

Analysis of Warranty Data to Identify Improvements to Vehicle Reliability and Service Information

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ABSTRACT

It is common for an automotive OEM to produce a wide variety of automotive models related to a common platform. As such, it is important to analyze how these variants perform with relation to reliability and warranty claims relative to each other. This paper illustrates techniques that have been applied to use warranty claim information to assess the relative reliability and incident rates for DTC occurrences, component removals, and co-occurrences with other DTCs for a family of Vehicle applications. These results are then used to identify common root cause failure modes and DTCs on specific vehicle applications that perform worse than fleet averages, and components with much lower reliability than components in similar applications.

The paper concludes with an assessment of how warranty information can be used to identify precursors to future failures, identify material requirements by region and to identify product improvements in either hardware, software or service procedures:

KEYWORDS: Reliability, warranty claims, unsupervised machine learning, supervised machine learning, data science

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INTRODUCTION

Automotive engineers are facing current pressures to cut costs, streamline component utilization across similar vehicle platforms, increase fuel efficiency and modernize vehicle connectivity. Closed loop architecture for automotive engineers, albeit software, electrical, mechanical, or material, all face the uphill climb and lack of visibility regarding how their assets perform on real world applications in various operating conditions. By comparing how components perform across common platforms e.g., engine types and emission systems on model variants within the same class, engineers can optimize performance specifications and allocate appropriate design changes when applicable. Establishing a common framework around component reliability is the first step in improving vehicle reliability, customer satisfaction and reductions in warranty burden on OEMs and their corresponding suppliers.

Diagnostic Trouble Codes are universally referenced as DTC's in the automotive industry. DTC's provide an inherent purpose for a vehicles self-diagnostic reporting capabilities i.e., On-board diagnostics OBD serve the primary method for vehicle operators and repair technicians diagnostic troubleshooting mechanism when problems occur. Additionally, basic frequency of specific DTC occurrences statistics trickles up the latter to various engineering component design teams and system engineers. The sheer quantity of sensors on today's automobiles which monitor whole systems and individual components can easily reach from a thousand different individual indicators to over a few thousand DTC's depending on the

complexity of the vehicle. Furthermore, the method of DTC occurrence information delivery varies from each automotive manufacturer. It is also entirely possible that some automotive manufacturers operate in a reactive fashion, hence they only concentrate on vehicles and components that are causing the most pain or have the largest impact on cost. Versus proactively utilizing precursors within the data they already capture and applying supervised and unsupervised machine learning techniques to peer into the future.

Problem Statement

Lack of transparency around how components and systems are performing in real world conditions across common vehicle platforms causes inherent stress and poor decision making. The inability to accurately predict, forecast and visualize DTC occurrences and subsequent component removals across a family of vehicle applications can sometimes cause additional component removals, reduced reliability ratings, loss of revenue, lower customer satisfaction scores, bad publicity, loaner vehicle depreciation and an unbalance responsive supply chain with component stock out problems.

To increase profits and simultaneously reduce cost, without having to reduce or negatively affect their workforce the automotive OEMs need to understand reliability warranty claims' information by product type and any difference in DTC occurrences and DTC

co-occurrences between vehicle applications and the behavior between OEM service locations when faced with the same occurrence of events.

General Overview

The purpose of this research is to explore and understand the relationship between DTC's, warranty claims, singular applications, family of applications, OEM service performance, location and application utilization such that recommendations can be made to improve profitability and subsequently reduce costs for automotive OEMs, improve OEM supplier relationships, increase vehicle reliability, technician training and accurately forecast future problems to provide a just-in-time component available stock level to reduce loaner vehicle utilization and depreciation. Through three distinct research stages including exploratory data analysis, pattern finding, forecasting future vehicle sales, research objective include:

- i. A thorough exploration and evaluation of key variables that may impact vehicle application reliability, including primary attributes: Application Model Name, Engine Type, Engine Emission Level, Engine Fuel Type
- ii. An analysis of normalized DTC occurrence ratios and co-occurrence ratios across an automotive OEMs entire platform of customer products through effective and intuitive suite of visualization tools
- iii. Quantification of the relationship between location and DTC occurrence ratios, vehicle application historical sales, forward looking and lagging economic indicators to help facilitate an accurate prediction of future automotive application sales

The synthesis of completed research provides Automotive OEMs with information and recommendations to Engineers to evaluate the appropriate corrective actions i.e., design engineering component changes, adjust electronic controller thresholds, isolate supplier quality control. This knowledge can be used to optimize component configurations across the vehicle family to improve reliability, increase visual awareness for automotive reliability analysts, improve supply chain issues related to component stock out, and improve negotiations and quickly isolate quality control issues with component suppliers.

VARIABLES

Key variables throughout research include:

Automotive Manufacturers Data

VIN

Vehicle Identification Number; a unique combination of letters and numbers used to identify the manufacturer, vehicle model year, model type, manufactured plant and production number.

Commercial Model

A name or number associated with a vehicle commonly referred to the type vehicle model e.g., Honda¹ "Accord."

1. American Honda Motor Co., Inc. data was not used for this publication. Reference is

Engine Type

Characteristics and features associated with a specific engine. Auto manufacturers frequently uses the same engine across the model family e.g., *Honda Accord Sport* 2.4L 16-Valve, DOHC i-VTEC 4-Cylinder Engine, *Honda Accord EX* 2.4L 16-Valve, DOHC i-VTEC 4-Cylinder Engine, or on different model types with little to no difference in engine output.

Engine Index

A unique code associated with an engine type to help identify any changes made to the engine type to accommodate a model type.

Emission Level

A unique code to identify the level of and type of emissions gas association with a specific model type. Different fuel types i.e., petrol, diesel, hybrid and electric vehicles vary in the amount and types of emissions gasses generated by the combustion process.

Date Vehicle was Manufactured

Gregorian Calendar date referencing the day of the month, the month and calendar year a specific automobile was assembled, past all quality control inspections and is approved for end consumer use.

Automotive Sales Data

VIN

Vehicle Identification Number; a unique combination of letters and numbers used to identify the manufacture, vehicle model year, model type, manufactured plant and production number.

Date Vehicle was Purchased

Gregorian Calendar date referencing the day of the month, the month and calendar year a specific automobile was purchased by a customer.

Location of Vehicle Sale

Country, State and City of vehicle sale. Essentially the location of a dealership.

Automotive Servicing Data

Diagnostic Record

An index number which references a vehicle that was connected to a diagnostic computer and some form of analysis and readings were performed.

VIN

Vehicle Identification Number; a unique combination of letters and numbers used to identify the manufacturer, vehicle model year, model type, manufactured plant and production number.

Diagnostic Trouble Code DTC

A series of specific letters and numbers used to identify malfunctions within a vehicle. Commonly referred to as a DTC, isolates a problem at a system level and sometimes at the component level.

Date of Diagnostic Reading

Gregorian Calendar date referencing the day of the month, the month and calendar year a specific automobile was attached to an OEM approved service tool.

Location of Service

Country and City name where dealership or OEM approved repair facility location.

Application

A distinct combination of Vehicle Model, Engine Type, Engine Index and Emissions Level.

Memorized DTC

A DTC from the vehicle which was present for a period but did not activate the Check Engine Light. The DTC could have been an anomaly or an initial threshold was breached.

Active DTC

A DTC or group of DTCs which are active or on and triggered a Check Engine Light or other vehicle dashboard light.

Vehicle Data**VIN**

Vehicle Identification Number; a unique combination of letters and numbers used to identify the manufacturer, vehicle model year, model type, manufactured plant and production number.

Stored DTC

DTCs require two failure detections to illuminate the check engine light. DTCs are set in three separate places based on the first or second detection.

- A DTC is set upon the first failure indicator in a monitored system (not by “telematics information”). It is stored in a location called “Pending” which indicates the first of the two detections required to illuminate the check engine light. This condition does not illuminate the light.
- The next, or second, time that the failure indicator is detected by a system or component monitor, the DTC is then stored in a location called “Confirmed” and is also stored in a location called “Permanent DTC.” This Permanent DTC setting illuminates the check engine light.
- After detection, Pending, Confirmed, and Permanent DTCs can be cleared and the check engine light extinguished by a proper repair of the faulted system and the vehicle driven in a manner which runs the monitor and the monitor can detect that the fault

no longer exists. This subsequent process of events is called “healing” of the DTC.

- Pending and Confirmed DTCs can also be erased, and the check engine light can also be cleared using a service command. However, Permanent DTCs cannot be erased using this command, and the DTCs and light return if the failure condition does not repair.

ECU Triggered Check Engine Light

Electronic, Engine, Transmission, Control Unit or Control Module. Each major system has its own ECU, hence a series of individual computers with various functions related to programmatic system optimization functions, monitoring and diagnostics. A fault message from one of these ECU's can trigger a check engine light, most commonly the transmission, fuel system, electronic or engine related.

Telematics Data

Individual Vehicle Information related to utilization and timestamp of vehicle condition e.g., odometer, battery voltage, engine temperature, oil pressure, transmission oil level, transmission oil temperature.

RESEARCH QUESTION

This research aims to determine the most problematic DTCs that seem to perform well on a few vehicle models within the model family but exhibit reliability issues on other variants.

Patterns in DTC occurrences tied to telematics data like vehicle utilization, environmental conditions and co-occurrences of DTCs to help facilitate a prediction of when the next event might occur.

Evaluate current forecasting methods and provide insight into improved multistage forecasting to prevent component stock out at OEM sales and repair facilities thus reducing loaner vehicles utilization and improving customer satisfaction thus maximizing profits by using less loaner vehicles and improving repeat buyers.

BACKGROUND

Effective approaches to DTC reliability management have developed significantly in response to challenges introduced by the nature of analytics in the automotive space, including the rapid evolution of technology, reduced sensor size and cost has greatly increased the number of and the orientation of sensor located in today's automotive applications. The vast amount of information one can gather from an automobile pertaining to component performance, utilization factors, component conditions and telematics should help solve technical and mechanical problems that arise during the vehicle warranty period.

Reliability analysis during the vehicle warranty period is an essential component of automotive supply chain management to maximizing profits by optimizing component performance and reliability issues across all variants in a vehicle family. Many methodical approaches to produce the best DTC improvement opportunity for automotive engineers' historically have relied on “warranty forecasting methods based on stochastic simulations of expected product warranty returns