The Use of Onboard Diagnostics to Reduce Emissions in Automobiles

by

Alberto Perez Jr.

Submitted to the Department of Mechanical Engineering
in partial fulfillment of the requirements for the degree of

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Abstract

The emissions from automobiles are very harmful and include gases such as Carbon Dioxide, Nitrous Oxide, and Sulfur Dioxide. One of the main reasons OBD was created was to control emissions however it currently only monitors the status of the systems set in place to reduce emissions. The goal of this project is to use the OBD II system currently available in vehicles to monitor fuel emissions from many cars at different locations. By placing a small OBD II scanner and GPS receiver into a fleet of vehicles, emissions from these vehicles can be monitored and mapped out to show the different emissions levels on different roads. Although the plan is to develop a cheaper OBD II scanner and GPS unit to place on a few cars, an already existing scanner and GPS receiver has been used to begin collecting data for analysis, which will be discussed in this paper. The data has been useful to prove that road design and driver input impact the fuel consumption and emissions of a vehicle heavily.

Thesis Supervisor: Sanjay Sarma
Title: Professor of Mechanical Engineering

Acknowledgements

I would like to thank a couple of people for their tremendous support and help through out this project. First and foremost, I am grateful to Professor Sanjay Sarma who has not only helped me throughout this thesis, but has also helped and advised me throughout my years at MIT. His friendly nature and enthusiasm for teaching has made some of the longest and toughest assignments at MIT seem more bearable. I am happy that he let me be a part of this big project and write my thesis on this section, and use his car to take data as well for this thesis. Sorry, about the radiator. Also, I would like to thank Stephen S. Ho for his help as well. His many graphs during one presentation made me realize that MatLab was the way to go for my thesis. His willingness to help me brainstorm ideas and develop my thesis is very much appreciated as well as his assistance with MatLab.

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Chapter 1

Introduction

Air pollution due to emissions from automobiles is a serious and expanding problem. The regulations on car emissions are getting more severe due to the rising concerns about the environment and the green house effect [1]. In this pass month, April of 2009, California has mandated carbon-based reductions in transportation fuels. This is done in an attempt to cut the state's overall greenhouse gas emissions, which is most likely to be pursued by other states [2]. Some of the main harmful chemicals in the exhaust from a car are CO_2, SO_2, and NOx[1], however the greatest focus by government officials and the public is on CO_2 since it is the most prevalent green house gas.

Currently, automobiles use a catalytic converter to minimize the three main pollutant classes, which are NOx, CO, and HC. With the use of oxygen sensors and the OBD-II system, the working status of the catalytic converter can be monitored. However cars are not currently equipped with a way to measure NOx emissions. There are NOx sensors available, but in order to ensure the integrity of the data, the tests need to be done at the tailpipe in a controlled environment, or NOx storage needs to be added to an exhaust pipe in order to analyze the data.

One of the simplest ways to predict levels of CO_2 emitted is to look at the gas consumption of vehicles. CO_2 emissions are directly proportional to fuel consumption, each 1% increase/decrease in fuel consumption results in a corresponding 1% increase/decrease in CO_2 emissions [3]. The emissions of CH_4 and N_2O are related to vehicle miles traveled rather than fuel consumption but can not be estimated for as easily as CO_2 [4]. With the use of an onboard diagnostic tool it is possible to record fuel consumption and other parameters available through OBD II. In this project fuel consumption, vehicle speed, rpm, and throttle position are recorded and analyzed. Also, GPS data is collected while driving and allows for mapping the routes driven and showing vehicle performance on these routes.

CO_2 emissions account for 94-95% of the GHG emissions from cars, while 5-6% is comprised of CH_4, N_2O, and HFC [4]. CO_2 emissions from cars in 2007 added up to 1180.5Tg. This accounts for 19.6% of the total CO2 emitted that year. Figure 1 is a table with the values for CO_2 emissions from the transportation sector from the years 1990, 1995, and 2000 to 2007.

[1] NOX- generic term for a group of highly reactive gases containing varying amounts of Nitrogen and Oxygen *http://www.raypak.com/lownoxtech.htm*

Table 10. U.S. Carbon Dioxide Emissions from Transportation Sector Energy Consumption, 1990, 1995, and 2000-2007
(Million Metric Tons Carbon Dioxide)

Fuel	1990	1995	2000	2001	2002	2003	2004	2005	2006	P2007
Petroleum										
Motor Gasoline	961.7	1,029.7	1,121.9	1,127.1	1,155.8	1,159.5	1,181.3	1,183.4	1,186.0	1,180.5
Liquefied Petroleum Gas	1.3	1.0	0.7	0.8	0.8	1.0	1.1	1.7	1.7	1.7
Jet Fuel	222.6	222.1	253.8	242.8	236.8	231.5	239.8	246.3	239.5	238.0
Distillate Fuel	267.8	306.9	377.8	387.1	394.5	414.5	433.9	444.4	469.2	472.5
Residual Fuel	80.1	71.7	69.9	46.1	53.3	45.0	58.3	66.0	71.4	73.5
Lubricants[a]	6.5	6.2	6.7	6.1	6.0	5.6	5.6	5.6	5.5	5.6
Aviation Gasoline	3.1	2.7	2.5	2.4	2.3	2.1	2.2	2.4	2.3	2.2
Petroleum Subtotal	**1,543.2**	**1,640.4**	**1,833.3**	**1,812.5**	**1,849.5**	**1,859.1**	**1,922.2**	**1,949.8**	**1,975.5**	**1,974.0**
Coal	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Natural Gas	**36.2**	**38.6**	**35.6**	**34.8**	**37.7**	**33.6**	**32.0**	**33.2**	**33.2**	**35.4**
Electricity[b]	**3.2**	**3.2**	**3.6**	**3.7**	**3.6**	**4.6**	**4.8**	**4.9**	**4.7**	**5.0**
Total	**1,582.6**	**1,682.2**	**1,872.6**	**1,850.9**	**1,890.9**	**1,897.2**	**1,958.9**	**1,988.0**	**2,013.4**	**2,014.4**

[a]Includes emissions from nonfuel uses of fossil fuels. See Table 12 for details by fuel category.
[b]Share of total electric power sector carbon dioxide emissions weighted by sales to the transportation sector.
P = preliminary data.
Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2006*, DOE/EIA-0573(2006) (Washington, DC, November 2007). Totals may not equal sum of components due to independent rounding.
Source: EIA estimates.

Figure 1 – Table of US CO2 Emissions from the Transportation sector [5].

In order to solve the harmful emissions and green house crisis, there has been a great focus on car design and manufacturing. As aforementioned, regulatory restrictions impacting the design of engines and vehicles are constantly being updated and enforced. However, it is not just the car that is responsible for high emissions level. Road conditions and designs, traffic, and the driver strongly affect emissions. By using an OBD-II scanner and a GPS sensor we are able to track the vehicle's performance, the user's input, and the location of the vehicle in order to see the road design.

Proposed research of Professor Sarma's Project

This information gathered from OBD can be for individuals, businesses and the government. There are two approaches proposed in the larger research project being headed up by professor Sarma at the Field of Engineering Lab at MIT: 1.) mapping the contribution of individual streets and street crossings to carbon footprint, and 2.) enabling an individual driver to drive in a more ecologically friendly way. The latter is also often referred to as "eco-driving." OBD can be used by individuals to map out the greenest route between two points. This contrasts with typical map software which only looks at the shortest path and the quickest path. When more than one route is available to reach a destination, the option to take the green route can be made available. With new vehicles being manufactured each year, this information can be integrated and cars can adjust their performance accordingly to the path ahead of them, therefore managing air and fuel consumption more effectively. This information can also be useful to facilitate the act of ecodriving by drivers [6].

The basic rules of ecodriving are;

- Shift up as soon as possible, between 2000 and 2500RPM
- Maintain a steady velocity
- Low engine RPM and high gear

- Decelerate smoothly
- Anticipate traffic flow

Whether greenest route or ecodriving, this information can be used for government city and state planning, and for road design. Also, mapping emissions can be useful to track which areas have high emissions and take appropriate actions to reduce emissions. Traffic lights can be adjusted to cut down on idling time if there seems to be a high emissions count at that intersection due to idling. Also, tolls can be adjusted according to the emissions on a specific highway. Since these chemicals are a health concern, this system can be used when deciding where to live. Zoning can be referred to as high or low emissions.

For commercial use, this system can improve fleet efficiency. Optimizing the performance of an entire fleet would reduce emissions significantly and cut down on fuel consumption therefore saving the owner a lot of money. This system can be used as well to regulate commercial fuel consumption and emissions and uphold any EPA standards in the future.

Chapter 2

OBD Background

In 1988 CARB, the California Air Resources Board, developed the first regulation that required cars sold in that state to install OBD, on-board diagnostics. Although it was not required at the time, most manufacturers equipped vehicles sold outside California with the system. In 1990, amendments to the Clean Air Act required vehicles and engine manufacturers to install OBD systems on light-duty vehicles and trucks, as well as heavy-duty engines [7].

OBD I Requirements were as follows:

1. Instrument panel warning lamp/malfunction indicator lamp (MLP).
2. Ability to record and transmit diagnostic trouble codes (DTCs) for emission-related failures.
3. Electronic system monitoring of the HO2S, EGR valve, and evaporative purge solenoid.

However, this system failed to monitor the catalytic converter, or monitor for evaporative system leaks, or engine misfire. This system was not sufficient enough to lower automotive emissions, therefore, OBD Generation II (OBD II) was created and applied to all 1996 and later models.

OBD II requirements were as follows:

1. Detect component degradation or a faulty emission related system that prevents compliance with federal emission standards
2. Alert the driver of any needed repair that is emission-related.
3. The system should use standardized DTCs and accept generic scan tools.

Although the same regulations are required of car manufacturers, they use different communication protocols for OBD II. Many different protocols have been used since OBD II was created. GM cars use SAE J1850 VPW (Variable Pulse Width Modulation). Fords use SAE J1850 PWM (Pulse Width Modulation) communication patterns. ISO 9141 circuitry is used by Chrysler cars, European and most Asian imported vehicles. However, these manufacturers, as well as others, have been switching to the CAN-BUS protocol [8]. Figure 2 is a schematic of the OBD II connector port located in vehicles.

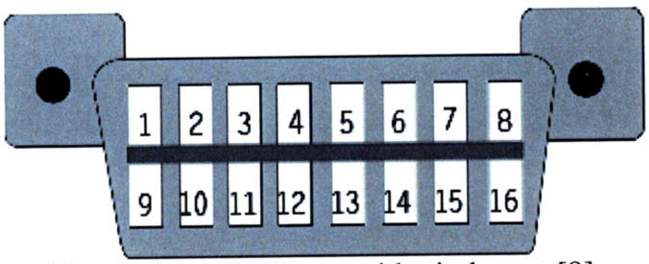

Figure 2 - OBD II port with pin layout [9].

Pin No.	Assignments	Pin No.	Assignments
1	Manufacturer's Discretion	9	Manufacturer's Discretion
2	Bus + Line, SAE J1850	10	Bus-Line, SAI J1850
3	Manufacturer's Discretion	11	Manufacturer's Discretion
4	Chassis Ground	12	Manufacturer's Discretion
5	Signal Ground	13	Manufacturer's Discretion
6	Manufacturer's Discretion	14	Manufacturer's Discretion
7	K Line	15	L Line, ISO 9141
8	Manufacturer's Discretion	16	Vehicle Battery Positive

Depending on the protocol used to communicate with the vehicle's OBD II system, the port will have some pins missing;

SAE J1850 VPW – The connector must have pins 2, 4, 5, 16, but not 10.
SAE J1850 PWM – The connector must have pins 2, 4, 5, 10, and 16
ISO 9141-2 – The connector must have pins 4, 5, 7, and 16. Pin 15 may be present.
CAN – The connector must have pins 4, 5, 6, 14, and 16. [10]

Breakdown of each digit in a DTC code

The DTC code is a diagnostics trouble code that OBD sends to a scanner.
First digit identifies the system

P = Powertrain
B = Body
C = Chassis
U = Undefined

The second digit identifies if the code is generic or manufacturer specific;

0 = generic
1 = enhanced (manufacturer specific)

Third digit identifies the sub-system that pertains to the code;

1 = Emission Management (fuel or air)
2 = Injector Circuit (fuel or air)
3 = Ignition or Misfire
4 = Emission Control
5 = Vehicle Speed & Idle Control
6 = Computer & Output Circuit
7 = Transmission
8 = Transmission
9 = SAE Reserved
0 = SAE Reserved

Fourth and fifth digits are variable and relate to the particular problem.

Future of OBD II

Although OBD II is useful to determine if a vehicle is performing poorly and has high emissions, it only turns on a Malfunction Indicator Lamp (MIL). Many drivers choose to ignore this until it is time for a state required emissions inspection. Some states require an inspection once or twice a year, others do not require inspection. The plans for the next generation of OBD II, referred to as OBD III, include telemetry. The use of miniature radio transponders will allow for vehicles to report any emissions problems along with their VIN (vehicle identification number) directly to an assigned regulatory agency as it happens. The OBD III system could be set to automatically report a problem immediately as it happens, or a query from a satellite, cellular, or roadside signal could trigger the OBD III to send its current emissions performance. This would allow a regulatory agency to focus on the high-emissions vehicles and eliminate them from the road or force them to do the appropriate repairs.

There is currently a prototype built by GM Hughes Electronics which can retrieve information from 8 lanes of bumper-to-bumper traffic traveling at up to 100mph. This system uses a roadside transmitter to query vehicles as they pass by instead of having it the car report on itself when it has a malfunction indicator lamp light up. The prototype uses low power 10 milliwatt receiver stations and 1 milliwatt transmitters with a broadcast frequency of 915Mhz [11]. The technology does exist, but having OBD-III be a requirement on new vehicles may take many years to approve.

Although this self-reporting OBD III system would reduce emissions and eliminate the hassle of having to get an inspection done yearly, privacy issues are a concern. Having the government checking the performance of your vehicle at any or all times and providing information of your location may be considered a violation of the Fourth

Amendment, which protects the rights of privacy and protection from government search and seizure[12]. If the self reporting transponders cannot be used due to privacy concerns, other sources mention that OBD-III will allow for police officers to do roadside tests of their own [13].

Chapter 3

Setup

After extensive research on different available OBD-II scanners available on the market, the Auterra DashDyno SPD was chosen for its ability to communicate with a GPS receiver and record a vehicle's performance along with GPS coordinates. In addition to being able to scan for DTCs, it has performance meters, and the ability to log and record data. Below is a list of the equipment used in this setup.

Vehicle tested: 1997 Honda CRV
OBD II scanner - Auterra DashDyno SPD - *Specifications in Appendix*
Connectors - DashDyno Serial GPS Cable- Male 8-pin Mini-DIN to Male D89
OBD II Cable (O-102)
Memory - SD card- 1GB
GPS Unit - Garmin GPS 18x PC *Specifications in Appendix*

Figure 3 is a schematic of the DashDyno and how it connects to most vehicles. OBD II diagnostic data ports are located near the driver, usually under the dashboard or behind ashtrays. In this Honda CRV, the connector is below the dashboard and to the right of the center console. No tools are ever required to access these ports.

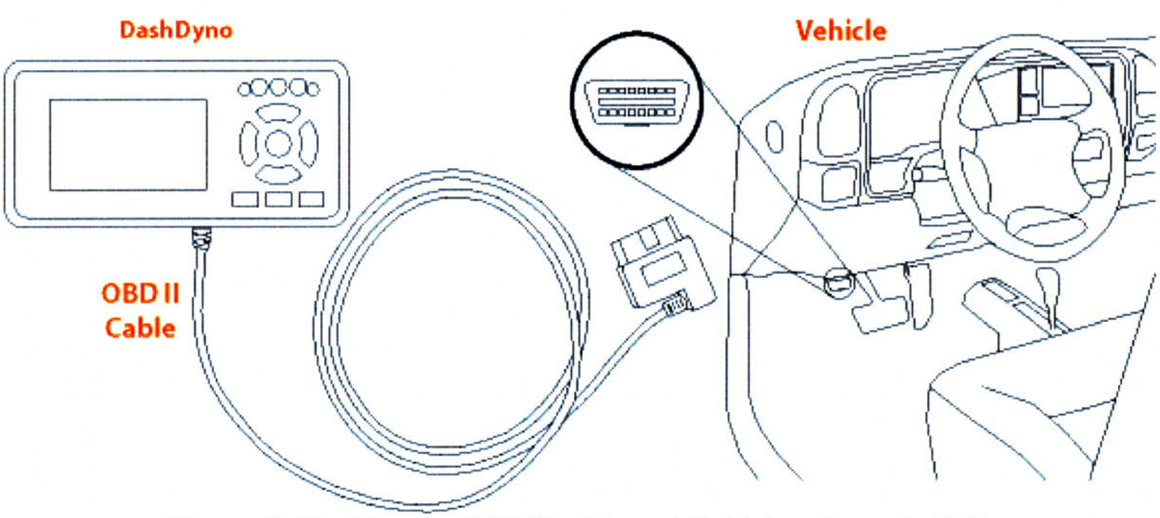

Figure 3- DashDyno, OBD II cable and Vehicle schematic [14]

Figure 4 was of the actual setup in the Honda CRV. The DashDyno is mounted over the dashboard with a suction cup attached to the windshield. The GPS is on the dashboard next to it and connects through the auxiliary port at the bottom of the DashDyno. The second cable coming out of the Dashboard is the OBD II cable, and collects the information from the vehicle.

Figure 4 - A: DashDynoSPD, B: Garmin GPS

GPS

By combining both of these units, the vehicle's data can be recorded along with position coordinates. The GPS receiver used in this project provided latitude and longitude coordinates. By using GoogleMaps one could track the path driven and also make note of fuel consumption, speed, and throttle position at each different location. Also by using http://www.latlontoelevation.com, it is possible to get the different elevation values for each data set, making it possible to correlate change in elevation with changes in the vehicle's performance. Figure 5 shows a sample of the collected data viewed on a map using GoogleMaps. The dots on the roads range from green to red to indicate fuel consumption. The red dots are the highest fuel consumption, the yellow points indicate a medium range fuel consumption, and the green dots represent the lowest fuel consumption range.

Figure 5 – Sample of GoogleMap with collected data inputed into map – Created by Stephen Ho using GoogleMap

Chapter 4

Data

Two different sets of data were recorded due to limitations added onto the DashDyno by the GPS receiver. In the first data set, Data 1, four parameters were recorded; fuel consumption (gallons/hour)[2], vehicle speed (miles/hour)[3], absolute throttle position[4], and RPM[5]. In order to record GPS coordinates, we had to eliminate one of the previous parameters from Data 1 and make a second set of data, Data 2. Data 2 does not contain information on the vehicles RPM, but it still has vehicle speed and fuel consumption along with the GPS coordinates of the vehicle.

Since the accelerator pedal is connected to the throttle through linkages, the driver has control of the throttle position, and this is the input that is used to define the driver's driving habits in this data. So we have analyzed the affects of this parameter on the rest of the parameters in order to see how the driver's way of driving affects fuel consumption.

As one can see from figure 6, as the throttle position is increased, fuel consumption increases as well. However, the slope increases after a throttle input of 17%, which indicates that the fuel consumption increases at a quicker rate above 17%.

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[2] Fuel Consumption – how much fuel is consumed, in this case we measure this in gallons/hour

[3] Vehicle Speed – Speed of the vehicle retrieved from the Engine Control Unit, not GPS

[4] Absolute Throttle Position- Measures how open the air passage in the throttle body is in a range from 0 to 100%. Air flow is controlled by the throttle plate which opens and closes as the accelerator is pressed. The throttle position sensor also requests more or less fuel from the Engine Control Unit in order to maintain the correct air/fuel ratio [15].

[5] RPM – engine revolutions per minute

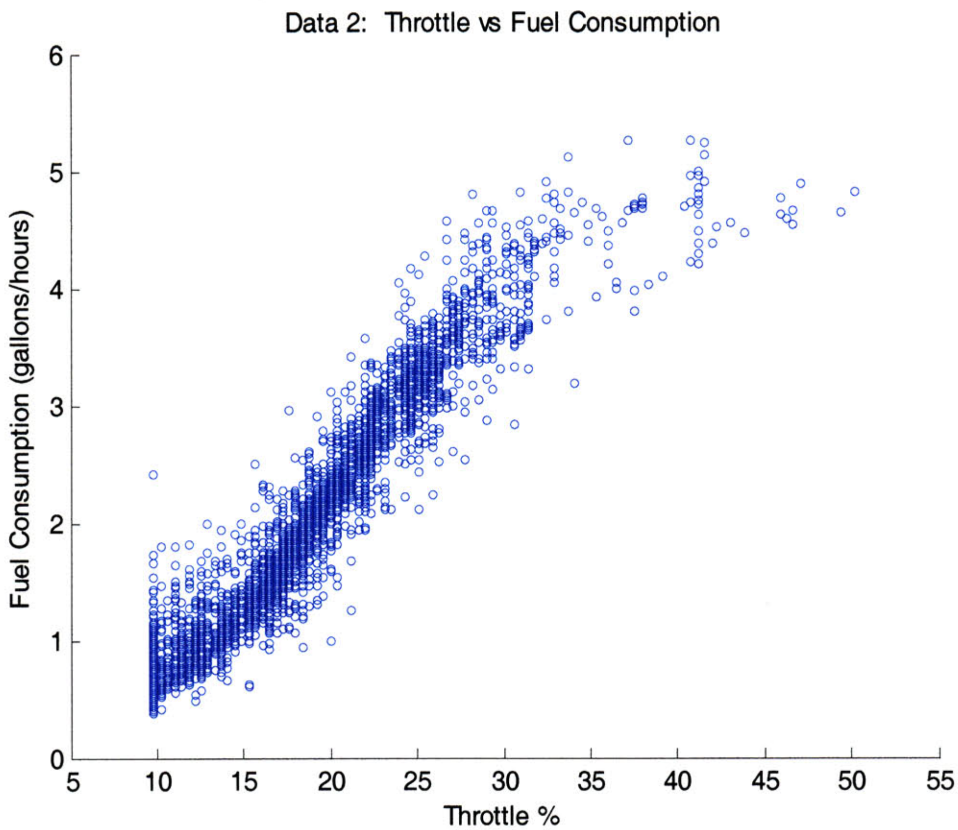

Figure 6 – Throttle versus fuel consumption rate using Data 2.

In the ecodriving recommendations that were discussed in the introduction it is stated that it is best to shift between 2000 and 2500 RPM. It is obvious from figure 7 that fuel consumption begins to rapidly increase in this vehicle at 2000 RPM.

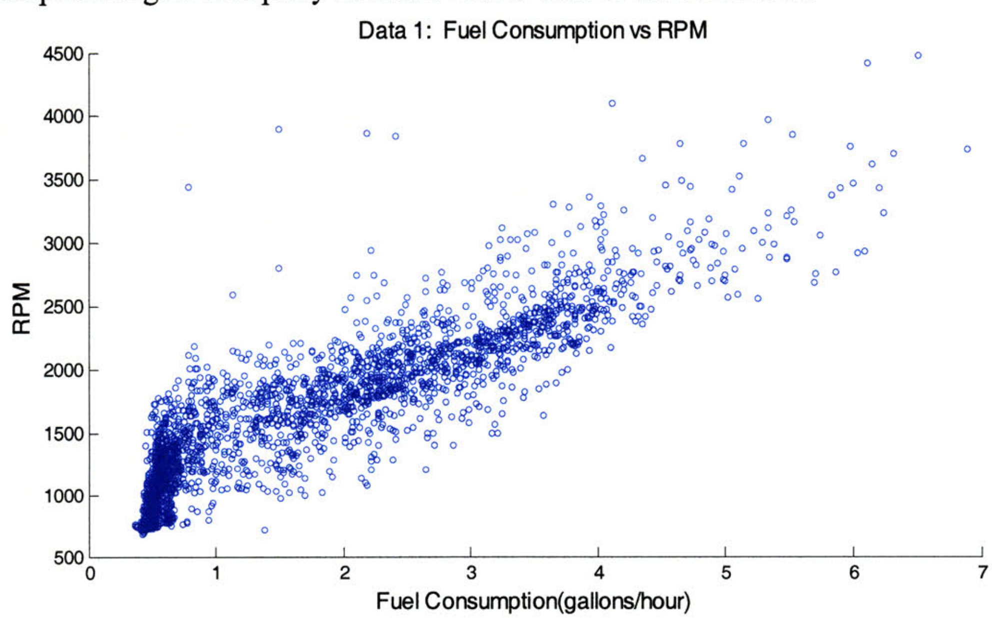

Figure 7 –Fuel Consumption versus RPM using data 1

The color scheme in figure 8 shows the fuel consumption as RPM and throttle changes. As the throttle position increases so does the RPM. However, depending on which gear the vehicle is in, the throttle position is high or low at any given throttle position. As throttle increases pass 28% all of the points lie above the 2000 RPM line and are indicative of high fuel consumption as expected from the article on ecodriving. As you move upwards on any throttle position in the graph you can see that the fuel consumption increases.

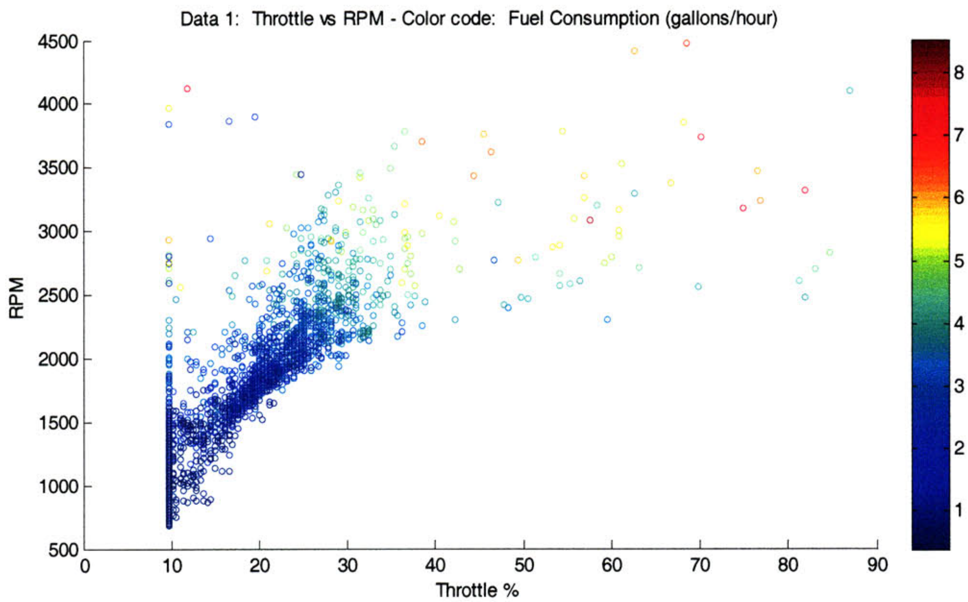

Figure 8 –Throttle versus RPM with a fuel consumption color bar(Data 1)

The graph in figure 9 has the same x and y axes as the previous graph, but a different color scheme. This color scheme demonstrates the speed of the vehicle at each point. As one can see, the section between 10 and 28% throttle and below 2000 RPM, which showed the lowest fuel consumption in the previous graph, is indicative of speed ranging from 0 to 40 mph. There is actually a good portion of that section in red which shows that in the correct gear, a car can travel 40 mph and still have a very low rate of fuel consumption. However, there are also blue points that indicate 0 mph velocities in the same range, this may be due to moments that the accelerator was pressed while parked in order to test the equipment's function. This test should be repeated to make sure it's not due to lag or other reason. Also recommendations listed in the conclusion of this paper may help solve this problem.

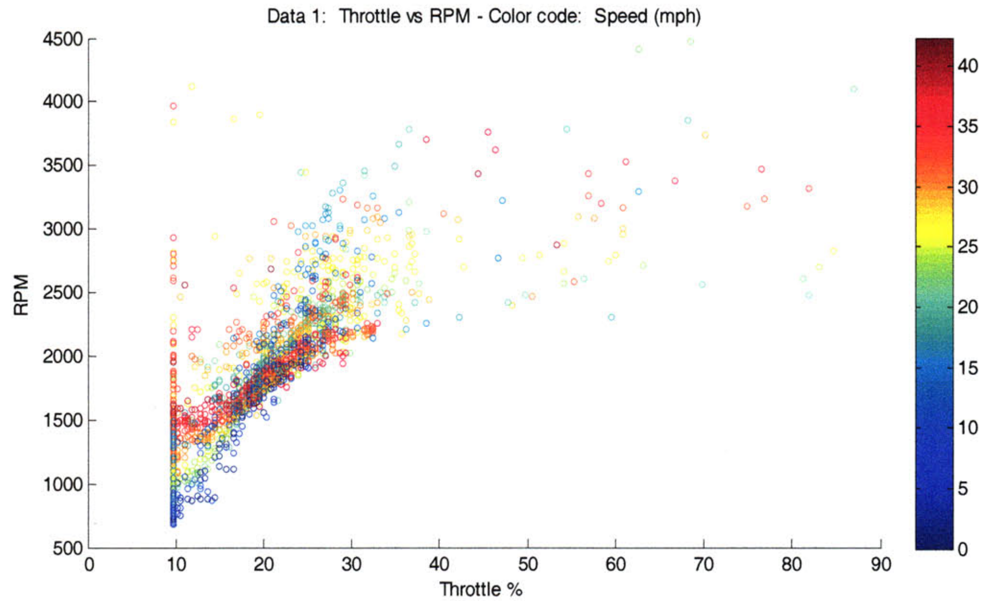

Figure 9 – Throttle versus RPM with a color bar representing speed(Data 1)

In order to make more sense of the data, a GPS unit was added to the test in order to see how the roads affect these parameters, but the RPM had to be eliminated in order to make room for the GPS data.

However, when GPS coordinates along with elevation are added, it is much easier to distinguish what is going on. One can see if change in vehicle performance is due to a turn, hill, or intersection

By analyzing the fuel consumption, the vehicle speed, and the throttle position one can possibly determine the state of the vehicle; whether the vehicle is going down hill going up hill or accelerating. This would be useful for better fuel and emissions management. Figure 10 show a section of the data that is indicative of driving downhill without accelerating. At first, it seems that the velocity increases in steps, but that is not the case here. Velocity increases gradually as the vehicle goes down hill, but velocity readings are only taking in intervals of 0.6mi/hr.

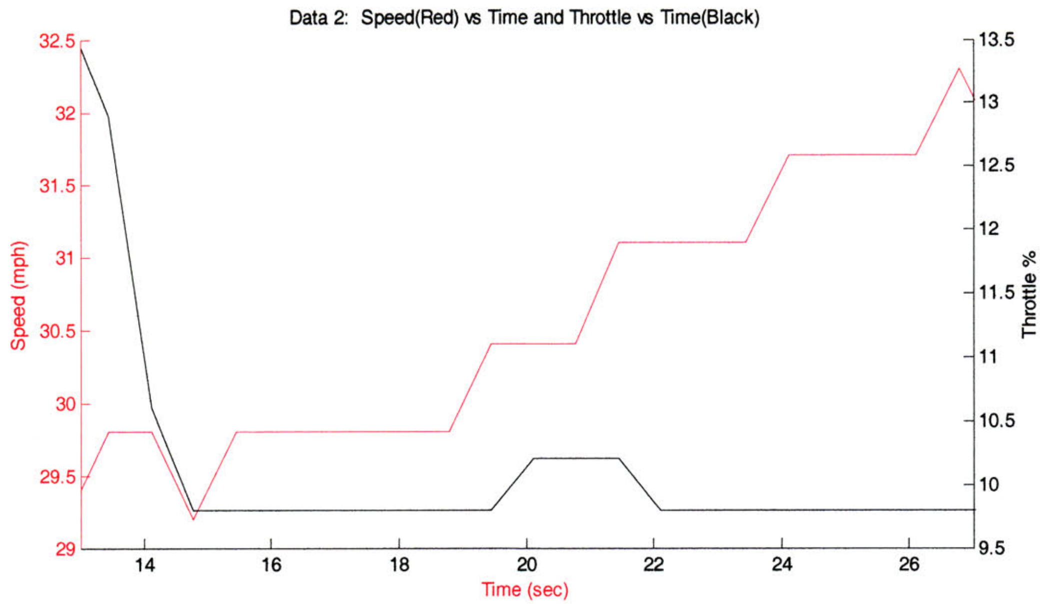

Figure 10 – Speed vs time graphed in red, and throttle vs time graphed in black(Data2)

Figure 11 is a graph that shows the elevation data gathered from inputting GPS data into a GIS. This data confirms that the vehicle is traveling downhill.

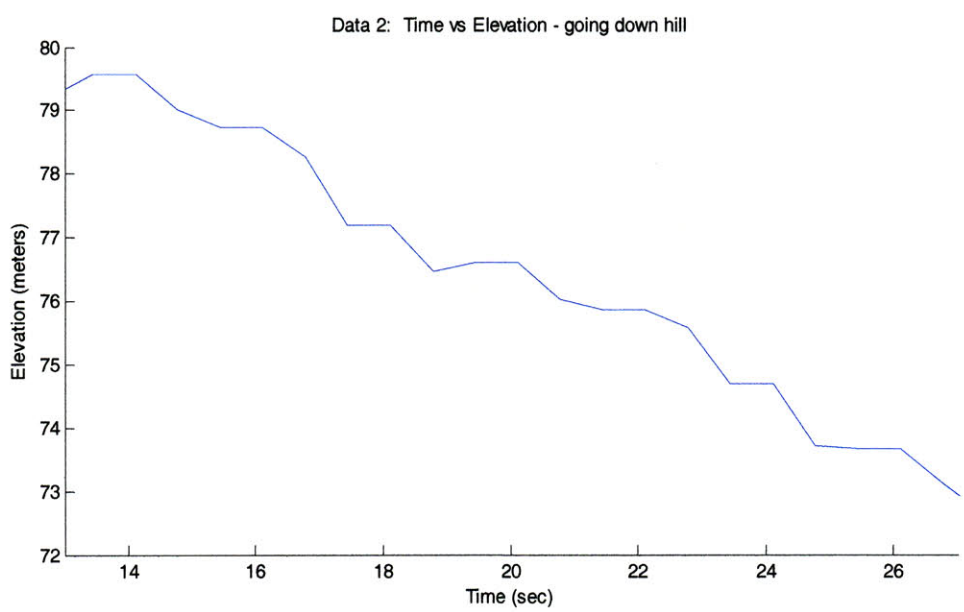

Figure 11 – Graph of elevation change during the same period of time as Figure 9.

During that down hill state, as seen in Figure 12, fuel consumption drops back down to about .5 gallons/hour.

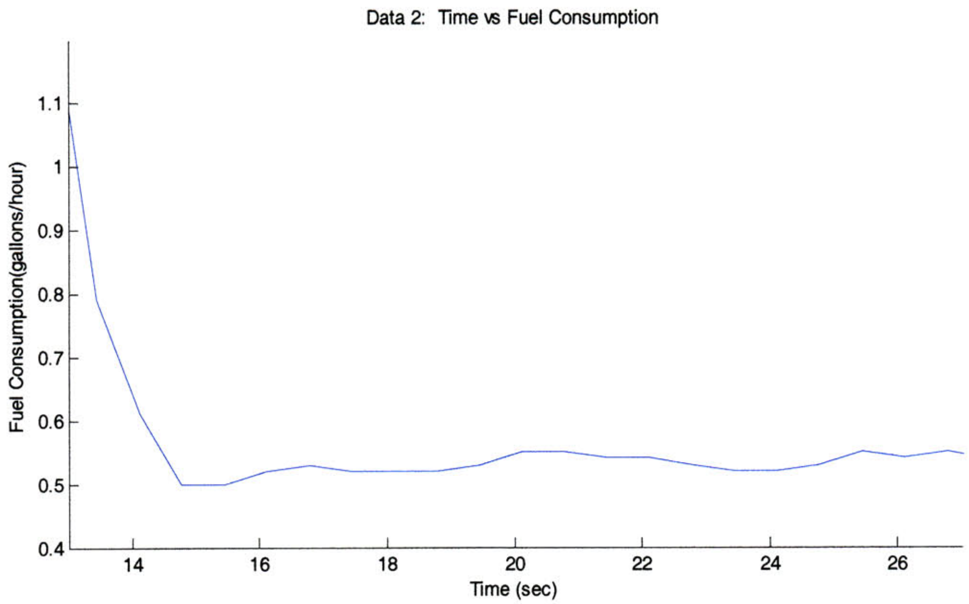

Figure 12 – Fuel Consumption change during same period as Figure 9 & 10

However, if the vehicle is aware that the road is going downhill, it can manage its fuel delivery system and lower its fuel consumption a lot more. Also if roads are mapped out with this type of information, a vehicle's ECU can decide to reduce the fuel sent to the engine right as the vehicle approaches the downhill. This may seem like a very miniscule saving, but if this is done for all the cars traveling the road, the savings on fuel wasted and emissions released would be huge.

If the throttle position is kept constant and the velocity is decreasing, than it is indicative of a restraint on the vehicle's motion, which would most likely be due to going uphill on a road. Figure 13 is a portion of the data, where the throttle position is kept at 17.6 percent and the vehicle speed keeps dropping. The elevation data from the GPS and the vehicle speed is graphed against time to show the effect from going uphill on the vehicle's speed.

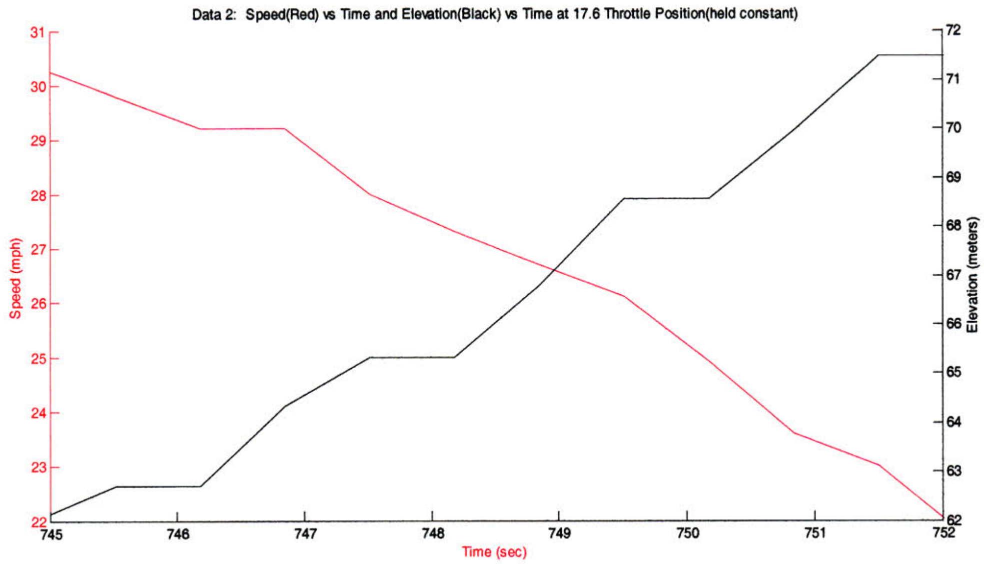

Figure 13 – Speed vs time graphed in red and elevation vs time graphed in black(Data2)

Determining a downhill moment in the data set is simple due to the ability to monitor the throttle position and the velocity. Distinguishing between going uphill or accelerating is not as simple, due different hill slopes and drivers not always accelerating at a consistent rate. Also, when the accelerator is not pressed and the velocity is slowing down, differentiating between going up hill, engine braking, or engine braking is difficult. Unfortunately, the DashDyno does not have a live parameter for the brake pedal. This will be addressed in future tests.

From the OBD II data collected it can be seen that during a state where the gas pedal is at its 0 position (9.8% throttle position), the vehicle is decelerating. In order to distinguish between the vehicle slowing down from engine braking or from going up the hill, the GPS data is used to determine any change in elevation. Figure 14 shows one of the few cases where braking can be predicted; braking while going downhill. In this vehicle the car begins to slow down at a slow rate, maybe from engine brake, or light taps on the brake, and then eventually the brake is definitely being used to slow the vehicle down to 7mi/hr.

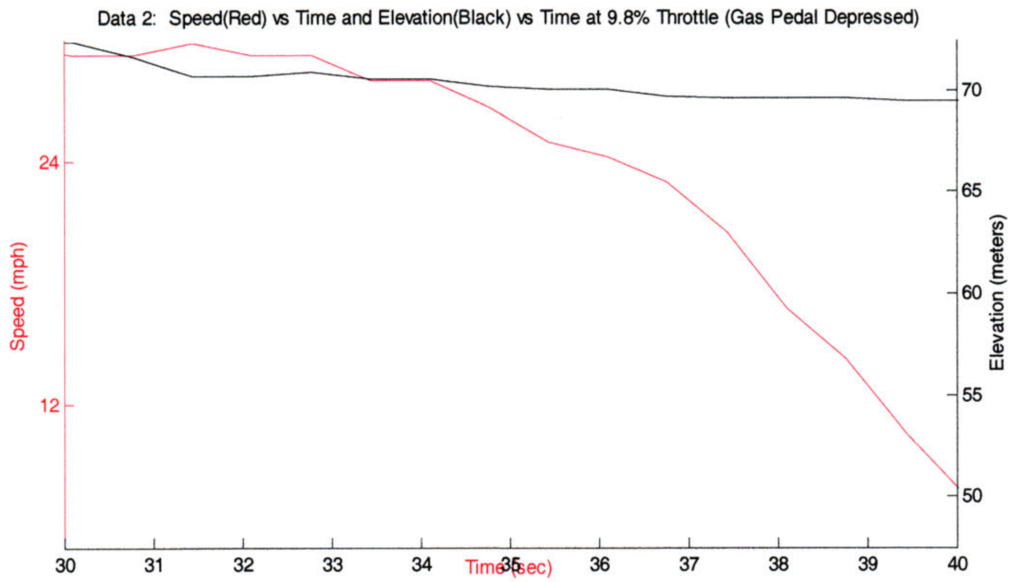

Figure 14 - Speed vs time graphed in red, and elevation vs time in black during a constant 9.8% Throttle Position (Data 2)

This next top graph shows that drivers like to accelerate heavily mostly between 0 and 30 mph, with a throttle position between 20 and 32. However, during most of the drive cycle, the throttle position is kept between 10 and 30, with a few higher positions due to extreme acceleration. Also seen is the lack of points between 5 and 20 mi/hr with a throttle position between 10 and 18. The data points that should be there are actually shifted to the right and show a higher level of acceleration as expected. This shows that drivers are very impatient when it comes to accelerating from a stop.

Figure 15 shows that a 0 acceleration is very common in the 55 and 35 mph due to the speed limits. However, in the previous graph plotted on the same axes and by comparing the two you can still see that the fuel consumption changes a lot even when acceleration is minimal, and as you increase the throttle position fuel consumption is increased regardless of zero acceleration. The blue dots on the vertical line at throttle position 10 are indicative of braking.

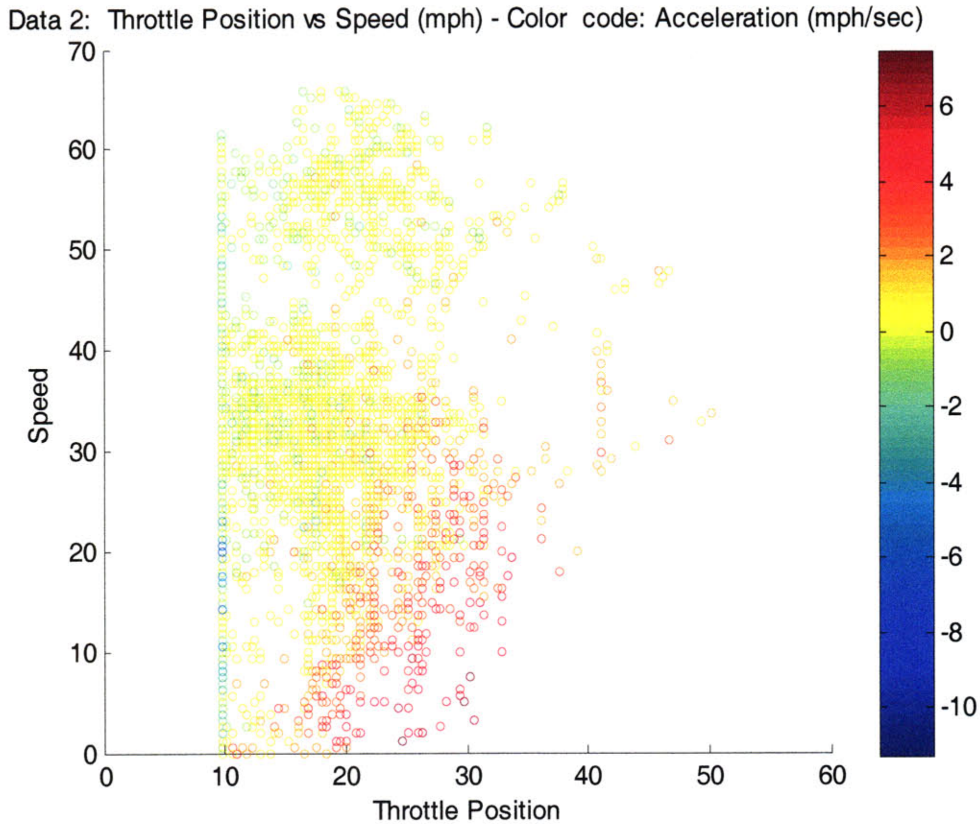

Figure 15 – Throttle position vs speed and color bar for acceleration (Data 2).

Figure 16 is a similar graph with the same axes of speed versus time, but the color scheme has been switched from acceleration to fuel consumption. As expected from looking at the previous graph, within speeds ranging between 5 and 20 mi/hr, data points with less than 2 gallon/hr of fuel consumption barely exists. This is due to the higher level of acceleration seen within this range. From this diagram it seems that throttle position is more influential on gas consumption then speed is, which is concident with ecodriving reccomendations. A throttle position above 27 will range between 3.5 and 5 gallons of gas consumed per hour.

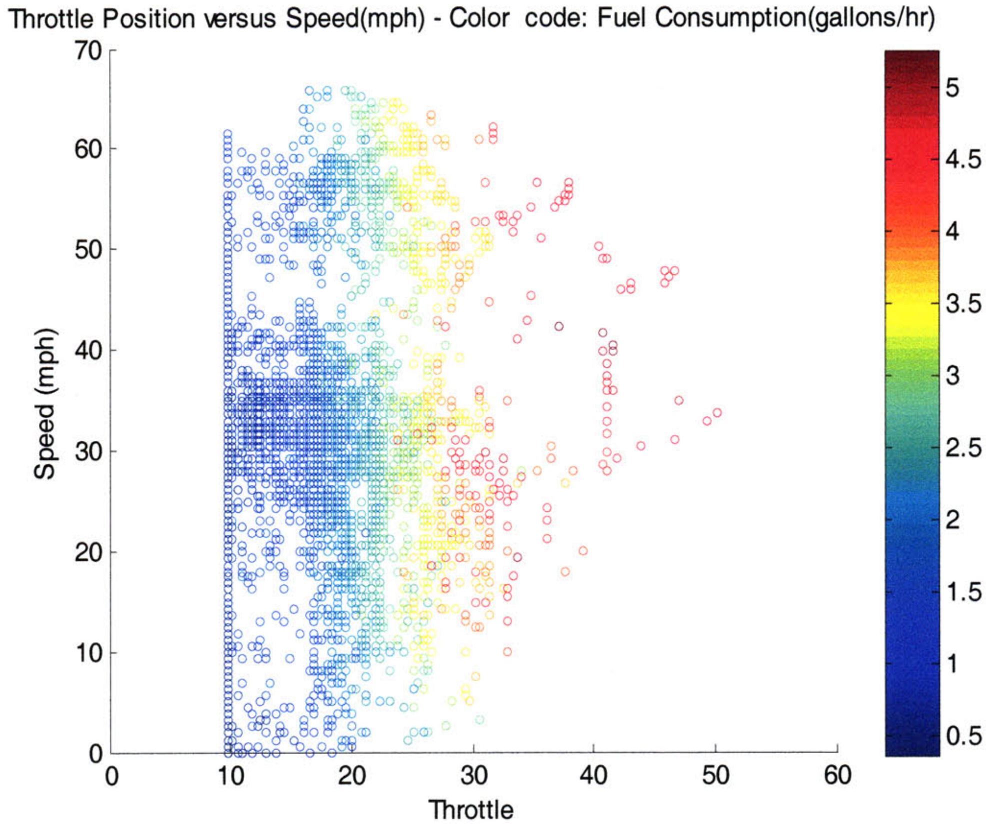

Figure 16 – Throttle Position vs speed with a color bar for fuel consumption (Data 2)

Chapter 5

Conclusion

Although a lot of lot research has been done and continues to be done to create the most fuel-efficient vehicles with minimal emissions, the information gathered from this specific research shows that high emissions can not be blamed solely on the vehicle. The blame must be shared with the driver and the road. Drivers like to accelerate heavily when leaving from a stop, instead of the gradual acceleration that is seen once their speed limit is reached. Either by creating a system that limits the driver's ability to accelerate this quickly during the range of speeds from 0 to 30 mi/hr, or just creating a system that makes the driver more aware of their tendency to inefficiently waste fuel and create high emissions, drivers may cut back on this needless acceleration. For one car, the savings might not be worth it, but if this repeated for many cars, than the savings are big.
Also, by collecting data on road characteristics and making it available for vehicles, the vehicle's fuel management can be improved so that fuel is kept at the lowest possible level while vehicles are going downhill or coming to a stop. This would be possible to do since the vehicle would than be aware of the path ahead of itself. Also, if road characteristics data is not available from previous travel, the OBD II system can also analyze its own parameters to determine which state it is in; driving uphill or downhill, hard braking, and engine braking. This information can than be used as well to improve the vehicle's fuel management.

For future data collection, the use of a dashcam is an option being discussed. This would be a camera placed on the dashboard using timestamps in order to match the video with the data, or it can be a camera synched with the data using TrackVision, a software developed for this purpose [16]. Also the ability to monitor brake usage will be added to the OBD II scanner. This would be useful to distinguish between engine braking, resistance from the road, and the driver's braking.

Once this project is fully developed, it will be easy to just look on a map and find the roads with the heaviest emissions and attempt to solve the problems on these roads.

APPENDIX

Auterra DashDyno SPD Specifications	
Size	5.2" W x 2.4" H x 1.4" D
Processor	32-bit, software upgradeable
Screen	High contrast monochrome, white LED backlight
Keys	Backlit silicon rubber
Expansion Slot	Support for MultiMediaCard, SD and SDIO cards
File Formats	FAT12, FAT16, FAT32
Card Size	1GB max
Power	OBD II cable or AC adapter
Sleep Mode	Auto power-off
Keypad	Backlit, secondary function keys
Aux Port 1	Mini-DIN, four analog inputs, 5V output
Aux Port 2	Mini-DIN, one digital input, one digital output, serial port, 5V output
Aux 5V Output	Current limited 25mA max (combined both ports)
Analog Inputs	Selectable ranges of 0-6V, 0-12V or 0-24V, 10-bit ADC
Analog Input Impedance	95k ohm 6V range, 62k ohm 12V range, 54k ohm 24V range
Oscilloscope Mode	200Hz bandwidth, 1mS sample rate
Digital Input	24V max, 4V high min, 1.6V low min
Digital Output	Open Collector, 15V max, 75ma sink max
External GPS Baud	4800, 9600, 19200, 38400
External GPS Protocol	NMEA 0183
USB Port	Mini USB type B
OBD II Port	Modular
OBD II Cable	6ft, low-profile OBD II connector
Alarm Lights	Three high intensity LEDs
Mounting	Two brass 8-32 rear mounting screw holes
Windshield Mount	Suction cup with quick release
OBD II Protocols	J1850 (VPW, PWM), ISO 9141, ISO 14320 (KWP), and ISO 15765 (CAN bus) protocols
Ambient Temperature Operation	14°F to 131°F (-10°C to 55°C)
Ambient Temperature Storage - Short Term	-4°F to 140°F (-20°C to 60°C)
Ambient Temperature Storage - Long Term	32°F to 86°F (0°C to 30°C)

GPS specifications

Width 2.4 in

Depth 2.4 in

Height 0.7 in

Weight 6.5 oz
GPS System
Product Type GPS receiver module
Receiver 12 channel - GPS receiver
SBAS WAAS
Interface NMEA 0183, Garmin Binary
Antenna Built-in
GPS Module Features Waterproof
GPS Compatibility
Interface Serial
Connections
Connector Type Serial - RS-232 DC power input - automobile cigarette lighter

Available Live Paramters	
+Analog In 1 - 12V	Equivalence Ratio B2-S2 2
+Analog In 1 - 24V	Equivalence Ratio B2-S3
+Analog In 1 - 6V	Equivalence Ratio B2-S3 2
+Analog In 2 - 12V	Equivalence Ratio B2-S4
+Analog In 2 - 24V	Equivalence Ratio B2-S4 2
+Analog In 2 - 6V	Evaporative System Vapor Pres
+Analog In 3 - 12V	Evaporative System Vapor Press
+Analog In 3 - 24V	Exhaust Gas Temp B1-S1
+Analog In 3 - 6V	Exhaust Gas Temp B1-S2
+Analog In 4 - 12V	Exhaust Gas Temp B1-S3
+Analog In 4 - 24V	Exhaust Gas Temp B1-S4
+Analog In 4 - 6V	Exhaust Gas Temp B2-S1
+Digital In 1	Exhaust Gas Temp B2-S2
+GPS HDOP	Exhaust Gas Temp B2-S3
+GPS Satellites	Exhaust Gas Temp B2-S4
+GPS Speed	Exhaust Pressure B1
Air Flow Rate From MAP	Exhaust Pressure B2
Air Fuel Ratio	Fuel Injection Timing
Air Fuel Ratio B1-S1	Fuel Level Input
Air Fuel Ratio B1-S1 2	Fuel Rail Press Relative Manifold
Air Fuel Ratio B1-S2	Fuel Rail Pressure
Air Fuel Ratio B1-S2 2	Fuel Rail Pressure (abs)
Air Fuel Ratio B1-S3	Fuel Rail Pressure (gauge)
Air Fuel Ratio B1-S3 2	Fuel Rail Pressure A
Air Fuel Ratio B1-S4	Fuel Rail Pressure B
Air Fuel Ratio B1-S4 2	Fuel Rail Temp A
Air Fuel Ratio B2-S1	Fuel Rail Temp B
Air Fuel Ratio B2-S1 2	Hybrid Battery Pack Life
Air Fuel Ratio B2-S2	Ignition Timing Advance
Air Fuel Ratio B2-S2 2	Injection Pressure A
Air Fuel Ratio B2-S3	Injection Pressure B
Air Fuel Ratio B2-S3 2	Intake Air Temp B1-S1

Air Fuel Ratio B2-S4	Intake Air Temp B1-S2
Air Fuel Ratio B2-S4 2	Intake Air Temp B1-S3
Average Economy	Intake Air Temp B2-S1
Average Speed	Intake Air Temp B2-S2
Battery Voltage	Intake Air Temp B2-S3
Boost Pressure	Intake Air Temperature
Distance Traveled	Intake Manifold Absolute Pressure A
Drive Time	Intake Manifold Absolute Pressure B
Fuel Cost	Intake Manifold Pressure
Fuel Rate	Long Term Fuel Trim B1
Fuel Used	Long Term Fuel Trim B2
Idle Percent	Long Term Fuel Trim B3
Idle Time	Long Term Fuel Trim B4
Instant Economy	Long Term Sec Fuel Trim B1
Absolute Evaporative Vapor Pres	Long Term Sec Fuel TrimB2
Absolute Load Value	Long Term Sec Fuel TrimB3
Absolute Throttle Pos B	Long Term Sec Fuel TrimB4
Absolute Throttle Pos C	Manifold Surface Temp
Absolute Throttle Position	Mass Air Flow A
Accelerator Pedal Pos D	Mass Air Flow B
Accelerator Pedal Pos E	Minutes Run with MIL On
Accelerator Pedal Pos F	NOx Concentration B1-S1
Actual EGR A Duty	NOx Concentration B2-S1
Actual EGR B Duty	O2 B1-S1 Wide Range mA
Actual Engine Torque	O2 B1-S1 Wide Range V
Air Flow Rate From MAF	O2 B1-S2 Wide Range mA
Alcohol Fuel Percentage	O2 B1-S2 Wide Range V
Ambient Air Temperature	O2 B1-S3 Wide Range mA
Average Demanded Consumption	O2 B1-S3 Wide Range V
Average Reagent Consumption	O2 B1-S4 Wide Range mA
Barometric Pressure	O2 B1-S4 Wide Range V
Boost Pressure A	O2 B2-S1 Wide Range mA
Boost Pressure B	O2 B2-S1 Wide Range V
Calculated Load	O2 B2-S2 Wide Range mA
Catalyst Temp B1-S1	O2 B2-S2 Wide Range V
Catalyst Temp B1-S2	O2 B2-S3 Wide Range mA
Catalyst Temp B2-S1	O2 B2-S3 Wide Range V
Catalyst Temp B2-S2	O2 B2-S4 Wide Range mA
Charge Air Cooler Temp B1S1	O2 B2-S4 Wide Range V
Charge Air Cooler Temp B1S2	O2 Sensor B1-S1
Charge Air Cooler Temp B1S2	O2 Sensor B1-S2
Charge Air Cooler Temp B2S1	O2 Sensor B1-S3
Commanded Boost Pressure A	O2 Sensor B1-S4
Commanded Boost Pressure B	O2 Sensor B2-S1
Commanded Fuel Rail Pressure A	O2 Sensor B2-S2
Commanded Fuel Rail Pressure B	O2 Sensor B2-S3
Commanded Injection Pressure A	O2 Sensor B2-S4
Commanded Injection Pressure B	PM Mass Concentrate B1-S1

Commanded Throttle Actuator A	PM Mass Concentrate B2-S1
Commanded Throttle Actuator B	Reagent Tank Level
Commanded Variable Turbo A	Relative Throttle A Position
Commanded Variable Turbo B	Relative Throttle B Position
Command Throttle Actuator	Relative Accelerator Pedal Pos
Commanded EGR	Relative Intake Air A
Commanded EGR A Duty	Relative Intake Air B
Commanded EGR B Duty	Relative Throttle Position
Commanded Equivalence Ratio	Run Time NOx Warn
Commanded Evaporative Purge	Short Fuel Trim B1-S1
Commanded Intake Air A	Short Fuel Trim B1-S2
Commanded Intake Air B	Short Fuel Trim B1-S3
Commanded Wastegate A	Short Fuel Trim B1-S4
Commanded Wastegate B	Short Fuel Trim B2-S1
Control Module Voltage	Short Fuel Trim B2-S2
Distance Since DTCs Cleared	Short Fuel Trim B2-S3
Distance Traveled MIL On	Short Fuel Trim B2-S4
DPF Delta Pressure B1	Short Term Fuel Trim B1
DPF Delta Pressure B2	Short Term Fuel Trim B2
DPF Inlet Pressure B1	Short Term Fuel Trim B3
DPF Inlet Pressure B2	Short Term Fuel Trim B4
DPF Inlet Temp B1	Short Term Sec Fuel Trim B1
DPF Inlet Temp B2	Short Term Sec Fuel TrimB2
DPF Outlet Pressure B1	Short Term Sec Fuel TrimB3
DPF Outlet Pressure B2	Short Term Sec Fuel TrimB4
DPF Outlet Temp B1	Time Since DTCs Cleared
DPF Outlet Temp B2	Time Since Engine Start
Driver Demand Torque	Total Engine Idle Time
EGR A Error	Total Engine Run Time
EGR B Error	Total Engine Run w/PTO
EGR Error	Total Run w/IE-ACED 1
EGR Temperature B1-S1	Total Run w/IE-ACED 10
EGR Temperature B1-S2	Total Run w/IE-ACED 2
EGR Temperature B2-S1	Total Run w/IE-ACED 3
EGR Temperature B2-S2	Total Run w/IE-ACED 4
Engine Coolant Temp	Total Run w/IE-ACED 5
Engine Coolant Temp 1	Total Run w/IE-ACED 6
Engine Coolant Temp 2	Total Run w/IE-ACED 7
Engine Fuel Rate	Total Run w/IE-ACED 8
Engine Oil Temp	Total Run w/IE-ACED 9
Engine Reference Torque	Turbo A In Compressor
Engine RPM	Turbo A In Turbine Temp
Engine Torque Idle Point 1	Turbo A Inlet Pressure
Engine Torque Point 2	Turbo A Out Compressor
Engine Torque Point 3	Turbo A Out Turbine Temp
Engine Torque Point 4	Turbo A RPM
Engine Torque Point 5	Turbo B In Compressor
Equivalence Ratio B1-S1	Turbo B In Turbine Temp

Equivalence Ratio B1-S1 2	Turbo B Inlet Pressure
Equivalence Ratio B1-S2	Turbo B Out Compressor
Equivalence Ratio B1-S2 2	Turbo B Out Turbine Temp
Equivalence Ratio B1-S3	Turbo B RPM
Equivalence Ratio B1-S3 2	Variable Turbo A
Equivalence Ratio B1-S4	Variable Turbo B
Equivalence Ratio B1-S4 2	Vehicle Speed
Equivalence Ratio B2-S1	Warm-ups Since DTCs Cleared
Equivalence Ratio B2-S1 2	Wastegate A
Equivalence Ratio B2-S2	Wastegate B

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