# CRC Project No. CM-138-13

# Evaluation of an Automated Driveability Rating System (AVL-DRIVE$^{TM}$) during the 2013 CRC INTERMEDIATE-TEMPERATURE E15 COLD-START AND WARM-UP VEHICLE DRIVEABILITY PROGRAM

**March 2016**

**COORDINATING RESEARCH COUNCIL, INC.**
5755 NORTH POINT PARKWAY • SUITE 265 • ALPHARETTA, GA 30022

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**COORDINATING RESEARCH COUNCIL, INC.**
5755 North Point Parkway, SUITE 265
ALPHARETTA, GA30022
TEL: 678/795-0506 FAX: 678/795-0509
WWW.CRCAO.ORG

# Evaluation of an Automated Driveability Rating System (AVL-DRIVE™) During the 2013 CRC INTERMEDIATE-TEMPERATURE E15 COLD-START AND WARM-UP VEHICLE DRIVEABILITY PROGRAM

(Part of CRC Project No. CM-138-13)



Prepared by the

CRC Volatility Group

March 2016

CRC Performance Committee
of the
Coordinating Research Council

# I. INTRODUCTION

An intermediate ambient temperature (40°F ± 5°F) vehicle test program was conducted by the Coordinating Research Council, (CRC) Inc. to determine the effect of Driveability Index (DI) and ethanol content level on cold-start and warm-up driveability performance in a group of US high sales volume, late model vehicles. The test program was conducted on an outdoor test track from February 4, 2013, through March 22, 2013, in Yakima, Washington. The program report was published in April 2014 and entitled, "2013 CRC INTERMEDIATE-TEMPERATURE E15 COLD-START AND WARM-UP VEHICLE DRIVEABILITY PROGRAM", (Report No. 666), which can be found on the www.crcao.org website.

The test vehicle fleet was made up of a mixture of late model car and light duty truck engine technologies including port fuel injected (PFI) fuel and direct injection spark-ignition (DISI) fuel systems, and a mix of turbocharged and naturally aspirated engines. The 18 vehicles making up the test fleet were selected from a group of 40 vehicles using a screening technique to determine the vehicles that responded to a low volatility hydrocarbon and high ethanol (E20) test fuel blend. The test fuel matrix consisted of 10 fuels ranging in ethanol content from zero to 20 volume percent (E0 – E20) with uncorrected DI values (no ethanol correction) as the primary control variable. DI for the fuel matrix was designed to match the current U.S. market and generally ranged from 1008 – 1250°F. The ambient testing temperature range target was 40°F ± 5°F with an acceptable overnight soak range of 40°F ± 10°F. Addition vehicle, test fuel, test procedure, and test temperature details can be found in CRC Report 666.

During the cold start and warm-up vehicle driveability program, a second parallel program was simultaneously conducted to evaluate an automated computer and sensor based driveability rating system called AVL-DRIVE™. Details of the AVL-DRIVE System can be found in the attached AVL report, PEI-PEI0695 Rev 3 April 2015, "*Investigation into Using AVL-DRIVE to Determine Fuel Quality Impacts of a Range of Fuel Blends.*" CRC personnel desired to become familiar with the automated rating system and determine its viability for potential future vehicle driveability programs. To do so, six of the 40 test vehicles were instrumented with the AVL-DRIVE equipment during the vehicle screening process. Two of the six instrumented test vehicles were then selected from the 18 screened vehicles to continue the automated ratings for entire test program and therefore were tested on all 10 test fuels. Post-test statistical analyses and correlations were developed between the CRC driveability raters and the AVL-DRIVE System driveability scoring. A summary of key learnings are listed in this cover letter section along with the full program report prepared by AVL.

# II. MOTIVATION

## Potential Uses of Automated Driveabilty Ratings

One of the main "tools" the CRC Performance Committee's Volatility Group has relied on for decades has been the human trained rater driveability rating evaluations to evaluate fuel effects on vehicle fleet driveability performance under various seasonal and driver behavior operating conditions. Using large fleets of marketplace production vehicles that are driven through a specific and controlled series of acceleration and idling maneuvers, trained human raters evaluate each vehicle's drive quality. This tool has worked very well for many programs and has enabled subjective drive quality ratings to be turned into quantitative ratings for subsequent statistical analysis.

The following list includes some of the potential uses and / or contemplated benefits of utilizing modern computer controlled automated equipment to supplement the traditional CRC driveability ratings.

- The typical CRC vehicle driveability program is very large, manpower intensive and financially expensive to conduct. An evaluation of automated rating is needed to determine if the number of test observations (fuel, vehicle, and rater combinations) can be scaled down, while maintaining high statistical fidelity. Specific objectives investigated in this cold start and warm-up intermediate temperature road track program include:
  - Understand the driveability rating correlation between a CRC rater and an automated system.
  - Compare the precision of driveability rating between the two types of raters.
  - Determine if an automated rater software system with multiple electronic sensors would provide additional insights into the impacts of the test fuels on the vehicle's operation. One example would be, if the automated system could better separate fuel caused driveability effects from driveline events (gear shifts) and test track condition effects, which are difficult to separate.

- Utilize an automated rater system in combination with indoor environmentally controlled chassis dynamometer lab to develop correlations between the "lab and test track" for both Cold Start and Warm-up programs and Hot Fuel Handling programs. Currently, programs are conducted outdoors and subject to weather effects that require additional testing days and limited test track availability.

- Because CRC vehicle driveability programs are run infrequently it's difficult to maintain a core group of human trained raters. Would an automated rating system help in this regard?

## III. SUMMARY AND CONCLUSIONS

1. The AVL-DRIVE system is a powerful tool to help understand fuel and vehicle effects on vehicle driveability.

2. There is an inverse correlation between the current CRC Rating system and the AVL-DRIVE automated system. However, note the figure below shows that the AVL Drive ratings are not normally distributed. ($R^2$ = 0.55) Additional correlation studies between the two rating systems are needed.

**Figure 16**

**CRC Rating (Corrected to Rater C) – AVL Rating**

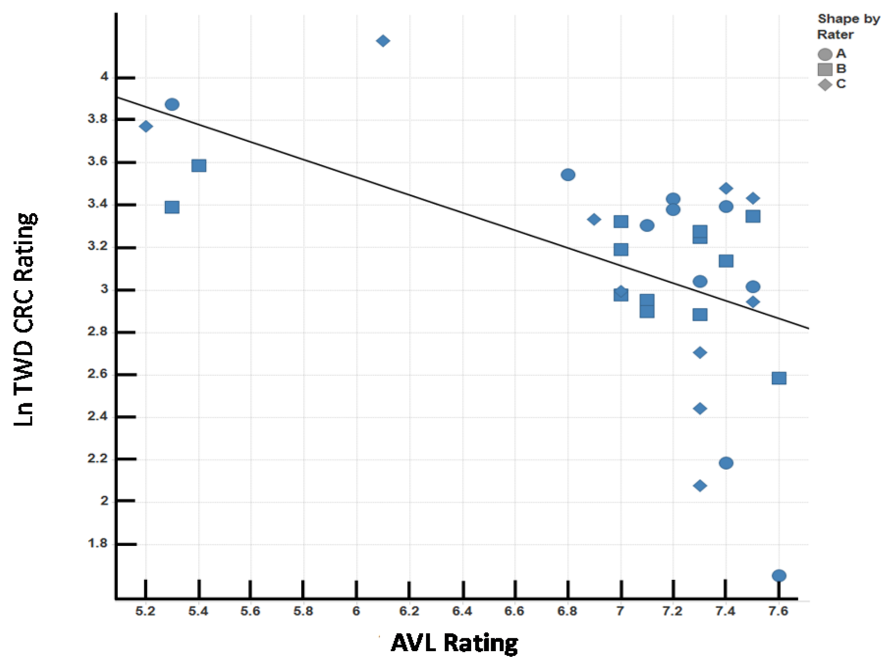


Figure 16 from the CRC Report No. 666: "2013 CRC INTERMEDIATE-TEMPERATURE E15 COLD-START AND WARM-UP VEHICLE DRIVEABILITY PROGRAM"

3. The correlation is not significantly affected by the Run or Soak temperatures, Vehicle, and Fuel. Rater does have a significant effect (P = 0.0045)

4. The CRC Rating has to be log-transformed, as is typically done, to meet normality and constancy of variance assumptions of regression analysis. The log transformed CRC rating has about twice the level of variation as the AVL-DRIVE system.

| Rating | Mean | Standard Deviation | Coefficient of Variation |
|---|---|---|---|
| CRC (Original) | 34.8 | 17.55 | 0.50 |
| CRC (LnTransformed) | 3.4 | 0.65 | 0.19 |
| AVL | 7.0 | 0.70 | 0.10 |

5. The charts and data presented in the attached AVL project report are evidence of how the AVL-DRIVE system can provide additional driveability rating details to assist in the interpretation of the driveability effects. For example, Figure 14 on page 26 of the AVL project report indicates the need for a greater match between the rates of acceleration during successive acceleration events before driveability ratings can be strictly attributed to fuel effects alone. However, the Conclusions and Recommendations section beginning on page 25 of this report does indicate a need for greater software and hardware customization to CRC's needs as well as user training before the AVL-DRIVE system can be readily utilized by the CRC Volatility Group as a standard work tool.

6. There are several pros and cons for each rating system.
   a. One of the big benefits of the current CRC rating system, which is done on an open road track with human raters is that many vehicles can be evaluated quickly giving a good representation of vehicle impacts in the marketplace.
   b. However, the variation in ambient test conditions and individual rater response requires greater test repeats and additional test points to enable statistical analysis for significant and insignificant effects.
   c. The automated AVL-DRIVE system has greater up-front investment costs in getting multiple copies of the equipment for numerous vehicles; particularly enough sensor wiring harnesses so that the harnesses can be permanently mounted in the vehicle for the duration of the test and only the data laptop being moved from vehicle to vehicle.
   d. The AVL-DRIVE system requires that each vehicle be initially set-up to learn what a driveline shift event is, as opposed to an abnormal combustion event due to the fuel. It should be pointed out that the AVL-DRIVE system does not drive the

vehicle down the track so trained drivers are still needed to drive the vehicle through the series of defined maneuvers.

e. And lastly, both rating systems still require numerous personnel that are needed for fueling, re-conditioning, and managing the vehicles. These last two points mean that significant manpower costs are likely to continue in order to execute the programs regardless of the rating tool used. Additionally, a correlation should be determined between the AVL rating scale and demerit quantity. For example, how many demerits qualifies as a "7" in the AVL rating.

7. An area of future CRC work that may provide significant cost savings and data quality benefits is the combination of the AVL-DRIVE automated rating system for a relatively small fleet of "highly instrumented" vehicles, which are then tested in a climate controlled chassis dynamometer with a robot driver. Correlation of such a set-up to the current CRC test track program is suggested.

8. The proper tool selection for future CRC Volatility programs depends on the specific objectives of the program. Periodically, it may be better suited to run the traditional program so many vehicles can be included, while other times a more in-depth R&D type approach may be needed.

47519 HALYARD DRIVE
PLYMOUTH, MI 48170-2438
PHONE: (734) 414 9618
FAX: (734) 414 9690

# REPORT PEI-PEI0695 Rev 3
# April 2015

# Investigation into using AVL-DRIVE to determine fuel quality impacts of a range of fuel blends

**Written by**

Phil Shaw
Chief Engineer
PT Int & Veh

**Reviewed by**

Jen Durfy
Technical Specialist
PT Int & Veh

**Approved by**

Paul Whitaker
Director
Technology

**Distributed to**

Coordinating Research Council

AVL PEI

AVL Graz Abteilung DEC

# Revision History

| Date | Rev # | Page | Description | Author |
|---|---|---|---|---|
| 07/12/13 | 0 | | Draft | Shaw |
| 07/24/14 | 1 | | Updates to correlation to include statistical analysis from Chevron | Shaw |
| 09/11/14 | 2 | | Updates to check for inconsistencies in references. | Shaw |
| 04/06/15 | 3 | | Vehicles blinded | Shaw |
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# Executive Summary

The following is a report of a project performed by AVL for the CRC to evaluate the use of AVL-DRIVE$^{TM}$ in the testing of a range of fuel blends and their impact on vehicle driveability.

The approach taken was to instrument 6 vehicles during the screening phase of the project, and then select two vehicles for the on-going fuel testing. The testing was performed in late February through to late March in Yakima, WA. The goal was to generate data-sets that could then be compared to the subjective evaluation results to confirm that AVL-DRIVE was able to detect the impact of the change of fuel. Additionally, AVL was required to evaluate the process used to determine how to best implement AVL-DRIVE into the testing to ensure success.

It was observed that the CRC evaluation process did not completely align with the way AVL-DRIVE identifies events and rates the various maneuvers / events being assessed. Therefore, the data evaluation was approached using two alternative methods. First, the screening data was filtered using the available AVL-DRIVE functions to achieve a reasonable comparison of the data. Second, for the fuel testing, since individual ratings were required for CRC events, the AVL-DRIVE event ratings were "compounded". The final comparison between the standard CRC demerit approach and the AVL-DRIVE ratings was performed by Chevron.

Some specific areas for improvement were identified in the debrief session, mainly focused on training requirements and some enhancements to the usability of the system. In fact, it is possible to address many of the concerns in the current software by including remote switches to start and stop the recording, and by implementing an available display.

The report also provides brief details on alternative methods of evaluation that are intended to improve the signal to noise ratio and therefore improve confidence that the response observed is the result of the fuel blend and not just noise in the testing.

Key conclusions from the exercise are:

- There is correlation between the CRC raters and AVL-DRIVE, as identified in section 5.

- The evaluation process does not readily lend itself to instrumentation and data acquisition; therefore modifications would need to be considered. The report identifies modifications that could be considered from the perspective of using AVL-DRIVE in this environment, but most data acquisition systems would have some similar requirements.

- Additional data analysis should be possible by combining the AVL-DRIVE data and the CRC rating data to more completely identify the ability to both rate and measure the impact on driveability for a range of fuel blends over a range of temperatures.

Finally, an alternative approach is presented to the CRC that identifies AVL's referred path for this type of investigation.

# Contents

## Figures

# 1. Introduction

## 1.1. Background

The Coordinating Research Council (CRC) periodically conducts subjective vehicle evaluations to determine the driveability impacts of a range of blends of fuels. This process requires a jury evaluation of a wide range of vehicles (and therefore a range of sensitivities to fuel quality) with a range of fuel blends.

AVL was requested to support the intermediate temperature evaluation event planned for February – March 2013 in order to both demonstrate AVL-DRIVE™ and to evaluate how the tool could be used to support similar evaluations in the future. This report details the process applied, and provides recommendations regarding alternative approaches for the evaluation. The report will describe the process used for instrumentation and testing and provide analysis of the acquired data.

This report is intended to supplement the overall CRC evaluation report. The statistical evaluation of the data is constrained to a comparison between the standard CRC evaluation process and AVL-DRIVE. Detailed statistical analysis of the impact of the range of fuel blends on the vehicle driveability is the subject of the report provided by the core team members of the CRC.

## 1.2. Project Objectives

As stated, the overall intention of the project is to demonstrate how AVL-DRIVE can be used in place of subjective evaluation for determining the impact of a range of ethanol blended fuels on driveability. Specifically, the project objectives were to:

- Instrument 6 or more vehicles during the screening evaluations to confirm that the DRIVE results show a performance impact as a result of the change in fuel in line with the subjective evaluations.
- Instrument 2 of the down-selected vehicles and acquire data over the remainder of the testing.
- Evaluate the process used to determine how DRIVE could be used within the constraints of the current approach
- Provide recommendations for alternative approaches by applying current technology to the evaluation methods.

## 2. Vehicle Instrumentation and Testing

The testing was performed in Yakima, WA, at the Renegade Raceway, in order to achieve the required ambient conditions for the evaluation.

### 2.1. AVL-DRIVE Instrumentation and set-up

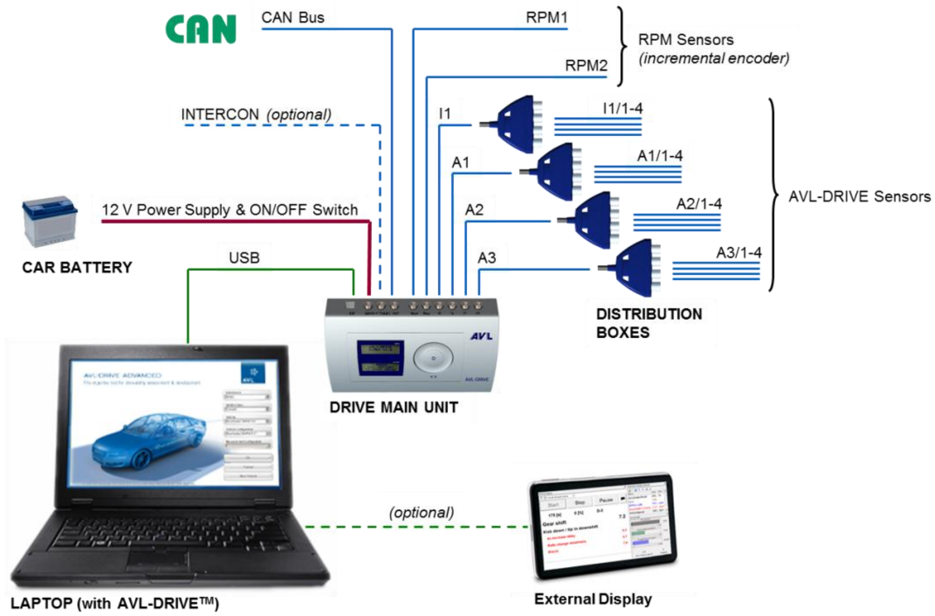
AVL-DRIVE provides an objective evaluation of a vehicles response to the drivers input, using a number of sensors to measure both the demand (for example, pedal input), and the response. The assessment made includes a comparison to both the expectation, established by creating a simple model of the vehicle during the software configuration process, and the competitor set for the class of vehicle. Appendix B includes a detailed description of AVL-DRIVE.

The following signals were acquired during the testing:

| | |
|---|---|
| Acceleration (3-axis seat track accelerometer) | Sensor |
| Accelerator pedal position | CAN |
| Engine Speed | CAN |
| Vehicle speed | CAN |
| Electrical load (L.E.M current clamp on alternator out) | Sensor |
| Brake switch | CAN |
| Engine temperature (ECT) | CAN |
| Seat track vibration | Sensor |
| Steering column vibration | Sensor |
| Gear Lever position (P,R,N,D,L) | CAN |
| Gear (1$^{st}$, 2$^{nd}$, 3$^{rd}$ etc.) | CAN |
| Air Conditioning (on / off) | CAN |

**Table 1 List of channels acquired during data acquisition**

Additional channels are calculated by the software based on filters, smoothing functions and equations to determine vehicle state and support signal processing. Note that it is feasible (and usual) to acquire a larger data-set, including turbine speed for more accurate assessment of the gear-shift, temperatures for intake air and transmission oil etc., and fuel flow. Due to the format of the testing and the limited time, it was agreed that this would not be required for this particular evaluation. Additional data is generally required to develop understanding of the cause of issues – in this case the focus was on the ability to identify the issues themselves (and therefore to compare the process to the demerit evaluation system usually used).




| Label | Sensor |
|---|---|
| A1/1 | 1-axis accelerometer (Seat) |
| A1/2 | 3-axis accelerometer (Chassis longitudinal) |
| A1/3 | 3-axis accelerometer (Chassis lateral) |
| A1/4 | 3-axis accelerometer (Chassis vertical) |
| A2/1 | Clamp on ammeter (Electric load) |
| A2/2 | 1-axis accelerometer (Wheel carrier) |
| A2/3 | Draw wire sensor (Clutch pedal) |
| I1/1 | Vibration sensor (Gear lever) |
| I1/2 | Vibration sensor (Steering wheel) |
| I1/3 | Vibration sensor (Seat rail) |
| I1/4 | Microphone (Seat) |
| RPM1 | RPM sensor (Engine speed) |

**Figure 1 Schematic of AVL-DRIVE installation**

The software configuration included populating a simple model of the vehicle via coastdown and acceleration measurements, sensor calibration and defining thresholds for accelerator pedal rates and other boundary conditions.

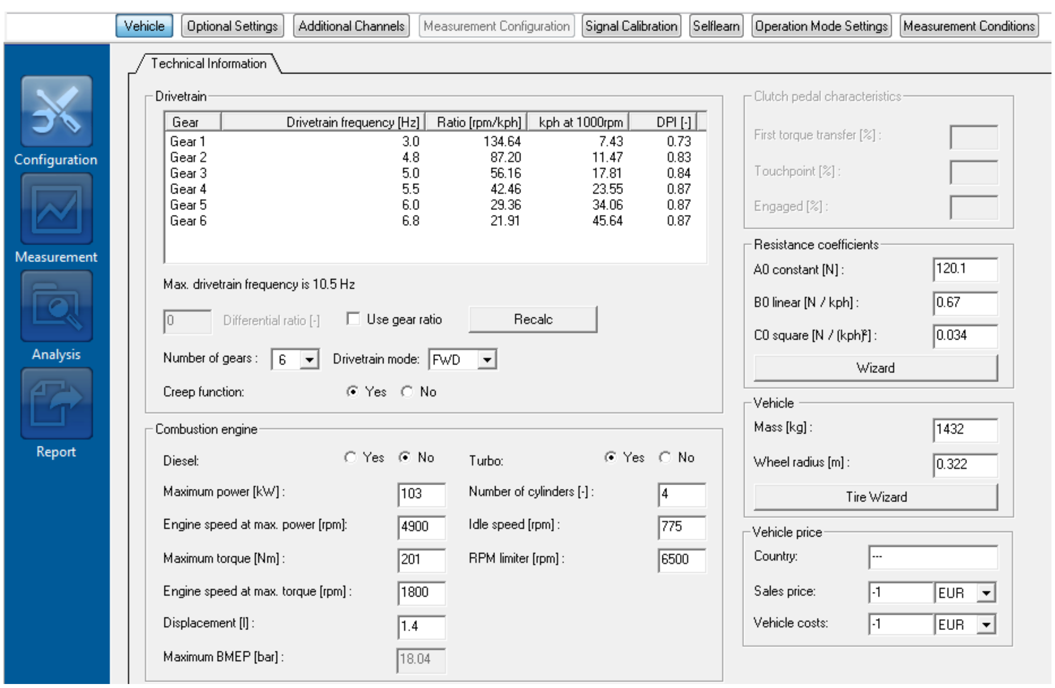



**Figure 2 Technical Information tab in the vehicle configuration**

Figure 2 shows the technical information tab for configuration for vehicle # 4  This information was used to build the basic lumped mass vehicle model that provided estimates for acceleration and deceleration that were used as reference points in the assessment.

Prior knowledge and information on a number of the vehicles was a key motivator in determining which vehicles should be instrumented during the screening process. Typically, the instrumentation and software configuration takes approximately 4 – 5 hours. Pre-selecting vehicles ensured that the team could be as prepared as possible to successfully test during the screening phase.

### 2.2. CRC Test Process

The standard CRC test process was used for the vehicle evaluation. A copy of this can be requested through the CRC and is not included in detail in this report. The process is intended to be completed in approximately 6 to 7 minutes with one of the goals being to maintain a low engine operating temperature. The maneuvers performed, in order of evaluation, were:

| **CRC Test Maneuver** |
|---|
| Idle Park |
| Idle Drive |
| 0 - 15 Light Throttle |
| 0 - 15 Light Throttle |
| 0 - 20 WOT |
| 0 - 15 Light Throttle |
| 0 - 15 Light Throttle |
| 10 - 20 Light Throttle |
| 0 - 20 Med. Throttle |
| Idle Drive |
| 0 - 15 Light Throttle |
| 0 - 15 Light Throttle |
| 0 - 20 WOT |
| 0 - 15 Light Throttle |
| 0 - 15 Light Throttle |
| 10 - 20 Light Throttle |
| 0 - 20 Med. Throttle |
| Idle Drive |
| 0 - 45 Crowd |
| 25 - 35 Detent |
| Idle Drive - 5 sec. |
| Idle Drive - 30 sec. |

**Table 2 CRC evaluation maneuvers**

The events that were automatically detected by AVL-DRIVE were not completely aligned with the subjective evaluation maneuvers as described, and so, for the assessment, the AVL-DRIVE events were evaluated in one of two ways.

For the vehicle screening, the events were filtered into the broad categories (operation modes) that described the maneuver. For the fuel testing, the AVL-DRIVE events were combined to meet the same boundary conditions as the subjective evaluation, for example, a 0—15mph acceleration was identified by AVL-DRIVE to be a Drive Away, followed by a gear-shift. This is described in greater detail in Section 3. Data Analysis.

Additional events detected and rated by AVL-DRIVE (such as braking events) were ignored during the data analysis, although the raw data is available upon request.

## 2.3. Vehicle screening

40 vehicles were included in the screening processes. Of these vehicles, AVL instrumented the following:

| Veh No |
|---|
| 4 |
| 6 |
| 11 |
| 12 |
| 13 |
| 15 |
| 19 |
| 33 |

**Table 3 List of vehicles evaluated during screening**

A number of data-sets were compromised as a result of the operator terminating the recording prior to the test run. This was a point of discussion during a feedback session held with the evaluators, and is covered in further detail in section 2.5 Feedback from Testers. Usable data was acquired from vehicles 4, 11, 13 and 33, and is shown in Section 3 Data Analysis.

## 2.4. Fuel Testing

The vehicle screening reduced the test fleet from 40 vehicles to 18. These vehicles were tested on a range of fuel blends over several weeks of testing to develop a statistical correlation of the vehicle response (as evaluated by the test drivers using a demerit scoring system) and the fuel quality. The process and results are described in detail in the CRC report and are not covered in this report.

AVL-DRIVE was instrumented into vehicle 19 and vehicle 33 for the duration of this testing.

The maneuvers performed adhered to the same test plan as was followed in the vehicle screening. Full details of the test process followed for this phase are included in the official CRC test report.

### 2.5. Feedback from Testers

At the end of the test program, AVL held a short debrief session with the evaluators in order to understand any issues identified with the implementation of AVL-DRIVE, and how this could be improved should a similar process be undertaken in the future.

The following comments are the key responses provided by the evaluators:

"The installation was not sufficiently robust"
"There was insufficient time to understand the tool"
"There is no feedback that the system is working / recording or that it has stopped."
"The system is not user friendly. More instruction is required."
"There seems to be some temperature sensitivity"
"System reports connection errors to the DMU2"
"The laptop should be secured somehow, or record the data to the DMU2"
"More AVL support is required."
"More convenient means of starting and stopping the recording is required"

Note that the issues identified are primarily a function of the lack of familiarity with the tool, and all are straightforward to resolve.

This process did highlight that the opportunity to use AVL-DRIVE in the current process is potentially awkward due to time limitations with the vehicles / the number of vehicles included in the assessment. Section 7 includes a brief description of AVL's preferred approach to this type of study.

## 3. Data Analysis

The following section is intended to provide insight into the method of data analysis applied for each of the tests. The more complete evaluation of the data is included in section 4 Results.

The usual approach to data analysis with AVL-DRIVE is to first evaluate the broad data-set in Report Generator (RG), a separate tool bundled with AVL-DRIVE that presents the complete set of ratings. For specific analysis, the data can be filtered to show only areas of interest (for example, based on maneuvers, vehicle speeds, gears etc).

There is a direct link between RG and AVL-DRIVE; if “outliers” are identified in the data, these can be quickly evaluated in AVL-DRIVE to more completely understand the root cause of the difference to other events in the same category.

As noted previously, the maneuvers performed as part of the evaluation do not directly align with the events as DRIVE detects and rates them. For the vehicle screening, the requirement was to generate a single score for the vehicle to enable a comparison of that vehicle on the base fuel (market fuel in vehicle as received) to one fuel blend. Filters were applied to the data to consider only operation modes that aligned to the evaluation. DRIVE ignores operation modes that do not meet the filter conditions and re-calculates the vehicles scores using only those remaining operation modes.

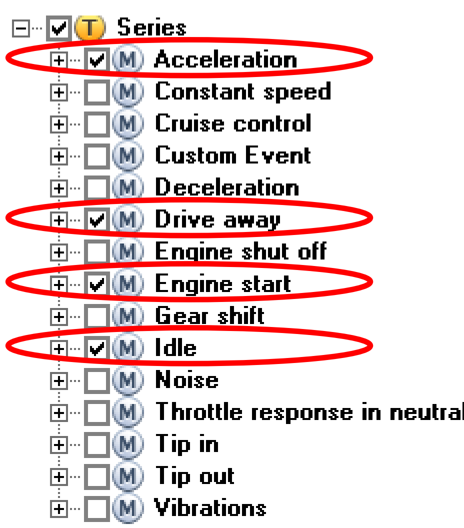



**Figure 3 Filter applied to the screening data.**

The operation modes above cascade down into sub-operation modes and then criteria. The structure for the highlighted operation modes can be found in Appendix B – AVL-DRIVE tree Structure

AVL-DRIVE uses a 1-10 rating scale for the evaluation that is similar to the scale used by OEMs, where a 1 is the worst and a 10 is the best rating achievable.

**AVL-DRIVE™ Driveability Assessment**

| DR | Evaluation | Description |
|---|---|---|
| 9 - 10 | excellent | The driveability exceeds all customer's expectations |
| 8 - 9 | good | The driveability meets all customer's expectations |
| 7 - 8 | satisfying | The driveability meets most customer's expectations |
| 6 - 7 | acceptable | Driveability at basic level only, does not meet most customer's expectations |
| 5 - 6 | poor | Some customers complain about driveability |
| 4 - 5 | unacceptable | Most customers complain about the driveability |
| 3 - 4 | defective | All customers complain driving the vehicle |
| 2 - 3 | unsafe operation | Only limited or unsafe vehicle operation possible |
| 1 - 2 | no operation | Vehicle not operational |

**Table 4 AVL-DRIVE Driveability Assessment**

### 3.1. Vehicle Screening Data

RG was used to generate the summary of the data for the screened vehicles. The following plot shows an example of the filtered data summary provided from RG.

The leftmost column is the overall score, determined as a weighted average of the scores for each of the operation modes (Drive away, acceleration, idle and engine start). The operation mode ratings are determined as an extreme value weighted average from each individual event performed (identified as a circle in the plot).

For example, for the idle evaluation with the vehicle running on the “bad” fuel, there were 7 events detected during the evaluation (7 circles). The score is heavily influenced by the one highlighted event resulting in a weighted average score of 5.3. The remaining events and operating modes, on inspection, do not appear significantly different between the fuel blends (comparing the grouping of red circles to the grouping of blue circles for the idle events).

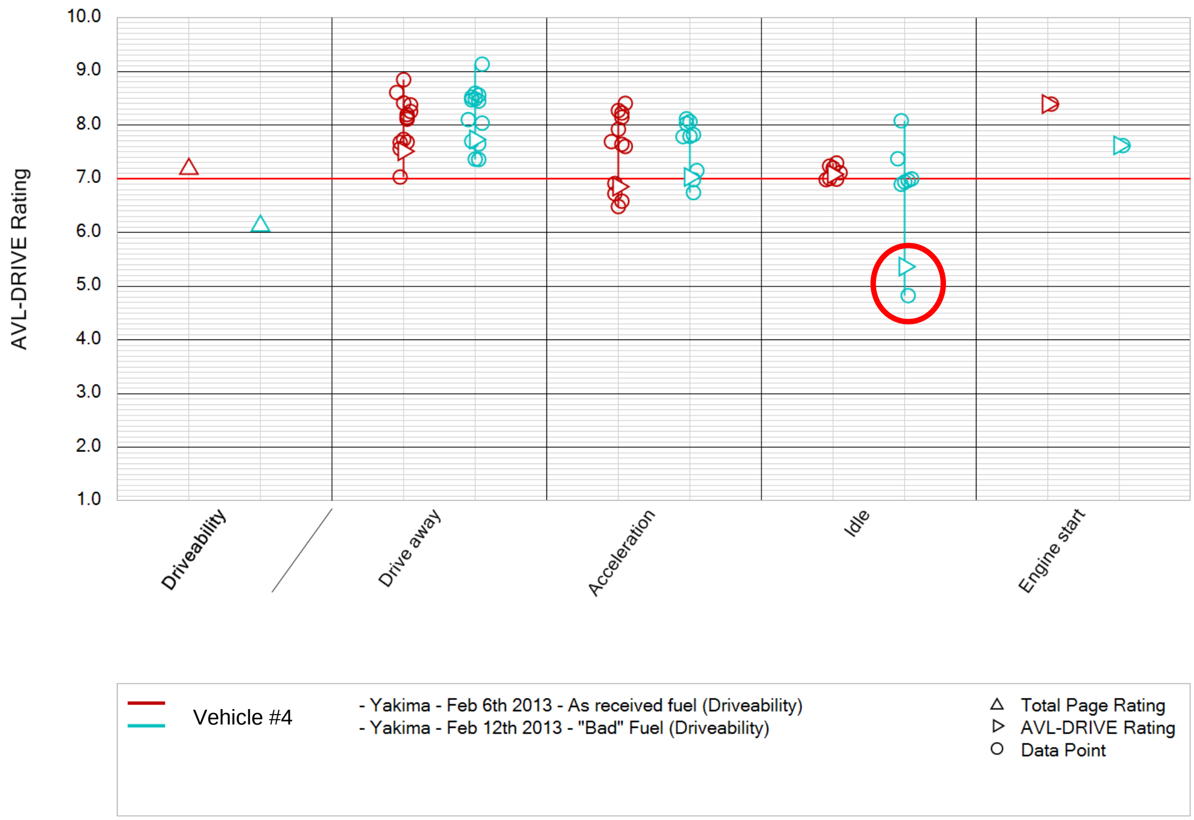



**Figure 4 Vehicle #4 data summary for screening data**

It can be seen in Figure 5 (below) that the remaining criteria evaluated as part of the overall idle assessment achieve a similar rating when comparing the two fuels. Investigation into the data to understand the variation in rating between the idle speed in one case compared to the other reveals that the AC was on for the first measurement (Feb 6$^{th}$), while in the Feb 12$^{th}$ case, there is an electrical load that switches part of the way through the idle event. AVL-DRIVE accounts for the use of accessories in idle as part of its assessment criteria, and therefore the rating is impacted.

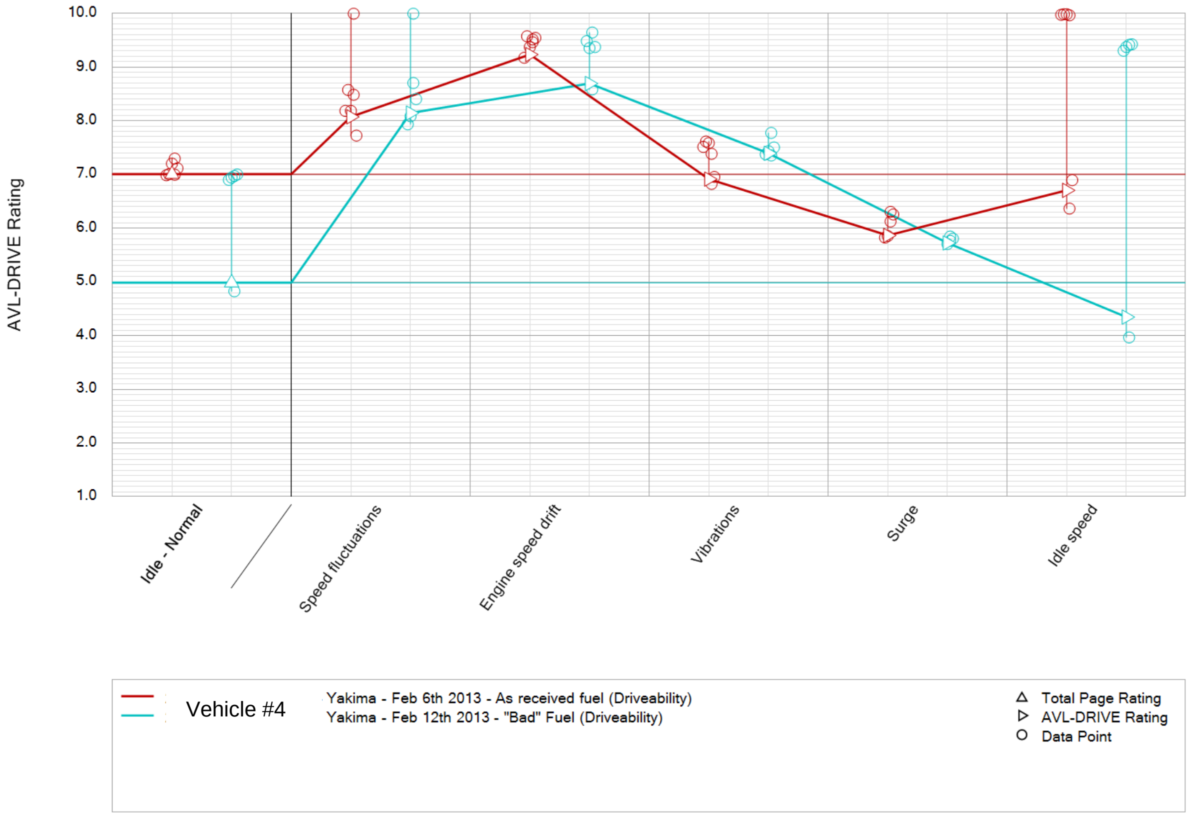



**Figure 5 Idle Normal assessment Criteria**

The poor score in this case is the result of a high idle set-point immediately following engine start. The variation between the target engine speed in the vehicle configuration (typically set to the hot engine target idle speed), and the actual engine speed, results in a low rating (greater variation results in lower rating). The subsequent idle assessments made during engaging the gear do not demerit the vehicle further.

Based on the data, it is not valid to conclude that the difference in rating observed in this case is a result of the change in fuel.

## 3.2. Fuel Blend Testing

Although a similar approach to the vehicle screening data analysis method could have been adopted, it was decided that a more comprehensive approach should be used for this level of analysis, enabling a more direct comparison of the subjective assessment to AVL-DRIVE data. In this case, to achieve comparable data-sets between the CRC maneuver list and the AVL-DRIVE assessments, the events were compounded and ratings calculated for the complete maneuver as performed by the CRC testers.

For this analysis, this process was performed manually, though AVL-DRIVE includes the capability to develop specific events in Matlab that can be used for custom assessments. In any future application this would be considered as an alternative to the manual approach.

Figure 6, below, shows the events that AVL-DRIVE detects during the 0-15mph light throttle launch. If the gearshift had occurred at a higher speed, then the drive away would have been followed by an acceleration event.

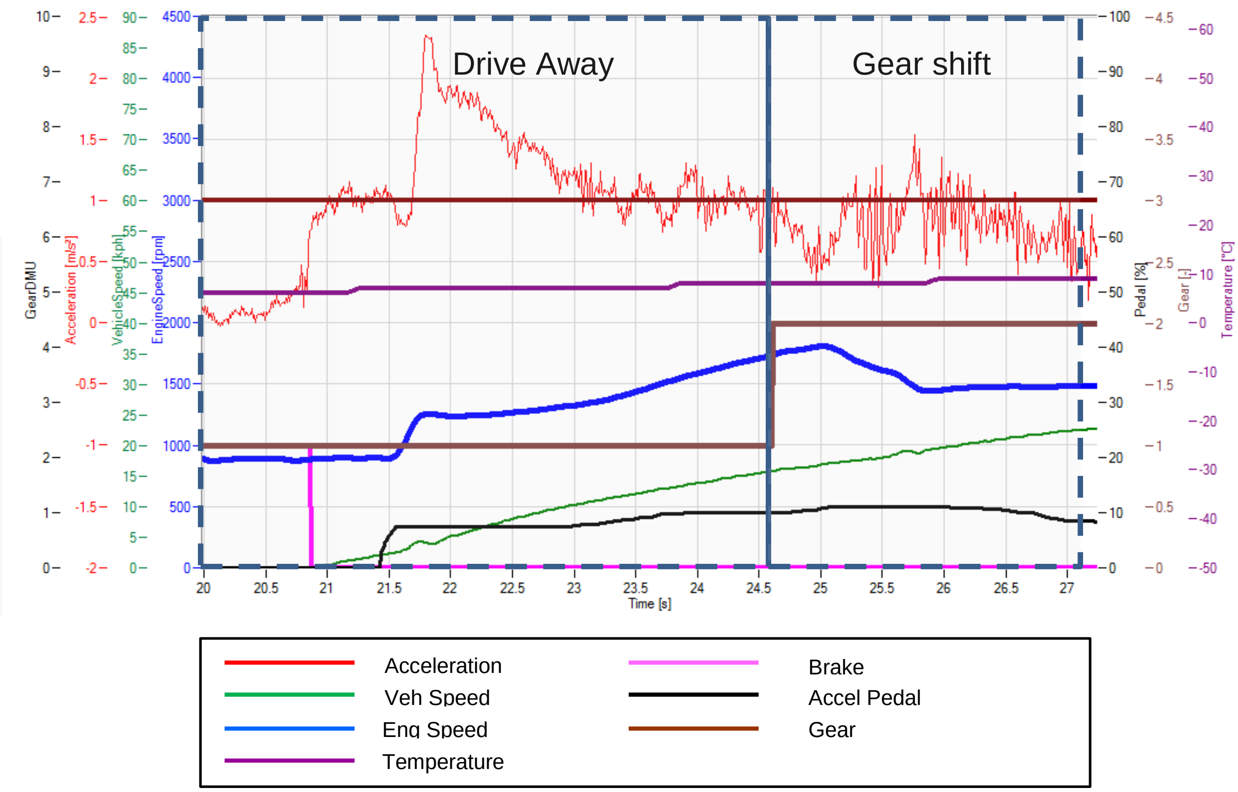



**Figure 6 0-15mph acceleration with AVL-DRIVE events overlaid**

The rating associated with the maneuver is calculated using the individual ratings and the AVL-DRIVE weighting to establish an overall rating. For example, the following calculation shows the ratings for the maneuver shown in the plot above:

| | Drive rating | Weighting | Normalised % weight | Weighted rating |
|---|---|---|---|---|
| Drive away | 7.3 | 0.12 | 44% | 3.2 |
| Gear shift | 7.1 | 0.15 | 56% | 3.9 |
| Sum | | 0.27 | | |
| Maneuver rating | | | | 7.2 |

**Table 5 Rating calculation for compounded events**

This process was repeated for all events for the tests performed during the fuel evaluation section of the testing.

Engine start is treated as its own event both as part of AVL-DRIVE and as part of the CRC assessment. In this case, AVL-DRIVE rates a number of items including the time to start. This is determined as the duration from 30RPM to a rate of engine speed increase of 500RPM/s. This time is the reported value included in the CRC report.

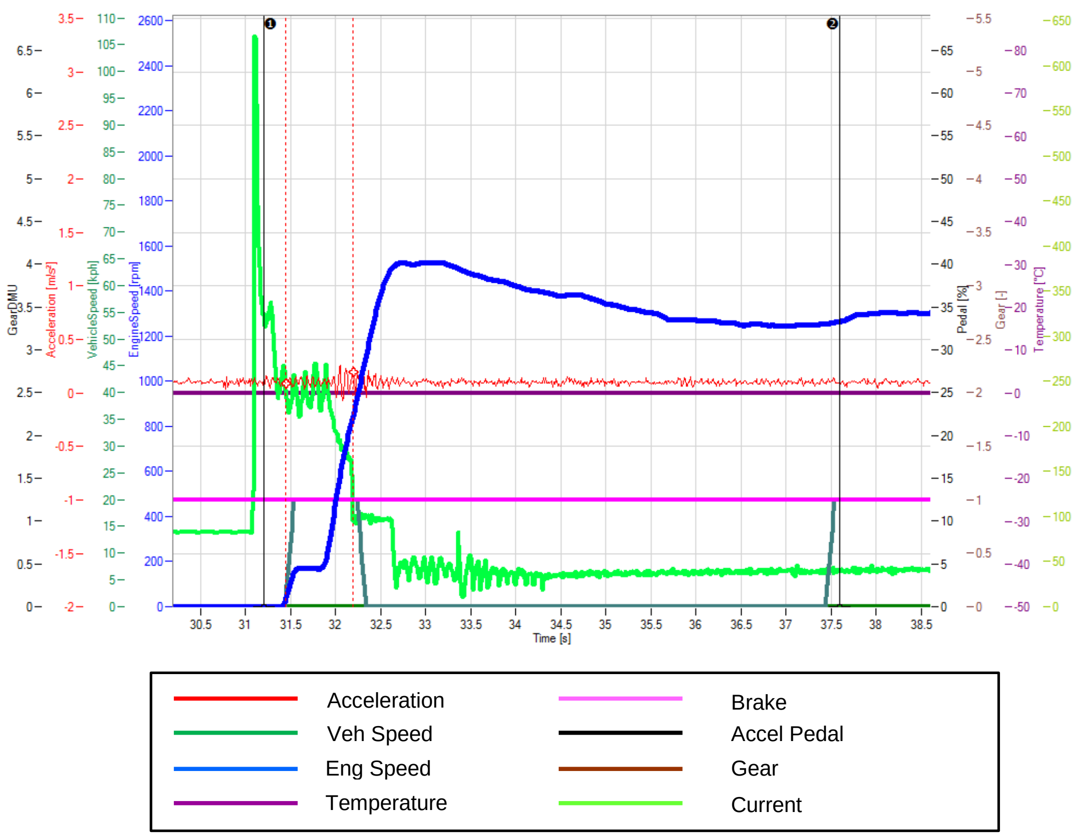



**Figure 7 Engine Start Event**

Figure 8, below, shows the additional parameters that are included in the AVL-DRIVE evaluation of an engine start (in this case the values relate to the data in Figure 7). Per the previous comment, only the start duration is used in the data provided to the CRC. The starter response delay may also be of interest – this is defined as the duration from crank request to 30RPM.

| 7.9 | Engine start - Manual start | 31.20-37.59 [s] |
|---|---|---|
| **DR** | Param 1 | Param 2 |
| **Surge [-]**<br>**7.1** | delta VDV [m/s²]<br>0.91 | VDV [m/s²]<br>0.95 |
| **Starter response delay [-]**<br>**7.7** | delay [s]<br>0.32 | engine temperature [°C]<br>0.00 |
| **Start duration [-]**<br>**8.2** | start duration [s]<br>0.42 | engine temperature [°C]<br>0.00 |
| **Starter speed [-]**<br>**8.8** | starter speed [rpm]<br>176.78 | count cyl [-]<br>6 |
| **Speed pickup duration [-]**<br>**9.2** | speed pickup duration [s]<br>0.77 | engine temperature [°C]<br>0.00 |
| **Stumble [-]**<br>**9.8** | rpm stumble [rpm]<br>4.08 | engine temperature [°C]<br>0.00 |
| **Overshoot speed [-]**<br>**9.6** | engine speed overshoot [rpm]<br>279.78 | engine temperature [°C]<br>0.00 |
| **Undershoot speed [-]**<br>**10.0** | engine speed undershoot [rpm]<br>0.00 | duration of n undershoot [s]<br>0.35 |
| **Idle stabilization duration [-]**<br>**7.7** | stabilization duration [s]<br>2.93 | engine temperature [°C]<br>0.00 |
| **Noise [-]**<br>**----** | noise level [dBA]<br>---- | trend of noise level [dBA]<br>---- |
| **Vibrations [-]**<br>**7.5** | DR seat [-]<br>7.47 | engine temperature [°C]<br>0.00 |

**Figure 8 Engine Start Criteria with parameter values shown**

The CRC evaluation requires that the vehicle is rated for idle in ‘P’ immediately after a start, for 5 seconds duration, but it can be observed in the data that there are tests that do not include an idle assessment from AVL-DRIVE. This is because AVL-DRIVE considers the end of a start event to be a stable idle speed, evaluated based on a smoothed engine speed signal showing less than 100RPM deviation over 1.5 seconds. In many cases, although the evaluator has maintained idle for the 5 seconds following the start as required in the CRC test plan, a stable idle was not achieved and therefore AVL-DRIVE does not categorize this as an idle event.

The required idle assessment during the evaluation was omitted in every case as the idle was not maintained for long enough to be detected as an event by AVL-DRIVE.

The following table shows the mapping used to compare events identified by AVL-DRIVE to the events as described in the CRC test plan. This particular example is from vehicle #19, other vehicles may vary based on transmission calibration (shift points). For the data provided from the evaluation, each dataset for vehicles #19 and #33 was individually analyzed.

| t start [s] | t end [s] | DR | DR Min.Crit. | DRIVE Deteceted Event | CRC Maneuver |
|---|---|---|---|---|---|
| 31.2 | 37.59 | 7.9 | 7.1 | Engine start Manual start | Engine Start |
| 37.51 | 40.33 | 8.6 | 8 | Idle Air conditioning on | Idle in P |
| 40.26 | 43.62 | 7.4 | 6.3 | Idle Engage | Idle in D |
| 44.47 | 47.63 | 7.3 | 6.2 | Drive away Normal | 0-15mph accel |
| 47.32 | 49.67 | 7.2 | 6.2 | Gear shift Power on upshift | |
| 51.24 | 53.68 | 5.5 | 4.2 | Gear shift Power on upshift | |
| 64.64 | 65.29 | 8.8 | 8.4 | Drive away Vehicle stop | |
| 65.29 | 68.45 | 7.8 | 6.9 | Drive away Normal | 0-15mph accel |
| 68.14 | 70.42 | 7.4 | 6.8 | Gear shift Power on upshift | |
| 76.67 | 79.97 | 9.7 | 9.7 | Gear shift Power on downshift | |
| 79.33 | 81.76 | 8.5 | 8.1 | Drive away Launch | 0-20mph WOT |
| 80.38 | 81.76 | 7.6 | 7.1 | Acceleration Full load | |
| 81.58 | 82.74 | 4.4 | 3.7 | Gear shift Tip out upshift | |
| 82.14 | 84.19 | 4.1 | 3.9 | Gear shift Tip out upshift | |
| 101.66 | 102.63 | 8.9 | 8.5 | Drive away Vehicle stop | |
| 102.63 | 105.47 | 7.8 | 7 | Drive away Normal | 0-15mph accel |
| 105.16 | 107.38 | 7 | 5.9 | Gear shift Power on upshift | |
| 107.08 | 109.39 | 5.4 | 5 | Gear shift Tip out upshift | |
| 119.69 | 120.55 | 8.9 | 8.4 | Drive away Vehicle stop | |
| 120.55 | 123.37 | 7.7 | 6.8 | Drive away Normal | 0-15mph accel |
| 123.06 | 125.52 | 7.3 | 6.6 | Gear shift Power on upshift | |
| 137.83 | 140.12 | 7.8 | 7.2 | Acceleration Part load rising pedal | |
| 141.16 | 143.34 | 5.7 | 5.3 | Gear shift Tip out upshift | |
| 156.32 | 157.23 | 7.8 | 7.2 | Drive away Vehicle stop | |
| 157.23 | 158.46 | 8.2 | 7.5 | Drive away Launch | 0-20mph Medium Throttle |
| 158.36 | 159.12 | 8.8 | 8.6 | Acceleration Part load falling pedal | |
| 159.06 | 160.54 | 5.6 | 4.8 | Gear shift Tip out upshift | |
| 159.94 | 162.01 | 5.6 | 4.9 | Gear shift Power on upshift | |
| 162.51 | 165.41 | 8 | 7.7 | Acceleration Part load constant pedal | |
| 182.78 | 186.37 | 7.9 | 7.2 | Drive away Vehicle stop | |
| | | | | | Idle in D |
| 186.37 | 189.41 | 7 | 5.8 | Drive away Normal | 0-15mph accel |
| 189.1 | 191.49 | 6.1 | 5.4 | Gear shift Power on upshift | |
| 199.43 | 200.45 | 9 | 8.6 | Drive away Vehicle stop | |
| 197.43 | 200.73 | 6.7 | 6.7 | Gear shift Coast / brake on downshift | |
| 200.45 | 203.45 | 9.1 | 8.8 | Drive away Normal | 0-15mph accel |
| 203.14 | 205.57 | 6.1 | 5 | Gear shift Power on upshift | |
| 205.78 | 206.64 | 7.5 | 6.5 | Tip out After acceleration | |
| 212.91 | 216.21 | 8.8 | 8.8 | Gear shift Power on downshift | |
| 216.09 | 218.4 | 8.9 | 8.5 | Drive away Launch | 0 - 20 WOT |
| 217.18 | 218.4 | 6.7 | 6 | Acceleration Full load | |
| 218.24 | 219.5 | 3.9 | 3.6 | Gear shift Tip out upshift | |
| 218.9 | 220.86 | 5.8 | 5.4 | Gear shift Tip out upshift | |
| 222.36 | 231.87 | 5.9 | 5.4 | Deceleration Transition to constant speed | |
| 237.83 | 238.77 | 8.8 | 8.3 | Drive away Vehicle stop | |

**Table 6 Mapping of DRIVE events to the CRC test plan**

| t start [s] | t end [s] | DR | DR Min.Crit. | DRIVE Deteceted Event | CRC Maneuver |
|---|---|---|---|---|---|
| 238.77 | 241.33 | 8.1 | 7.3 | Drive away Normal | 0-15mph accel |
| 241.02 | 243.5 | 5.5 | 4.7 | Gear shift Power on upshift | |
| 250.91 | 254.21 | 8.7 | 8.7 | Gear shift Power on downshift | 0-15mph accel |
| 253.37 | 255.71 | 7.9 | 7.1 | Drive away Normal | |
| 255.4 | 257.86 | 7.9 | 7.1 | Gear shift Power on upshift | |
| 258.36 | 262.85 | 7.9 | 7.3 | Acceleration Part load constant pedal | |
| 271.03 | 272.03 | 9.8 | 9.7 | Acceleration Part load rising pedal | |
| 272.71 | 273.9 | 7.4 | 6.5 | Acceleration Part load constant pedal | |
| 273.9 | 276.39 | 5.3 | 4.9 | Gear shift Tip out upshift | |
| 276.89 | 280.27 | 7.9 | 7.3 | Acceleration Part load constant pedal | 10 - 20 Light Throttle |
| 293.03 | 293.79 | 8.2 | 7.6 | Drive away Vehicle stop | |
| 293.79 | 296.05 | 8.5 | 7.9 | Drive away Normal | 0 - 20 Medium Throttle |
| 295.74 | 297.34 | 6.4 | 5.9 | Gear shift Power on upshift | |
| 297.04 | 299.17 | 6.3 | 5.9 | Gear shift Tip out upshift | |
| 321.44 | 324.61 | 8.3 | 8 | Drive away Vehicle stop | |
| | | | | | Idle in D |
| 324.61 | 327.41 | 6.9 | 5.7 | Drive away Normal | 0-45mph crowd |
| 327.1 | 329.67 | 7.3 | 6.5 | Gear shift Power on upshift | |
| 329.64 | 332.2 | 4.7 | 4 | Gear shift Power on upshift | |
| 332.7 | 334.2 | 7.8 | 7.1 | Acceleration Part load constant pedal | |
| 334.2 | 336.94 | 7.3 | 6.3 | Gear shift Power on upshift | |
| 337.44 | 340.5 | 8.1 | 7.6 | Acceleration Part load constant pedal | |
| 340.5 | 343.12 | 6.9 | 5.7 | Gear shift Power on upshift | |
| 343.62 | 351.06 | 8.2 | 7.8 | Acceleration Part load constant pedal | |
| 351.06 | 353.22 | 7.9 | 7.4 | Gear shift Tip out upshift | |
| 354.69 | 357.14 | 7.6 | 6.6 | Gear shift Coast / brake on downshift | |
| 357.69 | 360.15 | 6.6 | 5.3 | Gear shift Coast / brake on downshift | |
| 364.55 | 367.2 | 7.5 | 6.6 | Gear shift Power on downshift | |
| 367.88 | 373.01 | 6 | 5.8 | Constant speed Open pedal | |
| 373.69 | 376.08 | 7.2 | 6.7 | Acceleration Part load rising pedal | 25-35mph Detent |
| 375.78 | 377.75 | 7.8 | 7.3 | Acceleration Part load constant pedal | |
| 377.64 | 379.22 | 6.5 | 5.8 | Gear shift Tip out upshift | |
| 378.92 | 380.91 | 5.6 | 5.1 | Gear shift Coast / brake on upshift | |
| 380.61 | 382.65 | 7.5 | 6.5 | Gear shift Coast / brake on downshift | |
| 382.35 | 384.89 | 7.5 | 6.5 | Gear shift Coast / brake on downshift | |
| 391.88 | 394.38 | 7.9 | 7.3 | Drive away Vehicle stop | |
| 394.46 | 399.59 | 7.8 | 6.9 | Idle Normal | Idle in D |
| 399.59 | 404.72 | 7.9 | 7.1 | Idle Normal | Idle in P |
| 404.72 | 409.85 | 8.2 | 7.5 | Idle Normal | |
| 409.86 | 412.83 | 8.4 | 7.8 | Idle Normal | |

**Table 7 Mapping of DRIVE events to the CRC test plan - part 2**

# 4. Results

## 4.1. Vehicle Screening

As described in the data analysis section, the vehicle screening data was compared at the overall driveability level using filters to reduce the dataset to a good approximation of the CRC evaluation. The four vehicles for which there is useful data are:

| Veh No |
|---|
| 4 |
| 11 |
| 13 |
| 33 |

**Table 8 List of vehicles with the most useful data**

The following plots generated from RG show the comparison in each case of the standard fuel to the blended fuel used in the screening tests. Only the high level values are provided. The sub-operation modes and criteria level are included in Appendix C – Vehicle Screening Test Results, for reference. In each case, the data that has been provided to the CRC for the vehicle screening evaluation is the rating in the leftmost column, entitled “Driveability” on the x-axis.

Recall that as noted previously, AVL-DRIVE uses an extreme value weighting to develop the overall rating, and therefore a poor operating mode score will typically degrade the overall rating more than a good event will improve it. As the plots are reviewed this effect will be evident by inspection of the sub-operating modes ratings compared to the driveability rating.

The data for vehicle #4 included is the same data-set as shown in the previous section to describe the process applied to the analysis.

As also described in the section 3.1, Figure 9 shows the main issue encountered in vehicle #4 was the low idle score on the “bad” fuel. This has been left in the data as this was a real event, though the cause of the poor score can be identified as high engine speed, and as described, it is not reasonable to conclude that this was purely a result of the fuel used for the testing. The remaining test points didn’t show any significant difference between the two fuels, suggesting that vehicle #4 was not highly sensitive to the fuel variation in this case.

A similar conclusion could be drawn for vehicle #11 based on the available data.

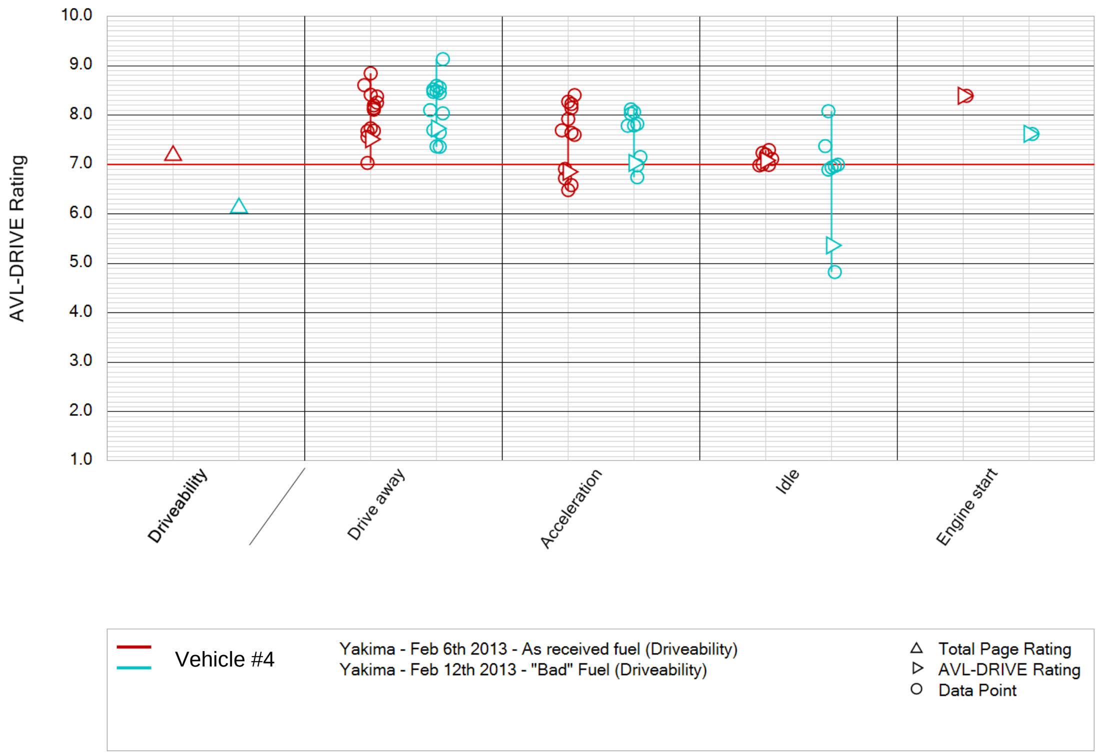



**Figure 9 Vehicle #4 Screening Data**

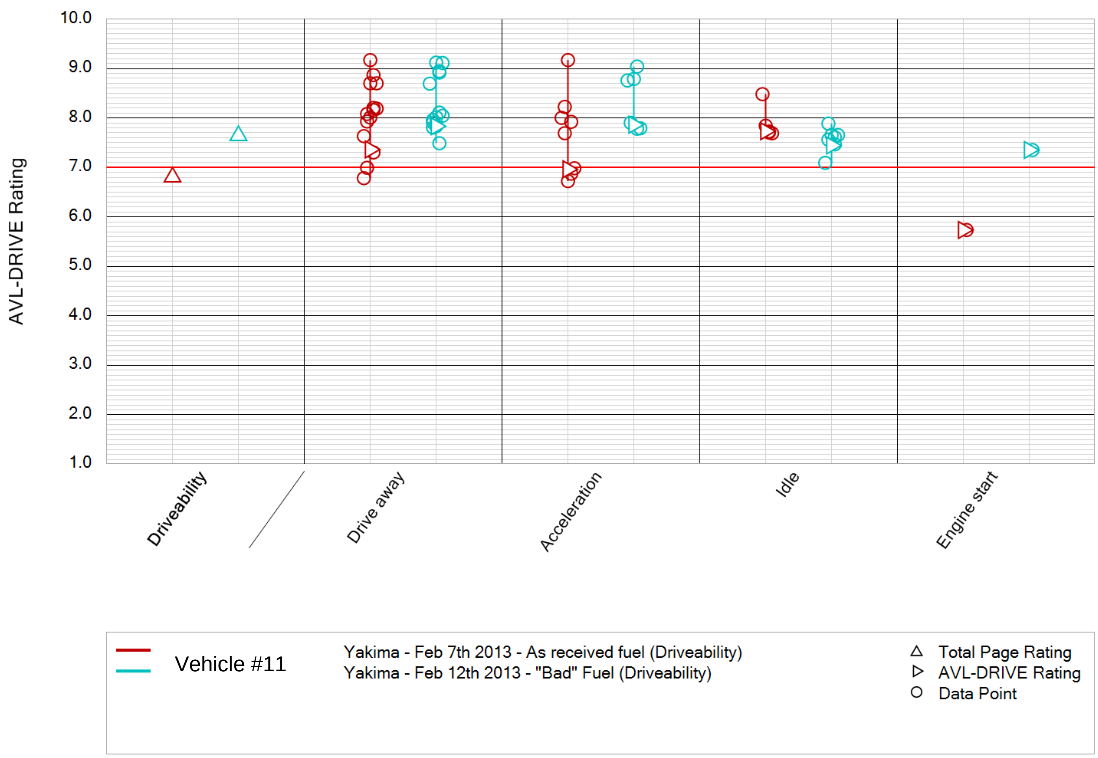



**Figure 10 Vehicle #11 Screening Data**

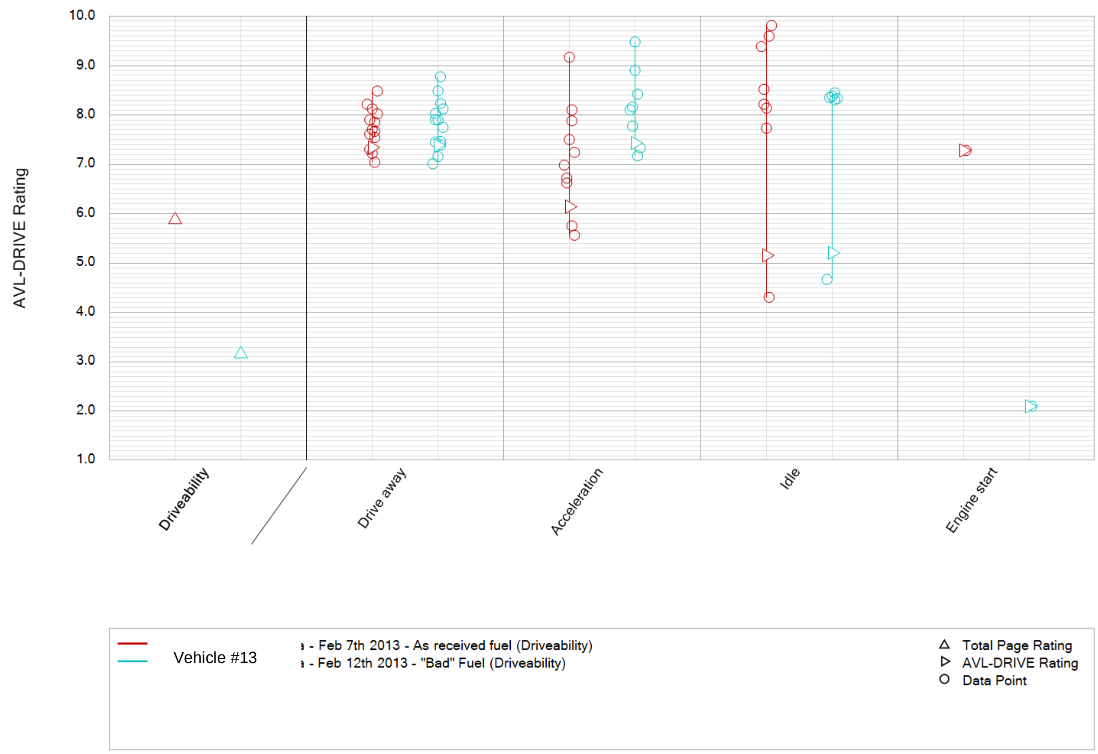



**Figure 11 Vehicle #13 Screening Data**

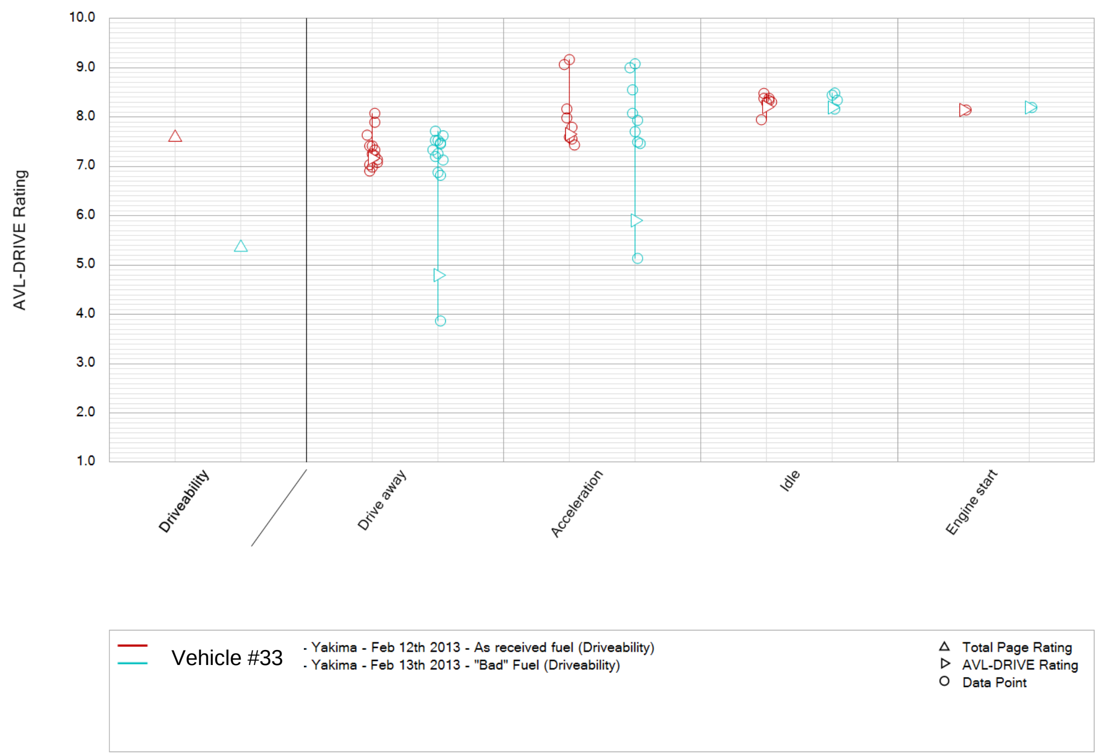



**Figure 12 Vehicle #33 Screening Data**

| Veh No | Overall AVL-DRIVE rating | |
|---|---|---|
| | Fuel as received | "Bad" fuel |
| 4 | 7.2 | 6.2 |
| 11 | 6.9 | 7.7 |
| 13 | 6 | 3.2 |
| 33 | 7.6 | 5.5 |

**Table 9 Summary of screened vehicles overall ratings**

In each case for the screened vehicles, there are single events that have degraded the overall score. The extreme value weighting employed in AVL-DRIVE results in a significant impact in some cases; in all cases, the single events that have degraded the result can be identified in AVL-DRIVE to attempt to identify any special cause. From investigation, each of the events is a "real" response, ie. The measured response was the result of an intended input, but this highlights some areas where further consideration for the test process may be required with respect to consistency of process.

The conclusion, based on this testing, was that Vehicle #13 and Vehicle #33 were the most sensitive to fuel quality.

## 4.2. Fuel Testing

Following the vehicle screening evaluation, AVL-DRIVE was instrumented onto vehicle #33 and vehicle #19 for the remainder of the test program. The following two tables (Table 10 and Table 11) show the total set of results acquired during the program. The rating included for each maneuver is the compounded rating as described previously (so for example, the 0-15mph light throttle acceleration is made up of two AVL-DRIVE events as identified in Figure 6).

| | | 1 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AVL Total Driveability Rating | Start Time | Idle Park | Idle Drive | 0 - 15 Light Throttle | 0 - 15 Light Throttle | 0 - 20 WOT | 0 - 15 Light Throttle | 0 - 15 Light Throttle | 10 - 20 Light Throttle | 0 - 20 Med. Throttle | Idle Drive | 0 - 15 Light Throttle | 0 - 15 Light Throttle | 0 - 20 WOT | 0 - 15 Light Throttle | 0 - 15 Light Throttle | 10 - 20 Light Throttle | 0 - 20 Med. Throttle | Idle Drive | 0 - 45 Crowd | 25 - 35 Detent | Idle Drive - 5 sec. | Idle Drive - 30 sec. |
| Date | | Seconds | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating |
| 2/20/13 | 7.4 | 0.42 | 8.6 | 7.4 | 7.3 | 7.8 | 8.5 | 7.8 | 7.7 | 7.8 | 8.2 | | 7 | 9.1 | 8.9 | 8.1 | 7.9 | 7.4 | 8.5 | | 7.2 | | 7.8 | 8.2 |
| 2/21/13 | 7.5 | 0.42 | 7.4 | 7.3 | 7.3 | 8.9 | 7 | 8 | 8 | 7.5 | 6.4 | | 7.6 | 8.2 | 8.6 | 7 | 8.2 | 9 | 7.7 | | 7.3 | 7.35 | 8.1 | 8.2 |
| 2/23/13 | 7.3 | 0.44 | | 7.2 | 7.5 | 7.3 | 6.3 | 8.5 | 8.3 | 7.8 | 7.6 | | 7.4 | 7.3 | 7.1 | 7.7 | 8 | 9 | 8 | | 7.3 | 7 | 7.4 | 8.2 |
| 2/24/13 | 7 | 0.44 | 7.4 | 7.2 | 7.8 | 7.8 | 7.5 | 8 | 8.4 | 7.7 | 6.1 | | 6.7 | 6.7 | 6.8 | 7 | 7.8 | 6.5 | 7.7 | | 7.4 | | 8.2 | 8.2 |
| 2/25/13 | 7.3 | 0.39 | | 7.1 | 6.5 | 8 | 6.9 | 8.1 | 8.1 | 8.5 | 6.7 | | 7.2 | 7.4 | 7.1 | 7.5 | 7.2 | 8.7 | 7.7 | | 7.4 | 8 | 8.2 | 8 |
| 2/27/13 | 7.5 | 0.42 | 7.7 | 7.3 | 7.4 | 7.7 | 7.8 | 8.5 | 8.3 | 6 | 6.4 | | 7.1 | 6.2 | 7.2 | 7.5 | 7.8 | 5.6 | 7.7 | | 8.2 | 7.7 | 7.9 | 8.1 |
| 3/3/13 | 7.3 | 0.53 | 7.4 | 7.5 | 6.6 | 8 | 7.6 | 8.7 | 7.5 | 6.1 | 7 | | 6.7 | 8 | 7.4 | 7.2 | 8.2 | 8.2 | 7 | | 7.3 | 7.6 | 8.3 | 8 |
| 3/8/13 | 7.3 | 0.39 | | | 7.3 | 7.6 | 8.1 | 7.6 | 8.4 | 6.8 | 5.9 | | 7.8 | | 7.4 | 7.2 | 7.7 | 6.8 | 7.3 | | 7.4 | 7.4 | 7.2 | 7.9 |
| 3/10/13 | 7.5 | 0.39 | | 7 | 7.2 | 8.2 | 7.5 | 7.3 | 8.3 | 8.3 | 6.3 | | 7.4 | 7.8 | 6.8 | 6.9 | 8 | 8.3 | 6.2 | | 7.4 | 8.2 | 7.9 | 8 |
| 3/13/13 | 7.3 | 0.36 | | 7.1 | 6.7 | 7.3 | 8 | 8.4 | 8.3 | 6 | 6.8 | | 8 | 8.1 | 7.1 | 7 | 8 | 7.6 | 6.5 | | 8.1 | 7.8 | 7.9 | 8 |
| 3/15/13 | 7.2 | 0.39 | 7.4 | 7.1 | 6.3 | 8 | 6 | 7.9 | 7.1 | 6.6 | 7.2 | | 7.5 | 7.7 | 6.8 | 6.6 | 7.7 | 7.1 | 7.2 | | 7.5 | 8.1 | 7.8 | 7.9 |
| 3/16/13 | 7.1 | 0.5 | | 7.2 | 6.8 | 7.6 | 6.2 | 7.1 | 8.2 | 7.5 | 6.2 | | 7.2 | 7.6 | 6.4 | 6.3 | 7.9 | 7.8 | 7.2 | | 7.2 | 8.4 | 7.7 | 7.7 |
| 3/17/13 | 7.5 | 0.51 | | 7 | 6.2 | 8.1 | 7.7 | 8 | 8.5 | 6.3 | 7.1 | | 7.7 | 6.8 | 7.8 | 7 | 7.4 | 6 | 7.4 | | 7.3 | 8.3 | 7.3 | 8 |
| 3/18/13 | 7 | 0.43 | | 7.6 | 7.7 | 7.7 | 6.3 | 8.2 | 8.6 | 8.1 | 6.3 | | 7.4 | 7 | 6.3 | 7.3 | 7.6 | 9 | 7.6 | | 7.8 | 8.5 | 8.3 | 8.4 |
| 3/19/13 | 7.4 | 0.43 | 7.8 | 7.4 | 7.1 | 8.1 | 7.9 | 8.3 | 7.4 | 8.2 | 6.2 | | 7.4 | 7.6 | 6.9 | 7.1 | 7.5 | 6.5 | 7.7 | | 7.4 | 8.2 | 7.5 | 8.3 |

**Table 10 AVL-DRIVE results for vehicle #19 Fuel Tests**

The two idle periods (events 13 and 21 in the table above) were not rated as there were no events that met the trigger conditions required by AVL-DRIVE.

| Date | AVL Total Driveability Rating | 1<br>Start Time<br>Seconds | 4<br>Idle Park<br>Rating | 5<br>Idle Drive<br>Rating | 6<br>0 - 15 Light Throttle<br>Rating | 7<br>0 - 15 Light Throttle<br>Rating | 8<br>0 - 20 WOT<br>Rating | 9<br>0 - 15 Light Throttle<br>Rating | 10<br>0 - 15 Light Throttle<br>Rating | 11<br>10 - 20 Light Throttle<br>Rating | 12<br>0 - 20 Med. Throttle<br>Rating | 13<br>Idle Drive<br>Rating | 14<br>0 - 15 Light Throttle<br>Rating | 15<br>0 - 15 Light Throttle<br>Rating | 16<br>0 - 20 WOT<br>Rating | 17<br>0 - 15 Light Throttle<br>Rating | 18<br>0 - 15 Light Throttle<br>Rating | 19<br>10 - 20 Light Throttle<br>Rating | 20<br>0 - 20 Med. Throttle<br>Rating | 21<br>Idle Drive<br>Rating | 22<br>0 - 45 Crowd<br>Rating | 23<br>25 - 35 Detent<br>Rating | 24<br>Idle Drive - 5 sec.<br>Rating | 24<br>Idle Drive - 30 sec.<br>Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/13/13 | 7.6 | 0.28 | 8.4 | 7.9 | 7.1 | 7.7 | 7.7 | 7.4 | 8.1 | 7.6 | 7.5 | | 7 | 7.5 | 7.1 | 6.7 | 8 | 8.2 | 7.7 | | 8 | 7.3 | 8.4 | 8.3 |
| 2/14/13 | 5.3 | 0.43 | | | 7.8 | 7.5 | 4.6 | 7.2 | 8.1 | 7.8 | 7.2 | | 6.7 | 8.1 | 7.7 | 6.6 | 7.2 | 8.1 | 7.4 | | 8.1 | 6.5 | 8.2 | 8.4 |
| 2/15/13 | 7.1 | 0.47 | 7.1 | 7.1 | 7 | 7.6 | 7.2 | 7.6 | 6.6 | 7.5 | 6.6 | | 7.1 | 7 | 7 | 6.7 | 6.9 | 8.6 | 7.6 | | 7.9 | 7.8 | 8 | 8.1 |
| 2/17/13 | 7.6 | 0.17 | | | 7.5 | 7 | 7.6 | 7 | 7.9 | 7.6 | 6.9 | | 8.3 | 6.8 | 7.3 | 7.4 | 8 | 8.3 | 7.7 | | 7.7 | 8.1 | 8.2 | 8.2 |
| 2/18/13 | 5.4 | 0.3 | 7.4 | 5.8 | 6.7 | 7.6 | 4.9 | 7.5 | | | | | | | | | | | | | | | 3.8 | 7.7 |
| 2/20/13 | 7.1 | 0.2 | | | 6.9 | 7.4 | 7.9 | | | | | | | | | | | | | | | | 8.2 | 8.4 |
| 2/21/13 | 5.8 | 0.48 | | 5.9 | 7.7 | 7.6 | 6.8 | 7.6 | 7.8 | | | | | | | | | | | | | | | |
| 2/23/13 | 7.2 | 0.32 | | | 6.8 | 7.6 | 7 | 8.4 | 8.3 | | 7 | | 7.5 | 7.2 | 9 | | | | | | | | 8.3 | 8.3 |
| 2/24/13 | 7.3 | 0.34 | | | 7.6 | 7.3 | 7.4 | 8 | 7.8 | 6.8 | 6.7 | | 7.3 | 7.7 | 7 | 6.9 | 7.6 | 8.5 | 7.6 | | 7.9 | | 8.3 | 8.3 |
| 3/8/13 | 5.2 | 0.18 | | | 7.7 | 6.7 | 4.5 | 6.6 | 8.1 | 8.1 | 7.2 | | 7 | 7.3 | 7.3 | 6.9 | 7.4 | 7 | 8 | | 8 | 7 | 7.2 | 7.8 |
| 3/9/13 | 7.4 | 0.46 | | | 7.6 | 7.3 | 7.2 | 7.4 | 8.2 | 7.2 | 7.2 | | 7 | 7.5 | 7.4 | 7.7 | 7.2 | 8.1 | 8.3 | | 8.2 | 8.2 | 8.2 | 8.5 |
| 3/10/13 | 5.3 | 0.47 | | | 7.8 | 7 | 4.7 | 7.9 | 7.8 | 8.2 | 6.5 | | 7.4 | 7.5 | 7 | 7.1 | 7.6 | 8.9 | 7.8 | | 8.1 | 7.4 | 8.3 | 8.3 |
| 3/12/13 | 7.3 | 0.18 | 7.5 | | 7.3 | 7.5 | 6.8 | 7.1 | 7.7 | 7.4 | 7.3 | | 6.8 | 7.3 | 7.8 | 6.9 | 7.9 | 8.5 | 7.6 | | 8.1 | 6.7 | 8.3 | 8.4 |
| 3/13/13 | 7 | 0.15 | | | 7.2 | 6.8 | 8.1 | 7.5 | 8.3 | 6.5 | 7.3 | | 7.1 | 7.5 | 6.7 | 7.7 | 7.4 | 8.4 | 8.1 | | 7.9 | 7.8 | 8.3 | 8.3 |
| 3/15/13 | 7.4 | 0.16 | | | 7.4 | 7.4 | 7.5 | 5.4 | 7 | 7.6 | 6.3 | | 7.4 | 6.9 | 7.3 | 7.2 | 7.1 | 8.4 | 7.6 | | 7.9 | 7.7 | 8.4 | 8.4 |
| 3/16/13 | 7 | 0.28 | | | 7.5 | 7.6 | 6.6 | 7.9 | 7.8 | 7.8 | 6.6 | | 7.8 | 8 | 7.7 | 7.4 | 7.2 | 8 | 8.4 | | 8.2 | 7.1 | 7.8 | 7.3 |
| 3/17/13 | 6.1 | 0.63 | | | 7.6 | 7.2 | 5.8 | 7.2 | 7.8 | 7.5 | 7.7 | | 7.7 | 7.8 | 7.3 | 8 | 7.9 | 6.3 | 8 | | 8.2 | 7.8 | 5.9 | 5.8 |
| 3/18/13 | 6.9 | 0.45 | | | 7.6 | 6.6 | 6.7 | 7.2 | 7.4 | 6.8 | 7.5 | | 7.1 | 7.5 | 7.7 | 7.2 | 7.4 | 7.9 | 7.5 | | 8.1 | 8.1 | 6.1 | 6.8 |
| 3/19/13 | 6.8 | 0.61 | 7.4 | 7.3 | 7 | 7.6 | | | | | | | | 7.7 | 8 | 7.3 | 7.6 | 8.4 | 8.2 | | 7.8 | 7.7 | 5.5 | 6.2 |

**Table 11 AVL-DRIVE results for vehicle #33 Fuel Tests**

A number of tests were impacted on the 18th, 20th, 21st and the 23rd of February, and also on the 19th March due to an issue on the accelerometer signal. The issue appears to be the result of track surface imperfections resulting in a high level of noise on the seat track (3-axis) accelerometer. Typically, AVL instruments vehicles with an accelerometer on one of the front wheel lower control arms in order to measure vertical motion (as a result of rough surfaces). It was agreed prior to the project that this would not be done for this study due to time and facility limitations at the test site. Inclusion of the sensor would have confirmed the hypothesis.

Many of the idle assessments after the engine start are incomplete due to the idle speed calibration for emissions / catalyst light off. As the engine speed decays over a period of time a stable idle is not achieved, and therefore not triggered by AVL-DRIVE.

## 5. Correlation of Data

Support for the correlation of the AVL-DRIVE data to the CRC demerit system was provided by Jo Martinez (Chevron) as the CRC rating data is not available to AVL. The following analysis provides a description of the correlation identified between the CRC testers and AVL-DRIVE.

ANOVA, or Analysis of Variance, is a statistical method that helps to identify sources of variability from one or more potential sources, sometimes referred to as factors. P-value < 0.05 indicates a statistically significant effect or source of variability. Fuel, Vehicle and Soak Temperature are not statistically significant.

**ANOVA - Dependent Variable: LnCRCRating**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **Model** | 13 | 9.61947818 | 0.73995986 | 4.02 | 0.0031 |
| **Error** | 19 | 3.49950508 | 0.18418448 | | |
| **Corrected Total** | 32 | 13.11898326 | | | |

| R-Square | Coeff Var | Root MSE | LnCRCRating Mean |
|---|---|---|---|
| 0.733249 | 12.66965 | 0.429167 | 3.387364 |

| Source | DF | Type III SS | Mean Square | F Value | P-value |
|---|---|---|---|---|---|
| **Rater** | 2 | 3.14015507 | 1.57007753 | 8.52 | 0.0023 |
| **Fuel** | 8 | 2.29755149 | 0.28719394 | 1.56 | 0.2027 |
| **Vehicle** | 1 | 0.08417831 | 0.08417831 | 0.46 | 0.5072 |
| **SoakTemp** | 1 | 0.04061892 | 0.04061892 | 0.22 | 0.6440 |
| **AVL Rating** | 1 | 0.28518106 | 0.28518106 | 1.55 | 0.2285 |

Rater and AVL Rating have significant effect on CRC Rating with p-values < 0.01.

**ANOVA - Dependent Variable: LnCRCRating**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **Model** | 3 | 7.30330678 | 2.43443559 | 12.14 | <.0001 |
| **Error** | 29 | 5.81567648 | 0.20054057 | | |

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **Corrected Total** | 32 | 13.11898326 | | | |

| R-Square | Coeff Var | Root MSE | LnCRCRating Mean |
|---|---|---|---|
| 0.556698 | 13.22024 | 0.447818 | 3.387364 |

| Source | DF | Type III SS | Mean Square | F Value | P-value |
|---|---|---|---|---|---|
| **Rater** | 2 | 4.25673466 | 2.12836733 | 10.61 | 0.0003 |
| **AVL Rating** | 1 | 2.65776681 | 2.65776681 | 13.25 | 0.0011 |

LnCRCRating residual plot, after taking into account Rater variability, indicates a trend that shows correlation between CRC Rating and AVL Rating.

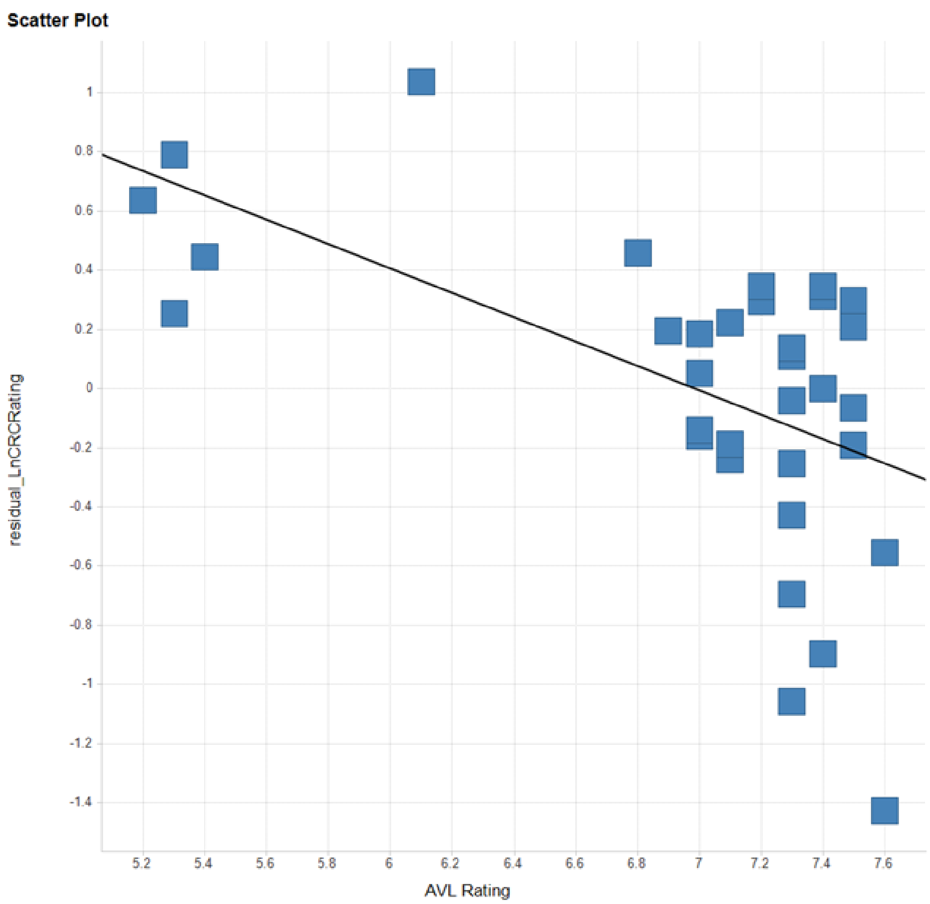



**Figure 13 Scatter plot of AVL-DRIVE ratings vs Ln of CRC ratings**

# 6. Conclusions and Recommendations

The main conclusion that can be drawn from the available data and study is that it is possible to correlate the AVL-DRIVE rating with the CRC tester rating. The original intent of the study was to identify if it is possible to use AVL-DRIVE to identify a change in fuel quality / blend based on the vehicle response. It is inferred that this is the case based on the assumption that the current process using experienced raters for the evaluation is capable of capturing the effects, and the correlation between AVL-DRIVE and the raters.

Based on the comments provided by the evaluation team, the style of testing in the current process does not readily accommodate the use of data acquisition equipment, and some modifications to the implementation will be required to ensure success. Specifically, these modifications are expected to include:

- Modifications to the interface / controls
  The CRC evaluators commented that they did not feel the equipment was easy or intuitive to use. There are a number of alternative ways that can be applied including screen mounted displays that can provide both start and stop controls and feedback that the system is working.

- Event collector filters
  AVL-DRIVE has the capability to include filters during data acquisition. This enables the user to confirm that specific events have been triggered. This would alleviate issues such as not triggering idles, though there may be some impact on the engine temperature as this could lengthen the overall process.

- Custom Events
  AVL-DRIVE has two alternative methods to include custom events. First, within the constraints of the current trigger engine, events can be created in the Custom Events operation mode. Second, Matlab can be used to create events that can subsequently be evaluated in DRIVE. This may provide the opportunity to create a custom evaluation that fully matches the current CRC process without the manual processing applied for this study.

- Training
  Additional training should be provided to improve familiarity with the tool. For future test programs, AVL would recommend having an engineer on-site for the complete duration of the testing.

AVL recommends further data analysis (paper study only) from available data acquired during the testing in Yakima, to more fully demonstrate the ability to identify the change in vehicle response as a result of the changing fuel quality. As AVL-DRIVE acquires data regarding boundary conditions for each maneuver (ambient temp, ECT, gear, speed etc) in addition to the vehicle response for a given driver input, it should be feasible to compare two or more similar maneuvers and determine if there is a difference in vehicle response that can be attributed to the fuel. For example, the chart below (figure 14) shows a direct comparison of the second vehicle pull-away for vehicle #19, on consecutive days (20th and 21st February). The boundary conditions and driver input conditions appear to be similar (~6 - 7°C, ~15% pedal demand), but there is a significant change in acceleration on one day compared to the other at approx. 1.5s. On inspection, at 1.4s the data from the 20th (represented by the blue trace) has an accelerator pedal input that is 7% greater than the second test. The change in acceleration may be a result of this rather than a change in fuel, as the pedal may can be somewhat aggressive at low to medium pedal positions.

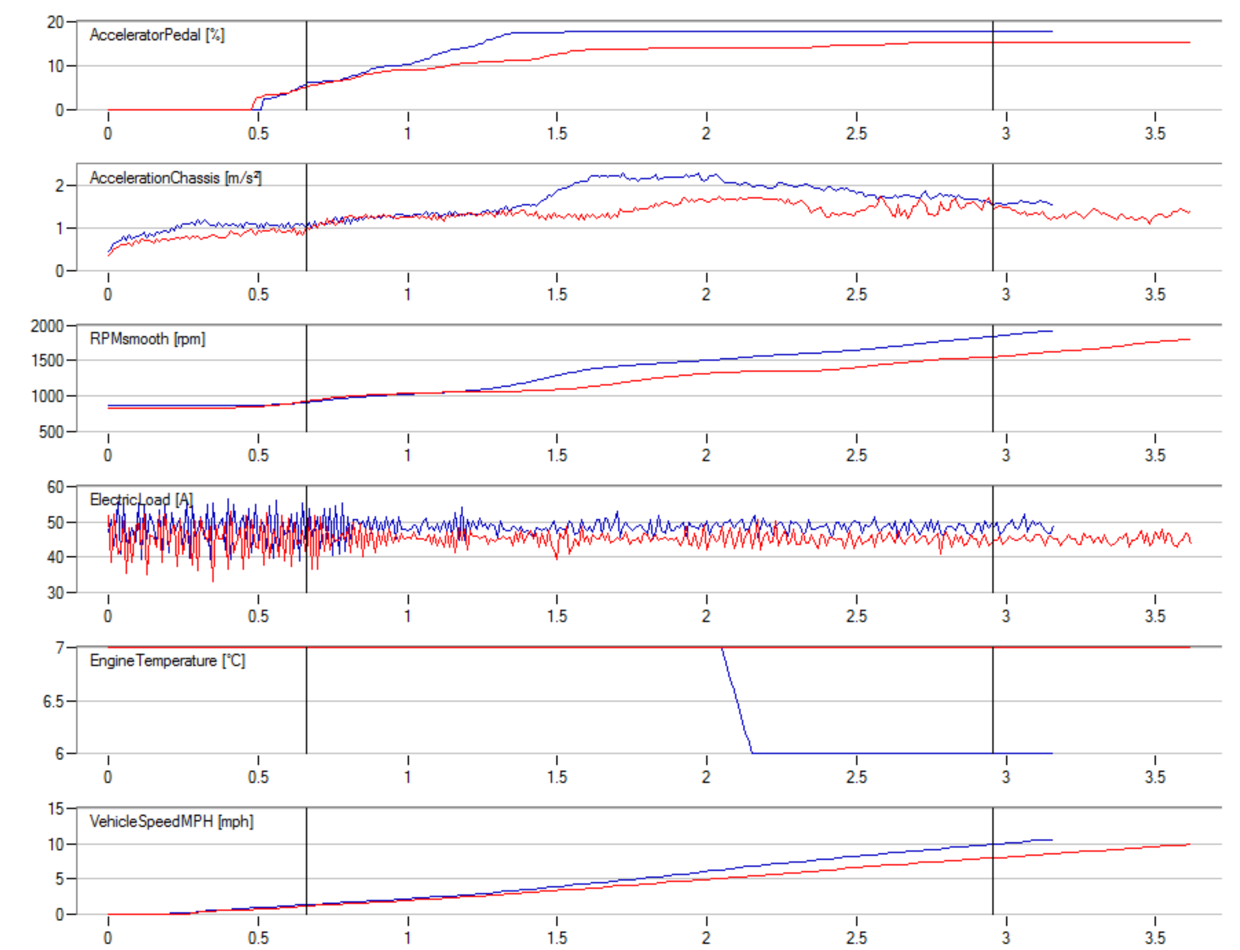



**Figure 14 Comparison of vehicle #19 pull-away between two tests (20th and 21st Feb)**

It is recommended that this evaluation is performed in conjunction with the CRC vehicle demerit data to identify real differences between the evaluation techniques and to support future process development.

As part of the discussion with members of the CRC, AVL was also requested to provide a recommendation of how a similar study would be performed by AVL. This is documented in the following section (Section 7 Alternative approach to the effects of a range of fuel blends on driveability).

# 7. Alternative approach to the effects of a range of fuel blends on driveability

AVL considers there to be 3 alternative approaches to evaluating the impact of fuel blends on driveability. The critical element is to reduce the amount of variability in the testing that results from the ambient conditions and the test process itself, in order to improve the signal to noise ratio in the data.

In each case, the vehicle maneuvers can be common with the current process, and as such can be compared to previous evaluations if necessary. Additional instrumentation is feasible in the test-cell, providing more detailed information regarding the vehicle response and the changes in combustion quality that occur as a result of the changes in fuel blend.

7.1.1. Chassis Rolls Testing

AVL has performed several evaluations of vehicles on chassis rolls. The basic set-up requires the test vehicle to be secured via a load-cell to a rigid restraint. The load cell is used to provide a surrogate acceleration signal that can be evaluated in AVL-DRIVE.


The test cell provides the capability to fully manage the ambient conditions, therefore largely eliminating a major potential source of variation in the testing. Controlled conditions can also potentially reduce the overall program duration as there are no "lost days" as a result of ambient conditions not falling within the test boundary condition requirements.

### 7.1.2. Powertrain Testbed testing

As an alternative to the chassis dynamometer, a powertrain testbed could be used for the testing. This results in similar benefits as identified for the chassis rolls, with the advantage that any interaction between the vehicle and the dyno can be eliminated easily. The set-up in this case (assuming full vehicles are to be tested), is to mount the vehicle at the wheel hubs. The vehicle responses are generated via a vehicle dynamics model running real-time on the dyno.

As before, AVL-DRIVE is used to provide the evaluation of the vehicle response, and therefore a link back to the "real world".


**Figure 15 Typical installation on to powertrain testbed for vehicle testing**

For this application, low inertia permanent magnet dynamometers are required to ensure sufficient fidelity can be achieved. It may be required (depending on the test site) to build a local “cell” for the engine to manage the conditions to the temperature and humidity required.

### 7.1.3. Engine Testcell

The third potential approach to evaluating the impact of fuel blends on driveability is to perform the testing in an engine test cell and simulate the transmission, driveline and vehicle real-time. AVL has successfully achieved this installation including correlation to the vehicle on a test-track.

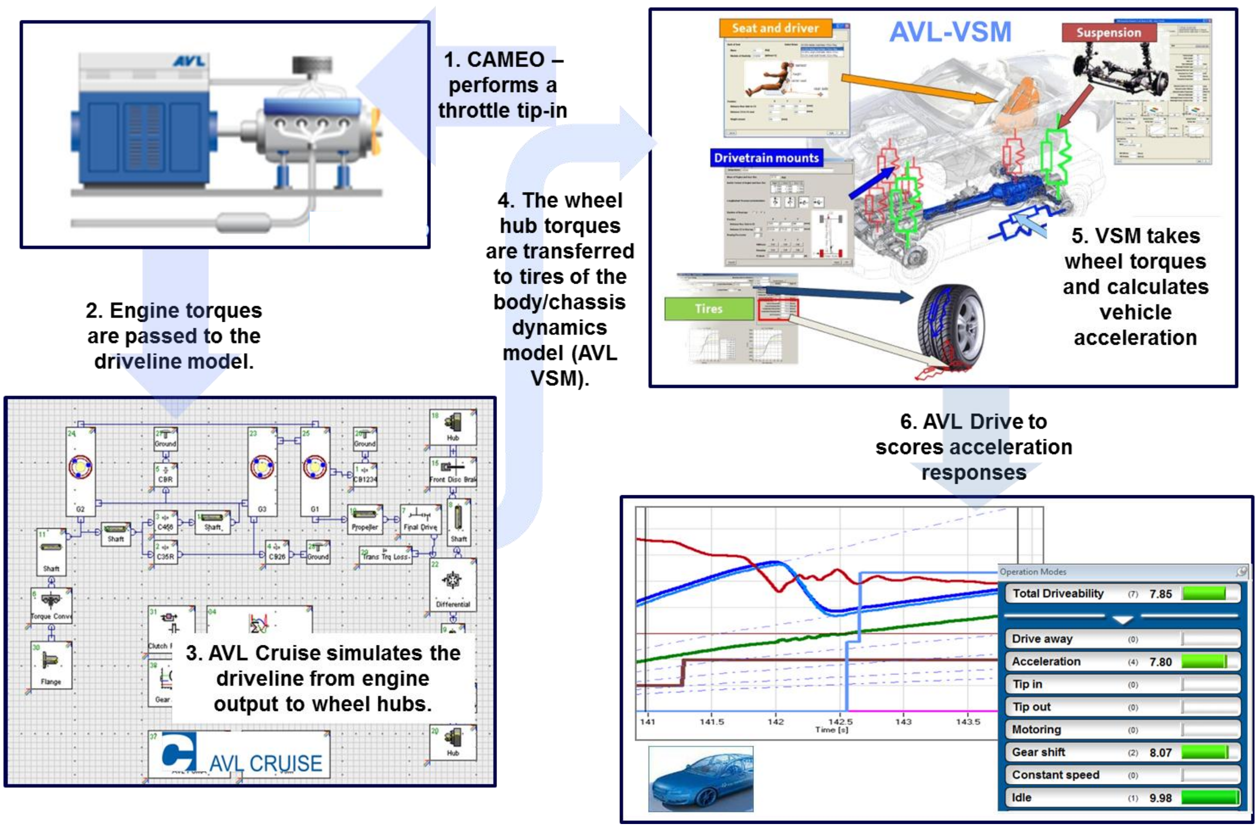



**Figure 16 AVL workflow for advanced testing and calibration in engine test cells**

# 8. Appendix A – AVL-DRIVE Overview

AVL-DRIVE is a fully automatic real-time tool for collecting, analyzing and rating vehicle drive quality, or “Driveability”. A rating is calculated for all driveability events (also referred to as “driving modes”) such as tip-ins, tip-outs, gear changes, etc. on the universal 1 to 10 scale. All individual ratings are combined using appropriate weightings to establish an overall score for the vehicle.

There are product variants available for:

- Passenger Car
- Commercial Vehicle
- Off-highway

## 8.1. AVL-DRIVE Key Characteristics

AVL-DRIVE has a number of unique characteristics to fully support both development and competitive benchmarking exercises:

- Automatic event detection
- Real-time event data analysis and scoring
- Interface to INCA in real-time enabling on-line use for calibration development
- Interface to AVL CRUISE and AVL VSM for driveability development in a simulation environment
- Data import and export capability in a wide range of formats
- Large number of additional channels can be input to facilitate problem solving and to analyze the impact of individual calibration parameters on driveability
- The vehicle can be instrumented and the software configured in approximately 1 day (application and customer requirements dependent).

## 8.2. AVL-DRIVE Applications

By producing accurate and repeatable drive quality measurements, AVL-DRIVE can be used in a wide variety of applications, some of which are listed below:

- Benchmarking / detailed vehicle comparison
- Target definition
- Target tracking

- Simultaneous calibration assistance
- Quality analysis and tracking
- Gateway definition
- Gateway sign-off
- Supplier quality assurance
- Quality/Warranty issue trouble shooting

## 8.3. AVL-DRIVE Hardware for Vehicle Use

The following hardware applies to both hybrid and conventional vehicles.

### 8.3.1. AVL-DRIVE Main Unit (DMU)

The DMU manages the data acquisition from the DRIVE sensors, other analog sources and from the vehicle CAN bus. Calculated channels from existing inputs can also be included. The system can be used as a data logger for AVL-DRIVE, or as a stand-alone data logger. Therefore the hardware is equipped with an SD memory card.

The DMU is typically used for engineering projects, advanced development and vehicle benchmarking. The DMU may also be added to an AVL-DRIVE for INCA system in order to add noise and vibration input.

Input Channels are:

- Analog voltage
- ICP standard sensors
- Rotation sensors (TTL, ind.)

Output:

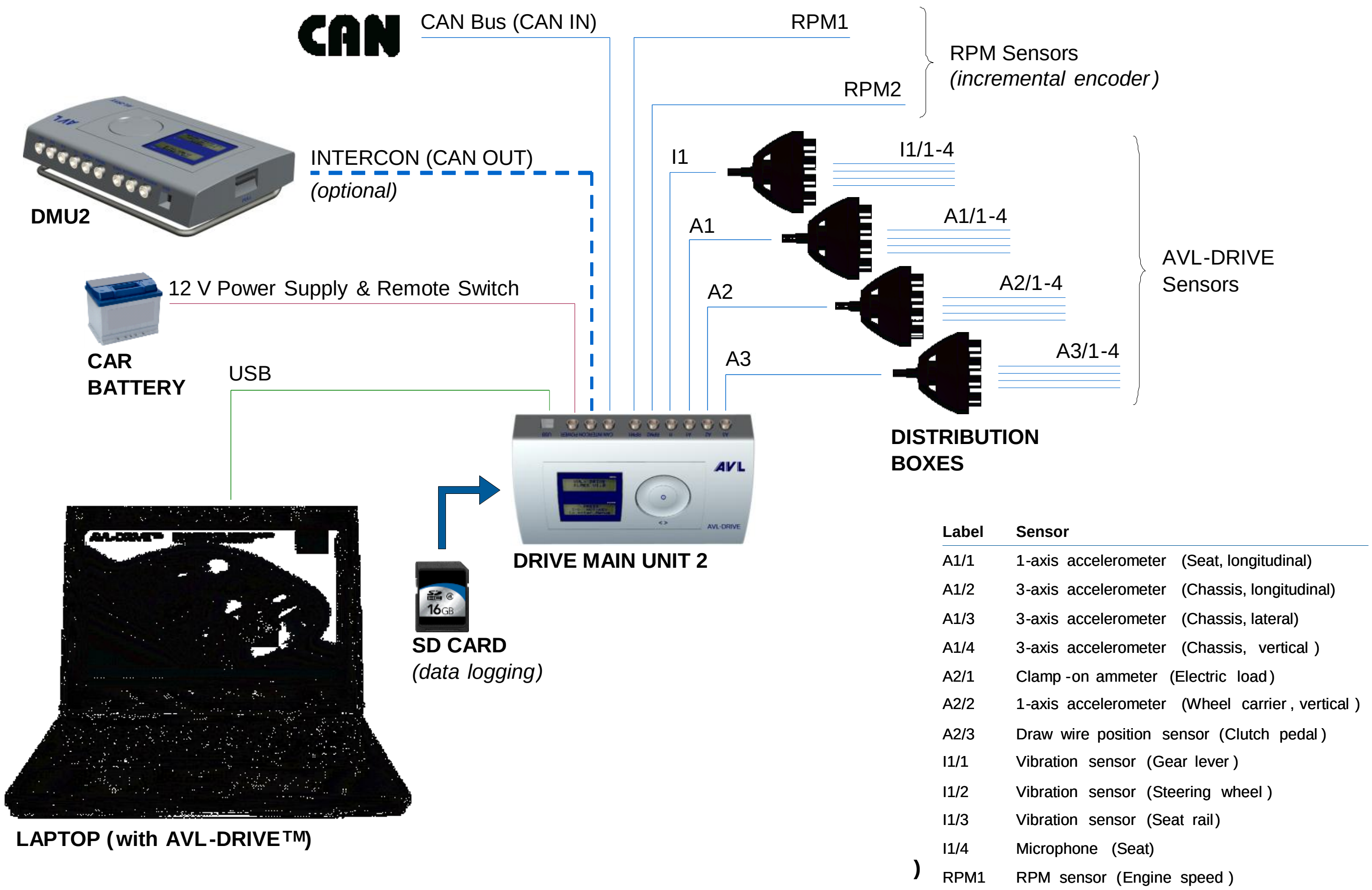
- CAN – BUS


**Figure 17 Drive Main Unit**

### 8.3.2. AVL-DRIVE Sensor and Cable Set for Vehicle

The AVL-DRIVE Sensor and Cable Set provides DRIVE with all necessary input signals that are generally not available on the CAN bus. It is comprised of the following sensors:

- 1 tri-axial acceleration sensor
- 2 single axis acceleration sensors (seat, wheel)
- 3 vibration sensors
- 1 microphone
- 1 pedal travel sensor
- 1 electric load sensor




| Label | Sensor |
|---|---|
| A1/1 | 1-axis accelerometer (Seat, longitudinal) |
| A1/2 | 3-axis accelerometer (Chassis, longitudinal) |
| A1/3 | 3-axis accelerometer (Chassis, lateral) |
| A1/4 | 3-axis accelerometer (Chassis, vertical) |
| A2/1 | Clamp-on ammeter (Electric load) |
| A2/2 | 1-axis accelerometer (Wheel carrier, vertical) |
| A2/3 | Draw wire position sensor (Clutch pedal) |
| I1/1 | Vibration sensor (Gear lever) |
| I1/2 | Vibration sensor (Steering wheel) |
| I1/3 | Vibration sensor (Seat rail) |
| I1/4 | Microphone (Seat) |
| RPM1 | RPM sensor (Engine speed) |

**Figure 18 AVL-DRIVE Wiring Diagram**

### 8.3.3. AVL-DRIVE for INCA

AVL-DRIVE for INCA is specifically designed to support vehicle calibration engineers in their daily work in order to achieve more consistent calibration quality and reduce iterations.

The DRIVE-INCA system interfaces to INCA v5.1 or higher. The AVL-DRIVE software (Analyzer) is installed on the same laptop or PC as INCA and the programs communicate via a software interface, resulting in a single machine solution.

AVL-DRIVE for INCA requires Etas-INCA v5.3 or higher. Additionally the vehicle must be equipped with:

- ES590 or ES591 – ECU & Bus Interface Module
- ES600 – Network Module
- ES611 or ES411 – A/D Module with Sensor Power Supply

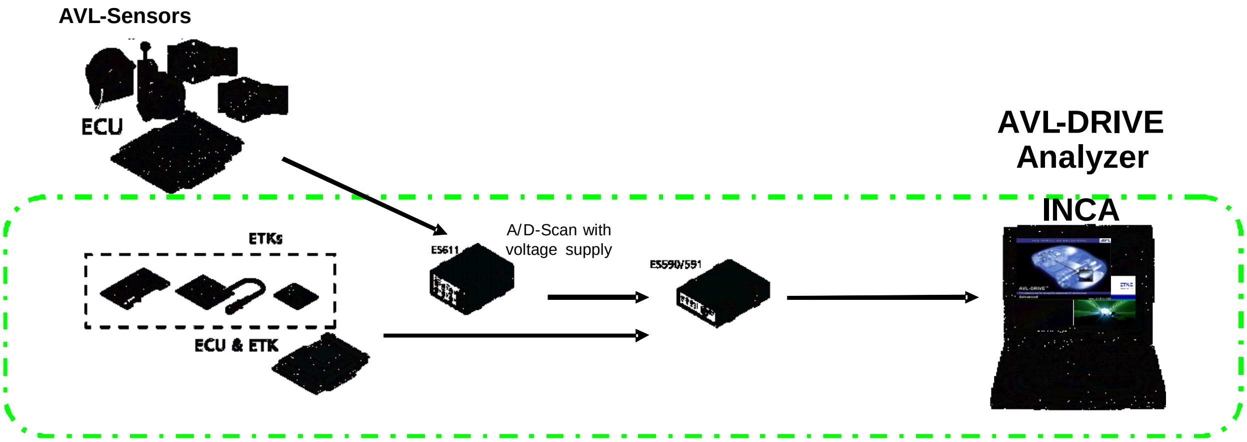



**Figure 19 AVL-DRIVE INCA Typical Configuration**

The AVL-DRIVE → ATI-Vision interface works in a similar way, utilizing the ATI provided hardware in place of the ETAS hardware.

## 8.4. AVL-DRIVE Software

### 8.4.1. AVL-DRIVE Analyzer

The AVL-DRIVE Analyzer is the main software for driveability evaluation and for the analysis of all recorded AVL-DRIVE data. The software consists of three main parts:

- Driving mode detection
- Physical parameter calculation
- Driveability evaluation

The analysis capability of the software provides the user with typical plots such as:

- Tables of all physical data and Driveability ratings
- 2D & 3D-Graphs of all physical data and Driveability ratings
- Full and part load acceleration plots
- Shift pattern
- Statistical analysis tools

AVL-DRIVE is configurable for different vehicles by modifying the relevant parameter data. Key vehicle parameters such as gear ratios and friction parameters can be determined using the configuration wizard included in the software.

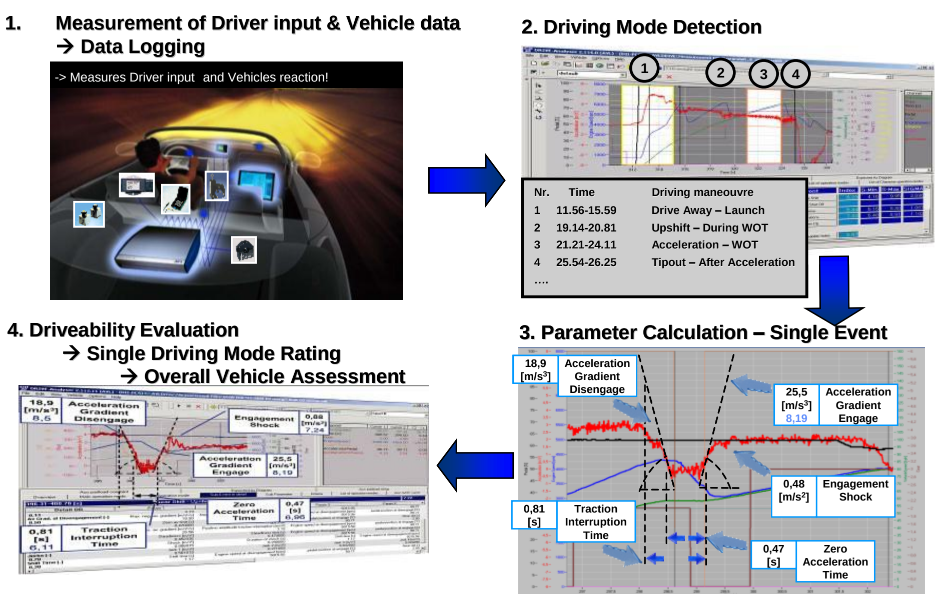



**Figure 20 Summary of AVL-DRIVE Data Acquisition and Analysis process**

AVL-DRIVE is able to read multiple data formats, including:

- AV-DRIVE .raw (native format – note that this file format is consistent with IMC format data)
- ATI Vision .rec files
- ETAS INCA .dat file
- CANape files
- .txt file
- Matlab .MAT files
- ASCII files

It can be used on-line in the vehicle in real-time, interfaced with Vision, INCA or using AVL's DMU2, and can be used off-line as a data post-processor.

#### 8.4.2. AVL-DRIVE Vehicle Class Modules

The AVL-DRIVE system evaluates up to 420 single physical criteria in up to 81 sub-operating modes and 15 main operating modes. The assessment of these criteria varies by vehicle category and transmission type. The following vehicle classes are currently available:

- Micro
- Small
- Compact
- Medium
- Large
- Luxury
- SUV
- Sports
- Pick-up truck

#### 8.4.3. AVL-DRIVE Transmission Types

The AVL-DRIVE system currently offers the following transmission types:

- Manual Transmission (MT)
- Automatic Transmission (AT)
- Automated Manual Transmission (AMT)
- Double Clutch Transmission (DCT)
- Continuously Variable Transmission (CVT)
- Single Speed Transmission

These transmission types contain mathematical and physical model data uniquely calibrated to process and score data and compare it against other vehicles with that transmission type.

### 8.4.4. AVL-DRIVE for Hybrids

AVL-DRIVE for hybrids provides additional capability to consider specific hybrid related maneuvers based on the technology available.
These maneuvers include:

- Vehicle rolling engine off
- Electric only launch
- IC engine restarts and launch
- Regenerative braking maneuvers

This, then, enables some evaluation of charge management strategies, and an understanding of constraints on the vehicle performance resulting from varying state-of-charge etc.

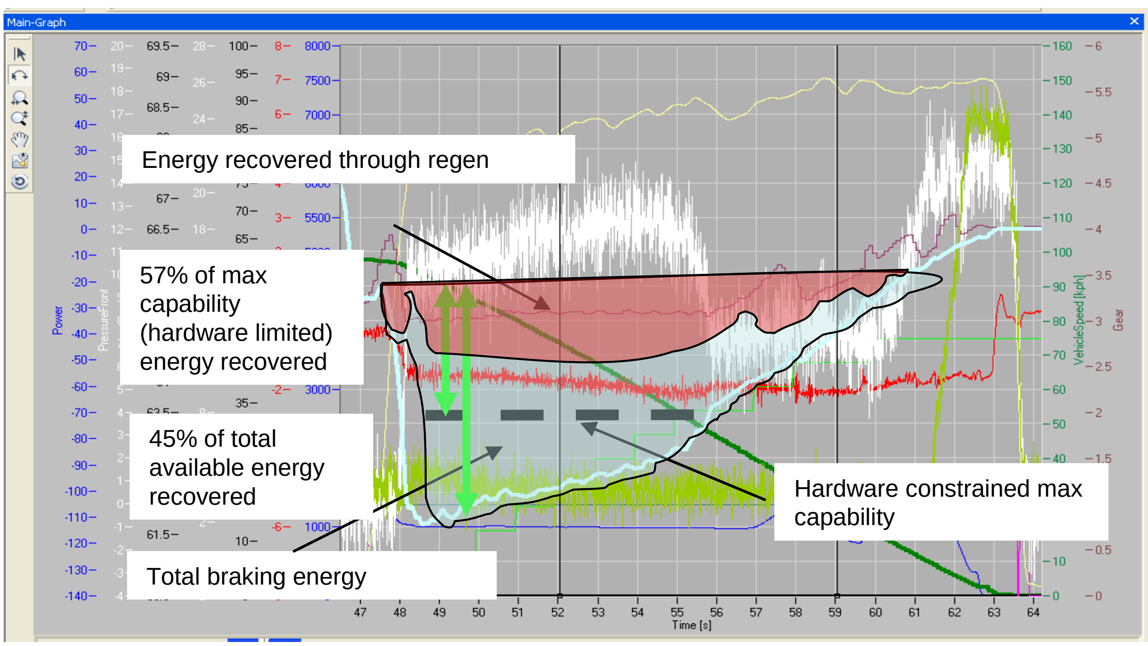



**Figure 21  Comparison of energy recovered vs energy available during deceleration**

8.4.5. AVL-DRIVE Report Generator (RG)

AVL-DRIVE RG is a free additional software installation provided with AVL-DRIVE. It automatically creates pre-defined benchmark reports consisting of scatter plots and comparison charts for main, sub and criteria event levels. Multiple vehicle variants can be compared in the same graph.

This can be particularly useful in providing a fast comparison between either vehicles, or on a specific vehicle with changes in software or hardware.

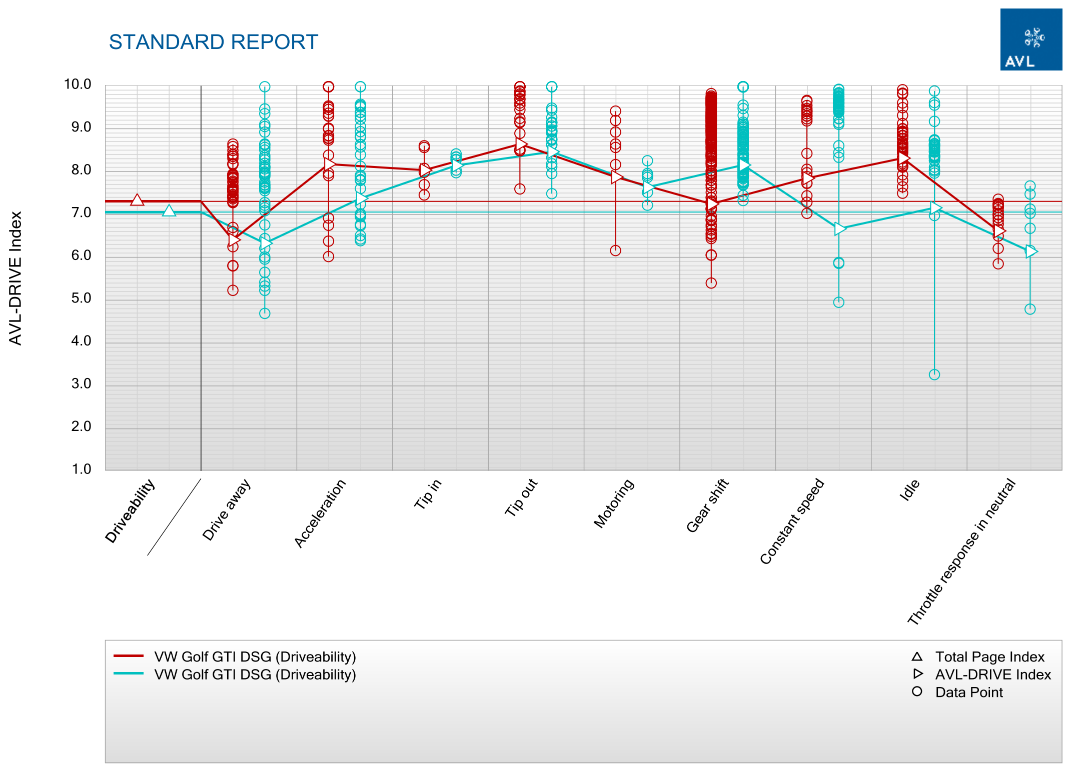



**Figure 22 Standard output from RG showing Drive Away comparison for alternative transmission modes**

## 8.5. DMU2 Specification

| Item | Characteristics | Features |
|---|---|---|
| | | DMU 2 |
| General | Dimensions (H x W x D) | 35x140x230 mm |
| | Weight | 1000 gram |
| | Temperature range | -20 TO +70 °C (operation) |
| | | -40 TO +85 °C (storage) |
| Power supply | Operating voltage | 8V to 16V (protected against load dump (reverse-polarity protected) |
| | Internal Battery | Stand alone Power supply up to 3h |
| Current consumption | Continuous operation / Standby | without Sensors 450mA at 12V |
| Interface | PC Connection | USB 2.0 up to 480 Mbit/s |
| | CAN OUT | Standard Protocol with 1MBit/s |
| | | (including Voltage-,ICP®-,Temperature, and RPM Inputs) |
| | Data logger | Stand alone Data logging for all Analog inputs plus Vehicle CAN |
| | | Supporting SD-CARD up to 16GB |
| | DMU Interconnection-bus | Cascade more DMUII to extend Voltage-,ICP®-,Temperature, and RPM Inputs |
| Inputs | Voltage Input | |
| | Channels | 12 (per unit, cascade more units to extent number of inputs) |
| | Input ranges | 0-5V, ±5V, ±15V |
| | Resolution | 12bits for each Voltage Range |
| | Sampling rate | 10Hz, 100Hz, 1kHz predefined (up to 50kHz for each Channel) |
| | ICP® Input Standart | |
| | Channels | 3 |
| | Resolution | 12bits |
| | Sampling rate | 10Hz, 100Hz, 1kHz predefined (up to 50kHz for each Channel) |
| | ICP® Input for Microphone | |
| | Channels | 1 |
| | Resolution | 12bits |
| | Sampling rate | 50kHz with A-Weighting |
| | RPM Input | |
| | Channels | 2 |
| | Sensor Types | TTL or INDUCTIVE Sensors |
| | Sampling rate | 10Hz, 100Hz, 1kHz predefined (up to 50kHz for each Channel) |
| | CAN Input | |
| | Channels | 1 (with optional Extention) |
| | Protocol | Standard or extended |
| | Bitrate | 100kBit/s up to 1MBit/s |
| | Temperature Input Cable | 2 incuded |
| | Channels | For each Analog Input Channel |
| | Sensor Type | K-Type |
| | Resolution | 12bits |
| | Sampling rate | 10Hz, 100Hz, 1kHz predefined (up to 50kHz for each Channel) |
| Sensor supply output | Output voltage Vout | 0-5V, ±15V |
| | Output current | Maximum Sum Load on all Outputs 500mA |

# 9. Appendix B – AVL-DRIVE tree Structure

| Operation Mode | Sub-Operation Mode | Criteria |
|---|---|---|
| Drive away | | |
| Drive away | Creep | |
| Drive away | Creep | Brake release delay |
| Drive away | Creep | Brake release bump |
| Drive away | Creep | Brake release surge |
| Drive away | Normal | |
| Drive away | Normal | Brake release delay |
| Drive away | Normal | Brake release bump |
| Drive away | Normal | Brake release surge |
| Drive away | Normal | Response delay |
| Drive away | Normal | Initial bump |
| Drive away | Normal | Overshoot |
| Drive away | Normal | Stumble |
| Drive away | Normal | Acceleration peak |
| Drive away | Normal | Acceleration performance |
| Drive away | Normal | Shock |
| Drive away | Normal | Engagement steadiness |
| Drive away | Normal | Jerks |
| Drive away | Launch | |
| Drive away | Launch | Brake release delay |
| Drive away | Launch | Brake release bump |
| Drive away | Launch | Brake release surge |
| Drive away | Launch | Response delay |
| Drive away | Launch | Initial bump |
| Drive away | Launch | Overshoot |
| Drive away | Launch | Stumble |
| Drive away | Launch | Acceleration peak |
| Drive away | Launch | Acceleration performance |
| Drive away | Launch | Shock |
| Drive away | Launch | Engagement steadiness |
| Drive away | Launch | Jerks |
| Drive away | Hill climbing | |
| Drive away | Hill climbing | Brake release bump |
| Drive away | Hill climbing | Brake release surge |
| Drive away | Hill climbing | Response delay |
| Drive away | Hill climbing | Initial bump |
| Drive away | Hill climbing | Stumble |
| Drive away | Hill climbing | Overshoot |
| Drive away | Hill climbing | Acceleration performance |
| Drive away | Hill climbing | Acceleration peak |
| Drive away | Hill climbing | Shock |
| Drive away | Hill climbing | Engagement steadiness |
| Drive away | Hill climbing | Jerks |
| Drive away | Hill climbing | Hill climbing |
| Drive away | Rolling stop | |
| Drive away | Rolling stop | Response Delay |
| Drive away | Rolling stop | Engagement steadiness |
| Drive away | Manoeuvring engage | |
| Drive away | Manoeuvring engage | Bump |
| Drive away | Manoeuvring engage | Delay |
| Drive away | Manoeuvring engage | Jerks |
| Drive away | Vehicle stop | |
| Drive away | Vehicle stop | Bump |
| Drive away | Vehicle stop | Engine speed fluctuations |
| Drive away | Vehicle stop | Engine speed overshoot |
| Drive away | Vehicle stop | Engine speed undershoot |

| Operation Mode | Sub-Operation Mode | Criteria |
|---|---|---|
| Acceleration | | |
| Acceleration | Full load | |
| Acceleration | Full load | Max, expected torque |
| Acceleration | Full load | 90% Torque threshold |
| Acceleration | Full load | 90% Torque range |
| Acceleration | Full load | Wide torque range |
| Acceleration | Full load | Engine free acceleration |
| Acceleration | Full load | Torque smoothness |
| Acceleration | Full load | Surge |
| Acceleration | Full load | RPM limiter |
| Acceleration | Full load | Vibrations |
| Acceleration | Full load | Noise |
| Acceleration | Full load | Expected acceleration |
| Acceleration | Full load | Reference acceleration |
| Acceleration | Part load rising pedal | |
| Acceleration | Part load rising pedal | Surge |
| Acceleration | Part load rising pedal | Correlation |
| Acceleration | Part load rising pedal | Torque response |
| Acceleration | Part load rising pedal | Torque build-up |
| Acceleration | Part load rising pedal | Expected acceleration |
| Acceleration | Part load rising pedal | Reference acceleration |
| Acceleration | Part load constant pedal | |
| Acceleration | Part load constant pedal | Surge |
| Acceleration | Part load constant pedal | Acceleration steps |
| Acceleration | Part load constant pedal | Expected acceleration |
| Acceleration | Part load constant pedal | Reference acceleration |
| Acceleration | Part load constant pedal | Pedal map |
| Acceleration | Low end torque | |
| Acceleration | Low end torque | Low end torque |
| Acceleration | Elasticity | |
| Acceleration | Elasticity | Elasticity |
| Acceleration | Full load 0-100 kph | |
| Acceleration | Full load 0-100 kph | Full load 0-100 kph |
| Acceleration | Full load 0-100 kph | Full load 0->>100 kph |
| Acceleration | Part load falling pedal | |
| Acceleration | Part load falling pedal | Surge |
| Acceleration | Part load falling pedal | Correlation |
| Acceleration | Part load falling pedal | Expected acceleration |
| Acceleration | Part load falling pedal | Reference acceleration |
| Acceleration | Full load through gears | |
| Acceleration | Full load through gears | Full load through gears threshold 1 |
| Acceleration | Full load through gears | Full load through gears threshold 2 |
| Acceleration | Full load through gears | Full load through gears threshold 3 |
| Acceleration | Cylinder deactivation | |
| Acceleration | Cylinder deactivation | Acceleration gradient |
| Acceleration | Cylinder deactivation | Steadiness |
| Acceleration | Cylinder deactivation | Engine speed change |
| Acceleration | Cylinder reactivation | |
| Acceleration | Cylinder reactivation | Acceleration gradient |
| Acceleration | Cylinder reactivation | Steadiness |
| Acceleration | Cylinder reactivation | Engine speed change |

| Operation Mode | Sub-Operation Mode | Criteria |
|---|---|---|
| Engine start | | |
| Engine start | Manual start | |
| Engine start | Manual start | Surge |
| Engine start | Manual start | Starter response delay |
| Engine start | Manual start | Start duration |
| Engine start | Manual start | Starter speed |
| Engine start | Manual start | Speed pickup duration |
| Engine start | Manual start | Stumble |
| Engine start | Manual start | Overshoot speed |
| Engine start | Manual start | Undershoot speed |
| Engine start | Manual start | Idle stabilization duration |
| Engine start | Manual start | Noise |
| Engine start | Manual start | Vibrations |
| Engine start | Auto start | |
| Engine start | Auto start | Surge |
| Engine start | Auto start | Start duration |
| Engine start | Auto start | Starter speed |
| Engine start | Auto start | Speed pickup duration |
| Engine start | Auto start | Stumble |
| Engine start | Auto start | Overshoot speed |
| Engine start | Auto start | Undershoot speed |
| Engine start | Auto start | Idle stabilization duration |
| Engine start | Auto start | Noise |
| Engine start | Auto start | Vibrations |
| Engine start | Change of mind | |
| Engine start | Change of mind | Surge stop |
| Engine start | Change of mind | Surge start |
| Engine start | Change of mind | Starter response delay |
| Engine start | Change of mind | Starter speed |
| Engine start | Change of mind | Speed pickup duration |
| Engine start | Change of mind | Overshoot speed |
| Engine start | Change of mind | Undershoot speed |
| Engine start | Change of mind | Idle stabilization duration |
| Engine start | Change of mind | Noise |
| Engine start | Change of mind | Vibrations |
| Engine start | Fault start | |
| Engine start | Fault start | Surge |
| Engine start | Fault start | Starter response delay |
| Engine start | Fault start | Fault start duration |
| Engine start | Fault start | Noise |
| Engine start | Fault start | Vibrations |

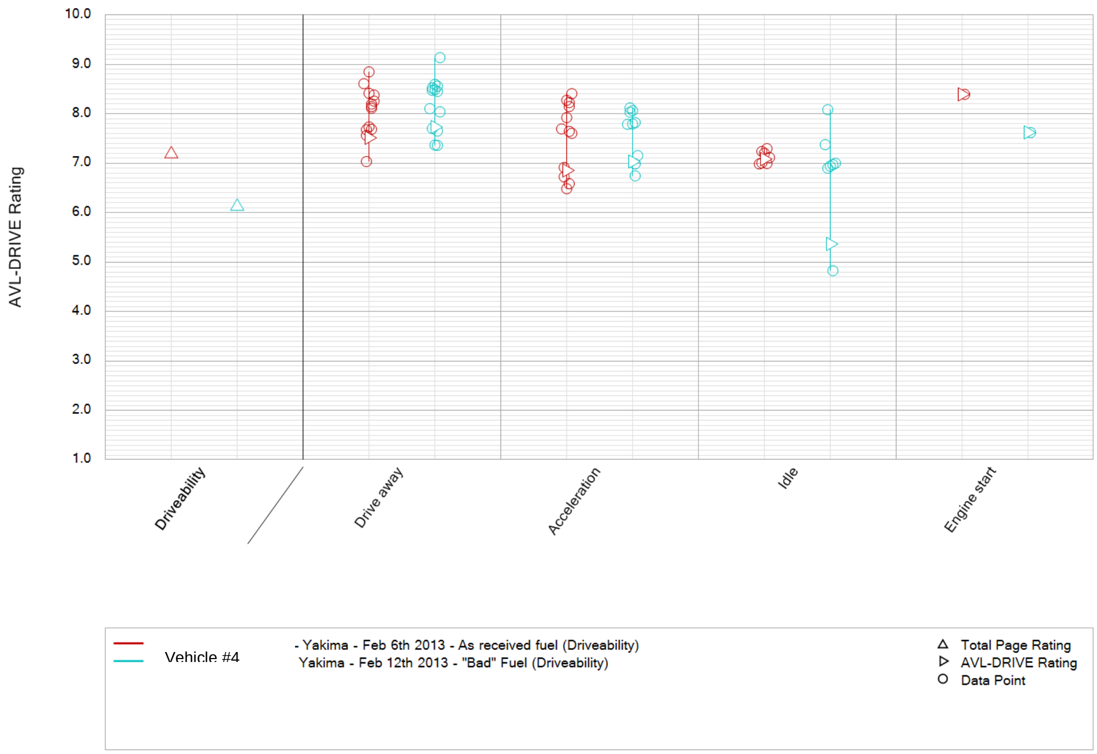
| Operation Mode | Sub-Operation Mode | Criteria |
|---|---|---|
| Idle | | |
| Idle | Normal | |
| Idle | Normal | Speed fluctuations |
| Idle | Normal | Engine speed drift |
| Idle | Normal | Vibrations |
| Idle | Normal | Noise |
| Idle | Normal | Cylinder balance |
| Idle | Normal | Surge |
| Idle | Normal | Idle speed |
| Idle | Normal | Combustion quality |
| Idle | Engage | |
| Idle | Engage | Speed fluctuations |
| Idle | Engage | Engine speed drift |
| Idle | Engage | Vibrations |
| Idle | Engage | Engine speed overshoot |
| Idle | Engage | Engine speed undershoot |
| Idle | Engage | Stabilization duration |
| Idle | Engage | Bump |
| Idle | Engage | Shift delay |
| Idle | Engage | Noise |
| Idle | Disengage | |
| Idle | Disengage | Speed fluctuations |
| Idle | Disengage | Engine speed drift |
| Idle | Disengage | Vibrations |
| Idle | Disengage | Engine speed overshoot |
| Idle | Disengage | Engine speed undershoot |
| Idle | Disengage | Stabilization duration |
| Idle | Disengage | Bump |
| Idle | Disengage | Shift delay |
| Idle | Disengage | Noise |
| Idle | Electric load on | |
| Idle | Electric load on | Speed fluctuations |
| Idle | Electric load on | Engine speed drift |
| Idle | Electric load on | Vibrations |
| Idle | Electric load on | Engine speed overshoot |
| Idle | Electric load on | Engine speed undershoot |
| Idle | Electric load on | Stabilization duration |
| Idle | Electric load off | |
| Idle | Electric load off | Speed fluctuations |
| Idle | Electric load off | Engine speed drift |
| Idle | Electric load off | Vibrations |
| Idle | Electric load off | Engine speed overshoot |
| Idle | Electric load off | Engine speed undershoot |
| Idle | Electric load off | Stabilization duration |
| Idle | Air conditioning on | |
| Idle | Air conditioning on | Engine speed drift |
| Idle | Air conditioning on | Vibrations |
| Idle | Air conditioning on | Engine speed overshoot |

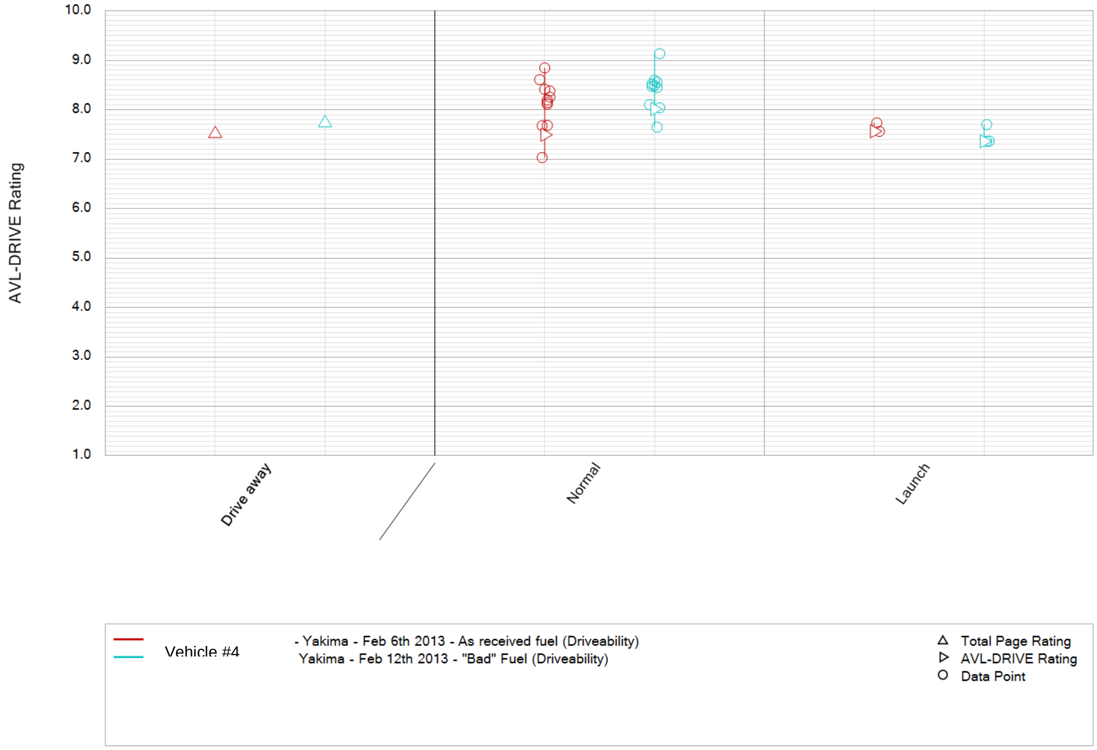
| | | |
|---|---|---|
| Idle | Air conditioning on | Engine speed undershoot |
| Idle | Air conditioning on | Stabilization duration |
| Idle | Air conditioning off | |
| Idle | Air conditioning off | Engine speed drift |
| Idle | Air conditioning off | Vibrations |
| Idle | Air conditioning off | Engine speed overshoot |
| Idle | Air conditioning off | Engine speed undershoot |
| Idle | Air conditioning off | Stabilization duration |
| Idle | After part load | |
| Idle | After part load | Stabilization duration |
| Idle | After part load | Speed fluctuations |
| Idle | After part load | Engine speed undershoot |
| Idle | While rolling | |
| Idle | While rolling | Speed fluctuations |
| Idle | While rolling | Engine speed drift |
| Idle | While rolling | Cylinder balance |
| Idle | While rolling | Idle speed |

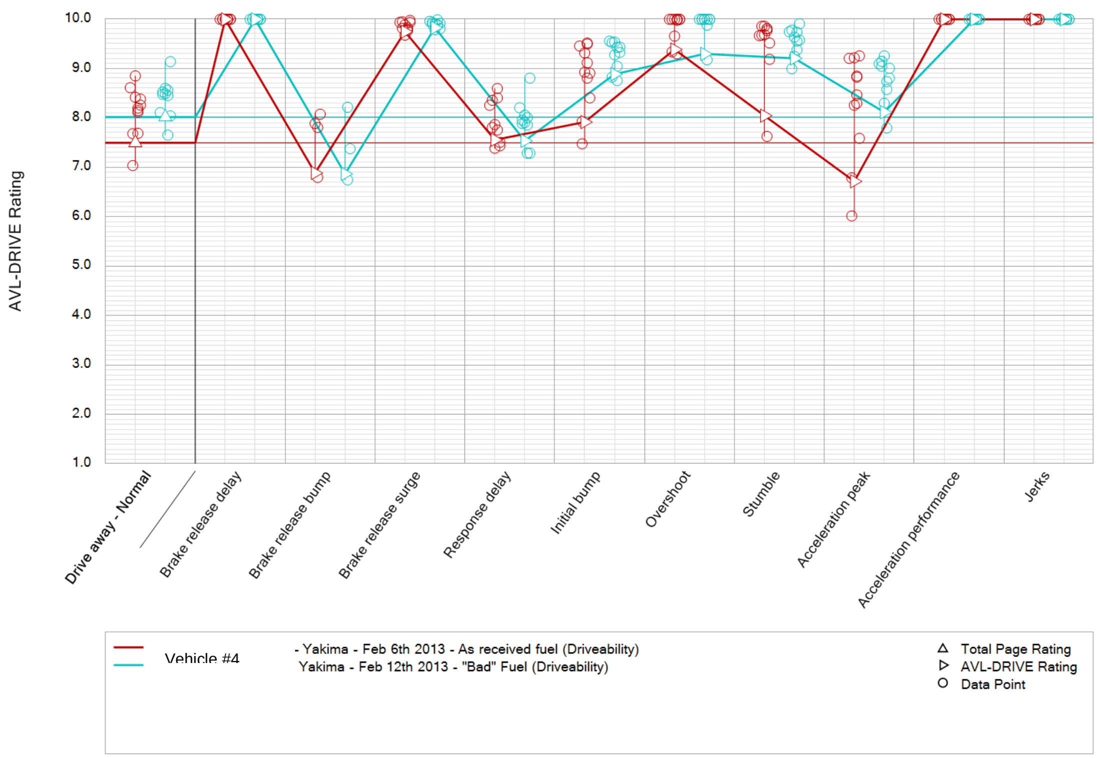
# 10. Appendix C – Vehicle Screening Test Results

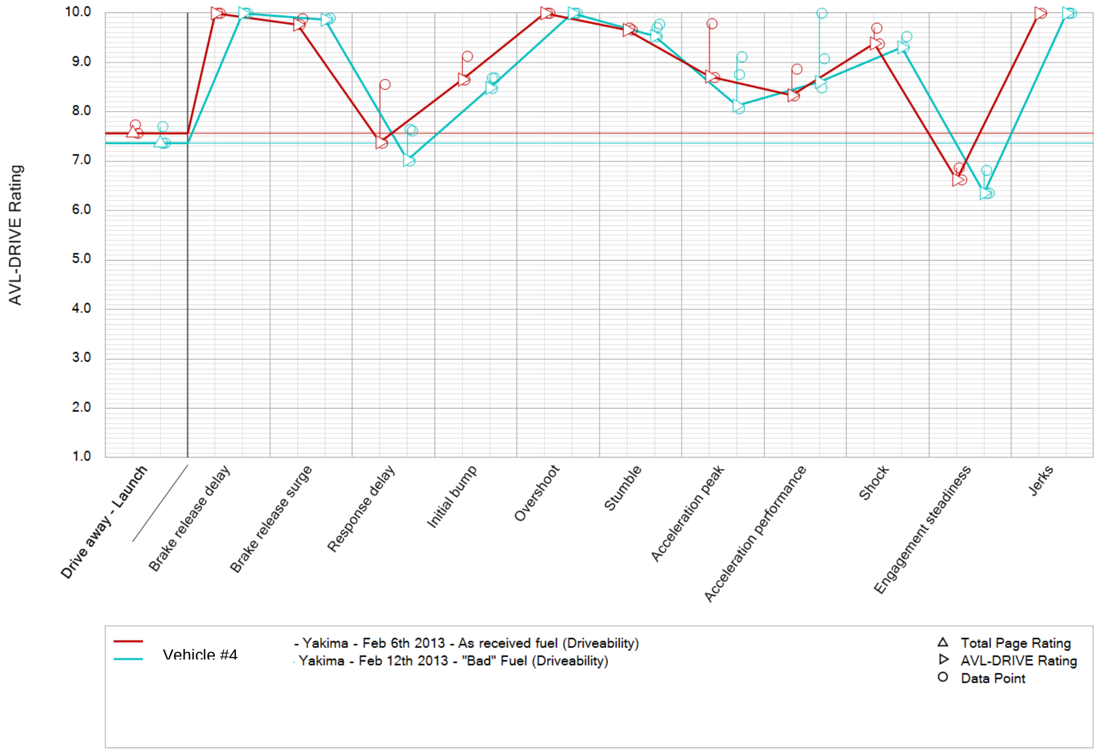
The following plots show the DRIVE ratings for the sub-operation modes for the screening test results. In each case the operation mode is cascaded down into the sub-operation modes and criteria. As per sections 3 and 4, the data is filtered to only include operation modes that broadly align with the CRC evaluation.

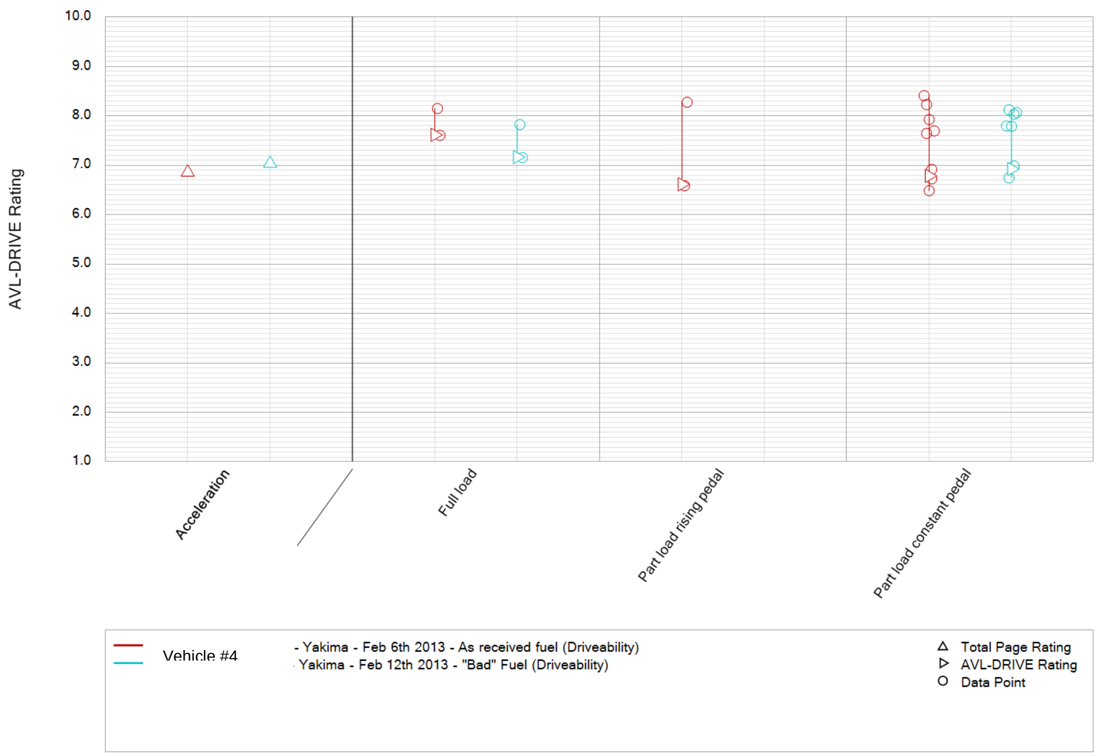
## 10.1. Vehicle #4

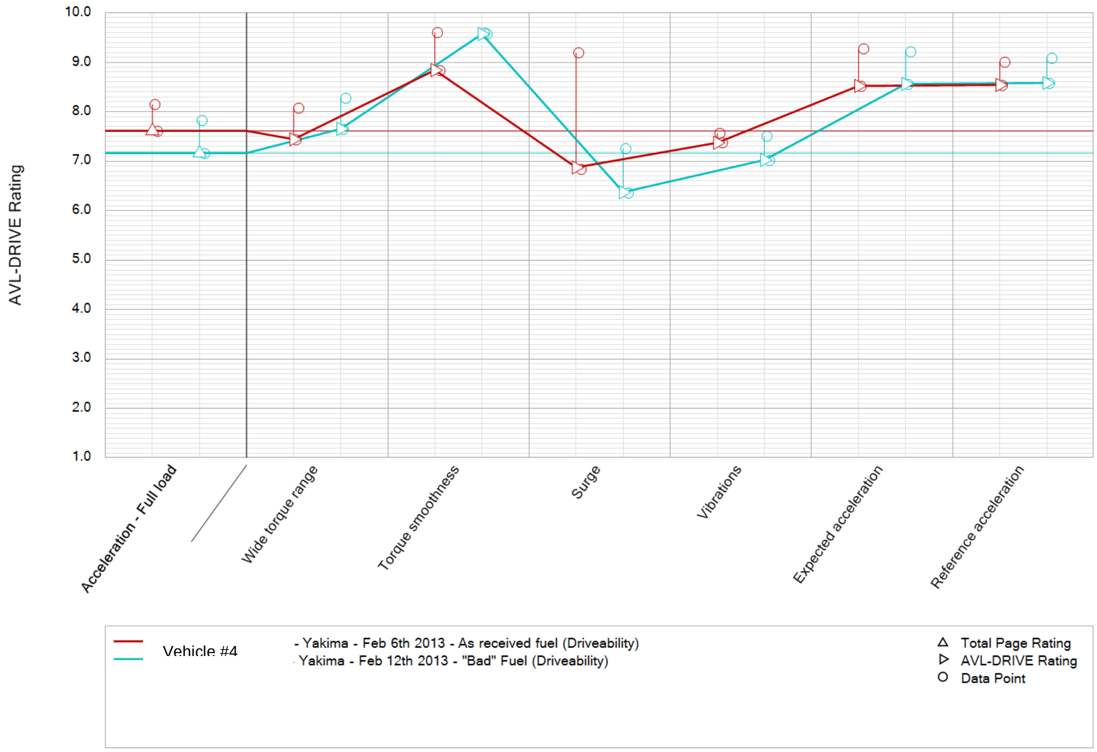


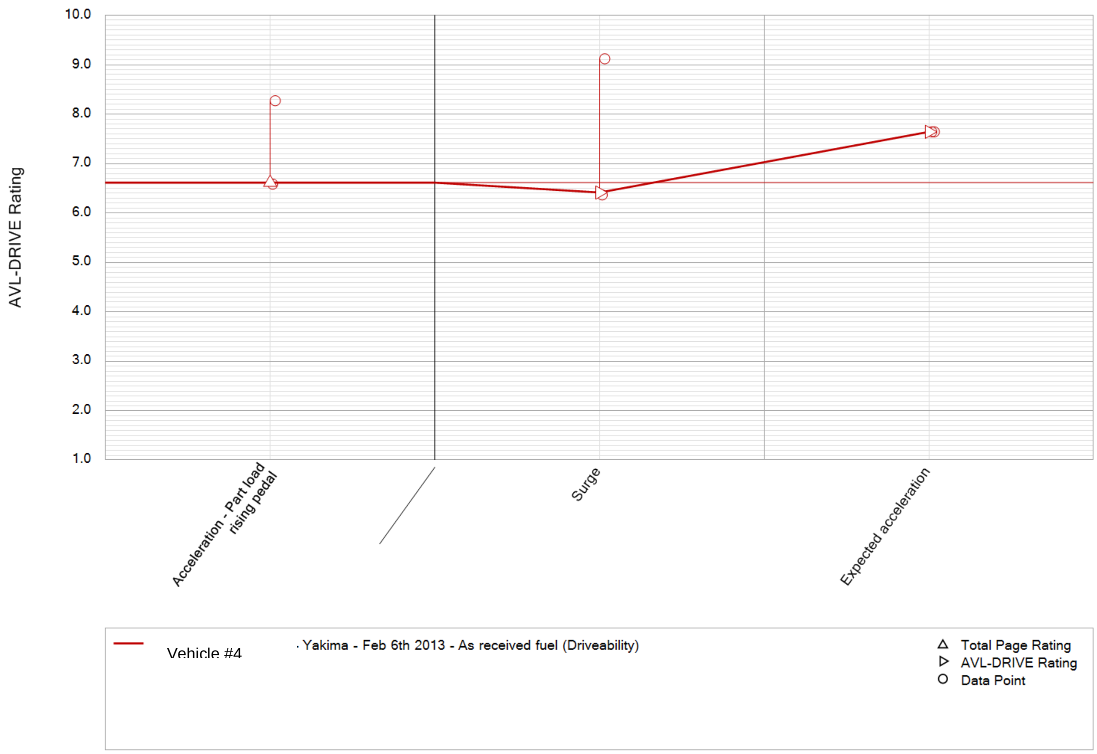

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Drive away
Normal
Launch
Vehicle #4
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

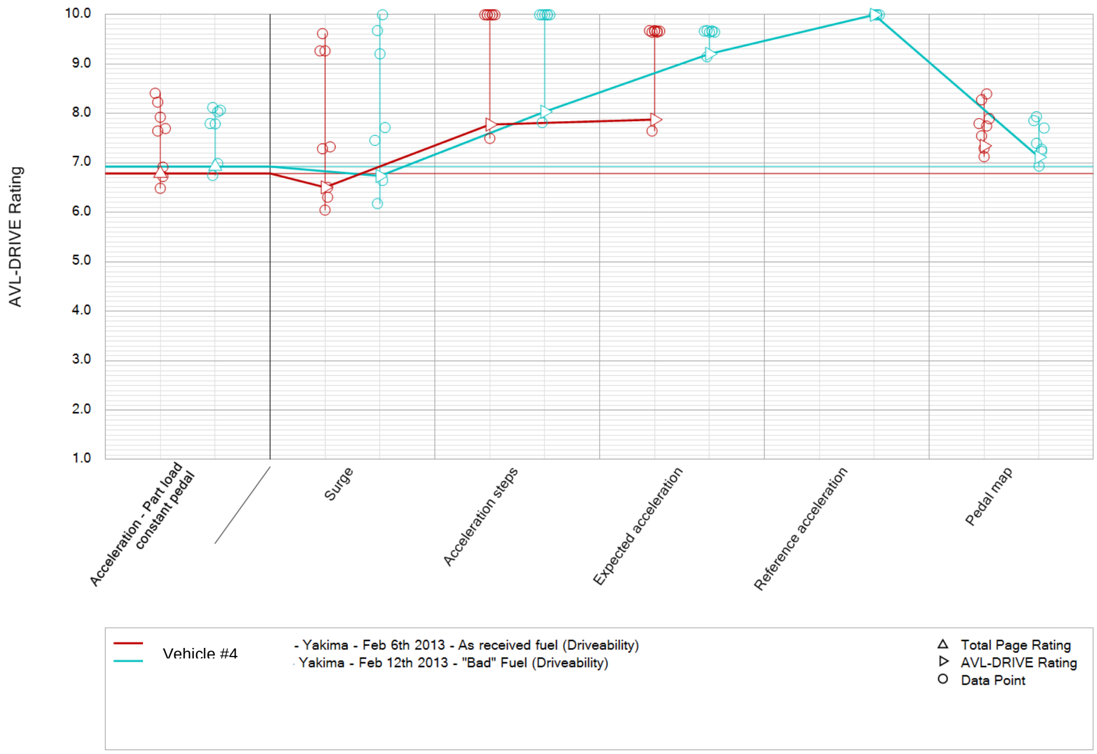

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Drive away - Normal
Brake release delay
Brake release bump
Brake release surge
Response delay
Initial bump
Overshoot
Stumble
Acceleration peak
Acceleration performance
Jerks
Vehicle #4
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

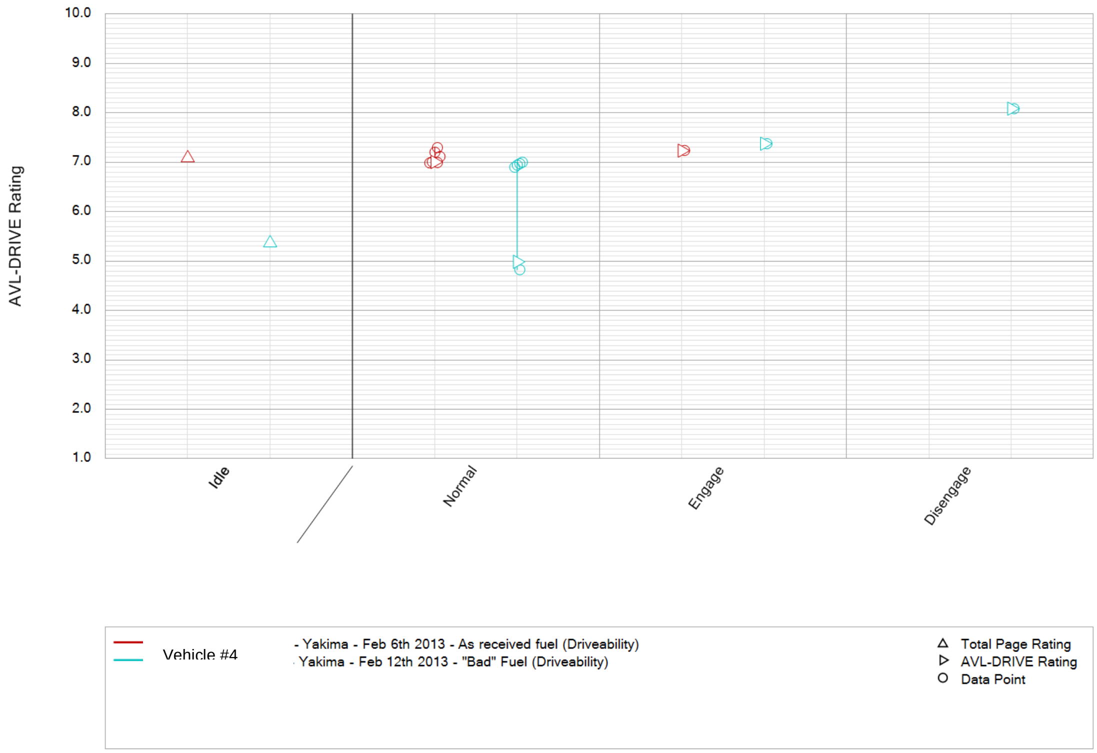

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Drive away - Launch
Brake release delay
Brake release surge
Response delay
Initial bump
Overshoot
Stumble
Acceleration peak
Acceleration performance
Shock
Engagement steadiness
Jerks
Vehicle #4
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

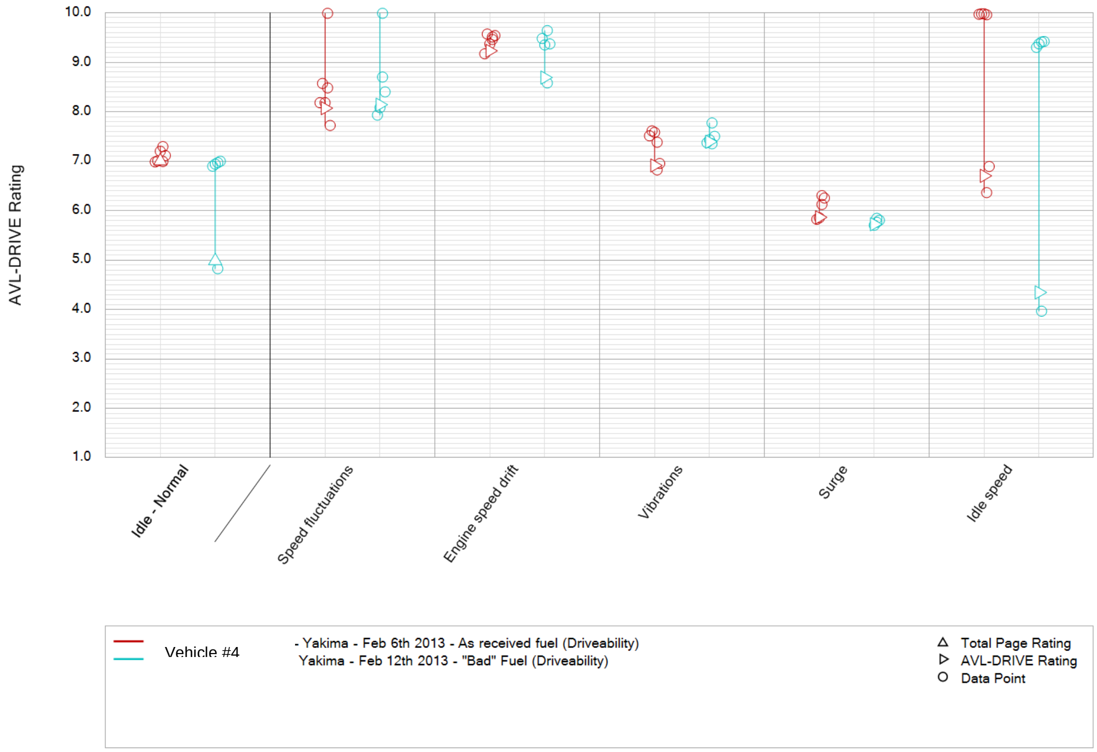

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration
Full load
Part load rising pedal
Part load constant pedal
Vehicle #4
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

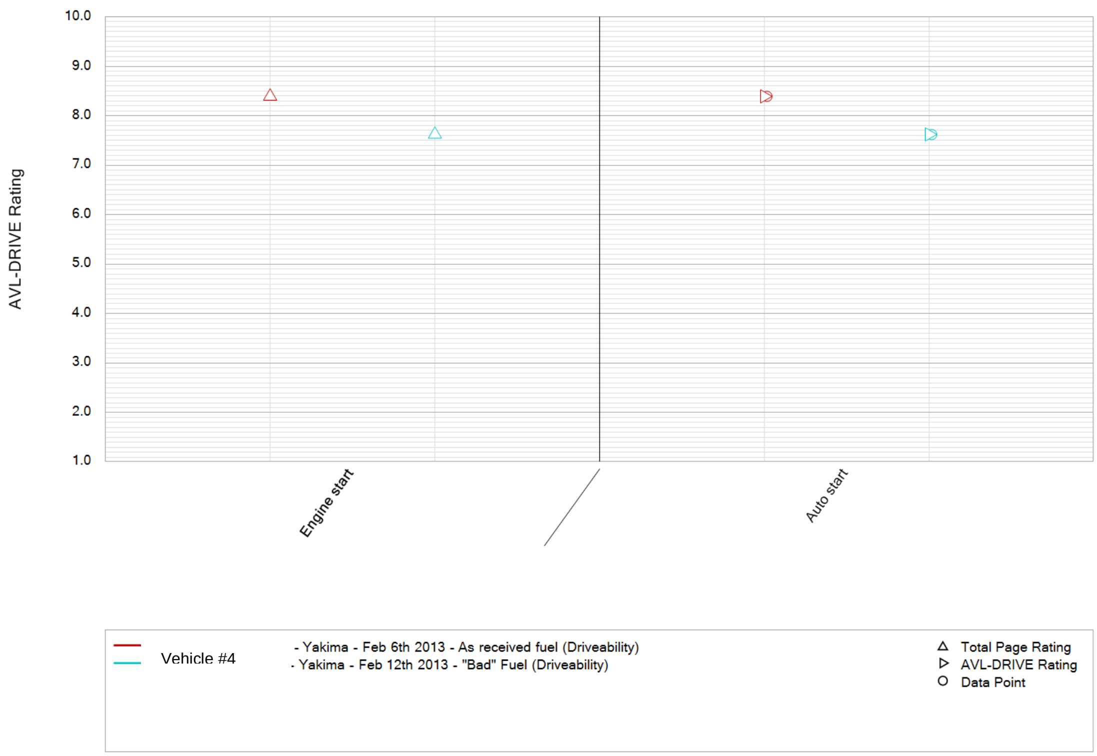

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration - Full load
Wide torque range
Torque smoothness
Surge
Vibrations
Expected acceleration
Reference acceleration
Vehicle #4
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
- Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

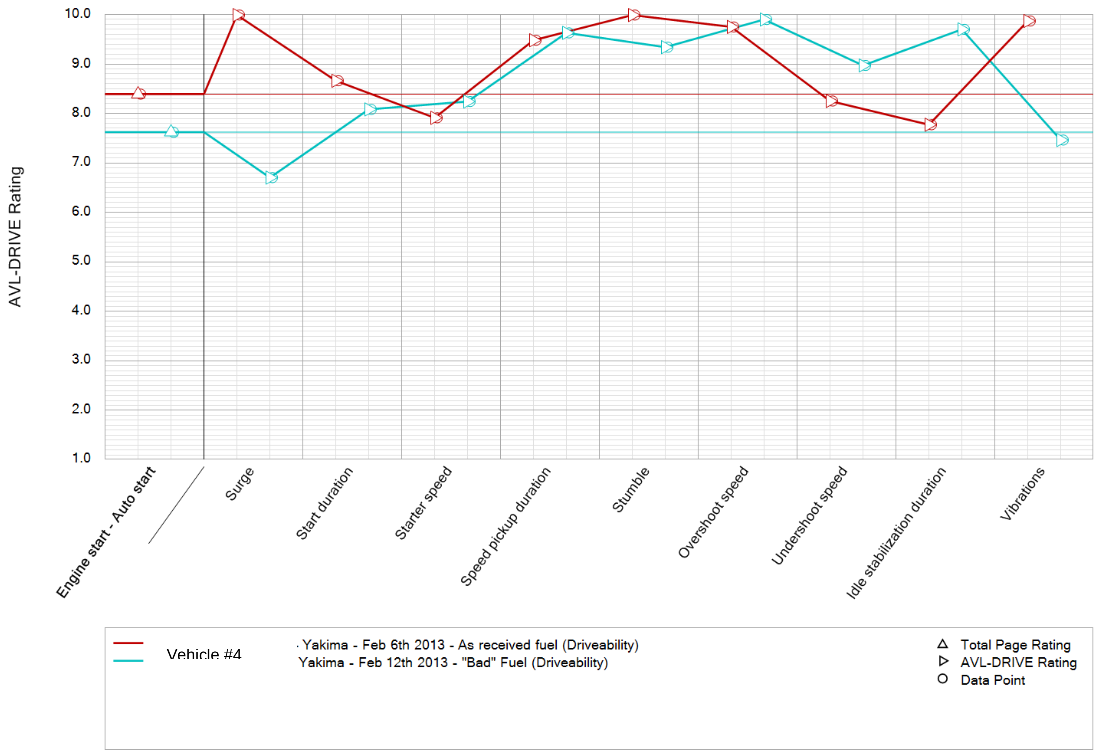

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration - Part load rising pedal
Surge
Expected acceleration
Vehicle #4
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point


AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration - Part load constant pedal
Surge
Acceleration steps
Expected acceleration
Reference acceleration
Pedal map
Vehicle #4
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

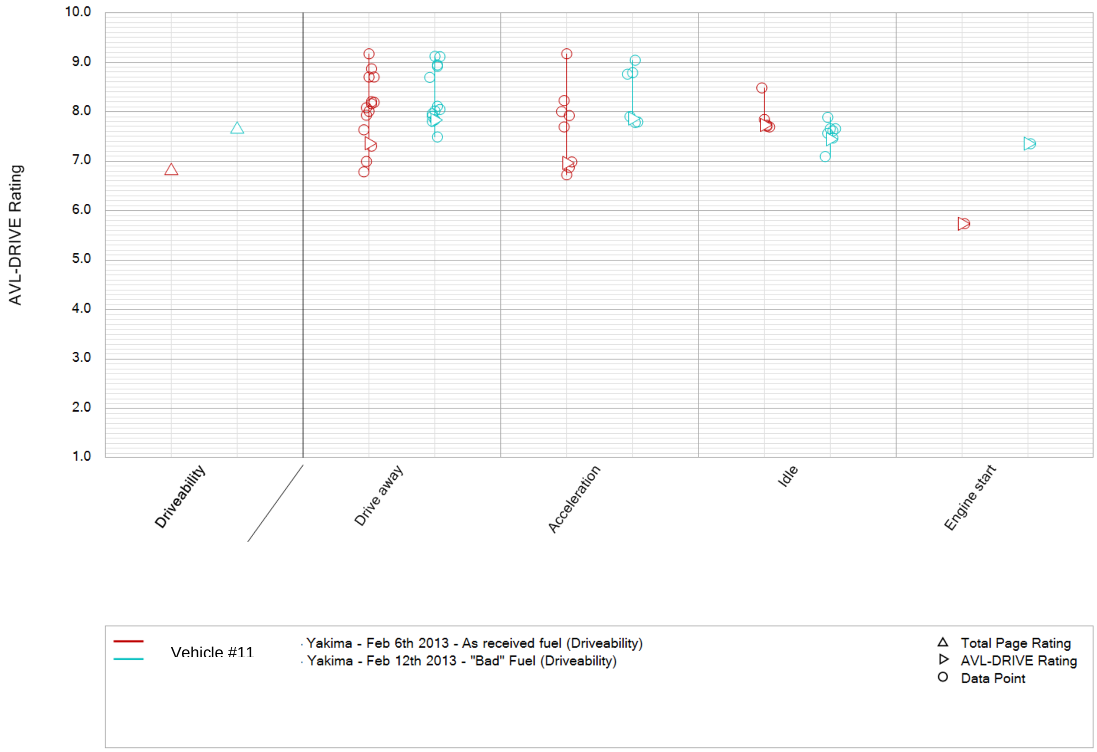

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Idle
Normal
Engage
Disengage
Vehicle #4
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

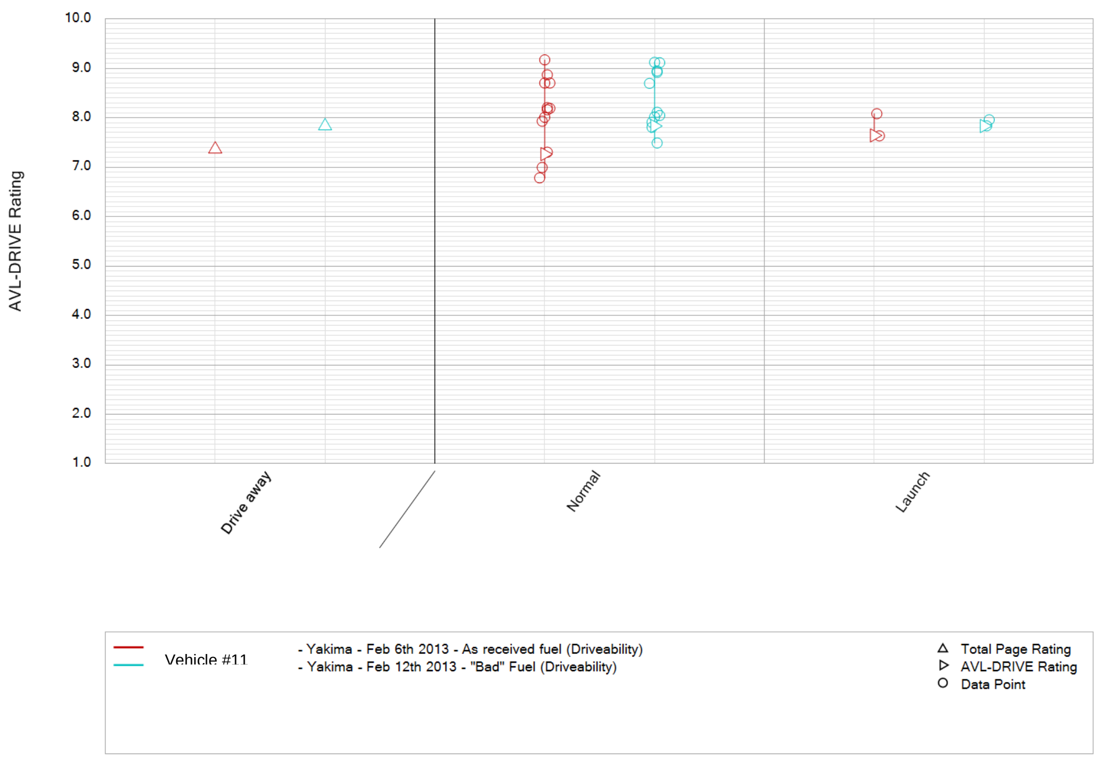

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Idle - Normal
Speed fluctuations
Engine speed drift
Vibrations
Surge
Idle speed
Vehicle #4
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

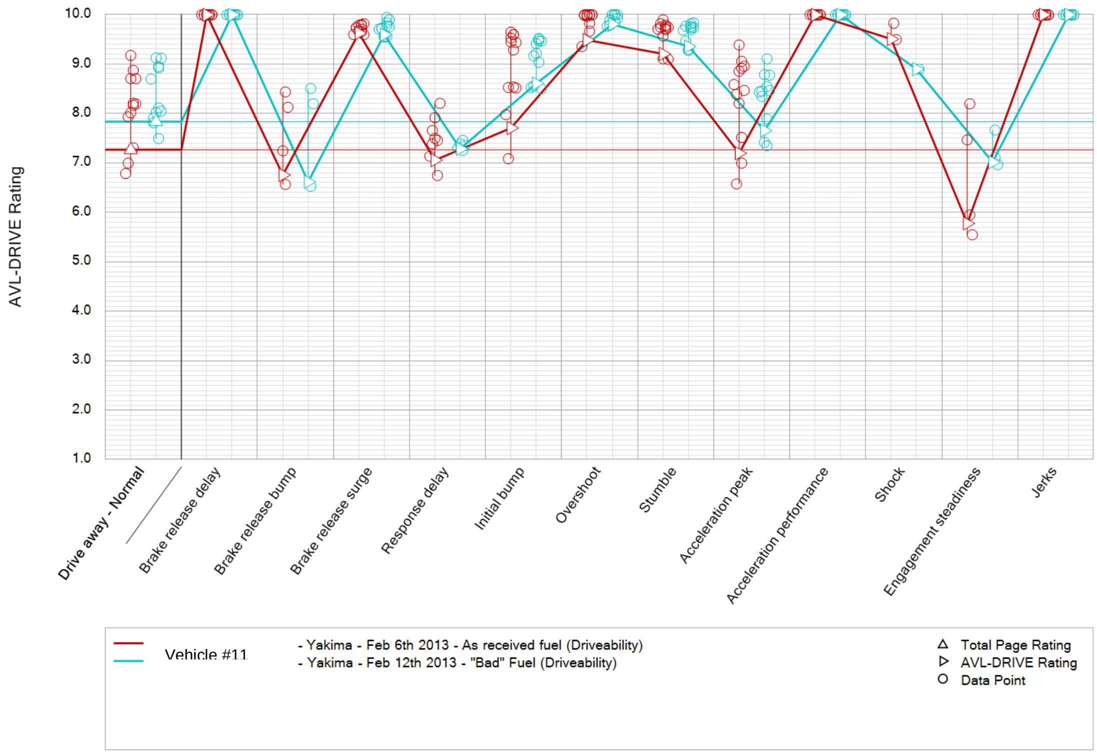

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Engine start
Auto start
Vehicle #4
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
- Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point


AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Engine start - Auto start
Surge
Start duration
Starter speed
Speed pickup duration
Stumble
Overshoot speed
Undershoot speed
Idle stabilization duration
Vibrations
Vehicle #4
Yakima - Feb 6th 2013 - As received fuel (Driveability)
Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

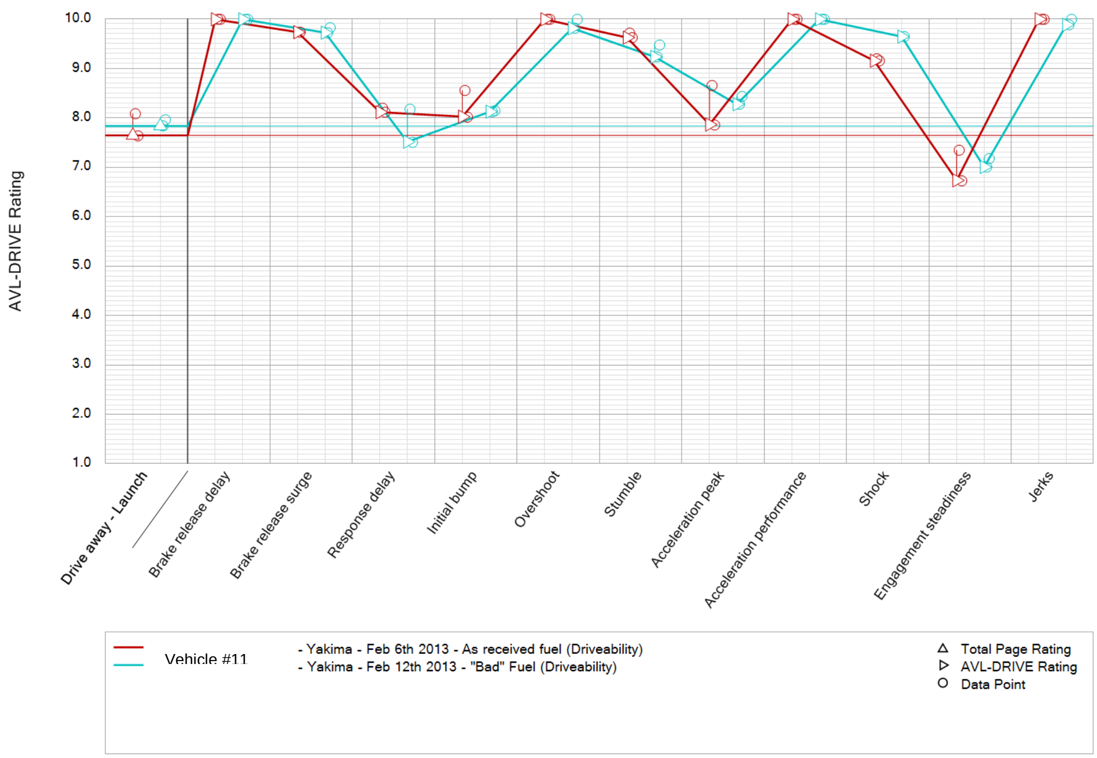
## 10.2. Vehicle #11



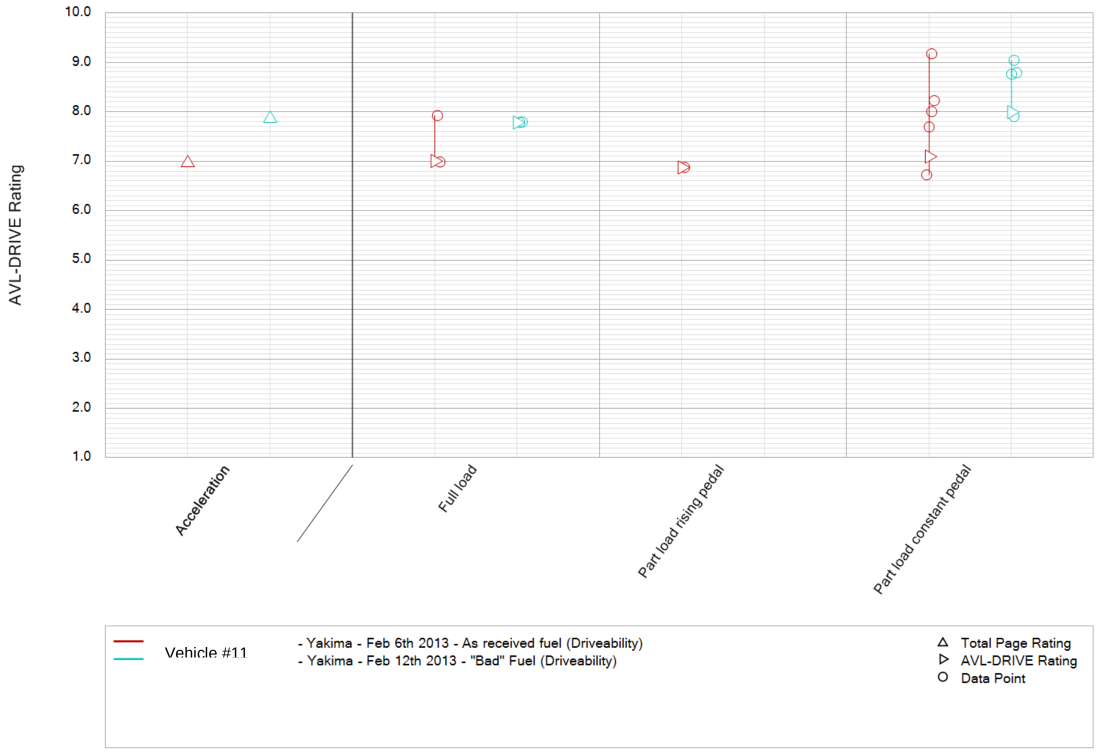



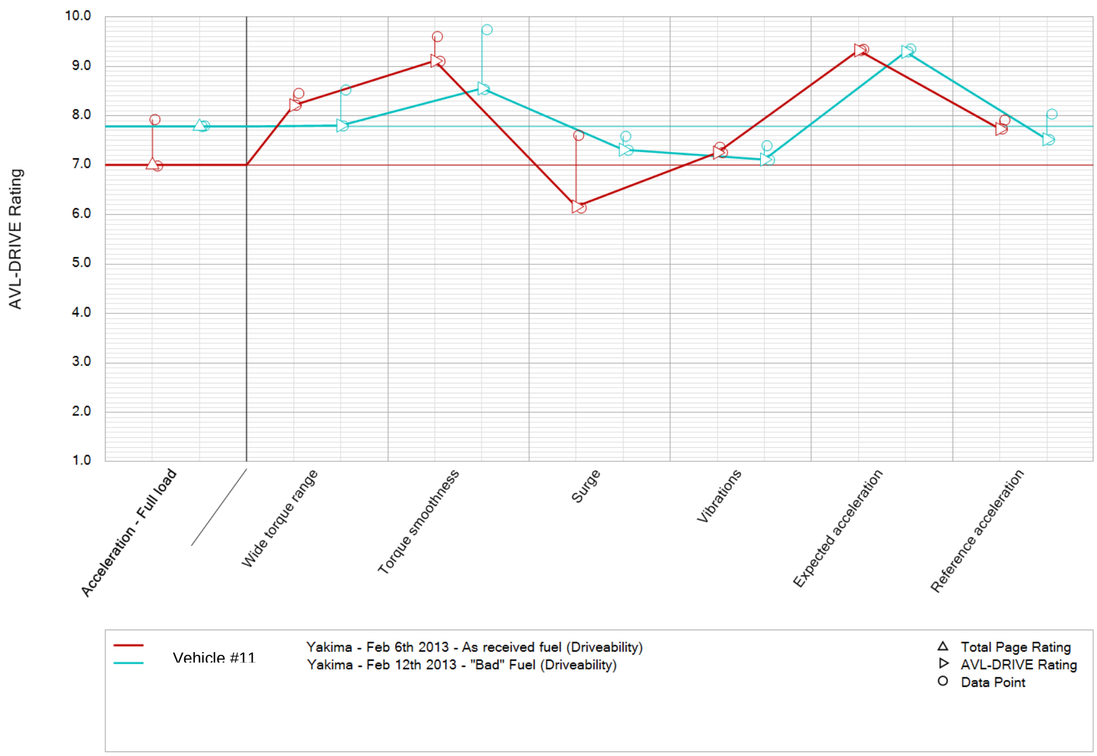


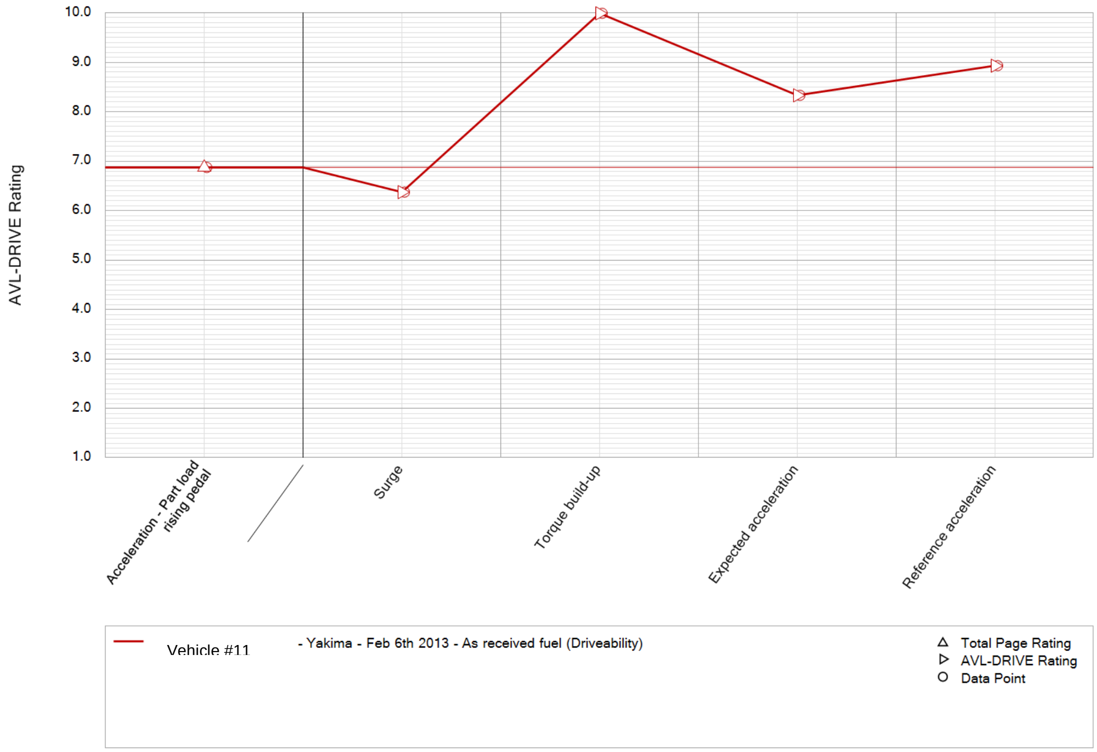
AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Drive away - Normal
Brake release delay
Brake release bump
Brake release surge
Response delay
Initial bump
Overshoot
Stumble
Acceleration peak
Acceleration performance
Shock
Engagement steadiness
Jerks
Vehicle #11
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
- Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

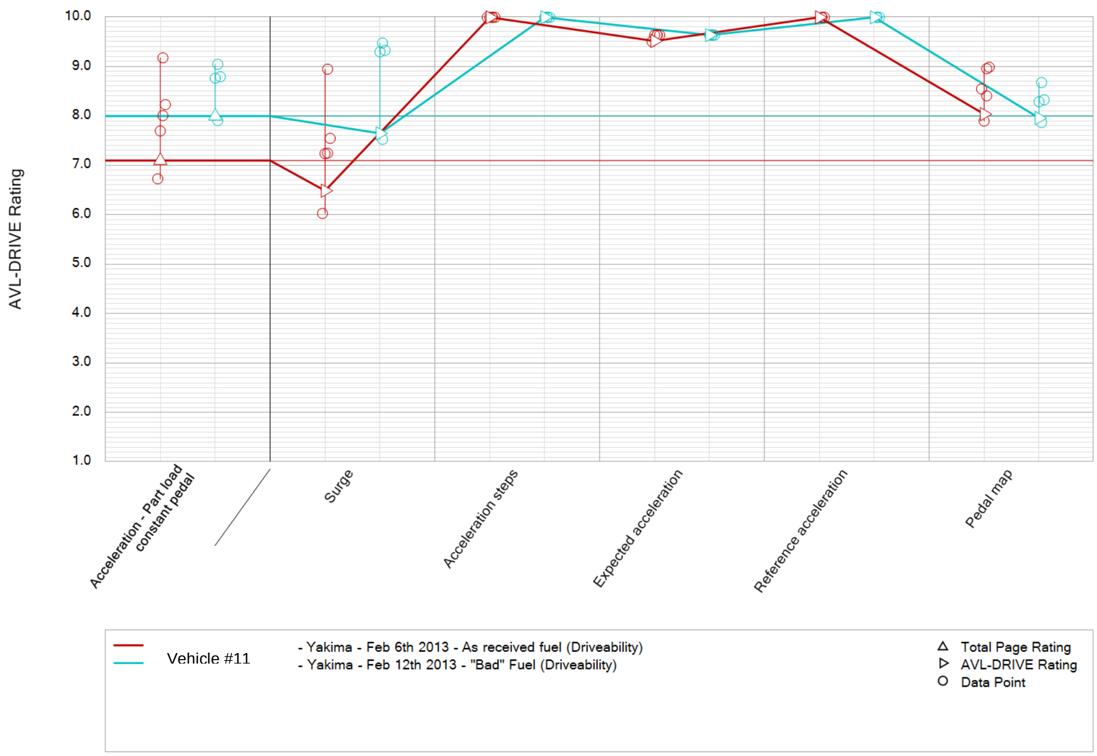



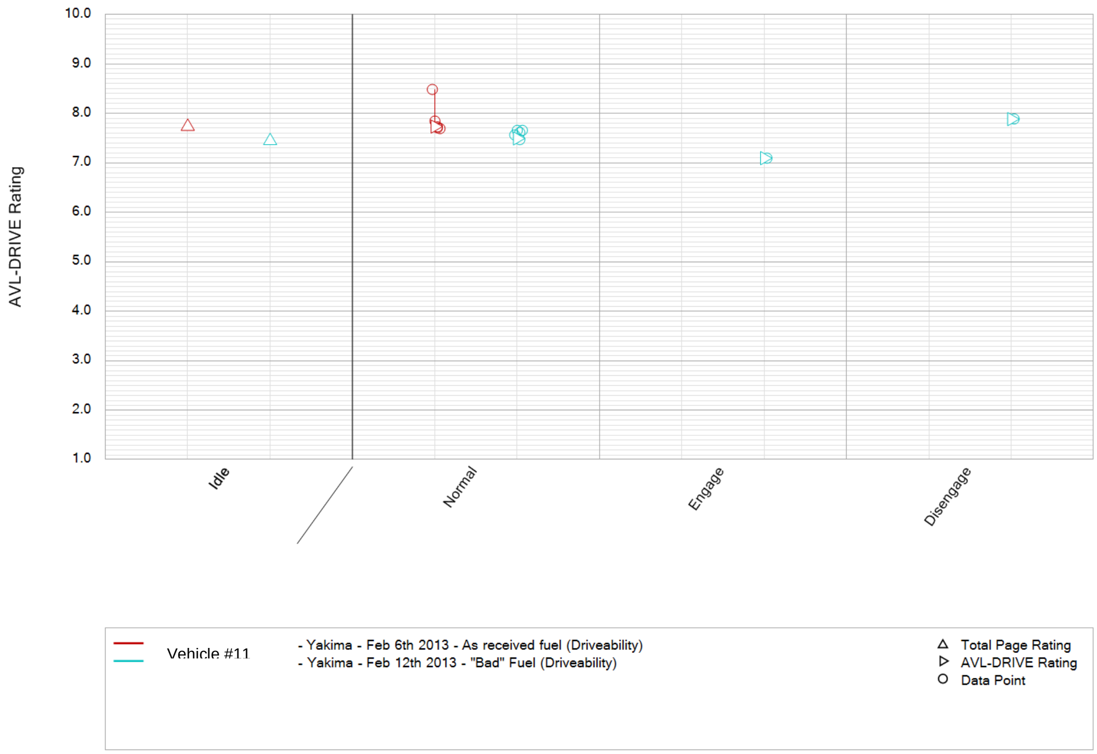
AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Drive away - Launch
Brake release delay
Brake release surge
Response delay
Initial bump
Overshoot
Stumble
Acceleration peak
Acceleration performance
Shock
Engagement steadiness
Jerks
Vehicle #11
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
- Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point


AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration
Full load
Part load rising pedal
Part load constant pedal
Vehicle #11
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
- Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

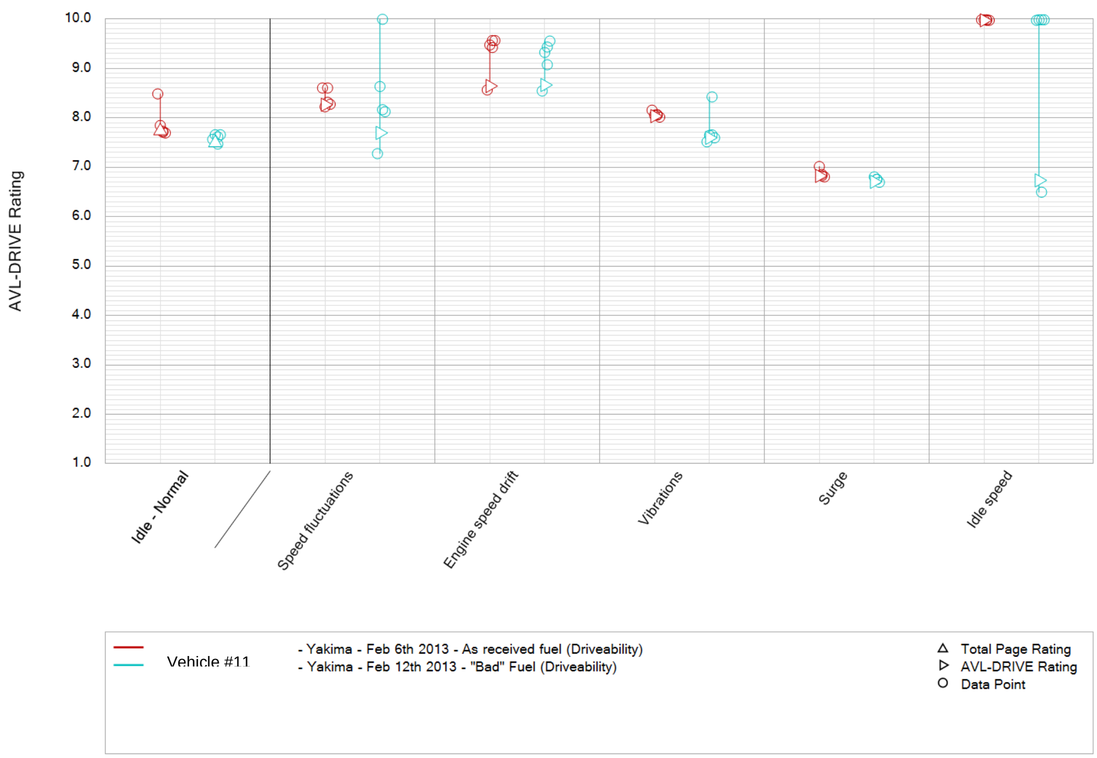

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration - Full load
Wide torque range
Torque smoothness
Surge
Vibrations
Expected acceleration
Reference acceleration
Vehicle #11
Yakima - Feb 6th 2013 - As received fuel (Driveability)
Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point


10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
AVL-DRIVE Rating
Acceleration - Part load rising pedal
Surge
Torque build-up
Expected acceleration
Reference acceleration
Vehicle #11
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

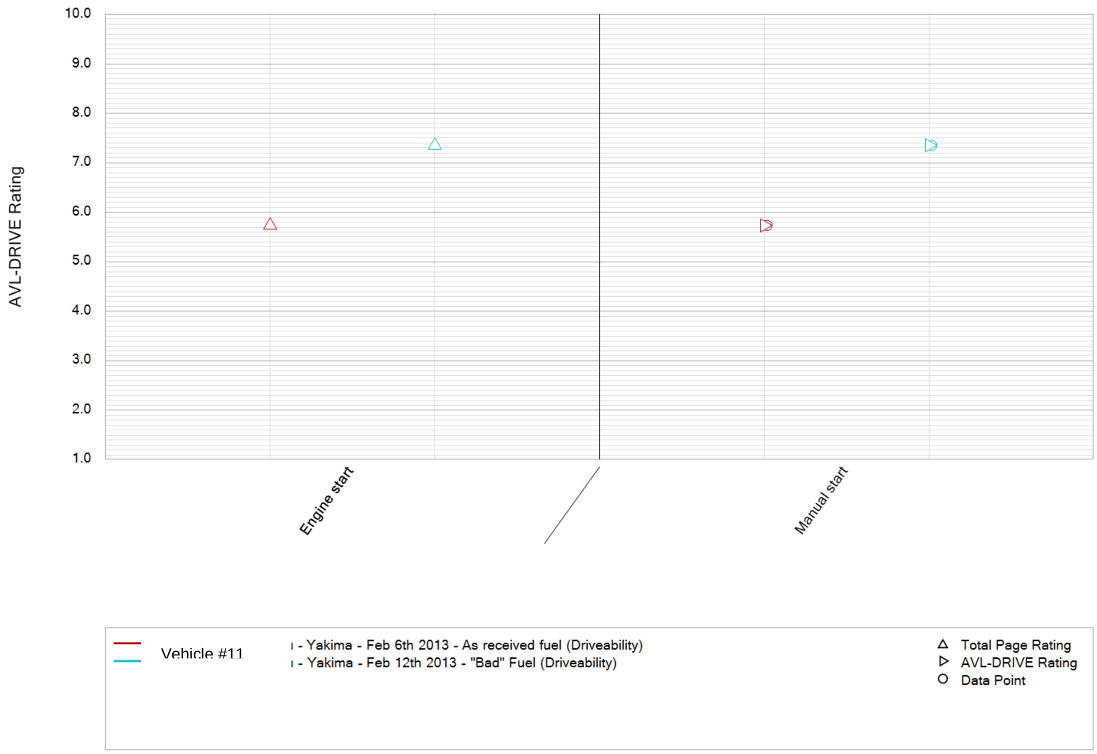

10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
AVL-DRIVE Rating
Acceleration - Part load constant pedal
Surge
Acceleration steps
Expected acceleration
Reference acceleration
Pedal map
Vehicle #11
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
- Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point



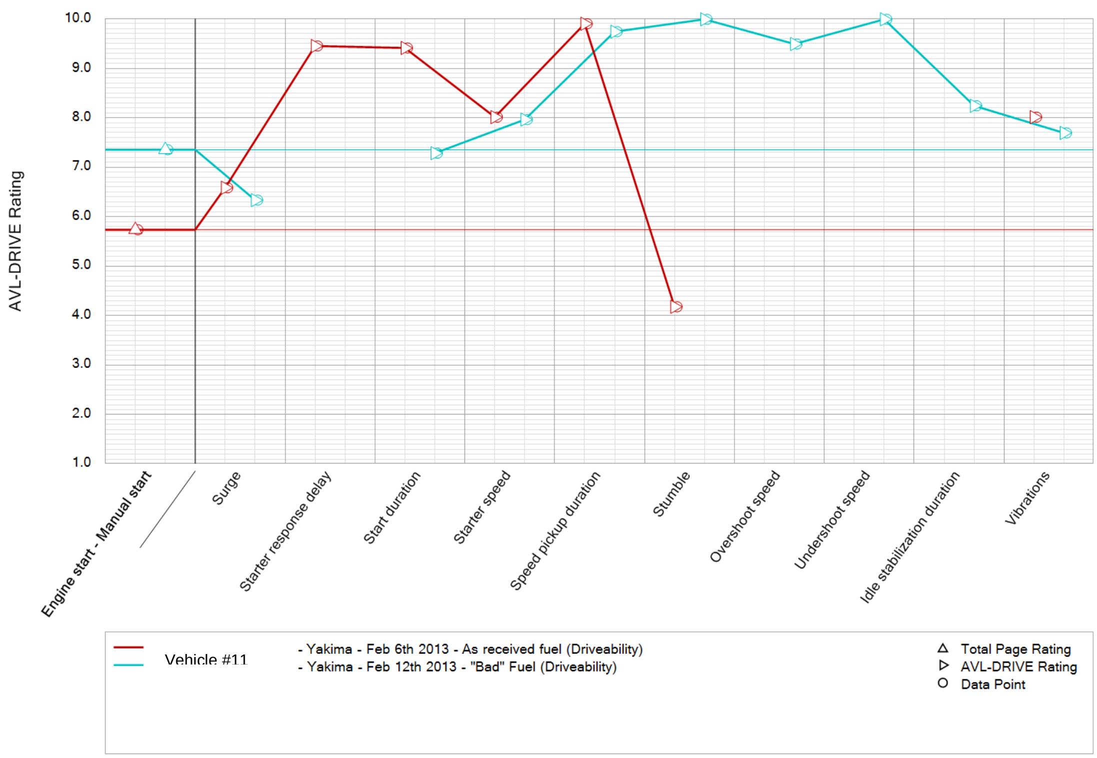
AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Idle
Normal
Engage
Disengage
Vehicle #11
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
- Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Idle - Normal
Speed fluctuations
Engine speed drift
Vibrations
Surge
Idle speed
Vehicle #11
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
- Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

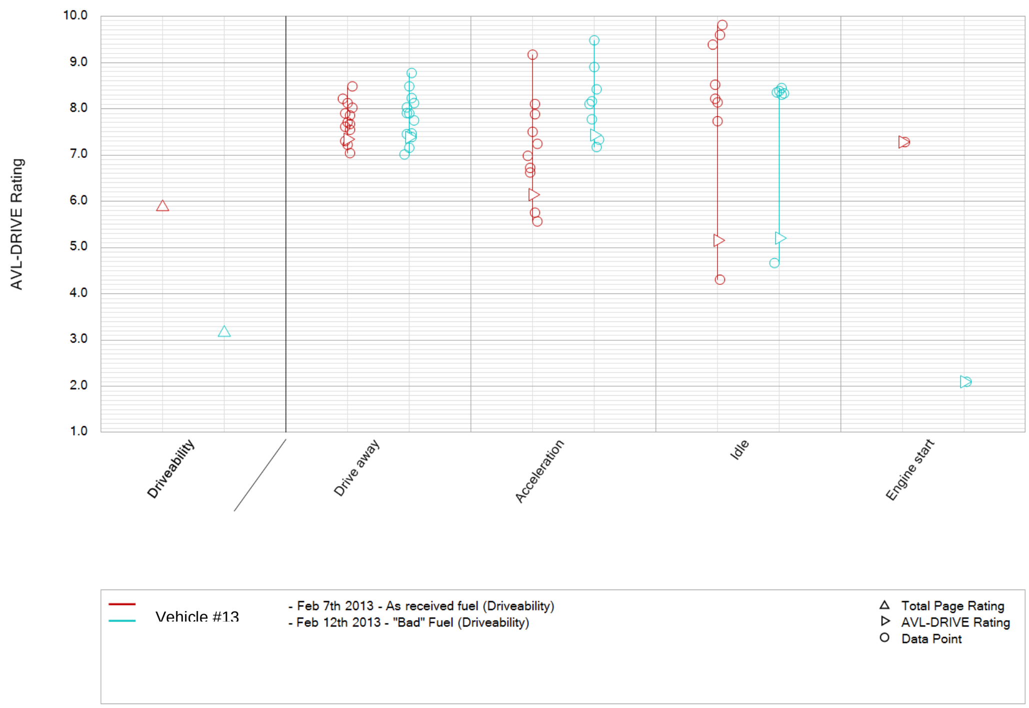


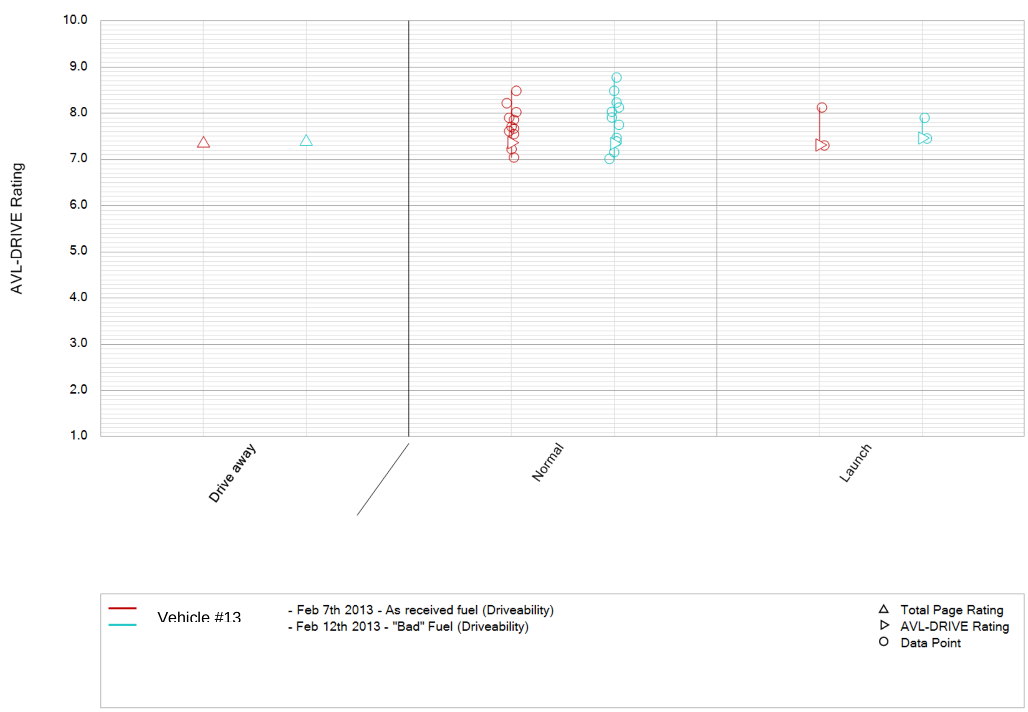
AVL-DRIVE Rating
Engine start
Manual start
Vehicle #11
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
- Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

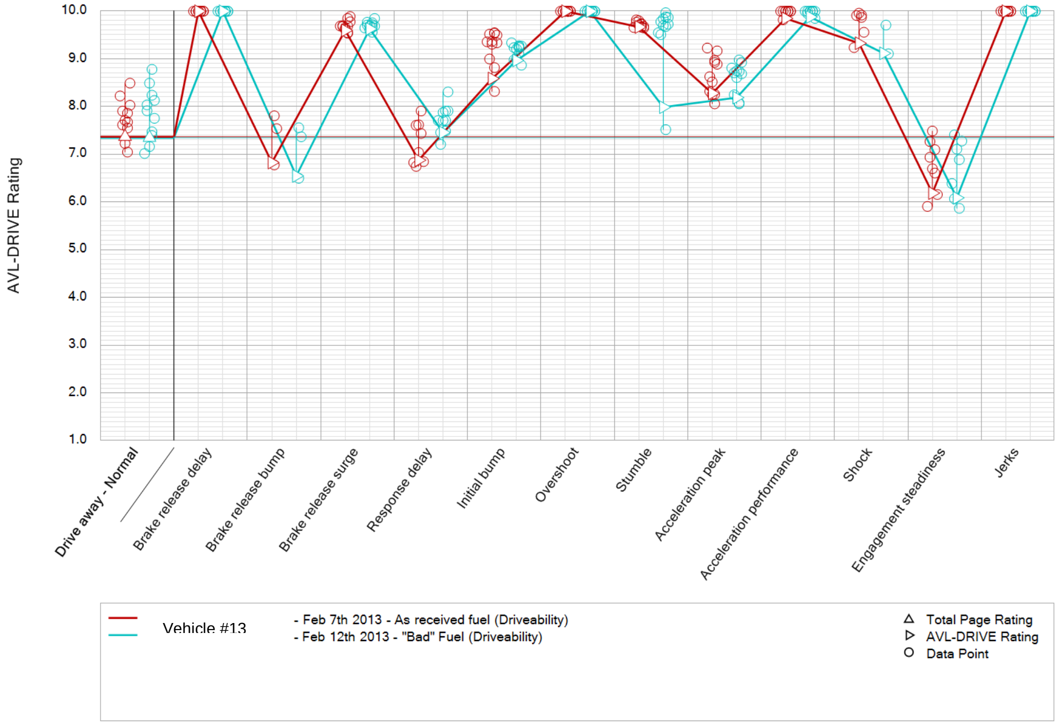



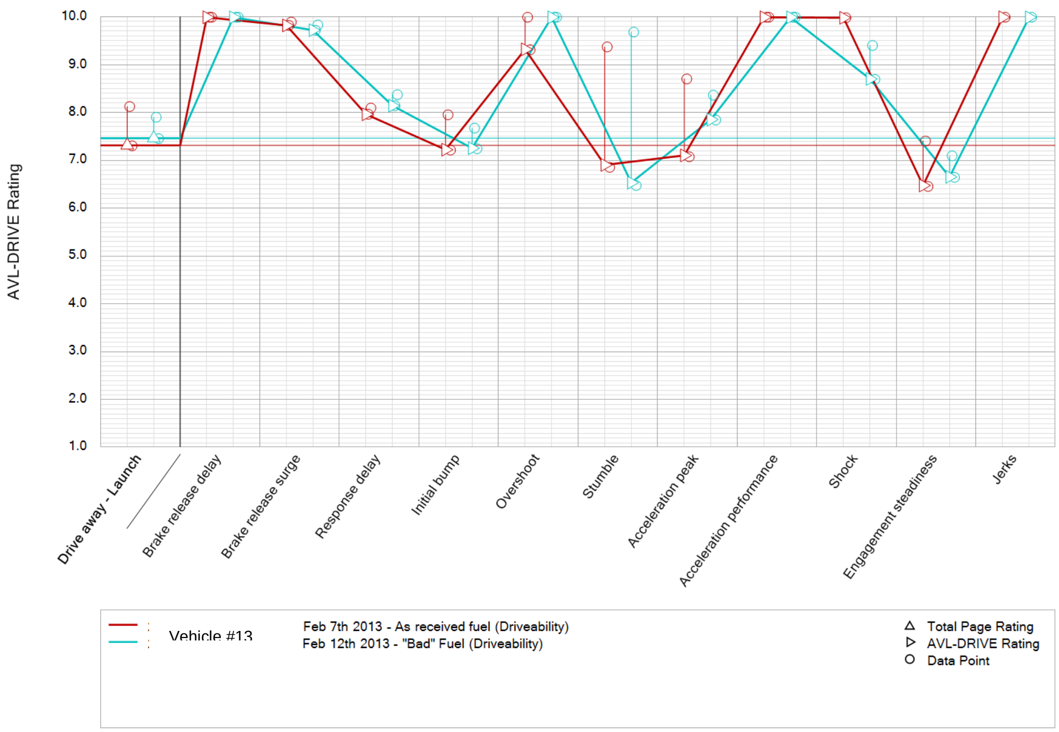
AVL-DRIVE Rating
Engine start - Manual start
Surge
Starter response delay
Start duration
Starter speed
Speed pickup duration
Stumble
Overshoot speed
Undershoot speed
Idle stabilization duration
Vibrations
Vehicle #11
- Yakima - Feb 6th 2013 - As received fuel (Driveability)
- Yakima - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

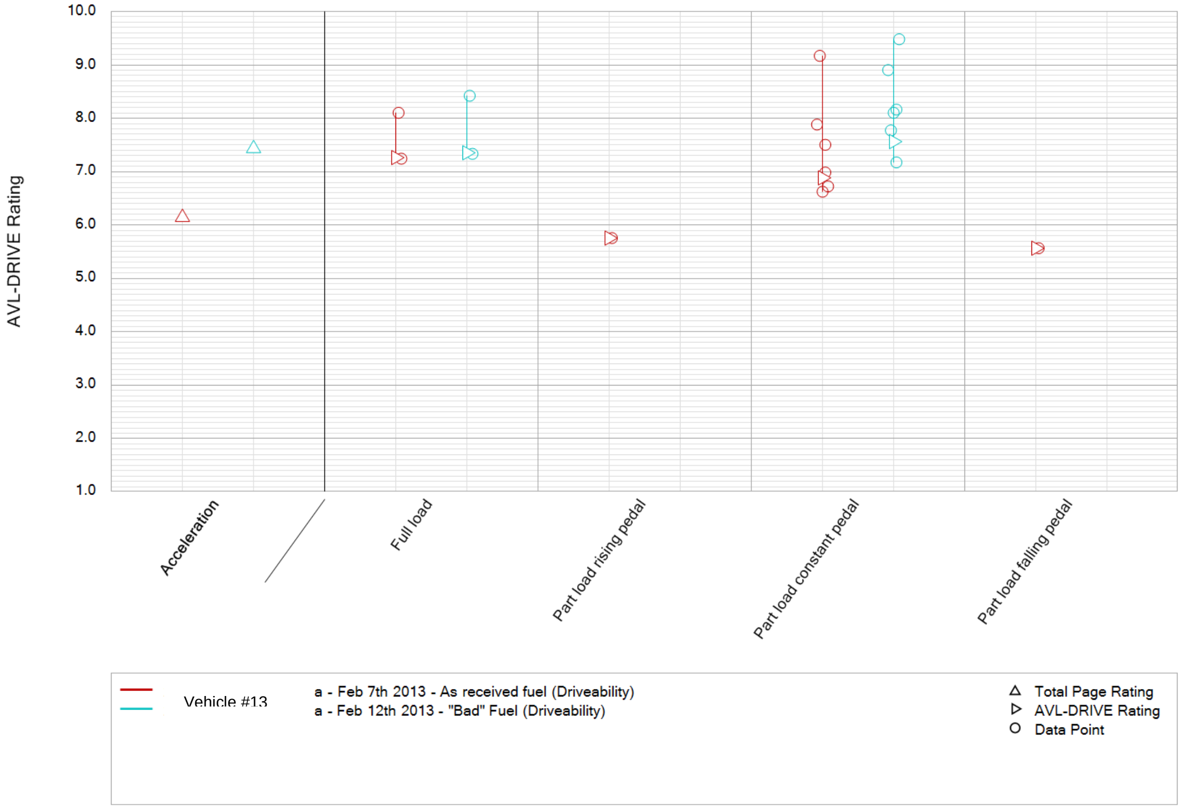
## 10.3. Vehicle #13

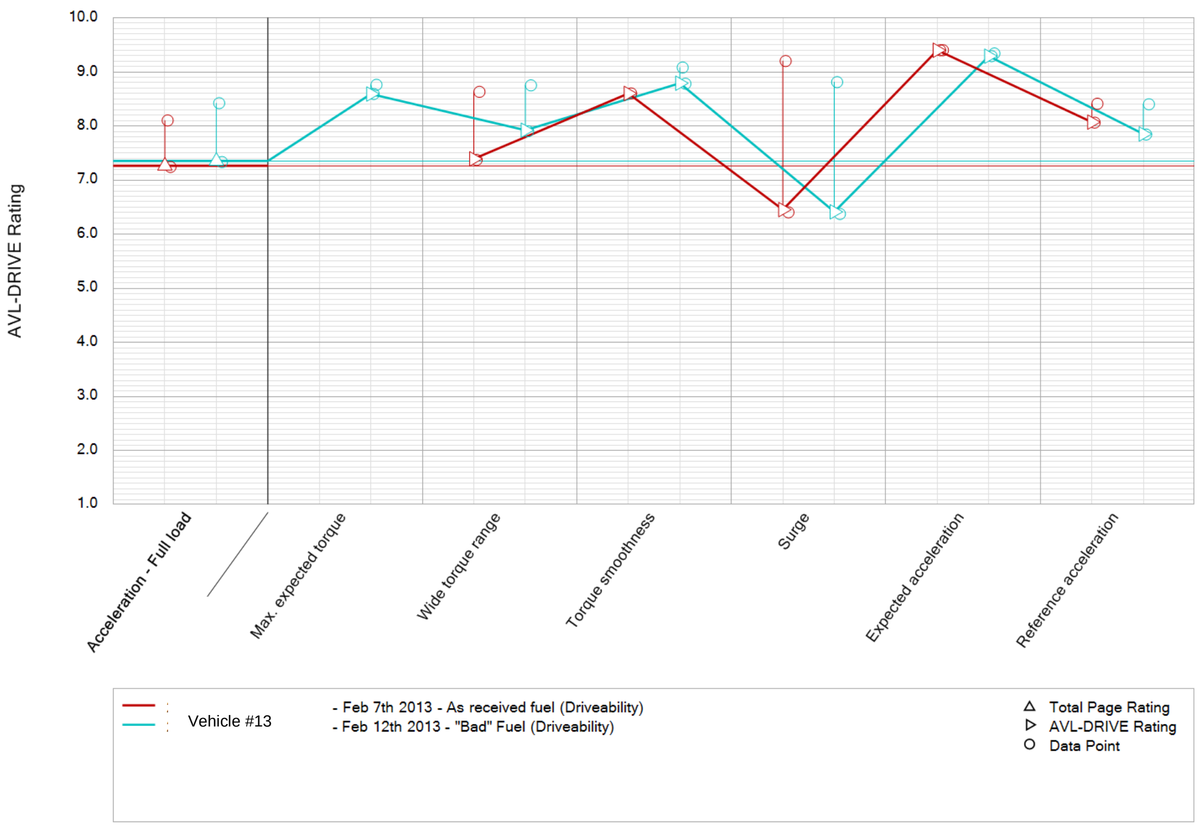


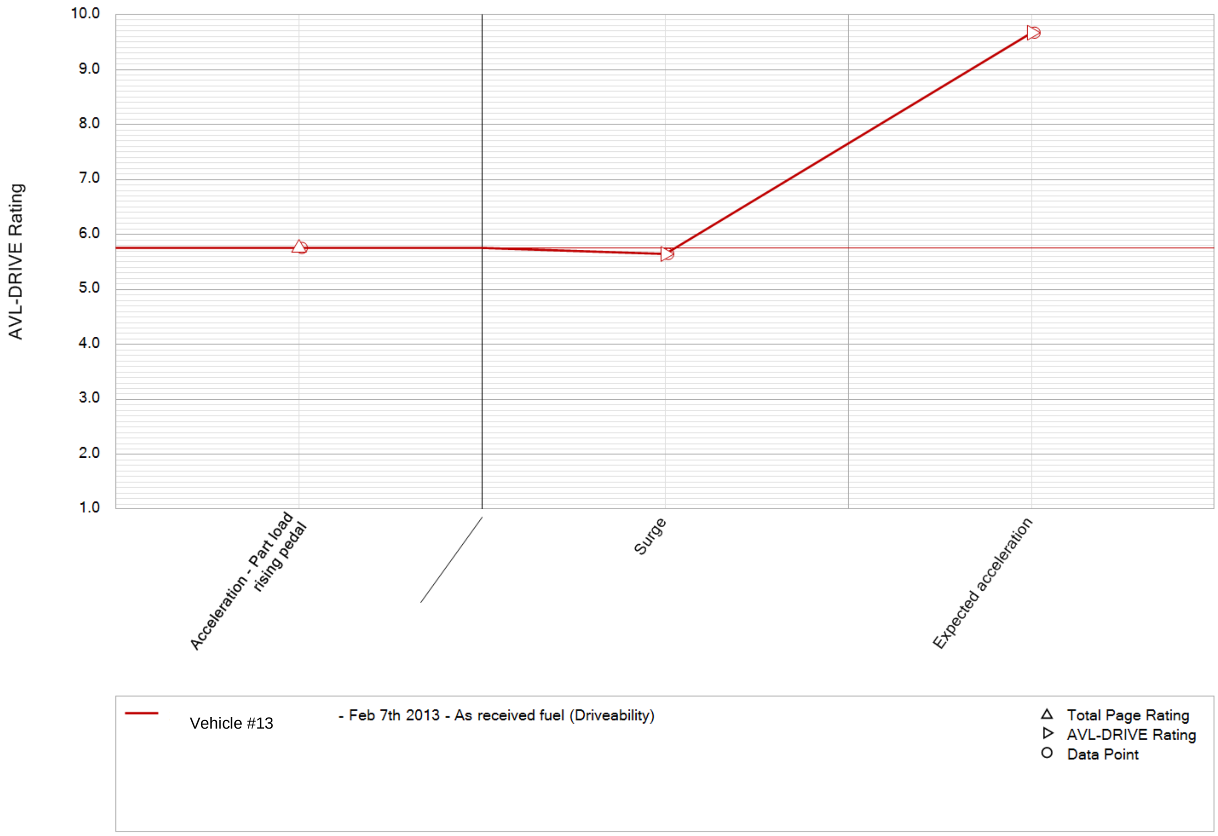



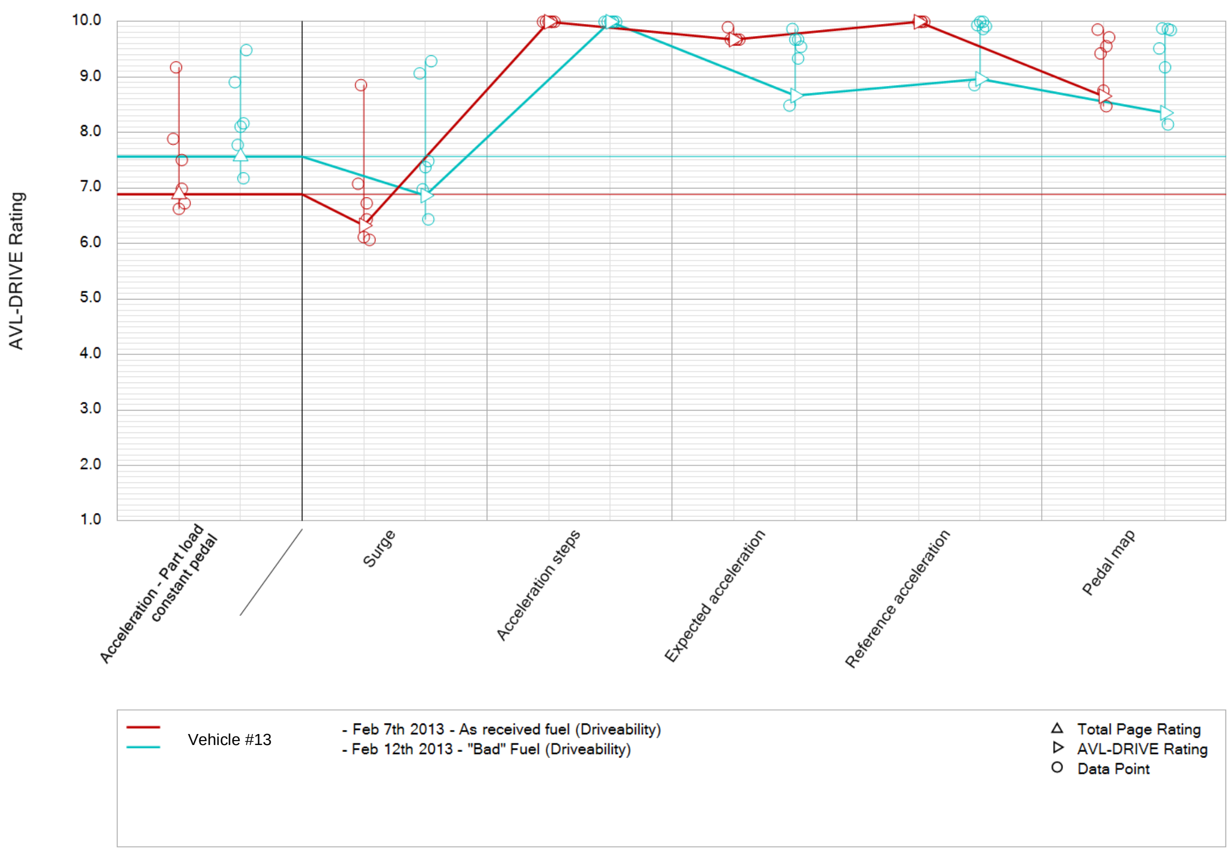

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Drive away - Normal
Brake release delay
Brake release bump
Brake release surge
Response delay
Initial bump
Overshoot
Stumble
Acceleration peak
Acceleration performance
Shock
Engagement steadiness
Jerks
Vehicle #13
- Feb 7th 2013 - As received fuel (Driveability)
- Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

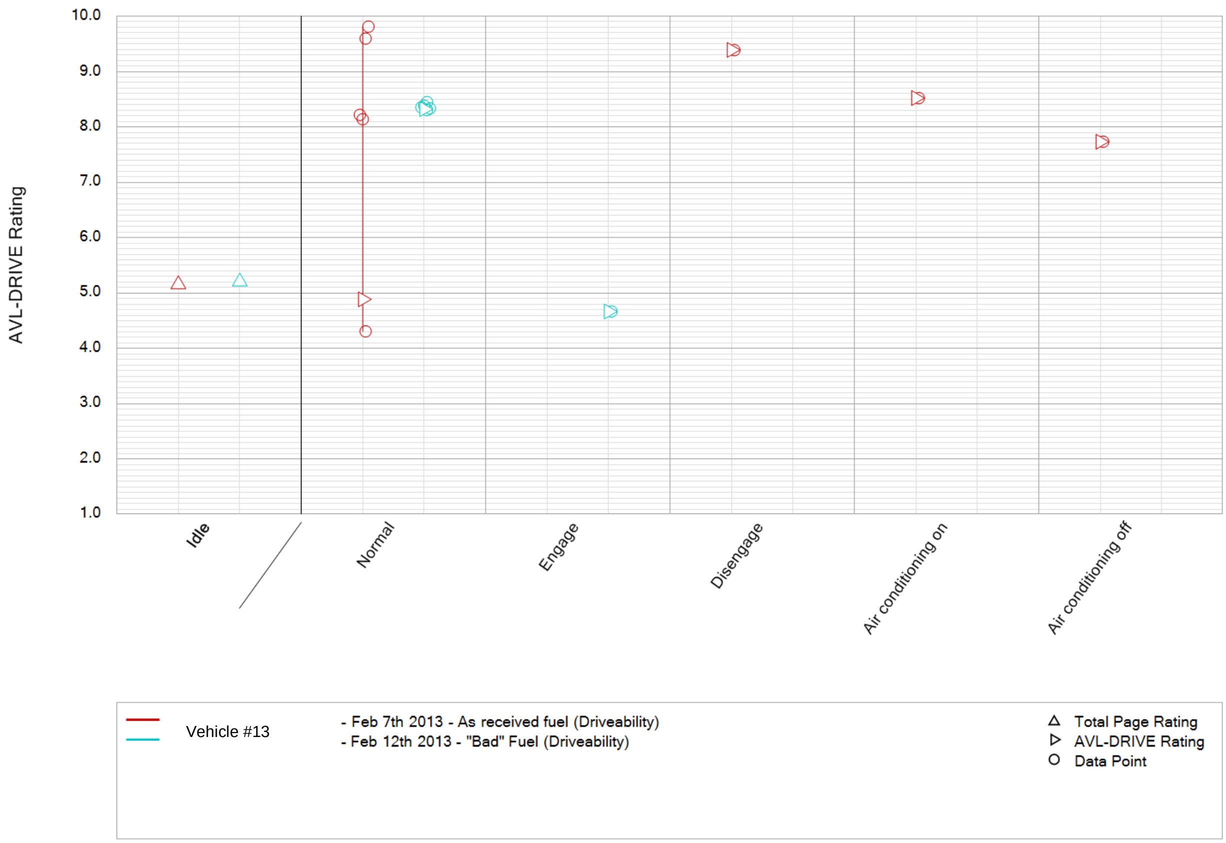

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Drive away - Launch
Brake release delay
Brake release surge
Response delay
Initial bump
Overshoot
Stumble
Acceleration peak
Acceleration performance
Shock
Engagement steadiness
Jerks
Vehicle #13
Feb 7th 2013 - As received fuel (Driveability)
Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point


10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
AVL-DRIVE Rating
Acceleration
Full load
Part load rising pedal
Part load constant pedal
Part load falling pedal
Vehicle #13
a - Feb 7th 2013 - As received fuel (Driveability)
a - Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

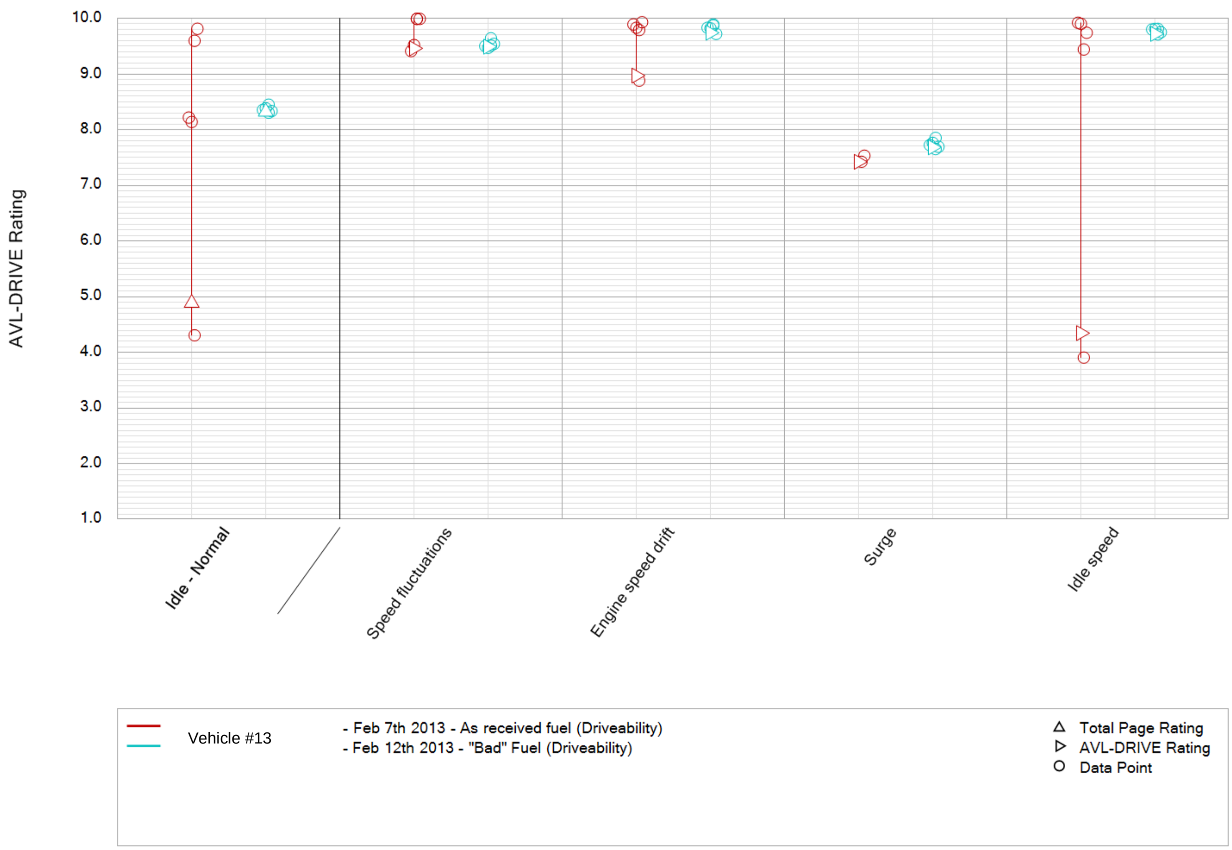

10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
AVL-DRIVE Rating
Acceleration - Full load
Max. expected torque
Wide torque range
Torque smoothness
Surge
Expected acceleration
Reference acceleration
Vehicle #13
- Feb 7th 2013 - As received fuel (Driveability)
- Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point


AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration - Part load rising pedal
Surge
Expected acceleration
Vehicle #13
- Feb 7th 2013 - As received fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

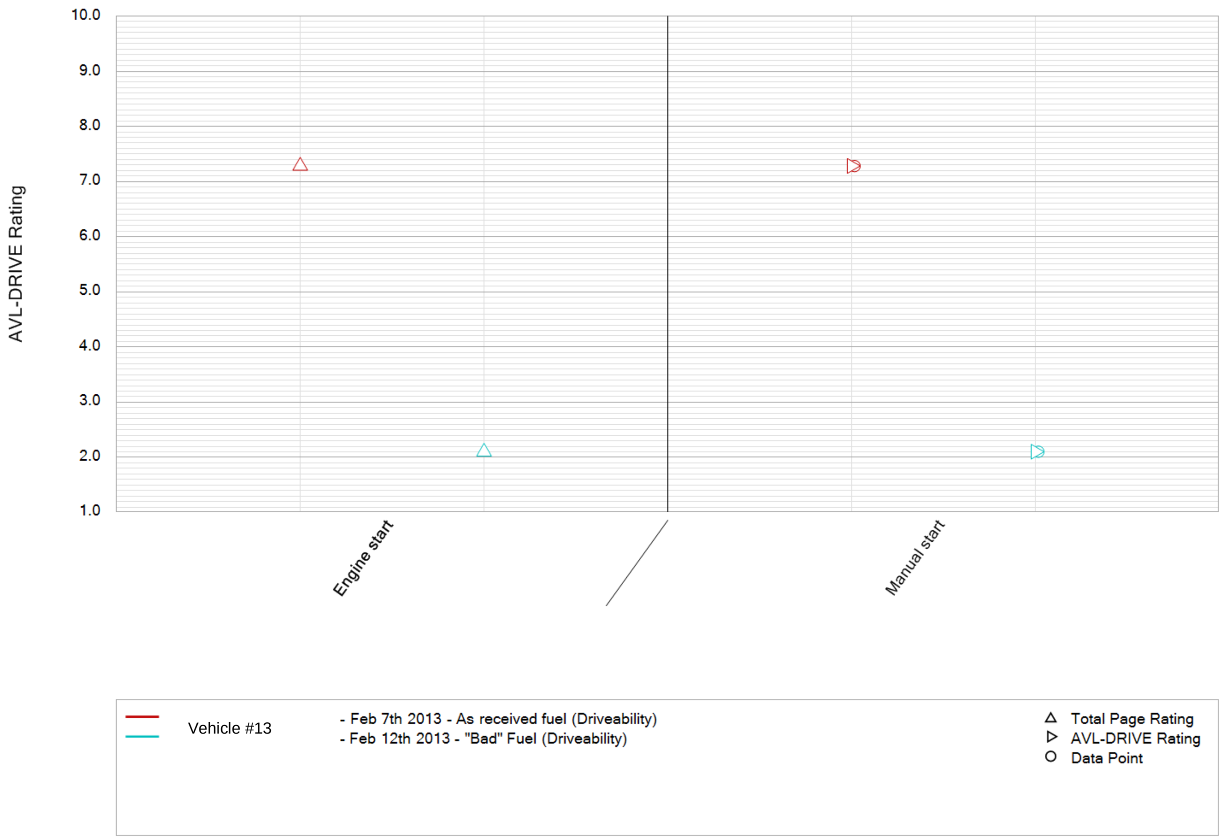

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration - Part load constant pedal
Surge
Acceleration steps
Expected acceleration
Reference acceleration
Pedal map
Vehicle #13
- Feb 7th 2013 - As received fuel (Driveability)
- Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point



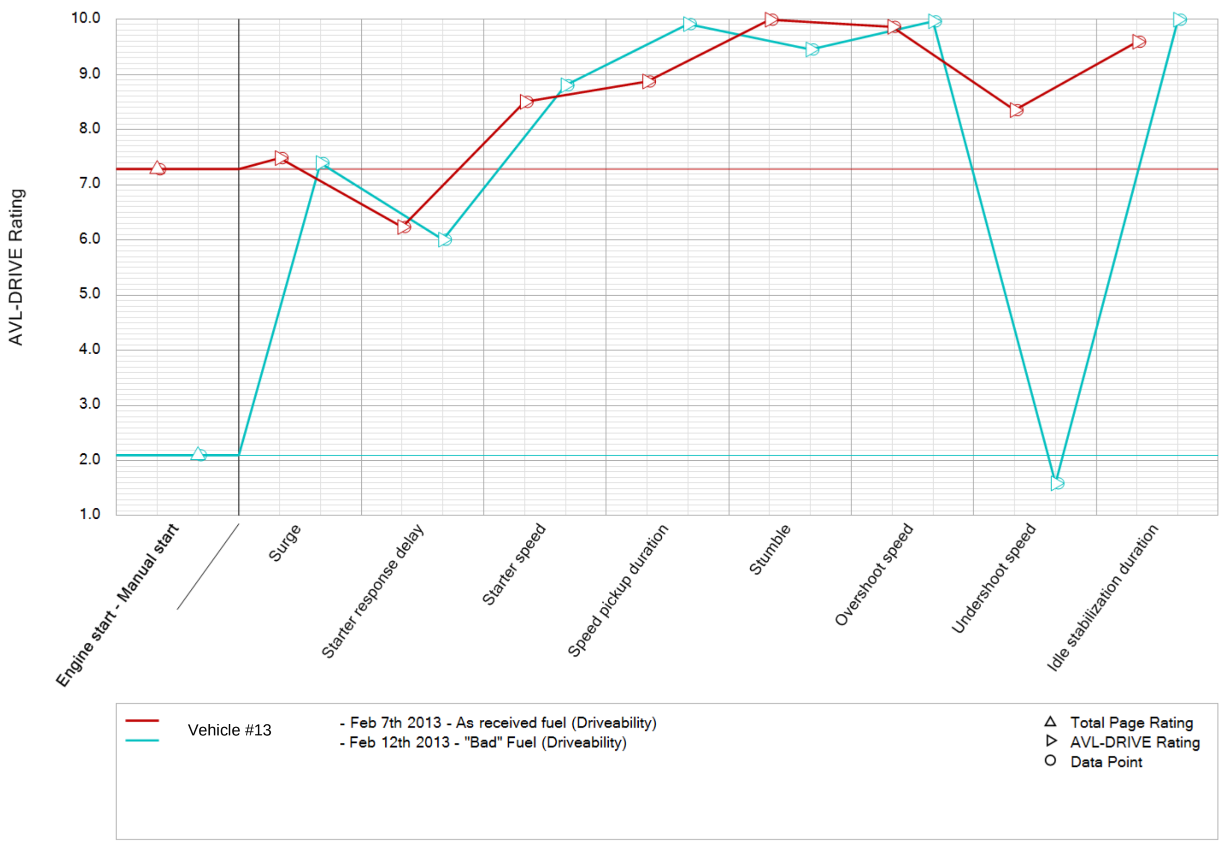
AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Idle
Normal
Engage
Disengage
Air conditioning on
Air conditioning off
Vehicle #13
- Feb 7th 2013 - As received fuel (Driveability)
- Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Idle - Normal
Speed fluctuations
Engine speed drift
Surge
Idle speed
Vehicle #13
- Feb 7th 2013 - As received fuel (Driveability)
- Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

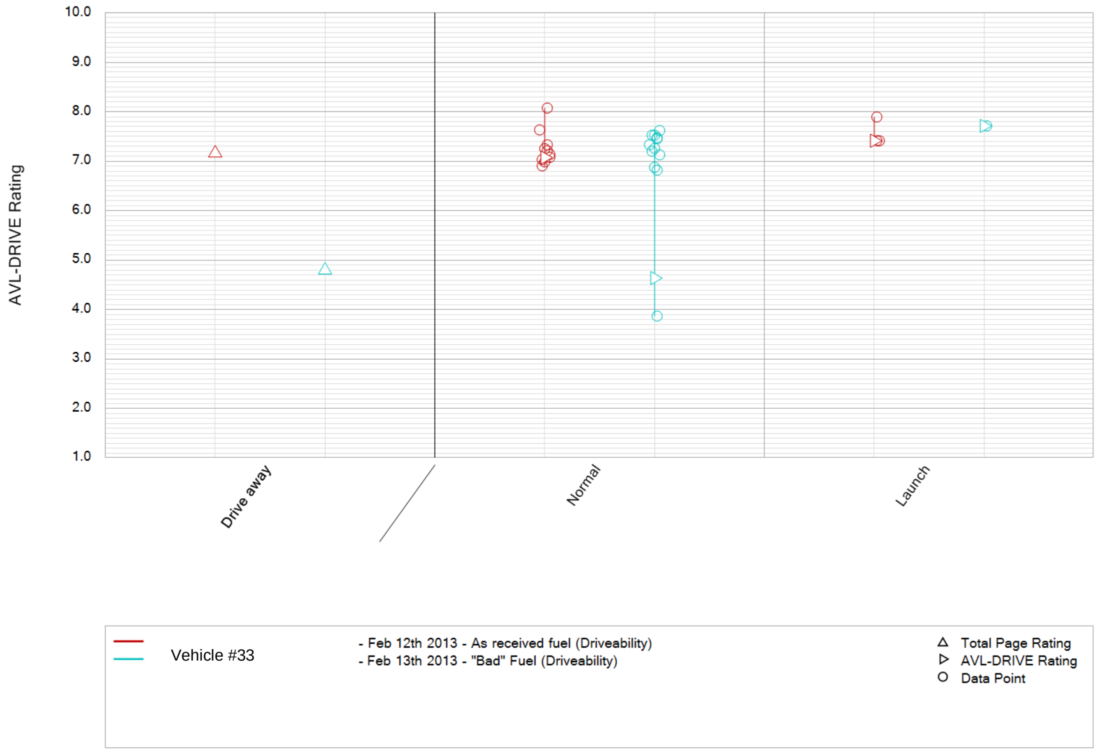


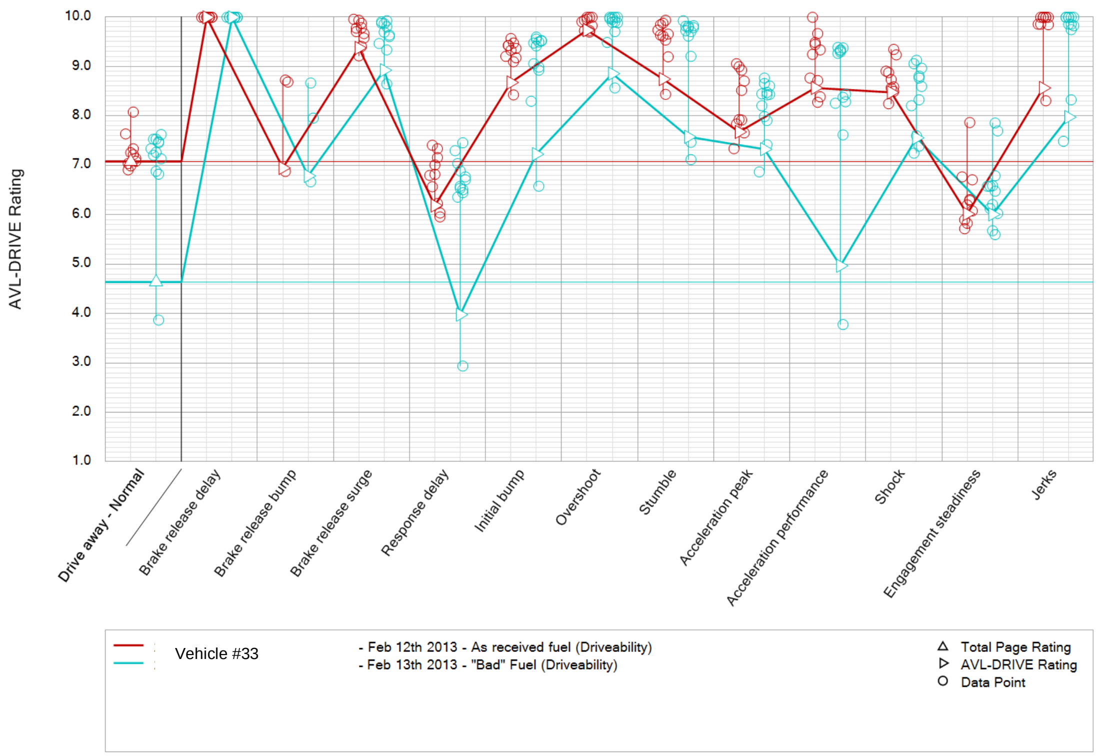
AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Engine start
Manual start
Vehicle #13
- Feb 7th 2013 - As received fuel (Driveability)
- Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

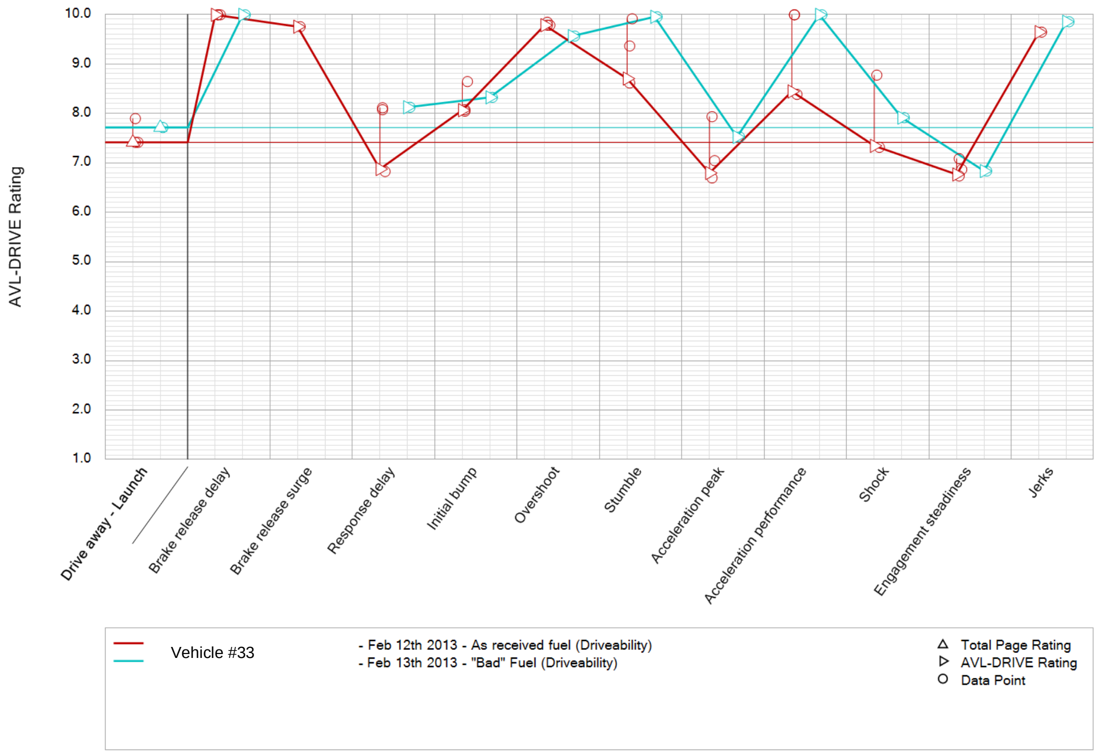



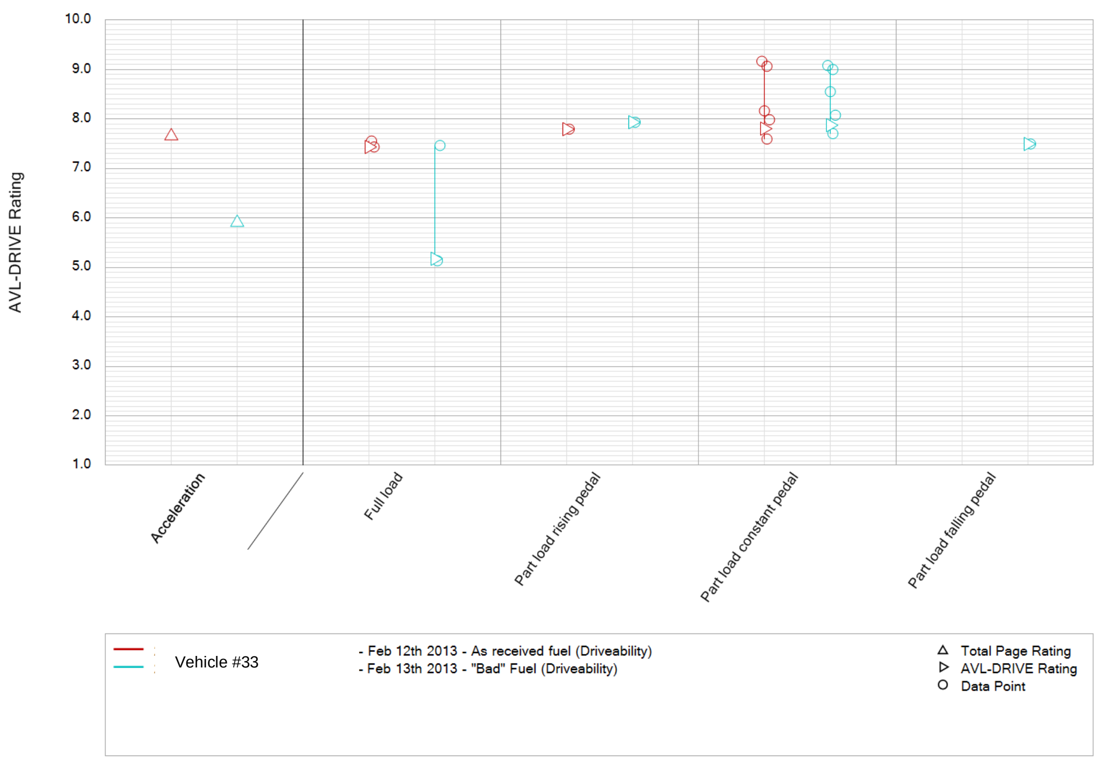
AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Engine start - Manual start
Surge
Starter response delay
Starter speed
Speed pickup duration
Stumble
Overshoot speed
Undershoot speed
Idle stabilization duration
Vehicle #13
- Feb 7th 2013 - As received fuel (Driveability)
- Feb 12th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

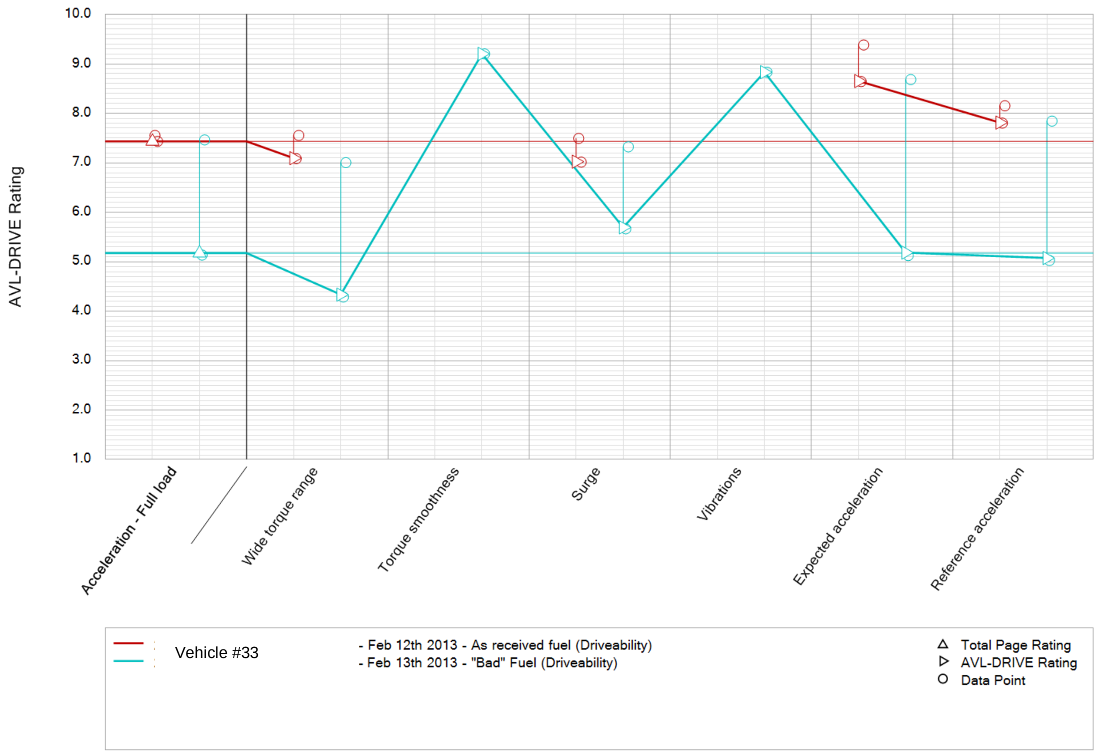
## 10.4. Vehicle #33



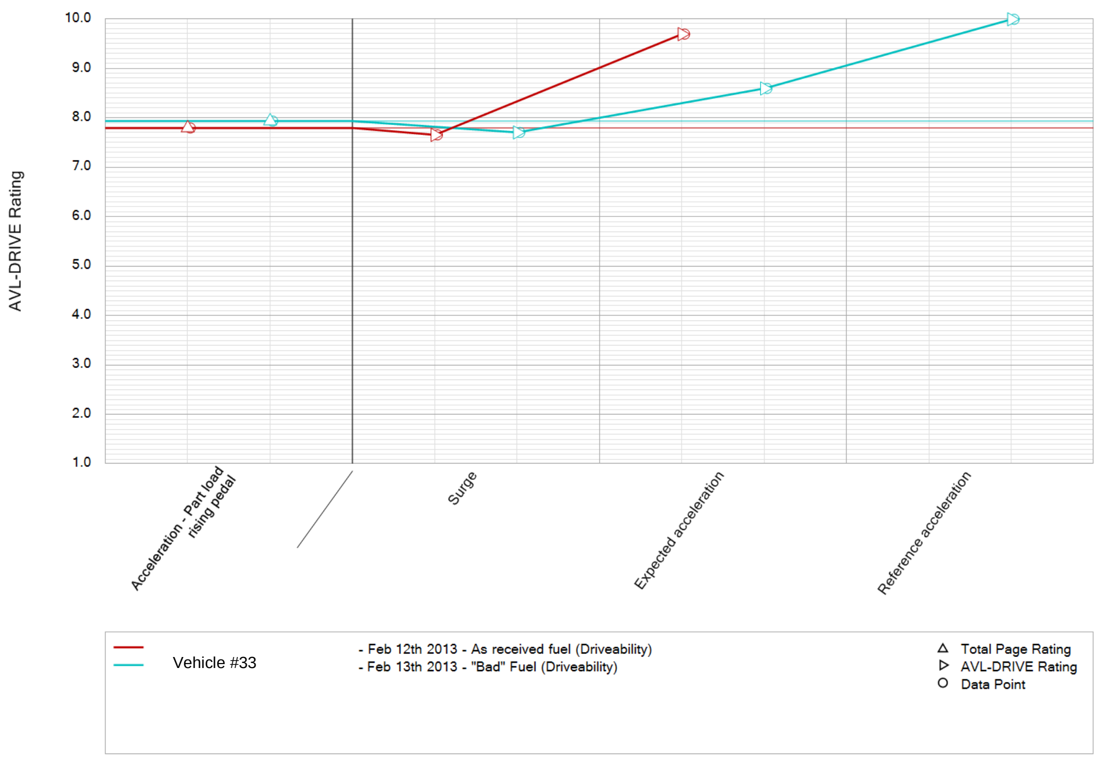




AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Drive away - Launch
Brake release delay
Brake release surge
Response delay
Initial bump
Overshoot
Stumble
Acceleration peak
Acceleration performance
Shock
Engagement steadiness
Jerks
Vehicle #33
- Feb 12th 2013 - As received fuel (Driveability)
- Feb 13th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

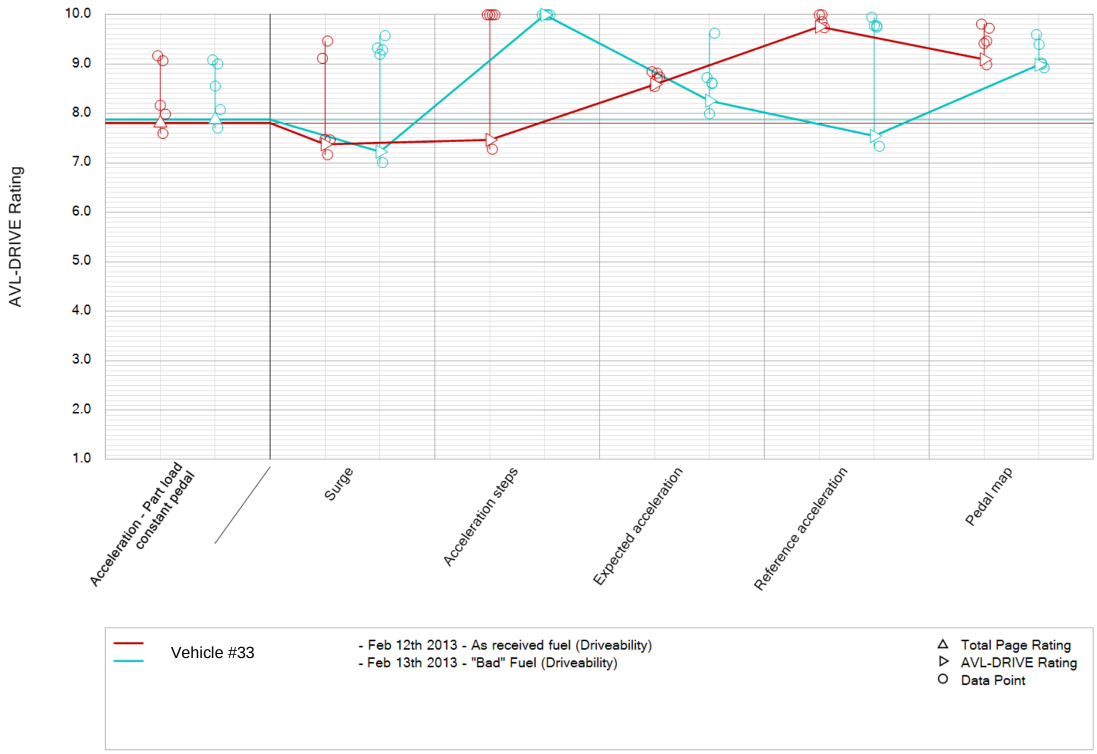

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration
Full load
Part load rising pedal
Part load constant pedal
Part load falling pedal
Vehicle #33
- Feb 12th 2013 - As received fuel (Driveability)
- Feb 13th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

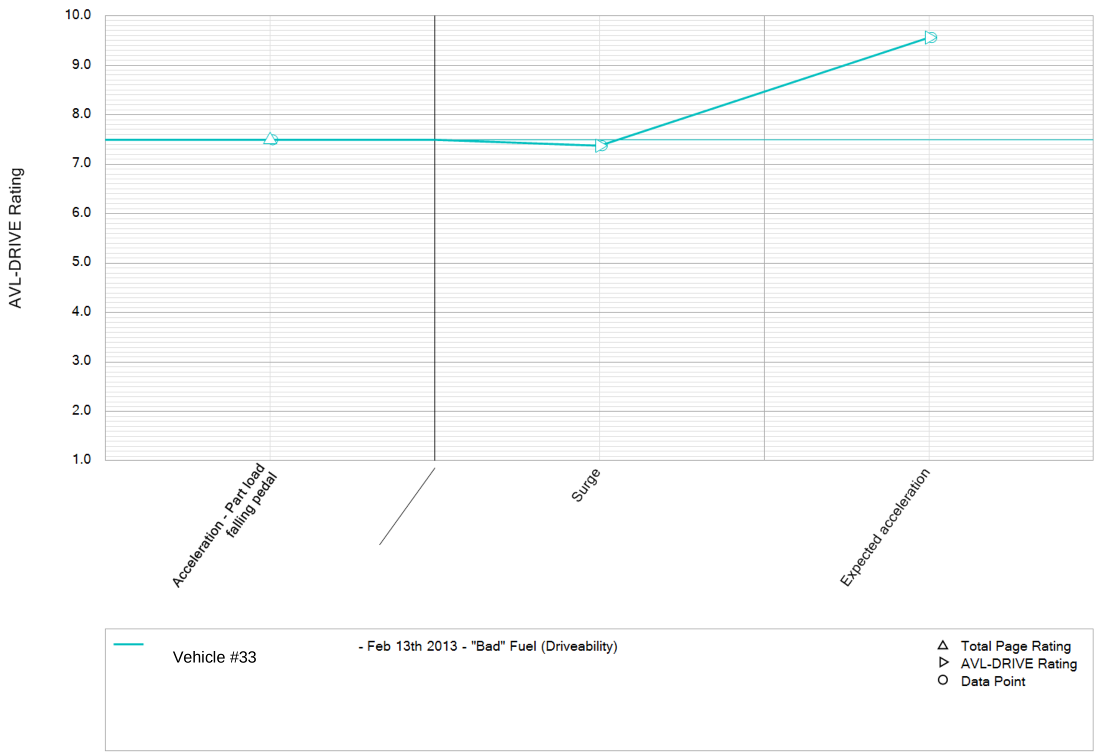


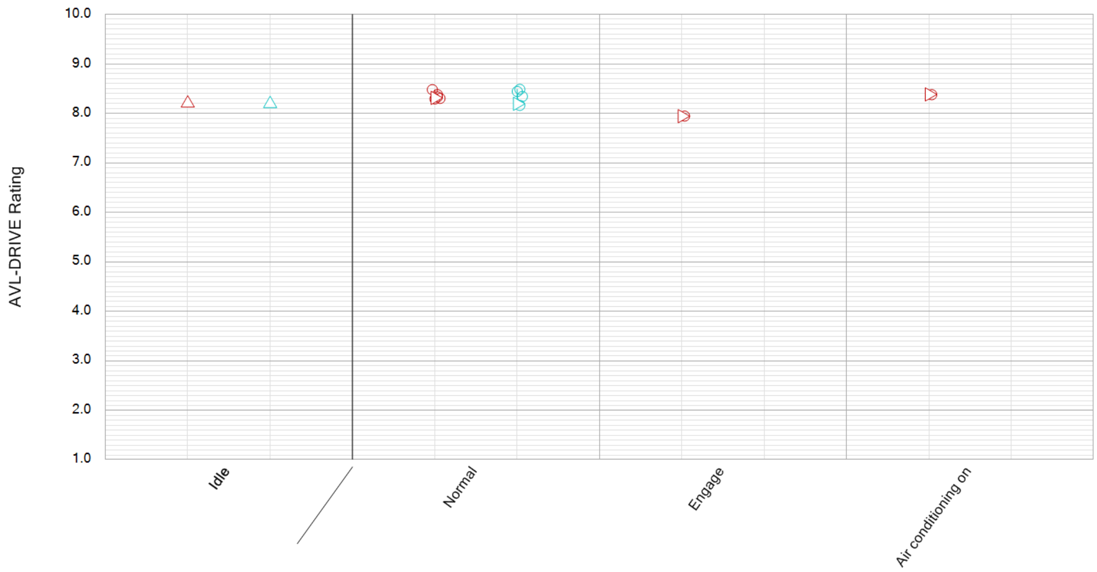
AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration - Full load
Wide torque range
Torque smoothness
Surge
Vibrations
Expected acceleration
Reference acceleration
Vehicle #33
- Feb 12th 2013 - As received fuel (Driveability)
- Feb 13th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Acceleration - Part load rising pedal
Surge
Expected acceleration
Reference acceleration
Vehicle #33
- Feb 12th 2013 - As received fuel (Driveability)
- Feb 13th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point

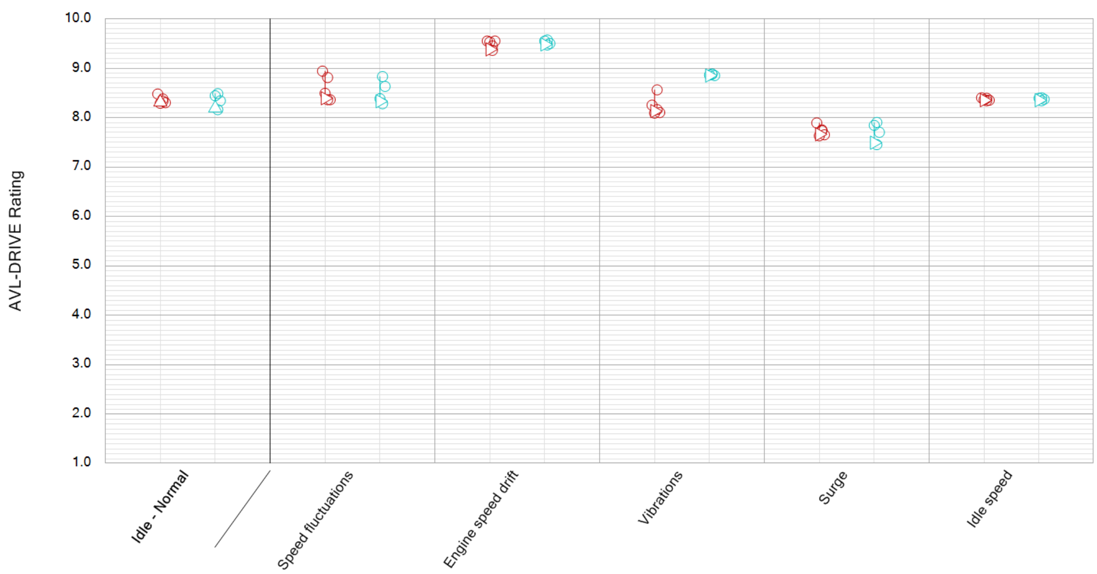

10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
AVL-DRIVE Rating
Acceleration - Part load constant pedal
Surge
Acceleration steps
Expected acceleration
Reference acceleration
Pedal map
Vehicle #33
- Feb 12th 2013 - As received fuel (Driveability)
- Feb 13th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point


10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
AVL-DRIVE Rating
Acceleration - Part load falling pedal
Surge
Expected acceleration
Vehicle #33
- Feb 13th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point



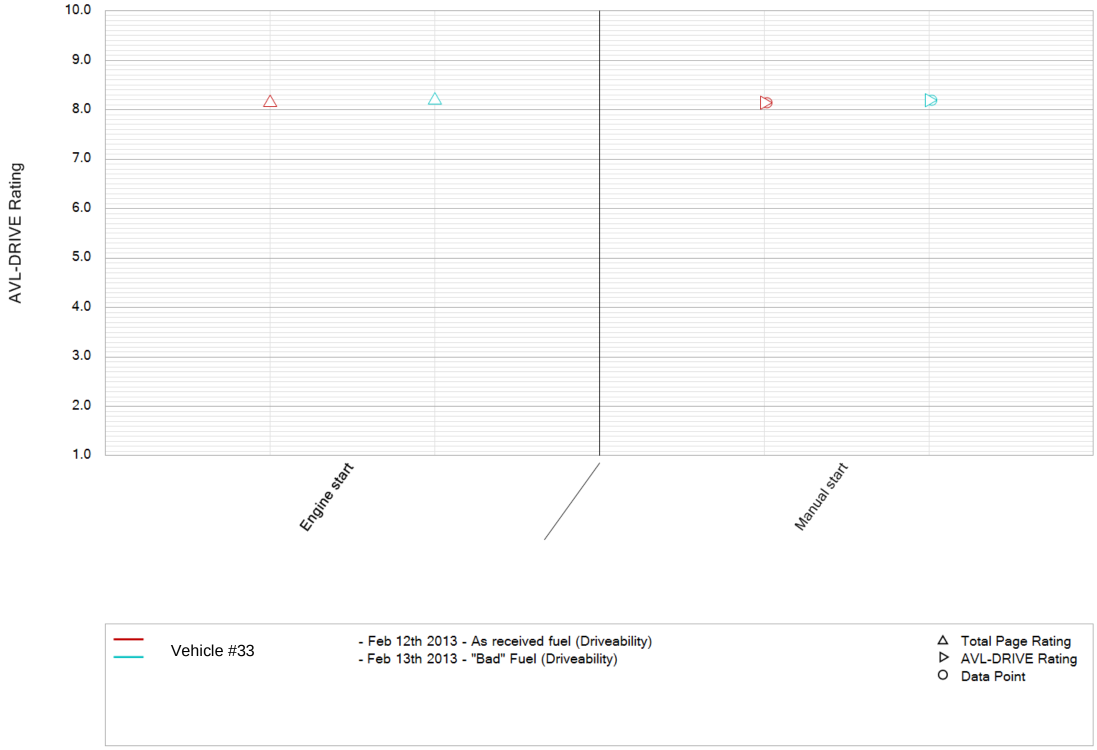

Vehicle #33 - Feb 12th 2013 - As received fuel (Driveability)
- Feb 13th 2013 - "Bad" Fuel (Driveability)

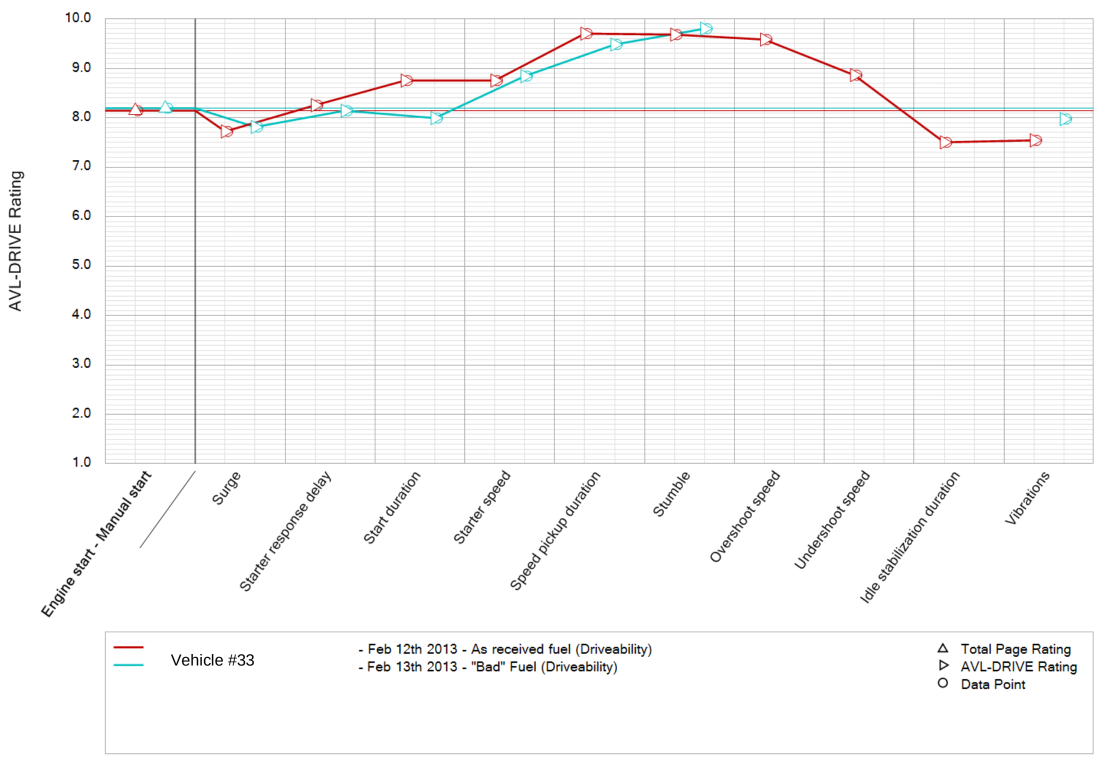
Total Page Rating
AVL-DRIVE Rating
Data Point




Vehicle #33 - Feb 12th 2013 - As received fuel (Driveability)
- Feb 13th 2013 - "Bad" Fuel (Driveability)

Total Page Rating
AVL-DRIVE Rating
Data Point


AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Engine start
Manual start
Vehicle #33
- Feb 12th 2013 - As received fuel (Driveability)
- Feb 13th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point


AVL-DRIVE Rating
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Engine start - Manual start
Surge
Starter response delay
Start duration
Starter speed
Speed pickup duration
Stumble
Overshoot speed
Undershoot speed
Idle stabilization duration
Vibrations
Vehicle #33
- Feb 12th 2013 - As received fuel (Driveability)
- Feb 13th 2013 - "Bad" Fuel (Driveability)
Total Page Rating
AVL-DRIVE Rating
Data Point