadcast + on-request data:** Most J1939 messages are broadcast on the CAN- bus, though some data is only available by requesting the data via the CAN bus.



- **PGN identifiers & SPN parameters:** J1939 messages are identified by 18-bit Parameter Group Numbers (PGN), while J1939 signals are called Suspect Parameter Numbers (SPN)



- **Multibyte variables & Multi-packets** Multibyte variables are sent the least significant byte first (Intel byte order). PGNs with up to 1785 bytes are supported via J1939 transport protocol.

3.2.5 CAN LOGGER

A CAN logger is a recorder for a CAN bus system. The benefits of a CAN logger make it one of the best solutions for logging information. It can be a valuable tool for troubleshooting and remote diagnosis. All the information passed on the CAN Bus network will be stored by a logger. The CAN Logger permits tracking of errors, faulty messages, or communication out of sync. Tracking will help hasten the repairs of the machinery using CAN Bus. The following are the primary benefits of a CAN logger:

- Rather than carrying a laptop, a CAN logger can record all your data for you.
- Lightweight device that doesn't sacrifice functionality. Including an easy-to-use configuration program, loggers can be set up to store any information needed onto internal memory or SD card.
- Simple design allows anyone to use it and more time for repairs as opposed to logging information.

For CAN logging various devices are used such as:

- PCAN-USB
- Kvaser USB CAN

❖ **BUSMASTER**

ETAS and Robert Bosch Engineering and Business Solutions (RBEI) jointly published BUSMASTER, a free open-source PC software for the design, monitoring, analysis, and simulation of CAN bus systems. The current BUSMASTER version is based on the preceding software tool CANvas, conceptualized, designed, and developed by RBEI. It offers import filters for network description files and simulation programs compliant with standard industry formats. For CAN connections, hardware from different vendors is supported.

4. PROJECTS ALLOTED DURING THE INTERNSHIP

4.1. DATA ANALYTICS

Data analytics (DA) is the process of examining data sets in order to find trends and draw conclusions about the information they contain. Increasingly, data analytics is done with the aid of specialized systems and software. Data analytics technologies and techniques are widely used in commercial industries to enable organizations to make more informed decisions.

- **Need for data analytics (DA)**

In a commercial truck, faults and failures are imminent. As a vehicle goes through its regular life cycle, it encounters various challenges from the outside world. A vehicle must be robust enough to be able to tackle all these challenges without the need for special attention. Although a part cannot be 100% robust, all factors that could adversely affect any part of the vehicle must be analysed thoroughly and any scope of improvement must be implemented to ensure that both the customer and company have the least chance of facing a vehicle breakdown which will benefit both parties and greatly improve vehicle health.

As there are thousands of VE commercial vehicles running on the roads, real-world data is collected from all these vehicles with the help of Telematics devices installed in every VECV model. This real-world data enormously helps in analysing and monitoring the proper functioning of all essential systems of the vehicle as well as the driver's driving pattern. This data is plotted in graphs and simulation software which provide anomaly points and give us an idea about scenarios that can affect in premature failure of vehicle parts.

- **Data Modelling and its types**

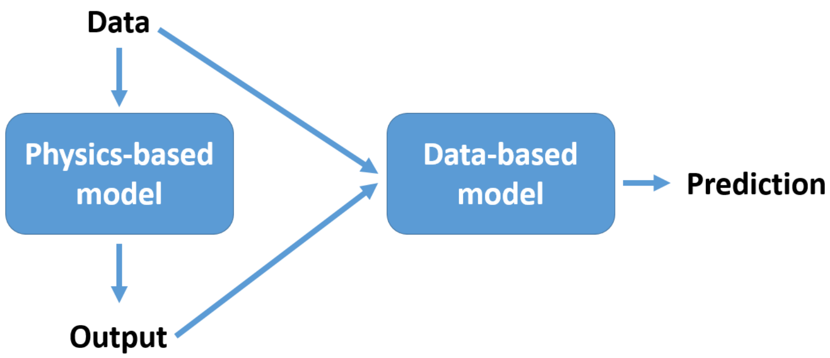
Data modelling is the process of creating a visual representation of either a whole information system or parts of it to communicate connections between data points and structures. The goal is to illustrate the types of data used and stored within the system, the relationships among these data types, the ways the data can be grouped and organized and its formats and attributes.

i. <u>Data-driven Modelling</u>

A data-driven model is developed using experimental input/output data measured from real-world systems. In control and systems engineering, data-driven based modelling is described through a system identification process that involves acquiring input-output data, selecting a model class, estimating model parameters, and then validating the estimated model.

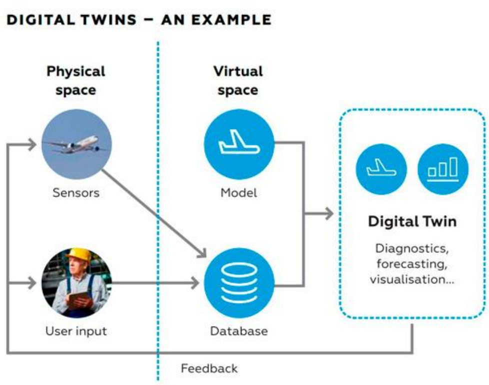
ii. <u>Physics-based Modelling</u>

A physics-based model is a representation of the governing laws of nature that innately embeds the concepts of time, space, causality, and generalizability. These laws of nature define how physical, chemical, biological, and geological processes evolve.



iii. <u>Digital Twin</u>

A digital twin is a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning, and reasoning to help decision-making. Once informed with such data, the virtual model can be used to run simulations, study performance issues, and generate possible improvements, all with the goal of generating valuable insights — which can then be applied back to the original physical object.

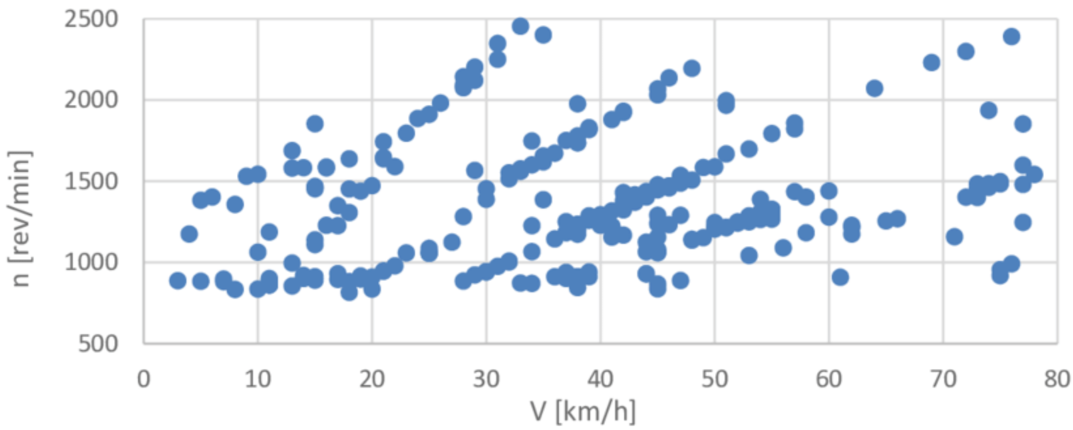


- **Possible Use Cases and Applications**

  - As these commercial vehicles undergo various challenging scenarios every day, it isn't every time that a smooth road awaits their presence. Road profile is always varying which is identified with the help of G-forces experienced by the telematics device. This G-Force is also helpful in identifying possible vehicle crashes which can prove helpful in such critical scenarios due to the fact that this information is provided in real-time to the company's servers and is even stored for future analysis.

g-force	Vehicle Speed
7.97	35.25
7.15	47.49
7.29	41.56
8.42	41.56
7.63	41.59
7.84	45.79
8.02	30.05

  - The clutch analysis is also done using data analytics which helps in determining various possible causes of clutch failure, events of clutch riding, and detection of clutch slip by extracting anomaly data points in engine speed vs vehicle speed graphs.



4.2. DATA CONDITIONING

Simply put, data conditioning optimizes the movement and management of data in order to protect it and increase its productivity. Using specialized techniques designed to route, optimize and protect stored data or data as it moves through a computer system, data conditioning allows both cloud and enterprise data centres to significantly increase the allocation of system resources while boosting application performance.

- **Availability of data**

  The telematics devices installed in VE commercial vehicles provide us with crude but extremely useful data which provides information regarding how the vehicle's electrical and mechanical subsystems behaved under real-world stress. More than 10 types of messages are sent depending on the condition and type of information that needs to be sent. The most common is CAN J1939 data which is received every minute and gives data on the vehicle's functioning under regular conditions. Some common parameters include vehicle speed, engine RPM, and throttle pedal status.

Timestamp	ID	Packet Type
01-04-2022 03:28	35921*********4	ALT_****E
01-04-2022 03:28	35921*********4	CAN
01-04-2022 03:28	35921*********7	ALT_***C
01-04-2022 03:29	35921*********1	CAN
01-04-2022 03:29	35921*********1	ALT_****E
01-04-2022 03:29	35921*********7	ALT_***C
01-04-2022 03:30	35921*********1	CAN

4.3. DATA VALIDATION

Data validation is the practice of checking the integrity, accuracy, and structure of data before it is used for an analytics operation. Data validation operation results can provide data used for data analytics, training a machine learning model, etc.

Data can be examined as part of a validation process in a variety of ways, including data type, constraint, structure, consistency, and code validation. Each type of data validation is designed to make sure the data meets the requirements to be useful.

Data validation is related to data quality. It can be a component to measure data quality, which ensures that a given data set is supplied with information sources that are of the highest quality, authoritative and accurate.

Example: Accident occurrence alert data.

In an event of a crash, the paramedics, police, and fire departments have to react immediately to rectify or at least minimize the unwanted conclusions of a crash. In such cases, imagine if a false crash packet is sent to the concerned emergency stations and they react immediately only to later realize that no crash has actually happened. A false alarm of such a critical event can lead to a significant decrease in the reliability of the telematics device as well as the reputation of the company. In addition to that, although no entity would want any accident to take place regardless of who the victim is, but any false information would result in wasteful actions in terms of essential resources which should be avoided at all costs for them to be used when in actual need.

To make sure every crash that is reported by the telematics device is legit, there are a set of rules created that each packet has to follow before it is considered an actual accident packet.

4.4. AUTOMATION OF DATA CONDITIONING AND VALIDATION

Every year, Eicher sells thousands of commercial vehicles. Every VECV vehicle that is performing every day on the road sends valuable data via the Telematics device installed within the vehicle to the designated servers. Every single vehicle will send tens of millions of packets every month and considering the road share that VE commercial vehicles hold make it impossible for the data to be analysed within an amount of time which results in faster predictive maintenance and other necessary actions.

Taking the example of accident packets, due to such a high number of vehicles, it isn't possible to manually filter accident packets received from thousands of chassis (as telematics device may sometimes experience very high G-Forces due to road profile which can result in possible false accident packets, but these packets are also important). For us to be able to make out a better use of these packets, we use python to program a code that will help us in segregating that accident packet data and filter out false alert packets for thousands of chassis within seconds at the click of a button.

In addition to that, graphs obtained in data modelling consist of thousands of data points for each chassis which also require filtering and conditioning. Automation of this process makes our work unsurprisingly easy as well as results in improved quality and efficiency of work.

The below figure shows the road profile and crash alert data which consists of more than 7 lakh rows or data points out of which we need to extract the actual crash packets using a set of rules which were created to achieve this objective.

```
                  Device Packet  ...                 time
0       [redacted]          RP  ...  03-07-2022 18:30:00
1       [redacted]          RP  ...  03-07-2022 18:30:00
2       [redacted]          RP  ...  03-07-2022 18:30:00
3       [redacted]          RP  ...  03-07-2022 18:30:00
4       [redacted]          RP  ...  03-07-2022 18:30:01
...            ...         ...  ...                  ...
753102  [redacted]          RP  ...  03-07-2022 18:29:56
753103  [redacted]          RP  ...  03-07-2022 18:29:58
753104  [redacted]          RP  ...  03-07-2022 18:29:59
753105  [redacted]          RP  ...  03-07-2022 18:29:59
753106  [redacted]          RP  ...  03-07-2022 18:29:59

[753107 rows x 57 columns]
```

This is the python code that implies the rules to the data in the crash data file and gives us actual/ required accident packet data.

```python
import pandas as pd
import numpy as np

# read crash file
dfcrh = pd.read_csv('crash.csv')
df = dfcrh[dfcrh.columns[0:57]]

# read CAN file
dfc = pd.read_csv('CANBS4_85CP15D.csv')

dfc = dfc[dfc['live'] == 1]
dfc.drop(dfc.columns[46:47], inplace=True, axis=1)
dfc.drop(dfc.columns[38:45], inplace=True, axis=1)
dfc.drop(dfc.columns[2:37], inplace=True, axis=1)
dfc.drop(dfc.columns[0], inplace=True, axis=1)

# Filtering out RP packets from dataframe
df = df[df['Packet'] != 'RP']

# RULE 1
df = df[df['Vehicle Speed from CAN'] != 0]
# RULE 4
df.drop(df.columns[49:55], inplace=True, axis=1)
df.drop(df.columns[1:48], inplace=True, axis=1)
df4 = pd.concat([df, dfc], ignore_index=True)

```

```python
# Filtering out unique Device ID's
Unique_ID = [[redacted]]
df_unique = df4[df4.Device.isin(Unique_ID)]

df5 = pd.read_csv('unique.csv')
df5['time'] = pd.to_datetime(df5['time'], format='%d-%m-%Y %H:%M:%S')
df5.drop(df5.columns[0], inplace=True, axis=1)
df5 = df5.sort_values(['Device', 'time'], ascending=[False, True])

df5['sno'] = np.arange(len(df5))
# print(df5)
crash_dataframe = df5[(df5.message == 'CRH')]
crash_list = []
forward_list1 = []
forward_list2 = []

for i in range(len(crash_dataframe)):
    sequence_number = crash_dataframe["sno"].iloc[i]
    crash_list.append(sequence_number)
    forward_list1.append(sequence_number + 1)
    forward_list2.append(sequence_number + 2)

```

```
        # print(crash_dataframe)
        print(crash_list)
        print(forward_list1)
        print(forward_list2)
        se = pd.Series(crash_list)
        dfc1 = df5[df5.sno.isin(forward_list1)]
        dfc1['snoc'] = se.values
        dfc2 = df5[df5.sno.isin(forward_list2)]
        dfc2['snoc'] = se.values
        crash_dataframe['snoc'] = se.values
        dfm1 = pd.merge(crash_dataframe,dfc1, on='snoc', how='left')
        # print(dfm1)
        dfm = pd.merge(dfm1, dfc2, on='snoc', how='left')
        print(dfm)
        dfm14 = dfm[dfm.columns[0:13]]
        result = []
        print(dfm)
        for q in range(len(dfm)):
            if dfm['Vehicle Speed from CAN_y'][q] == 0 and dfm['Vehicle Speed from CAN'][q] == 0:
                result.append("Crash")
            else: result.append("    ")
        # print(result)
        dfm14.insert(13, 'Result', result)
        dfm14 = dfm14[dfm14['Result'] == 'Crash']
        # dfm14 =dfm14.drop
        print(dfm14)
        dfm14.to_csv('C:/Users\ABHISHEK\Desktop\VECV\Rules Code/dfmx.csv')
```

After executing the above code, we get the following result which gives us the info of the vehicles following the set of rules to determine the occurrence of an accident

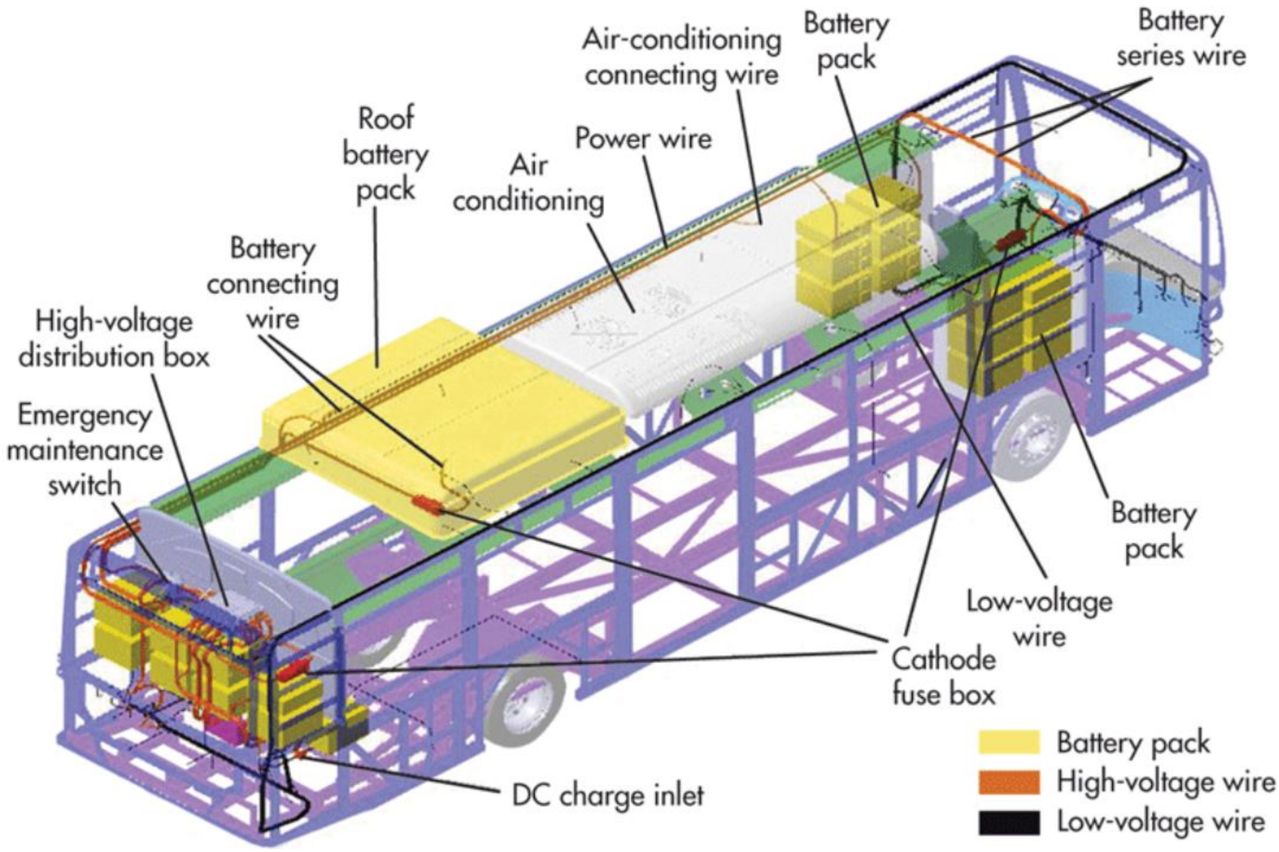
```
            Device_x  Vehicle Speed from CAN_x  ... Vehicle Speed from CAN Result
0   [redacted]                           29.70  ...                    0.0  Crash
1   [redacted]                           25.84  ...                    0.0  Crash
11  [redacted]                           55.13  ...                    0.0  Crash
17  [redacted]                           12.25  ...                    0.0  Crash
25  [redacted]                           29.61  ...                    0.0  Crash

[5 rows x 14 columns]
```

4.5. ELECTRIC VEHICLES (EV)

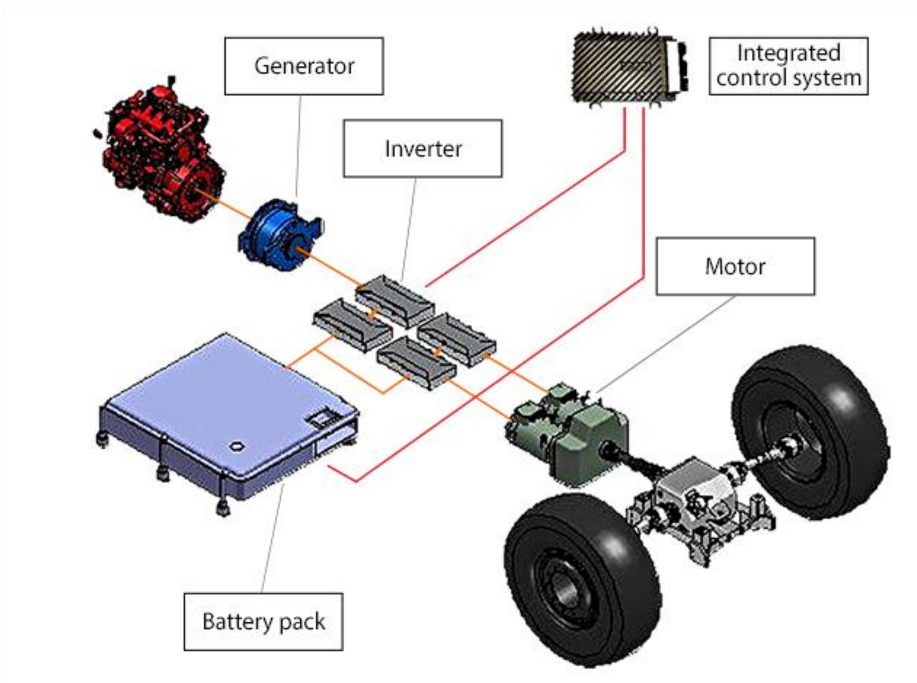
As we progress towards a new era where the dominance of IC engines will be on the decline due to various reasons which promote the transition for adopting electric vehicles as the primary option in the automobile sector. VECV has also introduced the Eicher Skyline Pro E-buses which have completed 4 successful years being deployed in West Bengal Housing Infrastructure Development Corporation (WBHIDCO) running 140 kilometres every day whilst having an uptime of 98%.

The Eicher Skyline Pro E buses are the most advanced in safety, comfort, and efficiency. These buses are powered by REVOLO technology, which is an innovative platform that operates on a lower voltage and allows regeneration to have the maximum possible range with the smallest possible battery.



- **Components of an EV**

As is well known, EVs use the electricity saved in the battery to cycle the motor and generate the power necessary for driving—this is the biggest difference from internal combustion vehicles, in which the engine exhausts fossil fuel to generate that power. As such, EVs have no need for the engine and transmission, the two of the most crucial components for internal combustion vehicles. Instead, EVs carry several components for electric power: the motor, the battery, the onboard charger, and the Electric Power Control Unit (EPCU). All are essential components to achieve the conversion of the battery's electricity into the kinetic force that drives the EV forward.



i. <u>Motor</u>

The motor converts electric energy into kinetic energy that moves the wheels. The advantage of using the motor instead of an engine is numerous: first, the noise and the vibration we typically associate with cars are minimized. Moreover, the EV powertrain is smaller than the engine, thus providing lots of additional space for efficient vehicle design—like expanded cabin space or storage.

The motor is also in part an electric generator—it converts the kinetic energy generated while in neutral gear (e.g., while the car is going downhill) into electric energy saved to the battery. The same energy-saving idea applies when the car is reducing its speed, culminating in the so-called "regenerative braking system."

ii. Reducer

The reducer is a kind of transmission in that it serves to effectively convey the motor's power to the wheel. But it carries the special name—reducer—for a reason: the motor has a far higher RPM than that of an internal combustion engine, so whereas transmissions change the engine RPM to match the driving circumstance, the reducer must always reduce the RPM to an appropriate level. With the reduced RPM, the EV powertrain can take advantage of the resulting higher torque.

iii. Battery

The battery stores electrical energy and is the equivalent of a fuel tank in an internal combustion engine. The maximum driving distance of an EV is often determined by the battery capacity—the higher the capacity, the higher the driving distance. In that light, increasing the capacity may seem an obvious choice, since a high driving distance reduces the annoying need for frequent stops at charging stations. But the choice isn't so obvious, because the battery's size and weight also have large implications on vehicle performance. The larger and heavier battery takes away from cabin/storage space and worsens the energy efficiency and fuel economy. The best way to optimize performance, then, is to maximize the battery's energy density—that is, having a small, lightweight battery that stores as much electric energy as possible. In an E-bus though, space and weight are not as big of an issue as they would be in a passenger vehicle. Hence, other factors are get worked upon for battery performance enhancement.

iv. Battery Management System (BMS)

The Battery Management System (BMS) manages the battery's many cells so that they can operate as if they are a single entity. The EV's battery consists of as little as tens to as many as thousands of mini-cells, and each cell needs to be in a similar condition to the others in order to optimize the battery's durability and performance.

Most often, the BMS is built into the battery's body, though sometimes it is incorporated into the Electric Power Control Unit (EPCU). The BMS mainly oversees the cell's charge/discharge status, but when it sees a malfunctioning cell, it automatically adjusts the power status of the cell(on/off) through a relay mechanism (the conditional mechanism for opening/closing other circuits).

v. <u>On-board Charger (OBC)</u>

The On-board Charger (OBC) is used to convert Alternating Current (AC) from slow chargers or portable chargers used on home outlets into Direct Current (DC). This may make the OBC look similar to the traditional inverter, but they differ crucially in function; the OBC is for charging, and the inverter is for acceleration/deceleration. Incidentally, the OBC is not needed in fast charging, since fast chargers already supply the electricity in direct current.

vi. <u>Electric Power Control Unit (EPCU)</u>

The Electric Power Control Unit (EPCU) is an efficient integration of nearly all devices that control the flow of the electric power in the vehicle. It consists of the inverter, the Low voltage DC-DC Converter (LDC), and the Vehicle Control Unit (VCU).

a. Inverter

The inverter converts the battery's DC into AC, which then is used to control the motor speed. The device is responsible for executing acceleration and deceleration, so it serves a crucial part in maximizing the EV's drivability.

b. Low voltage DC-DC Converter

The LDC converts the high voltage electricity from the EV's high-voltage battery into low-voltage(12V) and supplies it to the vehicle's various electronic systems. All electronic systems in the EV use electricity in low voltage, so the high voltage in the battery must be converted first to be useful for these systems.

c. Vehicle Control Unit

As the control tower of all electric power control systems in the vehicle, The VCU is arguably the most important component of the EPCU. It oversees nearly all the vehicle's power control mechanisms, including motor control, regenerative braking control, A/C load management, and power supply for the electronic systems.

- **Vehicle Telematics in Electric Vehicles**

Electric Vehicles have a very simple driveline, but managing it can get tricky when considering the ever-changing parameters a vehicle has to deal with, like the load, speed, acceleration, etc. We've had over a century to refine the fossil-fuel-powered vehicle, and some of that data can be used to help shape the responses of an electric car. Still, with the various energy efficiency demands included, a vehicle's system quickly grows in complexity. For example, regenerative braking needs to harvest the vehicle's kinetic energy, use the motors that drive it as generators this time, and charge the batteries – but the traditional brakes are still available on standby, in case hard braking is required. The switch from one system to the other is one that telematics can dictate. In addition, various other systems, like the HVAC system, the lights, the cooling system, etc., need optimization. All this falls to the vehicle's onboard computer, and all of this data can be used to optimize things further. Since there is such a high degree of electronic intervention in all systems of an EV, it is quite possible to bring about significant improvements in the vehicle's performance and efficiency via software updates, not unlike electronic devices such as smartphones and computers.

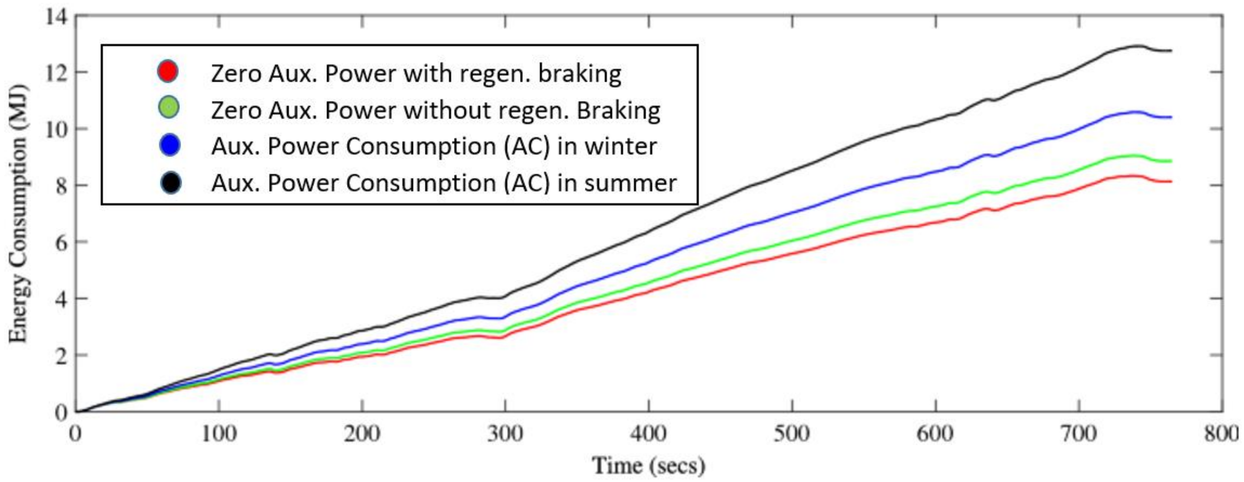
Range anxiety is undoubtedly the biggest hurdle in an all-out adaptation of EVs. Vehicle telematics can help an EV user select a route that involves less traffic or goes past the nearest quick charging station – and can be refined further to redirect the vehicle to the closest available charging outlet as well. Fleet managers can use vehicle telematics to assign appropriate cars for a job. The same logic can be applied to self-drive fleets that are increasingly available in developed cities across the globe.

Impact of Equipment on EV Performance		
Accessory	Range Impact	Comments
Air Conditioning	Up to 30%	Highly Dependent on ambient temperature, cabin temperature, and air volume
Heating	Up to 35%	Highly Dependent on ambient temperature and cabin temperature
Power Steering	Up to 5%	
Power Brakes	Up to 5%	
Defroster	Up to 5%	Depending on use
Other Lights, Stereo, Phone, Power-assisted seats, windows, locks	Up to 5%	Depending on use

Even a personal EV owner benefits from vehicle telematics in a straightforward sense; the EVs of today with Internet connectivity will allow you to lock or unlock the car, start the air conditioning system, etc., all remotely with a smartphone loaded with the appropriate app. This can be expanded to offer vehicle alerts to the manufacturer if a vehicle system looks increasingly likely to fail, thus helping avoid a bad experience during a journey for the driver and reducing downtime for fleet managers.

- **EV AUXILIARY POWER CONSUMPTION MONITORING**

Eicher Trucks & Buses (ETB) provides lease-based vehicle services for public transport in cities. Chandigarh is one of the cities where currently 40 electric buses run across the city everyday as a means of comfortable and affordable public transport. With the help of telematics devices installed in these buses, we can monitor their performance, ambient conditions, up-time, power consumption, etc. This section guides us through the parameters and approaches that were used to monitor auxiliary power consumption in electric vehicles.



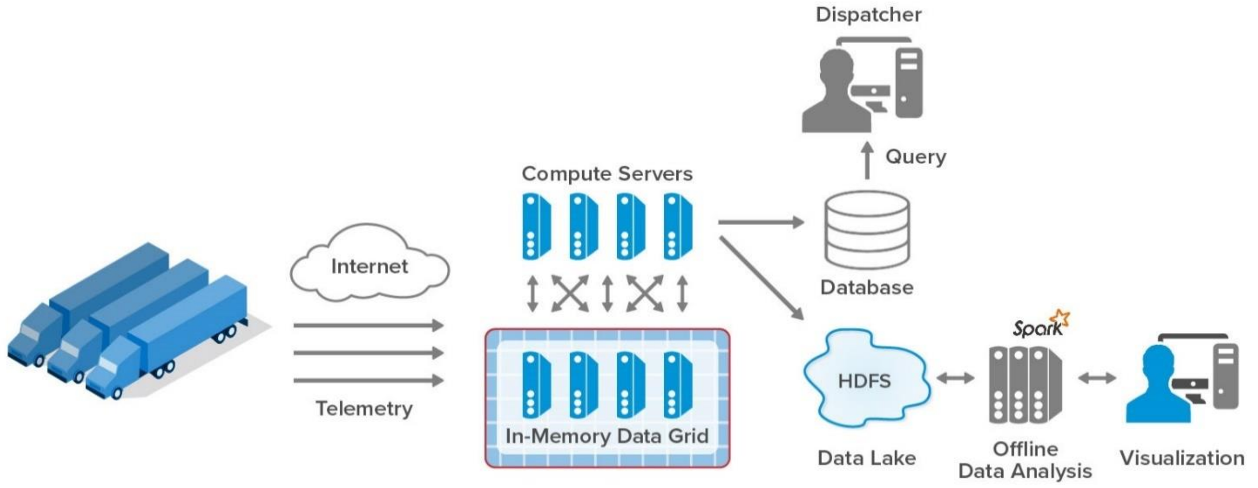
The above graph references the total power consumption with respect to time in an electric bus under different conditions. The power consumption parameters were taken from CAN telematics data which is uploaded on Eicher servers. With the help of this data, accurate monitoring of the vehicle fleet can be performed from any remote location. This monitoring includes AC running status (for passengers' comfort), overheating monitoring, route monitoring as well as dangerous road incidents, all of which ensures that the public transport which is used by thousands of citizens daily is safe and contented.

4.6. DIGITAL TWIN

Rapid advances in the telematics industry have dramatically boosted the efficiency of vehicle fleets and have found wide ranging applications from long haul transport to usage-based insurance. Incoming telemetry from a large fleet of vehicles provides a wealth of information that can help streamline operations and maximize productivity. However, telematics architectures face challenges in responding to telemetry in real time. Competitive pressures should spark innovation in this area, and real-time digital twins can help.

- **Current Telematics Architecture**

The volume of incoming telemetry challenges current telematics systems to keep up and quickly make sense of all the data. Here's a typical telematics architecture for processing telemetry from a fleet of trucks:



Each truck today has a microprocessor-based sensor hub which collects key telemetry, such as vehicle speed and acceleration, engine parameters, trailer parameters, and more. It sends messages over the cell network to the telematics system, which uses its compute servers (that is, web and application servers) to store incoming messages as snapshots in an in-memory data grid, also known as a distributed cache. Every few seconds, the application servers collect batches of snapshots and write them to the database where they can be queried by dispatchers managing the fleet. At the same time, telemetry snapshots are stored in a data lake, such as HDFS, for offline batch analysis and visualization using big data tools like Spark. The results of batch analysis are typically produced after an hour's delay or more. Lastly, all telemetry is archived for future use (not shown here).

This telematics architecture has evolved to handle ever increasing message rates (often reaching 2K messages per second), make up-to-the-minute information available to dispatchers, and feed offline analytics. Using a database, dispatchers can query raw telemetry to determine the information they need to manage the fleet in real time. This enables them to answer questions such as:

- "Where is truck 7563?"
- "How long has the driver been on the road?"
- "Which trucks have abnormally high oil temperature?"

Offline analytics can mine the telemetry for longer term statistics that help managers assess the fleet's overall performance, such as the average length of delivery or routing delays, the fleet's change in fuel efficiency, the number of drivers exceeding their allowed shift times, and the number and type of mechanical issues. These statistics help pinpoint areas where dispatchers and other personnel can make strategic improvements.

- **Challenges for Current Architectures**

There are three key limitations in this telematics architecture which impact its ability to provide managers with the best possible situational awareness. First, incoming telemetry from trucks in the fleet arrives too fast to be analysed immediately. The architecture collects messages in snapshots but leaves it to human dispatchers to digest this raw information by querying a database. What if the system could separately track incoming telemetry for each truck, look for changes based on contextual information, and then alert dispatchers when problems were identified? For example, the system could perform continuous predictive analytics on the engine's parameters with knowledge of the engine's maintenance history and signal if an impending failure was detected. Likewise, it could watch for hazardous driving with information about the driver's record and medical condition. Having the system continuously introspect on the telemetry for each truck would enable the dispatcher to spot problems and intervene more quickly and effectively.

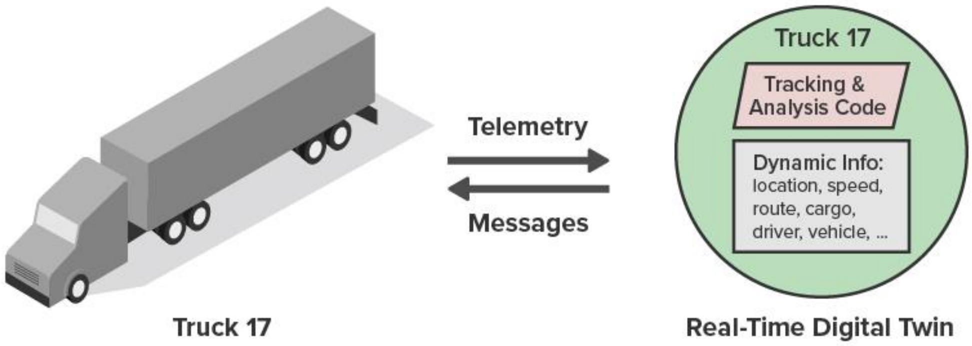
A second key limitation is the lack of real-time aggregate analysis. Since this analysis must be performed offline in batch jobs, it cannot respond to immediate issues and is restricted to assessing overall fleet performance. What if the real-time telemetry tracking for each truck could be aggregated within seconds to spot emerging issues that affect many trucks and require a strategic response? These issues could include:

- Unexpected delays in a region due to highway blockages or weather that indicate the need to inform or reroute several trucks
- An unusually large number of soon-to-be timed-out drivers or impending maintenance issues which require making immediate schedule changes to avoid downtime
- Congregated drivers who are impacting on-time deliveries

The current telematics architecture also has inherent scalability issues in the form of network bottlenecks. Because all telemetry is stored in the in-memory data grid and accessed by a separate farm of compute servers, the network between the grid and the server farm can quickly bottleneck as the incoming message rate increases. As the fleet size grows and the message rate per truck increases from once per minute to once per second, the telematics system may not be able to handle the additional incoming telemetry.

- **Solution: Real-Time Digital Twins**

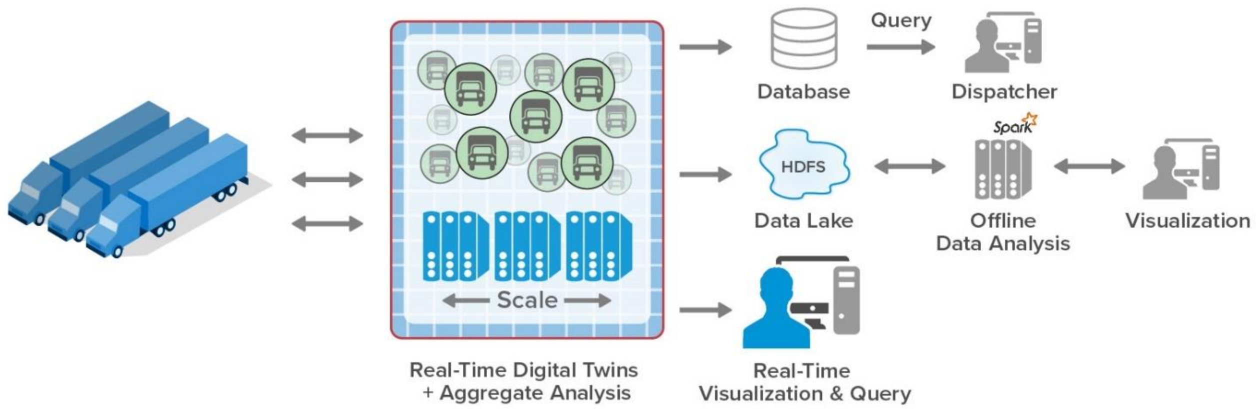
A new software architecture for streaming analytics based on the concept of real-time digital twins can address these challenges and add significant capabilities to telematics systems. This new, object-oriented software technique provides a memory-based orchestration framework for tracking and analysing telemetry from *each* data source. It comprises message-processing code and state variables which host dynamically evolving contextual information about the data source. For example, the real-time digital twin for a truck could look like this:



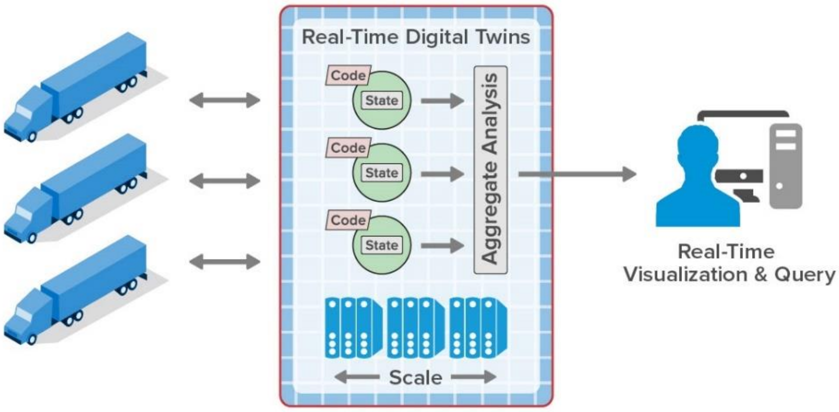
Instead of just snapshotting incoming telemetry, real-time digital twins for every data source immediately analyse it, update their state information about the truck's condition, and send out alerts or commands to the truck or to managers as necessary. For example, they can track engine telemetry with knowledge of the engine's known issues and maintenance history. They can track position, speed, and acceleration with knowledge of the route, schedule, and driver (allowed time left, driving record, etc.). Message-processing code can incorporate a rules engine or machine learning to amplify their capabilities.

Real-time digital twins digest raw telemetry and enable intelligent alerting in the moment that assists both drivers and dispatchers in surfacing issues that need immediate attention. They are much easier to develop than typical streaming analytics applications, which have to sift through the telemetry from all data sources to pick out patterns of interest and which lack contextual information to guide them. Because they are implemented using in-memory computing techniques, real-time digital twins are fast (typically responding to messages in a few milliseconds) and transparently scalable to handle hundreds of thousands of data sources and message rates exceeding 100K messages/second.

Here's a depiction of real-time digital twins running within an in-memory data grid in a telematics architecture:



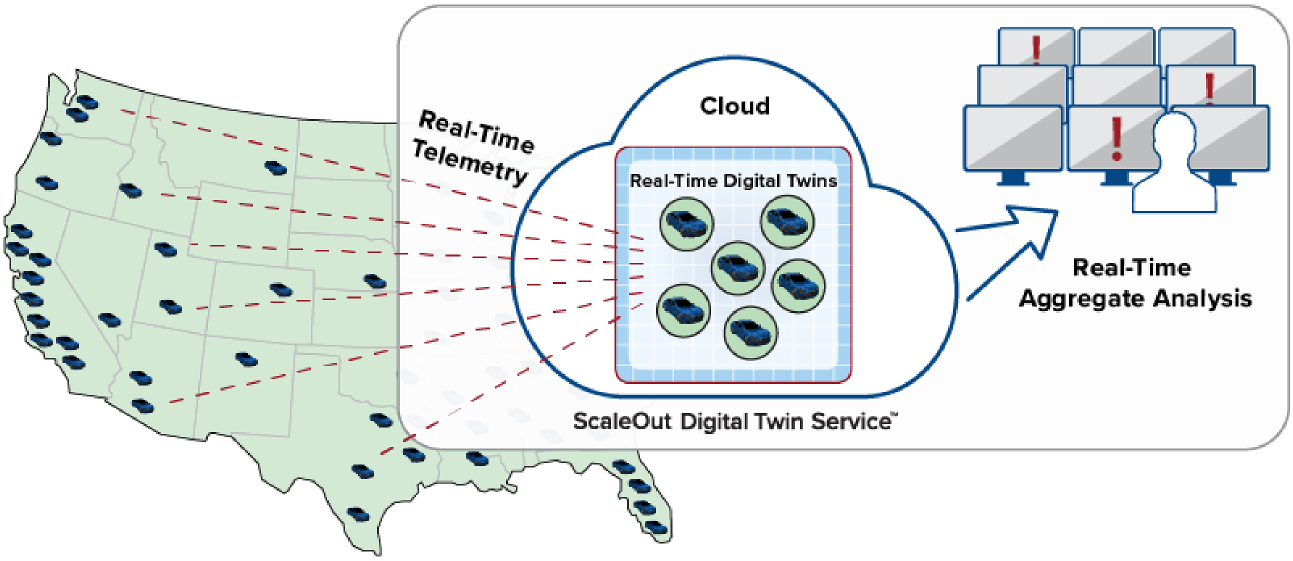
In addition to fitting within an overall architecture that includes database query and offline analytics, real-time digital twins enable built-in aggregate analytics and visualization. They provide curated state information derived from incoming telemetry that can be continuously aggregated and visualized to boost situational awareness for managers, as illustrated below. This opens up an important new opportunity to aggregate performance indicators needed in real time, such as emerging road delays by region or impending scheduling issues due to timed out drivers, that can be acted upon while new problems are still nascent. Real-time aggregate analytics add significant new capabilities to telematics systems.



Traditional stream-processing and complex event-processing systems focus on extracting patterns from incoming telemetry, but they can't track dynamic information about individual data sources. This makes it much more difficult to fully analyze what incoming telemetry is saying. For example, an IoT predictive analytics application attempting to avoid an impending failure in a population of medical freezers must look at more than just trends in temperature readings. It needs to evaluate these readings in the context of each freezer's operational history, recent maintenance, and current state to get a complete picture of the freezer's actual condition.

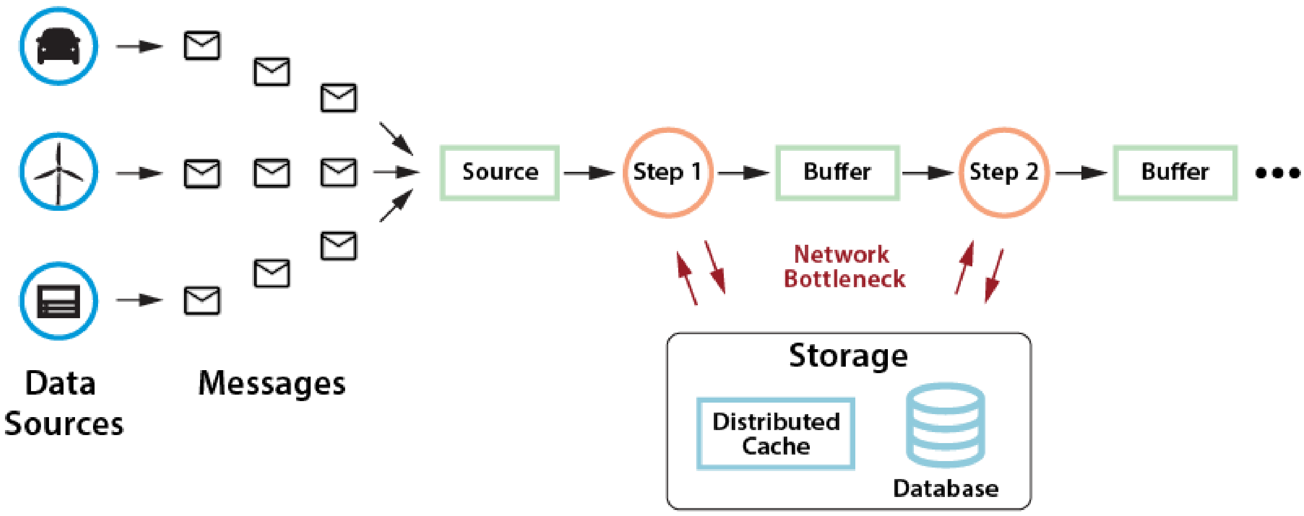
Real-time digital twins provide a powerful means for deploying machine learning (ML) capabilities that track incoming telemetry and look for anomalies that require alerting. By running within digital twins, ML algorithms can be tailored for each type of device and its parameters, and they can run independently and simultaneously for thousands of data sources.

Equally important, the state-tracking provided by real-time digital twins allows immediate, aggregate analytics to be performed every few seconds. Instead of deferring aggregate analytics to batch processing on server, real-time digital twins enable important patterns and trends to be quickly spotted, analyzed, and handled. This dramatically improves situational awareness.

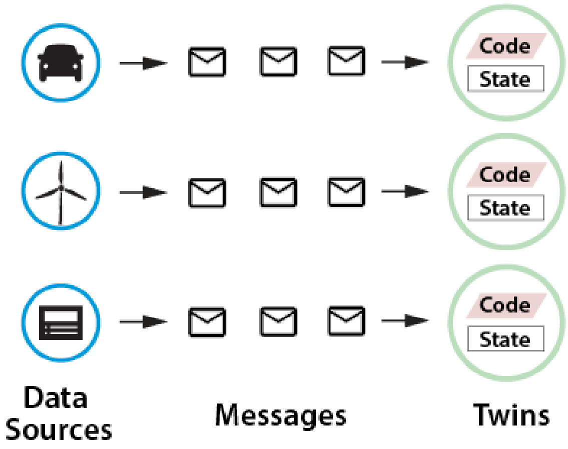


- <u>The Next Generation in Streaming Analytics</u>

Real-time digital twins both simplify the design of stream-processing applications and improve the quality of streaming analytics. The traditional approach relies on partitioning application code into multiple pipeline steps and using *ad hoc* techniques to access caches or databases. This adds complexity and puts the burden on the developer to ensure fast performance.

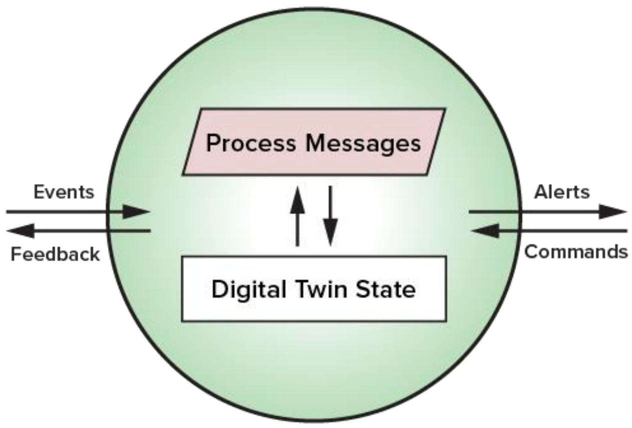


Real-time digital twins sidestep this complexity by offering a simple, straightforward model for processing incoming telemetry based on tracking each data source's dynamic state. This avoids the need to build streaming pipelines, and the execution platform automatically ensures high throughput and fast response times. The use of well understood, object-oriented development techniques further simplifies the design process.



What is a "Real-Time Digital Twin"?

Unlike traditional digital twin models, real-time digital twins focus on analyzing incoming event messages to provide immediate feedback to their data sources (e.g., devices) within a live system. Each twin comprises a state object holding dynamic information about the data source and an application-defined, message-processing method and/or machine learning algorithm that analyses incoming events and generates outgoing messages and alerts, as depicted in the following diagram:



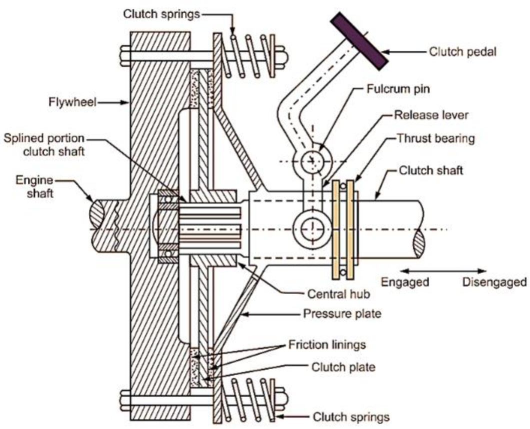
As event messages flow into the ScaleOut Digital Twin Streaming Service, a digital twin is created for each unique data source to process incoming messages from that data source. The message-processing method uses information in the state object to help analyse each event message and decide what action to take. It can send a message back to the data source and/or send an alert if further action is required. (Some incoming messages may take the form of commands, which can be forwarded to the data source.) The message-processing method also can update the state object to track dynamic changes in the data source and help analyse future events.

The cloud service can simultaneously process incoming messages from many thousands (or even millions) of unique data sources, and it forwards each message to its corresponding real-time digital twin. In addition, it can perform aggregate analytics across all digital twins by extracting information from the state objects, combining this information, and presenting the results in various types of charts and graphs.

4.6.1. Digital Twin for Clutch

A clutch is a mechanical device that engages and disengages power transmission, especially from a drive shaft to a driven shaft. In the simplest application, clutches connect and disconnect two rotating shafts.

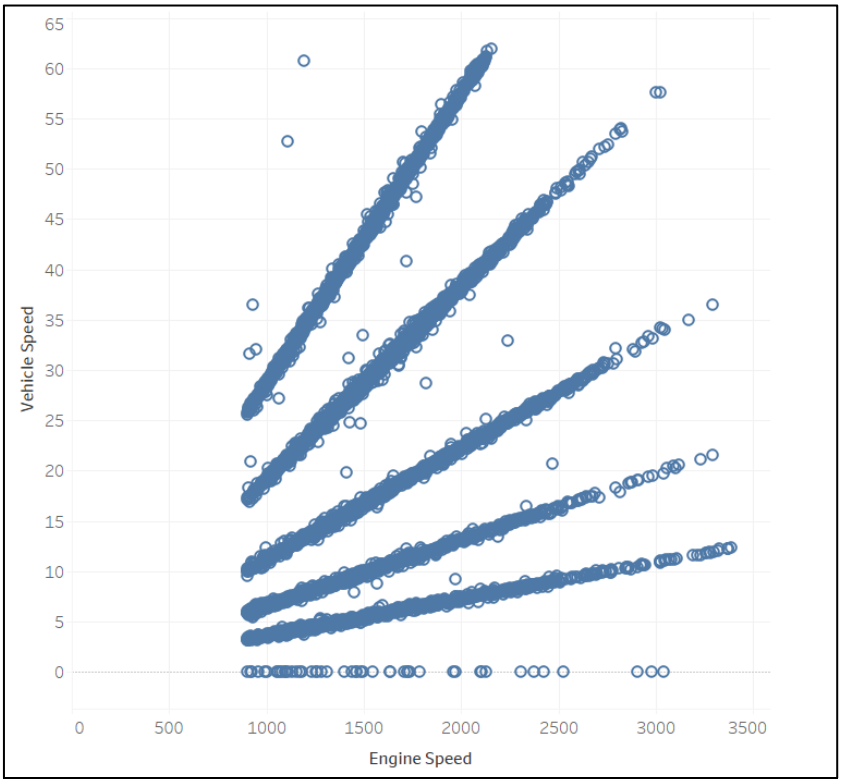
A clutch enables the connection and transfer of torque between two rotating shafts when engaged. Commercial vehicles generally has multiple disc wet clutch. A wet clutch is simply a clutch that operates while submerged in a lubricant, and this lowers the friction between the discs as compared to a dry clutch. The multiple ¨ disc wet clutches allow engagement while there is a large difference between the rotation speeds of the two shafts. A multiple disc wet clutch pack consists of separator discs, friction discs, lubricant, piston and two shafts. Components of multiple disc wet clutches are:



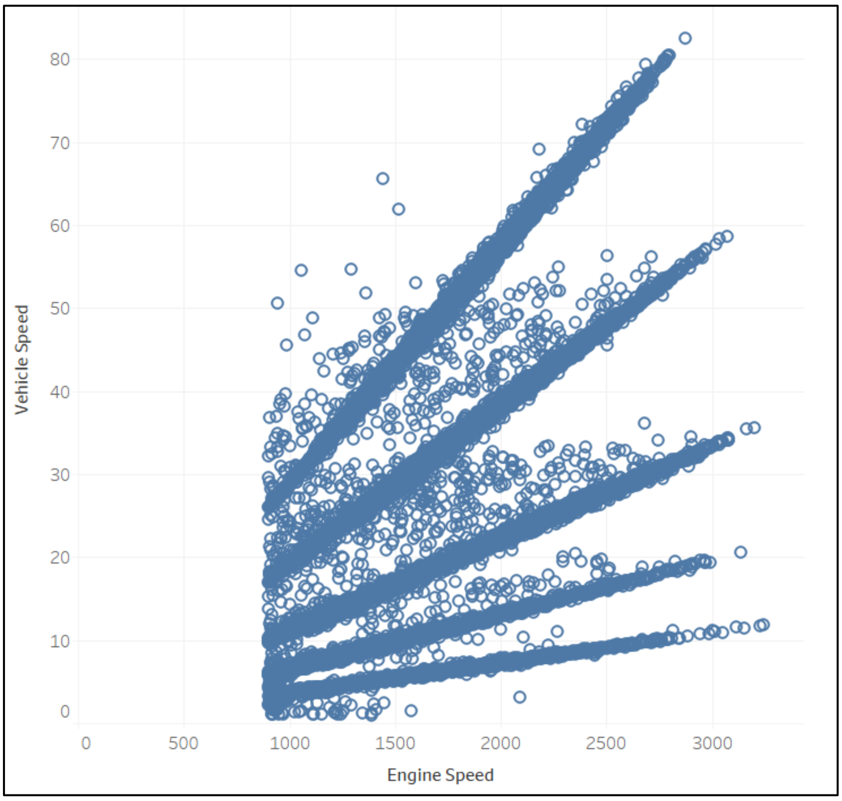
Gear /Output shaft, Hub (output shaft side), End plate, Friction disc, Returning spring, Separator disc, Drum (input shaft side), Piston, Input shaft , Lubrication line and Bearing.

The clutch plates are arranged in such a way that one of the discs is driven by a hub and the other by a drum. The drum and hub are driven by a joint that allows axial movement such as splines and lugs. In the clutch pack along its axial direction every other disc is a separator disc and in between the separator discs are the friction disc. The friction material in the friction discs are coated with either paper, asbestos or sintered bronze, while the separator discs are basically steel plates. To engage the clutch, a hydraulic induced normal force is applied to the clutch piston thereby clamping together the friction disc and the separator disc, which allows torque transfer between the two shafts. Clutch discs ¨ in the multiple disc wet clutch pack are designed to slip for a defined period of time (slip time) in order not to burn the clutch material due to excessive friction. Furthermore, a clutch is considered to have failed when it can no longer transmit the desired torque. The level of torque transfer in wet clutches is controlled by the generated friction in it, and a good and stable friction coefficient which keeps output torque at a required level is important. Thus, clutch slippage is a result of diminishing frictional characteristics of the clutch system. The friction characteristics of the clutch material are influenced by different factors such as the clutch material structure, porosity, lubricant and permeability. Furthermore, the coefficient of friction may be affected by sliding speed, varying load, boundary friction, contact temperature of clutch plates and friction due to fluid flow through the friction material. Thus, degradation of the wet clutch results in a continual drop in the coefficient of friction throughout the clutch service life. To sum up, many factors influence the service life of the multiple disc wet clutches and most of these factors are difficult to isolate and accurately measure.

To perform predictive maintenance of clutch, several parameters such as engine speed (RPM), vehicle speed, UTC, clutch count, clutch pedal switch, etc. Vehicle speed data was plotted against engine speed which gives a graph that shows datapoints on different gears which are regions of concentrated data in the graph. In the figure shown below, we can clearly see undesired anomaly points between gear ratios the excess presence of which indicates of possible failure of the clutch assembly soon. In figure 2, a normal vehicle which was nicely driven that with proper clutch and gear use has been plotted and the absence of large number of anomaly datapoints confirms that that vehicle will not suffer from possible clutch failure due to reckless driver behaviour.



Normal vehicle plot



Failed vehicle plot

4.6.2. Digital Twin for Brake

According to statistics published by the National Highway Traffic Safety Administration (NHTSA), trucks only account for about 7% of road traffic but are involved in 12.6% of annual traffic accident deaths. What these disproportionate numbers tell us is that an accident involving a truck is more likely to result in a fatality than a crash involving cars. Based on these findings, it is imperative that truck drivers and trucking companies take every precaution in maintaining their vehicles properly to avoid unnecessary and preventable accidents.

One of the essential tools for preventing truck accidents is a truck's brake system. Unfortunately, brakes do suffer wear and tear over time, which can result in brake failure, which is why proper maintenance and testing are so necessary.

Trucks can weigh as much as 80,000 pounds when fully loaded; this means they take longer to come to a full stop. When a regular passenger car is traveling at 55 miles per hour, it takes about 135 feet to come to a complete stop. However, a fully-loaded semi-truck can take as much as 200 feet to stop. If the truck's brakes are "hot"—meaning the driver has been using them for a while—the commercial vehicle may take up to 450 feet to come to a halt. These variances in slowing distances may seem inconsequential, but 75 feet can make a life or death difference in an accident.

- **Brake Maintenance and Accident Prevention**

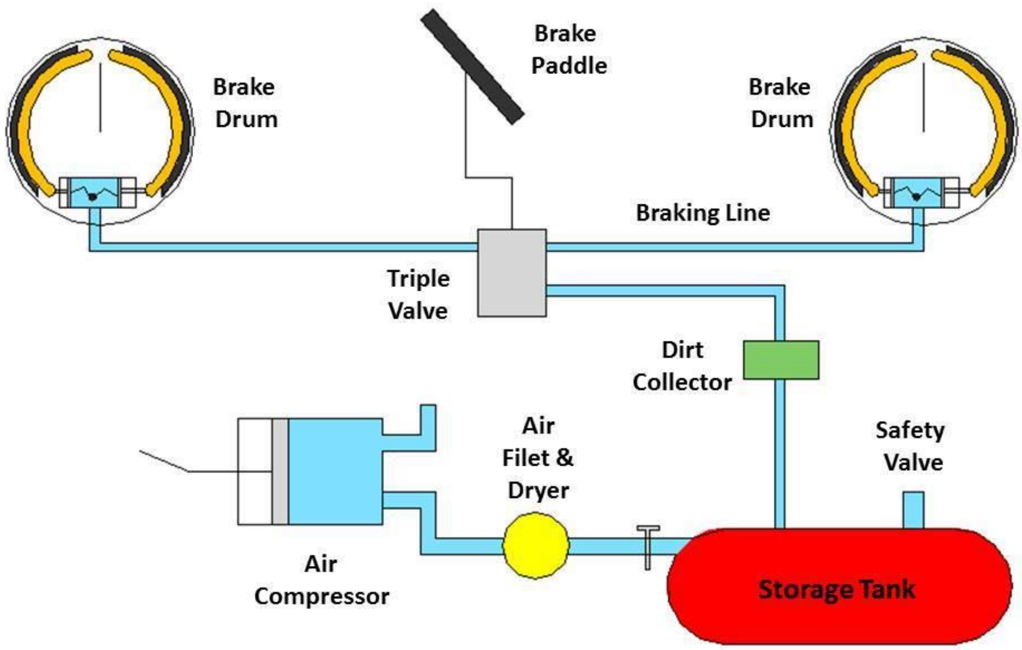
As mentioned, truck stopping distances are longer than that of a smaller vehicle. Therefore, any wear or tear on the brakes adds to the time it takes to stop a truck. That is why brake maintenance is so essential for commercial truck drivers. Even if it is only a matter of feet, good brakes help truck drivers anticipate stop distances for their vehicles, which keeps other motorists safe. Additionally, brakes that are up to code can help truck businesses save money from costly accidents and citations. In fact, it is the legal responsibility of the truck owner and operator to ensure that the brake system meets federal regulations and that they maintain all parts of the system as stated by law.

- **Air Brake**

Air brake systems are commonly used in heavy commercial vehicles and trucks. They require a heavy braking effort that can be applied by the driver's leg alone. You apply compressed air pressure to operate the air brake instead of just the foot pressure acting against the flexible diaphragm in the brake chamber. There are only two types of braking systems.

The first one is known as the disc brake, and the second one is the drum brake. These brakes are driven by humans or some other power source. According to the power source, these brakes can be classified into other types such as hydraulic brakes, air brakes, vacuum brakes, etc. When driving a heavy load vehicle, it is impossible for humans to generate braking force.

So, another power system is used to generate the braking force that forces the braking pad and produces a frictional force between the brake and the tire that goes to stop the vehicle. The air brake system uses air to generate this force. This type of braking is similar to hydraulic brakes, requiring that these brakes use compressed air to apply brakes instead of hydraulic pressure.



Air Brake System

- ***What causes Air Brakes to fail?***

There are many reasons why air brakes may fail on a semi-truck. Some of the most common causes include:

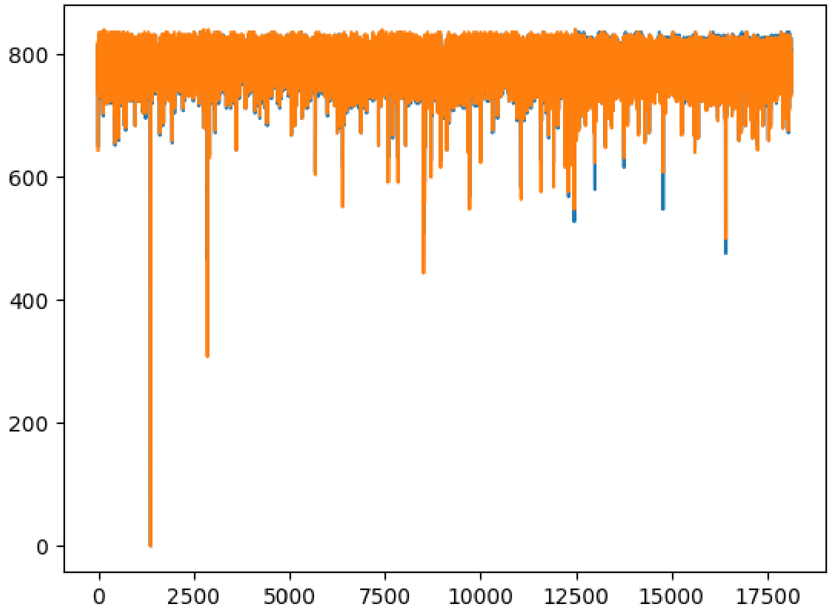
i. Improper brake alignment
ii. Condensation
iii. Worn-out components
iv. Bad driving
v. Overloaded truck
vi. Water in the air tank
vii. Oil in the air tank
viii. Air compressor failures

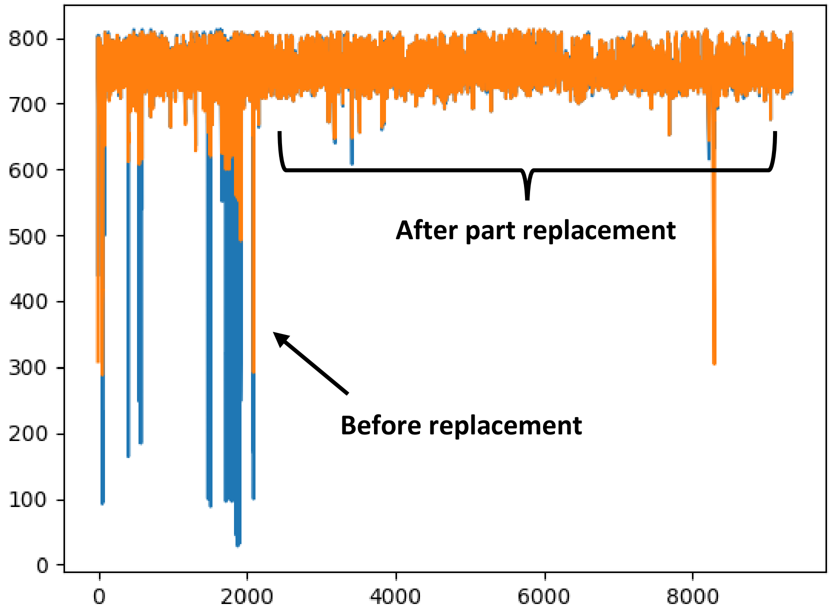
It is difficult to know what caused an air brake failure without the appropriate investigation and accident analysis. It is important to determine whether an accident was caused by an equipment failure, human error, or both.

<u>The Approach</u>

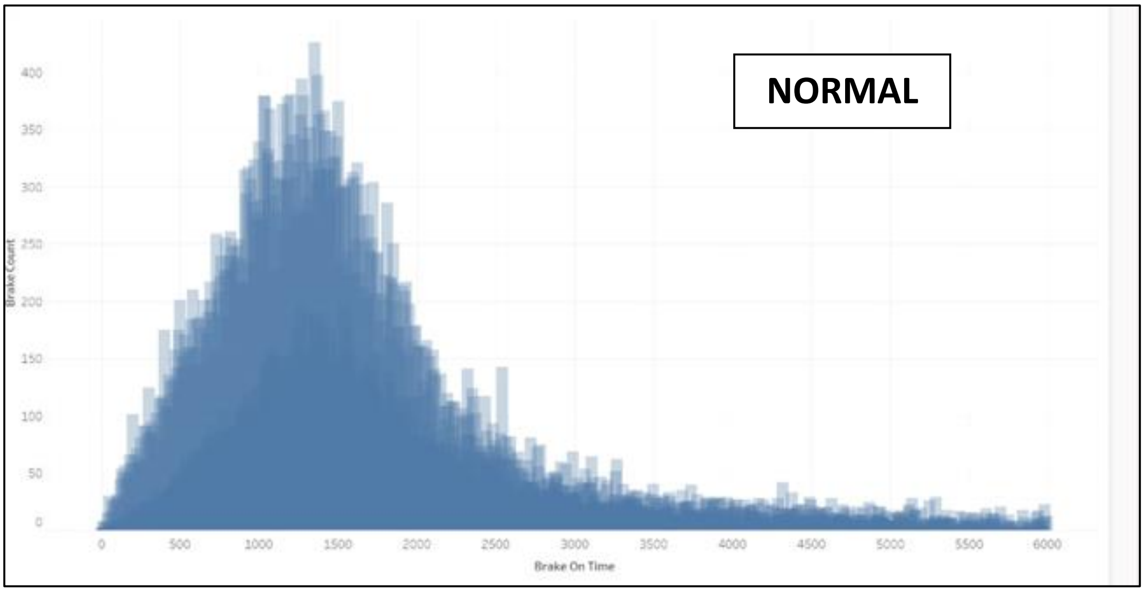
In case of brakes, there are many reasons why a brake can fail as well as different components which can fail but still fall under the category of brake failure (that is when the brake has partially or fully stopped working). For different cases, we need to perform different analysis using different vehicle parameters in order to attain accurate results.

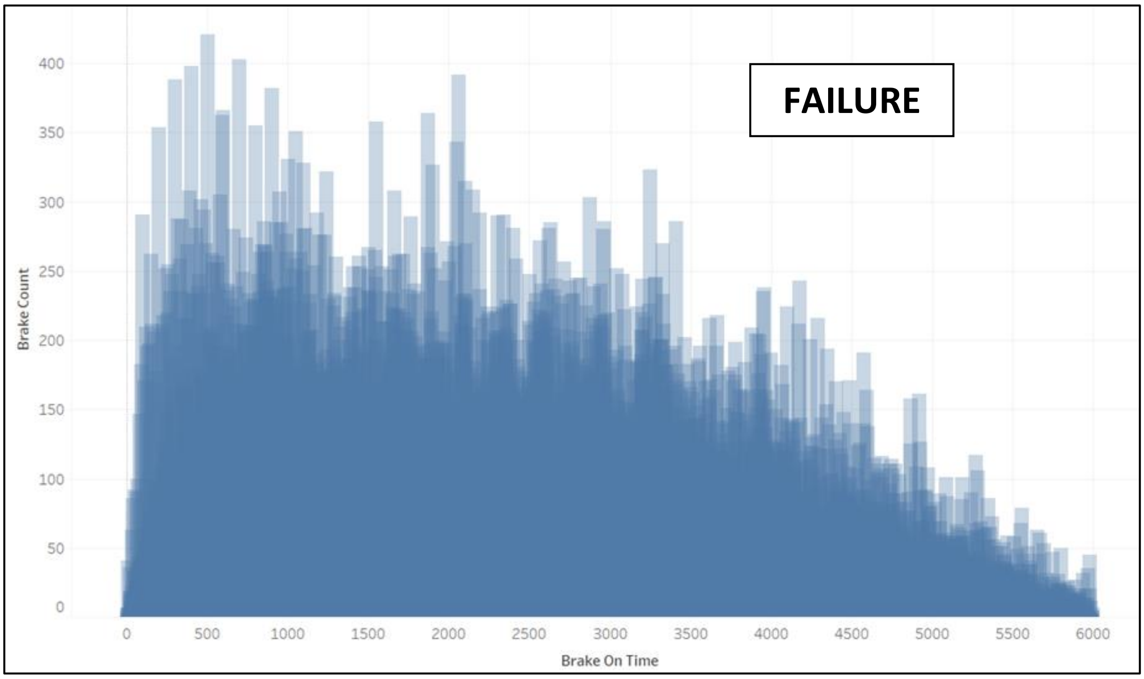
For the first approach, we aim to find a solution for 'Air leak from brake boosters'. Here, due to leakage in brake valve, the primary or secondary brake pressure drops which mitigates effective braking and causes brake failure. This can be detected by plotting the primary and secondary brake pressure with respect to total distance. In the obtained plot, we can see that in the chassis whose brake failed, the primary and secondary brake pressures dropped before the actual failure. Whereas, in a normal running chassis, no pressure drop was observed thus, providing a solution for proactive detection of brake failure due to air leak.


800
600
400
200
0
0
2500
5000
7500
10000
12500
15000
17500


800
700
600
500
400
300
200
100
0
0
2000
4000
6000
8000
After part replacement
Before replacement

In the second approach, we target 'Poor Braking'. Now, poor braking can be due to various reasons, but the most common one among them is brake lining wear out. For predictive maintenance of this, we use 2 parameters viz 'brake count' and 'brake on time' and plot them as a histogram bar graph against each other. With this, we get a clear bell curve in normal chassis, but the chassis in which the brake usage by driver isn't adequate, we can see a more scattered pattern. Getting such a pattern can be helpful in determining whether and when the given chassis might incur brake failure.





4.7. DRIVER SCORECARD

The vehicle fleet and drivers are the assets that power the business. The logistics industry relies on transporters to offer timely end to end shipment and safety of the goods transported to the consignor.

Among the biggest challenges of fleet management is, unlike with traditional office jobs, you will rarely be able to observe employees and shape their performance. This distance can feel especially concerning in a line of work with as many potential safety hazards as freight and transportation. One can regain some control over this challenge with driver scorecards.

For this industry, the primary reason to score the drivers is to incentivize good driving and to remove stress from the driver during implementation. If this is done successfully, it will automatically increase driver retention, keep your fleet safe, fuel efficient, and high performing while reducing wear and tear, accident expenses, and other costs.

- **How it works**

Driver scoring algorithms focuses on 'telematics alerts' such as harsh acceleration and harsh braking. Alerts generated over a period—and the driver's ability to learn from it will result in safer driving. This will lead to improvement in driver performance, which will be indicated by the improved scores.

Remember, each alert is not a penalty! It is meant to assist the driver.

Metrics tracked in driver scorecards

- **Speeding:** Perhaps the most important aspect of driver safety, the speeding metric tells you how often your drivers are moving at dangerously high speeds.

- **Acceleration:** It's one thing for a driver to gradually increase their speed to keep up with the traffic around them and another if they step on the gas excessively or forcefully. Harsh braking can lead to the sort of highway pile-on that leads to standstill traffic and, worse yet, injuries.

- **Braking:** Since much of fleet transportation involves highway driving, your drivers shouldn't brake excessively or strongly. Doing so can lead to the sort of highway pile-on that lead to standstill traffic and, worse yet, injuries.

- **Coasting:** Coasting is when vehicle is put in "neutral" or depress the clutch when going downhill. Most of the time, this driving technique is used to save fuel as the thought is that the engine is idling and therefore using less fuel. But coasting in neutral while going downhill can be dangerous because you don't have the optimal control of the car's throttle. While coasting, the car's drivetrain is disconnected from the engine, making engine braking impossible.

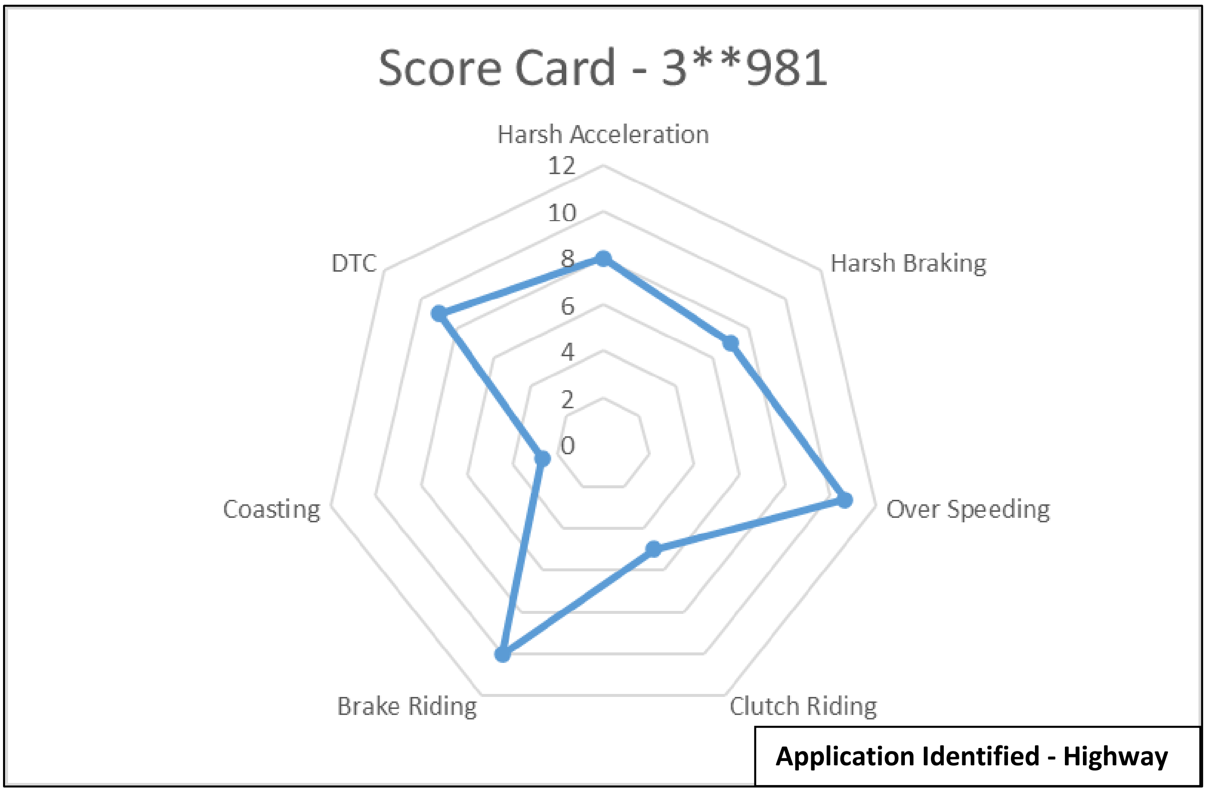
- **Brake Riding:** Riding the brakes usually refers to someone resting their foot on the rear brake lever, and/or their hand on the front brake lever and slightly applying pressure in an almost imperceptible fashion for an extended period.

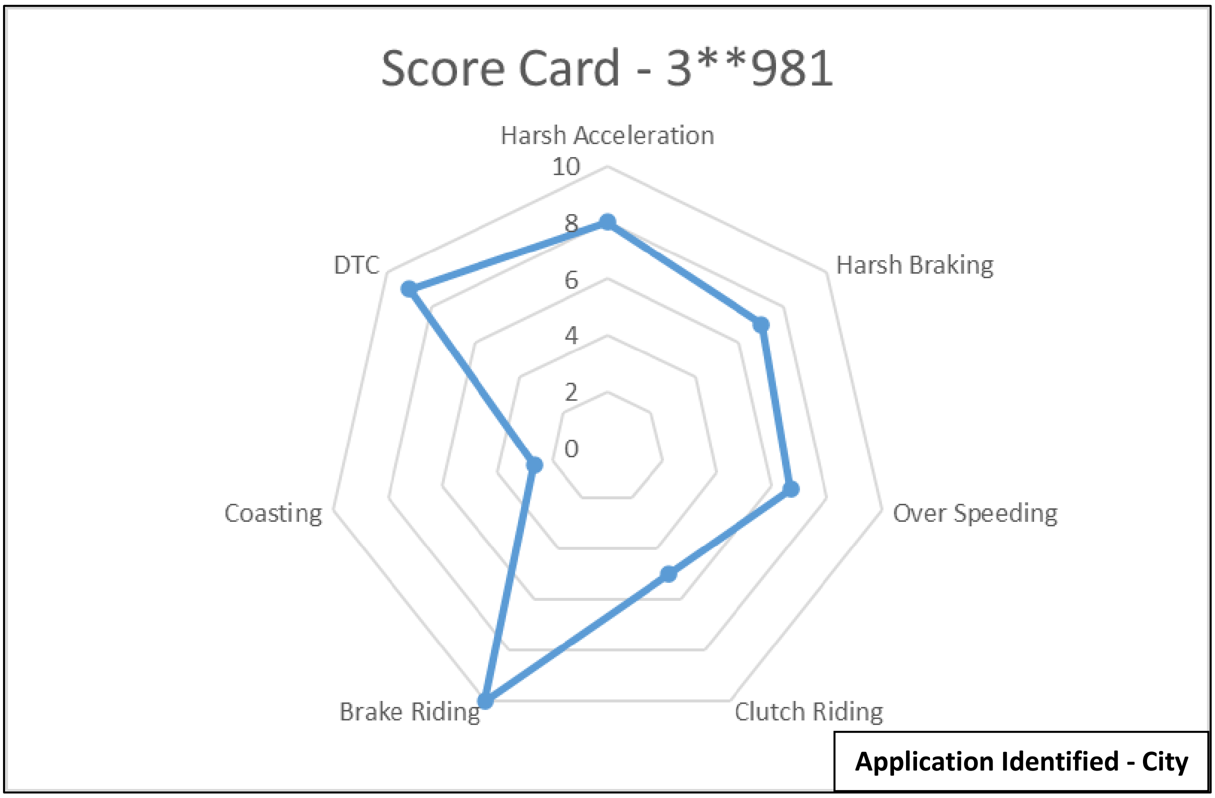
- **Clutch Riding:** Riding the clutch occurs when the driver does not fully release the clutch pedal. This results in the clutch disc slipping against the flywheel and some engine power not being transferred to the drive train and wheels.

- **DTC:** Some of the Diagnostic Trouble Codes (DTC) are generated by the ECU because of driver's negligence, such as low level of AdBlue, etc.

• Application Classification

One of the major problems while creating driver scorecard was that the vehicles are used for different applications. For example, the major application of tipper is in mines and construction area but some of the tippers are used on highways. So, scoring tipper based on haulage vehicle would not be a fair deal. Other applications are city and highway driving. On highway, vehicles drive at high speeds while at lower speeds in the city using the brakes more in city than on the highway. Hence, this should also be classified. The below figure provides an overview of how the driver scorecard will appear on the customer portal.


Score Card - 3**981
Harsh Acceleration
12
10
8
6
4
2
0
Harsh Braking
Over Speeding
Clutch Riding
Brake Riding
Coasting
DTC
Application Identified - Highway


Score Card - 3**981
Harsh Acceleration
10
8
6
4
2
0
Harsh Braking
Over Speeding
Clutch Riding
Brake Riding
Coasting
DTC
Application Identified - City

5. CONCLUSION

In the 6 months tenure of my technical internship at Volvo Eicher Commercial Vehicles Ltd., I was very fortunate to witness how the industry works while also being a part of it. It has been an outstanding experience so far and I can confidently say that I have nurtured numerous technical and soft skills that'll help me to enhance my growth further.

Coming to the technical aspects, I learnt about how a fleet management system (FMS) is implemented and worked upon to have efficient communication and data exchange among adjacent vehicles as well as between vehicles and users. I also learnt about the development of commercial electric vehicles and the implementation of telematics in them. In our department, we performed data analytics frequently as a proactive approach to improve vehicle reliability and fault diagnostics. I also actively worked on the automation of data analytics techniques with the help of programming which resulted in faster and more accurate results even for large sums of data.

I also had the opportunity to work on several projects which were successfully completed and will also be used in future Eicher vehicles. Some of the most interesting projects that I did were Digital Twin, automated crash data validation, Driver Scoring Algorithm, and EV power consumption monitoring.

VE Commercial Vehicles proved to be a great place for me to polish and expand my technical skills as I worked on many new familiar and unfamiliar software such as MS Excel, Tableau, Tera Term, and BUSMASTER as well as got the chance of improving my command on the Python Programming Language by using it for overcoming project challenges and getting familiar with different libraries viz Pandas, NumPy, Matplotlib etc.

Apart from all the technical aspects, I learn the importance of teamwork and the importance of a healthy work environment which I got to witness at VECV. My mentor and senior officials in the team offered their valuable knowledge and ideologies which helped me get closer to the person I dream of becoming. They helped me overcome my mistakes and their constant encouragement amplified my confidence and belief in my ideas.

Conclusively, I look forward to keeping constantly improving and using all that I've learnt at this prestigious organization for the same.

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