Characterising Eco-driving using GPS and CANBus data

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***Abstract*—Abstract**

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I. Introduction

Reducing fuel consumption and greenhouse gas (GHG) emissions is one major approach towards controlling global warming. The focus has mainly been on large consumers as power plants, air planes, etc. but everybody will have to contribute if the goals for GHG reductions shall be met. About one fifth of EU's total emission of CO_2 comes from road transportation and has increased with about 23 % from 1990 to 2010 [4]. Politians are focusing on setting guidelines and requirements for improving vehicular technologies such as engine performance and alternaive fuels, but the individual drivers can contribute by driving more fuel efficient. This will not only help reduce GHG emissions but also reduce fuel expenditure for the drivers.

Eco-driving aims to changes the driving behaviour by giving simple advices such as maintain a steady speed, accelerate moderatly, do not drive too fast, anticipate traffic flow and maintain your vehicle [1], [15]. The advices are designed to reduce fuel consumption and hence reduce GHG emmisions, ~~but~~ traffic safety and improvement of traffic flow have shown to be possitive side effects. Feedback on ones eco-driving performance is imparative for improvement. This can either be simple visulisations of fuel consumption or more elaborate observations. These observations could for example be whether the driver accelerates too much or idles ~~too often~~. In order to make these observations access to detailed information of driving patterns is needed. GPS data provides location, speed and direction at a high frequence, and the data is easy and cheap to collect. Additional data is, however, needed in order to evaluate if many of the eco-driving advices are followed. CANBus data can provide detailed information about the dynamic state of the vehicle, e.g. rounds per minute, kilometers driven and more. As of today the data is not yet avaiable in the same ~~amount~~ as GPS data, and the quallity varies.

Say we have four vehicles, A, B and C, that drive at different kilometers per liter fuel (see Table I). Is it then possible to pinpoint why vehicle A is ~~much~~ less fuel efficient than vehicle C using GPS and CANBus data? With a gas price of 12 kr/l vehicle A spend 2,400 kr a week if he drives 1,000 km where as vehicle B spend 2,000 kr and vehicle C only 1,500 kr a week. Over a year vehicle A could save a around 45,000 kr if he could drive with the same fuel efficiency as vehicle C. We aim to identify which factors available through GPS and CANBus data, has an influence on fuel consumption and how one explains the difference in the fuel consumption of different vehicles of the same type. That is, why does vehicle C use less fuel than vehicle A and can vehicle C improve his fuel efficiency using eco-driving strategies? High accelerations are a potential factor for fuel consumption. Figure 1 shows five different acceleration profiles and the amount of fuel consumed in the depicted period. Clearly high accelerations leads to high fuel consumtion in this example. The remainder of this article will extend this and other analysis of the driving behaviours and investigate which factor influence their fuel consumption.

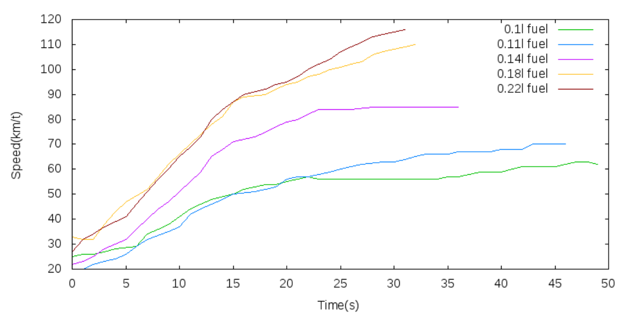

Figure 1. Five trips driving the same road segments with diffrent accelerrations

The main contributions of this paper are:

- Specification of existing eco-driving advices
- Analysis of selected eco-driving advices from real data set
- Comparison of vehicles eco-driving techniques

II. Related Work

The authors of [5] investigates the impact of providing real time eco-driving advices to the drivers based on real-time traffic speed, density and flow. They find that a reduction

Vehicle	km/l
A	5
B	6
C	8

Table I. Example

in fuel consumption of 10-20% can be achieved without a significant increase in travel time, and that the effect is greater in severly congested senarios. The authors of [7] also investigate how real time feedback affect driving behaviour. From simply displaying the instantanious fuel economy to 20 sample drivers they show a reduction of 6 % in fuel consumption on city streets and 1% on highways. Most of the drivers where willing to adopt eco-driving advises after the study. The long-term effects of eco-driving courses are evaluated in [9]. A study on 10 vehicles over 10 months shows a mean reduction in fuel consumption of 5.8 %, but that the effect is very different from individual to individual. 20% saw no fuel reduction. Fuel consumption at high speeds and at aggressive accelerations are investigated in ~~the thesis~~ [6]. They find that reducing the velocity on highways generally gives about the same reduction in fuel as reducing acceleration on all roads. ~~The thesis~~ [8] investigates why the benefit of eco-driving decrease over time. The study finds that group behaviour needs to be taking into account when teaching eco-driving principles.

The exact eco-driving advices vary from reference to reference. Both [1] and [15] details a number of advises.

Eco-routing is about saving fuel by finding the most fuel efficient routes. GreenGPS [10] is an example of participatory approach to eco-routing and they see a 10 % reduction in fuel consumption. EcoMark [11] is an evaluation framework for evaluating evironmental models. Eleven known models for environmental impact are evaluated to investigate whether they can be used to do eco-driving and eco-routing. The evaluation finds that instatanious models can be used for eco-driving and aggregated models can be used for eco-routing. The INTEGRATION model framework [14] is a model for quantifying environmental impact on a microscopic level. The study showed that the predicted the emissions and fuel consumption are consistent with actual data from a field study when the vehicles do not accelerate.

III. Eco-driving Advices

The authors of [1] and [15] list a number of advices for eco-driving that will reduce fuel consumption. The advices are detailed below and will be evaluated in the follwing sections separately.

1) **Drive in the heigest possible gear at lowest possible rounds per minut (RPM~~'s~~).** Fuel consumption is lower at low RPM~~'s~~ due to ~~internal~~ friction. Keep a high load on the engine and shift gear at around 2,500 RPM for gasoline cars and 2,000 RPM for diesel cars.
2) **Maintain a steady speed.** Fuel is primarily consumed when accelerating. Constantly breaking and accelerating will use more fuel than maintaining a steady speed. It also has a positive influence on exhaust emissions, traffic safety and flow.
3) **Anticipate traffic flow and avoid frequent starts and stops.** Adjusting the speed to traffic lights, turns and other vehicles in good time will make it easier to maintain a steady speed.
4) **Decelerate smoothly.** Slow down by using the engine brake or the neutral gear in-stead of the actual brakes. Modern vehicles use little ~~to~~ no fuel when using the engine brake, i.e. the vehicle is in gear and the accelerator is released. It also reduces wear and tear and reduce exhaust emmisions, increase traffic safety and flow.
5) **Accelerate moderatly.** Rapid acceleration especially at high speeds consumes much fuel, and one should accelerate at low gears with the throttle at half position.
6) **Eliminate idling.** It is more fuel efficient to switch off the engine than leaving the engine running. The average modern vehicle use about 0.5 liters per hour (l/h) during idling.
7) **Drive at or below the speed limit.** Fuel consumption increases at higher speeds.
8) **Do not press the accelerator when switching on the engine.** This is not neccesary in modern vehicles and only consumes fuel.
9) **Approach curves at correct speed and in the highest possible gear.** This will reduce the need for acceleration after the curve and improve traffic safety.
10) **Minimise extra weight and air resistance.** Both increase the load on the engine and thereby increse fuel consumption.
11) **Maintain correct tyre pressure.** Incorrect tyre pressure increases the rolling resistance and thereby the fuel consumption.
12) **Avoid fuel consumption accessories.** Air-conditioning and other accesories consume fuel.

IV. Data Foundation

A number of data sources are avaiable with information about vehicles.

A. Global Positioning System (GPS) Data

GPS~~'s~~ provide spatio-temporal information with high accuracy and reliablity at a low cost. GPS data is therefore often used when analysing driving behaviour and patterns because much data exists.

GPS data records a vehicles latitude and logitude position, speed and direction at some UTC time with some frequency. With such information it will for example be possible to analyse how well the driver is at keeping a steady speed (advice 2) and how he accelerates and decelerates (advice 4 and 5). By comparing the positions with a map we will also be able to analyse how well the driver analyses the traffic flow for example avoids stopping at traffic lights (advice 3). The coordinates can also matched to road segments on a map, from which one for exampple can see the types of roads that are used.

B. CANBus Data

CANBus data allows access to the state of ~~the electronic devices in~~ a vehicle giving more detail information about the state of the vehicle. This allows more detailed analysis of driving behaviour. CANBus data always annotates GPS data, but as of today, little GPS data with CANBus information is available.

CANBus data can include many different values, here we only mention the most common. The engines rounds per minute (RPM) will indicate the load on the engine, e.g. if the vehicle is turned off, idling or under high load. The current gear can be utilised to understand if the driver drives in neutral gear and changes gears at the correct places. Knowing the driving distance is also usefull and can be access through the vehicles mileometer. Fuel consumption is often avaiable in different formats, i.e. the fuel level in the tank, the instantaneous fuel consumption and the total fuel consumed. Instantaneous fuel consumption is estimated based on other CANBus data such as RPM and fuel flow. This makes it a good estimate of fuel consumption at drive time, but it is not useful and too inaccurate at an aggregate level. The total fuel consumption is more accurate when looking at consumption over time. The acceleration can be avaliable in the CANBus data, but can also be calculated from the speed. The position of the throttle indicates how agreesively the vehicle is driven. An engine works best at certain temperatures, and this temperature is also available through the CANBus.

C. Avaliable Data Foundation

The data set contains records from four real-life vehicles of a minibus type. All vehicles are assumned to be comparable based on statements from the data provider. Table II list the number of records for each vehicle and the time the data expands over. About 90% of the data is recorded with 1 Hz frequency, the remaning is collected at ~~larger~~ frequencies (See Figure 2).

In the following, we will be using 8 of the data values provided in the data set. The remaining are either lacking data, the data is erroneous or not usable in this context. Let **r** be a recording and **r**.**vid** be the vehicle identifier, **r**.**time** be the timestamp of the recording, **r**.**lng** and **r**.**lat** be the longitude and latitude position, **r**.**speed** be the speed in km/h as an integer, **r**.**RPM** be the RPM of the engine, **r**.**kmcounter** be the read-out of the mileometer and **r**.**fuel** be the total fuel consumption of the vehicle with a granularity of 1 ml. **r**.**fuel** can on rare instances be measured incorrectly. If the GPS looses signal, then the speed values might be set to zero or interpolated to smoothly decrease and the smoothly increase. Acceleration is calculated from the speed, and these errors sometimes leads to very unrealistic acceleration values (See Table XVI in appendix). To account for this we even out the

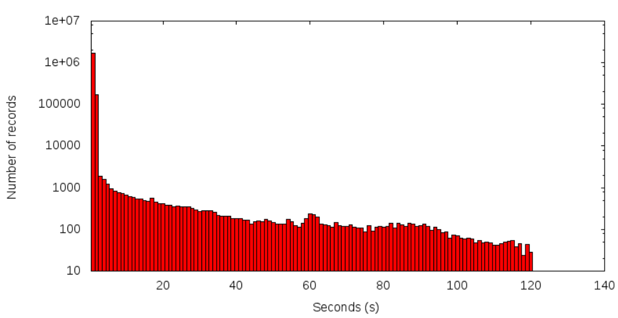

Figure 2. Data frequency

Vehicle id	Number of records	Total time span (s)	Total time span (days)
1	1,828,107	19,955,136	266.04
2	1,760,566	20,633,200	265.97
3	931,119	20,653,811	252.76
4	1,717,139	20,945,256	267.76
Total	6,236,931	21,294,798	271.51

Table II. VEHICLE STATISTICS

speed values if the acceleration is too low or too high, i.e. below $-10m/s^2$ or above $3m/s^2$. Algorithm 1 shows how the new speed vaule is calculated from the original values. Line 1 orders all records for the trip on their timestamp. In line 2-3 we begin looping all records in the trip except the first as we cannot calculate the acceleration for that. In line 4 we use Algorithm 2 to calculate the acceleration from the previous record to the current record. In Line 5 we check if the accelerration is out of the realistic values. If they are, we continue to calculate the acceleration from the previous record to the next record in line 6. If this acceleration is within the realistic values, then we interpolate the curent speed from the previous and next record using the algorithm 3 line 8-9. The value is saved in a temporary column and is hence not used in the next iterations of the algorithm. If $acc2$ is not within realistic values then the record is discarded and nspeed is set to null. In line 14-15 we continue with the next record. Finally, in line 16-18, we update speed to the temporary values. Algorithm 3 performs a simple linear interpolation. It uses four arguments, first the dataset R, then the index to interpolate r, and finally the two indexes to create the interpolation from $r1, r2$. Line 1 calculates the slope and line 2 calculate the interpolated value.

Algorithm 1 Calculate Speed Mod

1: $R =$ **trip**.$timeOrderRecords$
2: $i = 1$
3: **while** $i < len(R)$ **do**
4: $\quad acc = CalculateAcc(R[i-1], R[i])$
5: $\quad$ **if** $acc < 3$ **or** $acc > 3$ **then**
6: $\quad\quad acc2 = CalculateAcc(R[i-1], R[i+1])$
7: $\quad\quad$ **if** $acc2 < -10$ **and** $acc2 > -10$ **then**
8: $\quad\quad\quad s2 = InterpolateSpeed(R, i, i-1, i+1)$
9: $\quad\quad\quad R\_nSpeed = s2$
10: $\quad\quad$ **else**
11: $\quad\quad\quad R\_nSpeed = null$
12: $\quad\quad$ **end if**
13: $\quad$ **end if**
14: $\quad i++$
15: **end while**
16: **for** r **in** R **do**
17: $\quad r\_speed = r\_nSpeed$
18: **end for**

Algorithm 2 CalculateAcc(r1,r2)

1: $acc = ((r2_{speed} - r1_{speed})/(r2_{time} - r1_{time}))/3.6$
2: **return** acc

Algorithm 3 InterpolateSpeed(R,r,r1,r2)

1: $h = (R[r2]_{speed} - R[r1]_{speed})/(R[r2]_{time} - R[r1]_{time})$
2: $g = R[r1]_{speed} + (h * (R[r]_{time} - R[r1]_{time}))$
3: **return** g

The tool M-GEMMA [13] is used to match each record to a road segment from a map from OpenStreetMap[2] ~~using the latitude and longitude coordinates~~. The map-matching process uses a collection of records to match records to segments and annotates the data set with a **r**.**segmentkey** refering to a road segment on the map and a **r**.**mdirection** being either **Forward** or **Backward** on the segment. M-GEMMA filters out 33 % of the records due to various criteria (e.g. records too far away or opposite headings) and these records are not map-matched to a road segment.

Some of the advices from Section III can be evaluated with the avaliable data and some cannot. Table III gives an overview which advices can be evaluated with what data. The category 'Other' indicates that aditional information not avaiable in the data set is necessary. Advice 2, 6 and 7 can be evaluated solely on the provided data set. Advice 1 requires both the state of the gear and the RPM, and as the gears are unavailable, this advice cannot be evaluated properly. Anticipating traffic flow (advice 3) include several aspects, some of which can be evaluated ~~som some of which cannot~~. One major aspect is adjusting the speed to traffic lights, such that the driver avoids stopping. This can be evaluated from the data set. Other aspects, such as adjusting speed to other vehicles is not possible. I is, however, possible to evaluate the impact of the traffic density by looking at which roads is driven and what the corresponding fuel efficiency is. Accelerating moderatly (advice 5) can~~, to some extent~~ be evaluated on this data set, but the gears would have provided valuable information. Advice 4 about smooth deceleration requires knowledge of the gears and breaks as this advice mainly is about using the gears and breaks to slow down. It can hence not be evaluated. Advice 8 requires the possition of the throttle, which is not available. Approching curves at correct speed and gear (advice 9) is difficult to evaluate with this data set. Too much of the required information is lacking. No evaluation can be made of advice 10, 11 and 12 as they require other data than what is available.

Advice	GPS	CANBus	Map	Other
1: High gears	-	✓	-	✓
2: Steady speed	✓	-	-	-
3: Anticipate flow	✓	-	✓	✓
4: Deceleration	✓	✓	[illegible]	✓
5: Acceleration	✓	-	-	✓
6: Idling	✓	✓	-	-
7: Speed limit	✓	-	✓	-
8: Startup	✓	✓	-	✓
9: Curves	✓	-	✓	✓
10: Weight & air	-	-	-	✓
11: Typ[illegible]ure	-	-	-	✓
12: Acc[illegible]s	-	[illegible]	-	✓

Table III. WHICH ADVISES CAN BE EVALUATED?

V. DATA GROUPING

Only grouping the data on vehicles will give too few and too diverse groups of which it will be difficult to make usable conclusions. The data therefore needs to be grouped into smaller units. In the following we will use two different grouping strategies, periods and trips, explained in the sections below. Figure 3 shows the two concepts. The top lines indicate three trips where the "gaps" represent time between two trips. A trip can thereafter contain smaller periods indicated by the boxes below. A period is a stretch of time where some property holds, e.g. the vehicle drives at the same speed or the vehicle is idling.

A. *Trips*

This temporal and sometimes spatial grouping looks primarily on the time difference between trips, the length of the trip and sometimes the location of the vehicle. The data set is

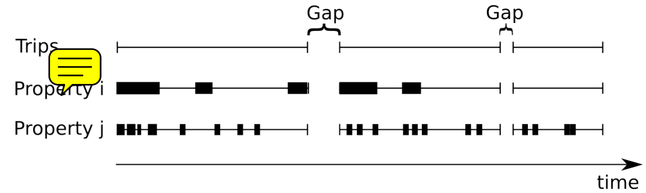

Figure 3. Example of periods and trips

split into trips by annotating each record with a trip identifier, $\mathbf{r}.\mathbf{tid}$. A trip, $\mathbf{trip}_i$ is defined as a consecutive sequence of at least 30 records with the same vehicle identifier where the engine is turned on and any two consecutive records are within 120 seconds.

$$\begin{aligned} \mathbf{r}_{j+1}.\mathbf{time} - \mathbf{r}_j.\mathbf{time} &< 120 \\ |\mathbf{trip}_i| &\geq 30 \\ \mathbf{r}_j.\mathbf{tid} = \mathbf{r}_{j+1}.\mathbf{tid} &= \mathbf{trip}_i.\mathbf{tid} \\ \mathbf{r}_j.\mathbf{vid} = \mathbf{r}_{j+1}.\mathbf{vid} &= \mathbf{trip}_i.\mathbf{vid} \end{aligned}$$

where j ranges over the records in the trip.

Idle time, i.e. when the engine is running but the vehicle is not moving (see Section XI), is an important factor for fuel consumption, and we therefore need to ensure that these records are included in the trips. A trip is hence defined from when the engine of the vehicles engine is running, that is when $\mathbf{r}.\mathbf{RPM} > 0$. In order not to split a trip into two just because the engine stalls, we say that a trips ends when the time cap between two consecutive records is too large. Figure 4 shows the number of trips when varing the time gap from 5 seconds between two trips to 200 seconds. We see that the curve flattens around 120 seconds and we choose this as the gap. Short trips with few records will not give a usable idea of which factors influence fuel consumption. Figure 5 show the number of trips varying the minimum number of records in a trip. The curve flattens around 30 records, which in most cases will correspond with 30 seconds. A similar test using time as the minimum requirement on trips show no clear result.

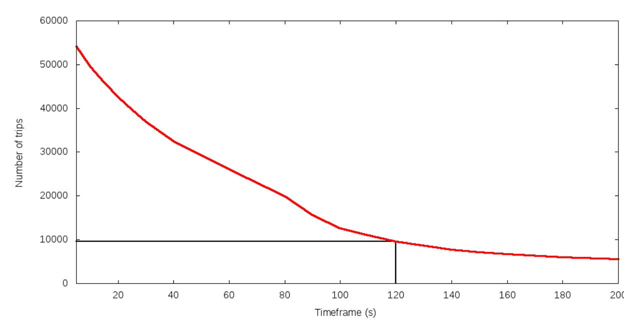

Figure 4. Number of trips at different timeframes

Vehicle id	Time span of trips s	$days$	Kilometers driven km
1	2,154,336	24.93	18,877.88
2	2,198,987	25.45	23,069.04
3	1,159,756	13.42	17,356.94
4	2,224,390	25.75	28,705.04
Average	1,934,367.25	22.39	22,002.22

Table IV. TRIP STATISTICS

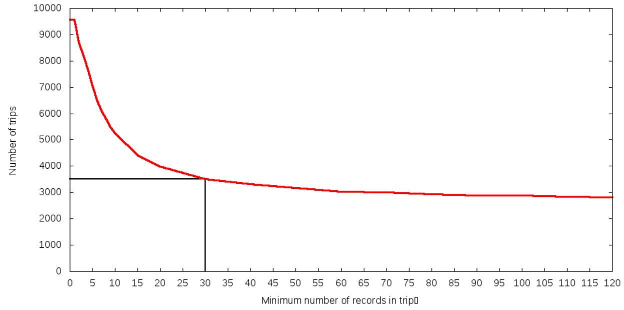

Figure 5. Number of trips at different lengths

B. Periods

It will some times be more interesting to look at records with a similar propery than looking solely at trips. Let a period be a sequence of consecutive records within a trip with some similar property. The example in Table V shows two period groupings on a small sample set. The property of period X is that the speed is exactly the same as that of the previouse record. The sample set hence contains 2 periods with this property. The propery of period Y is that the vehicle is accelerating which results in two different periods. Let $\mathcal{T}(p)$ be the length of period, p in seconds.

VI. Classifying Data

Fuel consumption is a measure of effectiveness, and how many kilometers per liter fuel (km/l) a vehicle drives will indicate how fuel efficient the vehicle is. The main goal of a vehicle is transportation and hence, the more kilometers one can drive per liter fuel, the cheaper it is. Let $\mathbf{trip}_i.\mathbf{kml}$ be the total number of km driven devided by the total fuel consumption of $\mathbf{trip}_i$.

Figure 6 plots the distributon of $\mathbf{trip}.\mathbf{kml}$ for all trips grouped in intervals of $0.25km/l$. All trips are classified into four classes based on their $\mathbf{trip}_i.\mathbf{kml}$ marked as vertical lines on the figure. The majority of the trips has a $\mathbf{trip}.\mathbf{kml}$ between 3.5 to 11.5 and the curve peaks at $8.125km/l$. A class 'outliers' is made of the trips with unusually low $\mathbf{trip}.\mathbf{kml}$, being those where km/l is less than $3.5km/l$. The trips in class 'outliers' are the irregular trips, e.g. very short trips or idling trips. The distribution of the remaining trips resembles a normal distribution. We split these remaining trips into three equally sized classes, 'low', 'medium' and 'high' each containing one third of the trips. Three classes are chosen as fewer classes makes it difficult to distinqush the more fuel efficient trips from the less, and having more classes makes it increasingly complex to understand for an end-user. The four classes are hence

$$\begin{aligned}
\text{'outliers':} \quad & 0 && \leq \mathbf{trip}.\mathbf{kml} < 3.5 \\
\text{'low':} \quad & 3.5 && \leq \mathbf{trip}.\mathbf{kml} < 7.08 \\
\text{'medium':} \quad & 7.08 && \leq \mathbf{trip}.\mathbf{kml} < 8.37 \\
\text{'high':} \quad & 8.37 && \leq \mathbf{trip}.\mathbf{kml}
\end{aligned}$$

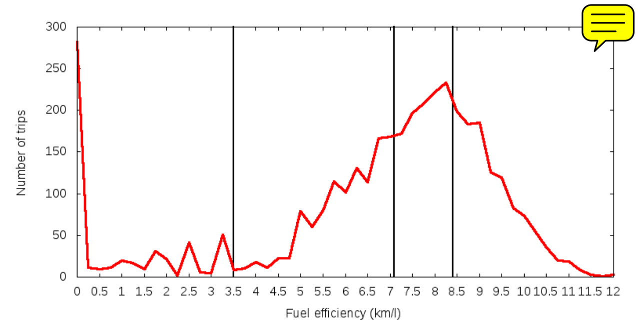

Figure 6. Distribution of all trips grouped by km/l in intervals of 0.25

Figure 7 plots $\mathbf{trip}_i.\mathbf{kml}$ for all trips ordered by time and grouped by vehicles with the four classes from Figure 6 marked by horizontal lines. When the trip is 0 km long then $\mathbf{trip}_i.\mathbf{kml} = 0$. Overall, the values are very consistent with what can be expected from minibusses. Some odd values can be seen around 2.5 and $3.33km/l$ where several trips have the exact same $\mathbf{trip}.\mathbf{kml}$. This is due to inaccuracies in the measurements of the kilometer counter on very short trips.

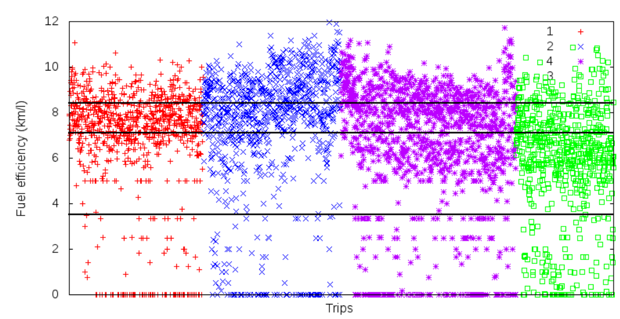

Figure 7. km/l for all trips

Table VI lists the fuel efficiency and the standard sample deviation of the four vehicles and of the total data set. Vehicle 3 is the most inefficient and vehicle 2 is the most efficient vehicle. Vehicle 1 and 4 lie close to the average.

VII. Accelerate Moderatly

Fuel consumption increases when accelerating especially at high velocities [11]. Acceleration is calculated from the speed

record id	speed	tid	Period X	Period Y
$\mathbf{r}_1$	59	0		a
$\mathbf{r}_2$	60	1	1	a
$\mathbf{r}_3$	60	1	1	
$\mathbf{r}_4$	60	1	1	
$\mathbf{r}_5$	63	1		b
$\mathbf{r}_6$	64	1		b
$\mathbf{r}_7$	67	1	2	b
$\mathbf{r}_8$	67	1	2	
$\mathbf{r}_9$	67	2		

Table V. Example of period grouping

Vehicle id	Average km/l	Standard Deviation
1	6.75	2.64
2	7.39	2.75
3	5.77	2.57
4	6.77	2.69
Average	6.73	2.72

Table VI. Fuel efficiency

and timestamp.

$$\mathbf{r}_{i+1}.\mathbf{acc} = \begin{cases} \frac{\mathbf{r}_{i+1}.\mathbf{speed} - \mathbf{r}_i.\mathbf{speed}}{\mathbf{r}_{i+1}.\mathbf{time} - \mathbf{r}_i.\mathbf{time}} \cdot \frac{1}{3.6} & \text{if } \mathbf{r}_{i+1}.\mathbf{time} - \mathbf{r}_i.\mathbf{time} \leq 2 \\ null & \text{otherwise} \end{cases}$$

Figure 2 shows that the most data is by far recorded with a frequency of 1-2 second but some of the data is recorded with a lower frequency. A frequency of 1-2 seconds is frequent enough ~~for reasonable~~ estimate~~s of~~ the acceleration, any higher will lead to very inaccurate results. The minimum frequency is hence chosen at 2 as this provide the best compromise between usable data and presision.

Figure 1 shows the speed of five trips accelerating and the associated fuel cost for a road segment as a function over time. The road begins right after a roundabout and the measured part shown in the graph is 0.7 km long. See Figure 34 for details of the area. The starting speed of the trips are almost the same, but the accelerations are quite different, which both results in different end speeds and fuel consumptions. The most accelerating driver use more than double the amount of fuel than the least accelerating driver. These examples show that the higher the accleration profile the more fuel is consumed. A figure with all trips driving on this road segment can be seen in Figure 38 in the appendix and a similar example from a diffrent road segment can be seen in Figure 39 and it location in Figure 35.

Looking at the fuel consumption in periods of acceleration results in the same tendency. We define the property of an acceleration period as always having a positive acceleration and that the period is at least 10 seconds long. Too high or too low acceleration values might occure because acceleration is calculated from the speed meassured by the GPS. This is partially accounted for by interpolating the speed values (see Section IV-C and Equation ??), but some errors still exists. Figure 8 shows the standard deviation on the average acceleration values of periods of some minimum length. The curve breaks around a minimum length of $10s$, and we choose this as the limit. The worst errors has been removed at $10s$, while the risk of removing usable data is mimimal.

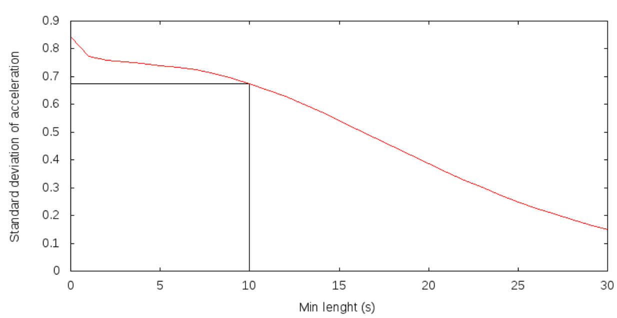

Figure 8. Number of positive acceleration periods at varying minimum lengths in seconds

Figure 9 shows the fuel consumption at different average accelerations with a plot for different starting speeds and Table VII shows the gradients of the plots. Only the regression lines are show for simplicity, see Figure 41 for data points. The fuel consumption clearly increases as the acceleration increases, but the slopes also increase slightly as the speed increases. Values above $90km/h$ are inaccurate due to lack of data. The graphs indicate that higher accelerations espcially at high speeds results in high fuel consumption.

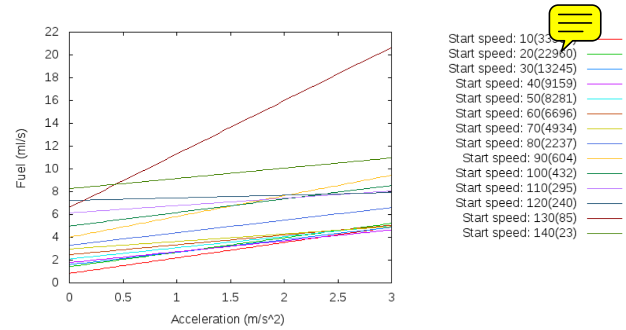

Figure 9. Fuel consumption at different accelerations and starting speeds

Figure 10 shows the normalised distribution of acceleration periods grouped by their average acceleration. All vehicles seem to accelerate mostly around $0.75m/s^2$. Vehicle 2 mostly accelerates moderatly around $0.625 - 0.75m/s^2$ and rearly have rapid accelerations compared to the other vehicles. Vehicle 1 also mostly accelerates between $0.625 - 0.875m/s^2$ but also has some rapid accelerations. Vehicle 4 generaly has more rapid accelerations and mostly accelerates at $0.75 - 1m/s^2$ Vehicle 3 does not have as high peaks as the other vehicles and his acceleration profile is more evenly spread with both higher and moderate accelerations. This might indicate that vehicle 3 use the least amount of fuel on accelerating. This figure does, however, not show the speed at which these accelerations are made. Figure 11 shows the average fuel consumption per second of the acceleration periods at various start speeds and accelerations for all vehicles. The x-axis shows the starting speed in ranges of $5km/h$, the y-axis shows the average acceleration of the period in ranges of $0.25m/s^2$ and the z-axis shows the fuel consumption per second of the acceleration period. The indivudial graphs for the four vehicles can be seen in Figures 42, 43, 44 and 45. I can be seen from Figure 11 that there is a strong correlation between speed and fuel consumption. The higher the speed, the higher the fuel consumption per second. A small correleation can also be seen between acceleration and fuel consumption, but this is less pronounced. The drop in fuel consumption at $20km/h$ and $2m/s^2$ might be due to lack of data.

Drawing conclusions on which vehicles accelerates moderately is difficult on this data set.

Starting speed	Gradient
10	2.9
20	3.0
30	3.1
40	3.0
50	3.2
60	3.4
70	4.7
80	5.9
90	2.4
100	9.9
110	2.2
120	6.7

Table VII. GRADIENTS OF GRAPHS IN FIGURE 9

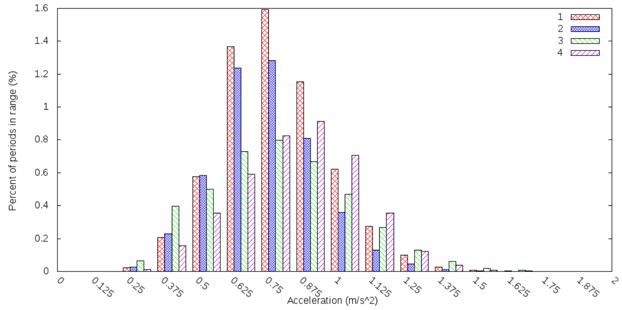

Figure 10. Number of accelerations for all vehicles

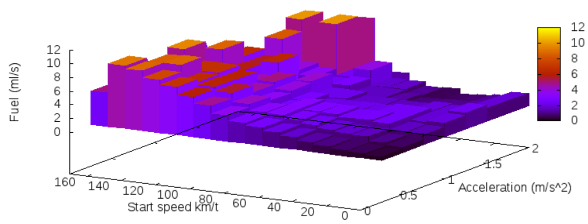

Figure 11. Fuel efficiency at start speed and acceleration

VIII. Maintain a Steady Speed

Driving at a steady speed is more fuel economic than an flucuating speed as more fuel is consumed when accelerating [11]. It is therefore interesting to evaluate how good the drivers are at maintaining a steady speed.

It is very difficult to drive at a constant speed for longer periods of time. The speed will always fluctuate with a few km/h due to changes in the road and weather conditions amongst others. From observing a small data set where cruise control has been used, we see that the speed only varies with $\pm 1km/h$. Observing data where cruise control has not be use, we see that an experienced driver is able to maintain a steady speed over a longer time period without cruise control but the speed tends to vary more. Most drivers can drive with a constant speed for a short period.

The property of a period of steady speed is that the speed does not vary with more that $\pm 1km/h$ from the speed at the beginning of the period (the *cruise speed*) for at least 20 seconds. The property is ilustrated in Figure 12 where the black boxes marks periods, and the thin black line marks the cruise speed.

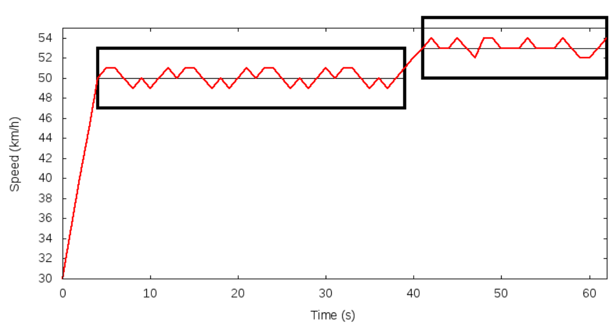

Figure 12. Example of two periods of steady speed

Figure 13 plots the number of records that maintain a steady speed over the minimum duration of the period with a plot for different speed variations. All four plots break at 20 seconds why this is chosen as the minum duration. There are more than twice as many records with a steady speed when a speed variation of $1km/h$ is allowed as opposted to requiring a constant speed with no fluctuations. Increasing the allowed variation to $2, 3$ and $4km/h$ does not increase the number of records as significantly. A speed variation of $1km/h$ is therefore chosen.

Figure 14 plots the class distribution of how much of all trips are at a steady speed as percent. It is clear that the trips that often maintain a steady speed primarily belongs to class 'high', and that all trips in class 'low' rearly maintains a steady speed. This indicates that the advice of maintaining a steady speed will reduce the fuel consumption.

Table VIII shows how long the vehicles maintains a steady speed and what that corresponds to in minutes per day where the driving times from Table IV is used. The numbers should therefore be read as if the vehicles drives 24 hours a day. Vehicle 3 is the vehicle with the worst fuel efficiency ($5.77km/l$) and the one that drives second rarest with at steady speed. This may indicate a connection, but vehicle 2, on the other hand, is the most fuel efficient vehicle but is not the one that drives most often with a steady speed being vehicle 4.

IX. Drive at or below Speed Limit

The fuel consumption depends on how fast one drives, and driving too fast will use more fuel. Figure 15 shows the fuel efficiency of 27 trajectories driving on a 11.1 km road section as a function of their average speed. The number of liters per km increase as the speed increases, supporting the claim that more fuel is consumed at higher speeds. Figure 16 show the l/km for all periods of steady speed at different cruise

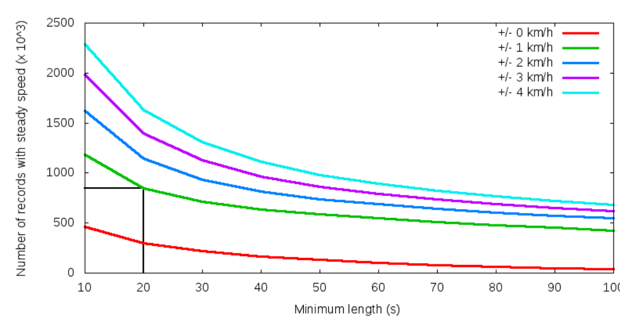

Figure 13. Steady Speed at varing minimum duration and speed variations

Vehicle id	Steady speed		
	s	$\%$	min/day
1	113,751	5.28	78.99
2	304,594	13.85	203.06
3	108,656	9.37	139.30
4	459,742	20.67	306.49
Avg.	246,685.75	12.29	181.96

Table VIII. Time spend maintaining a steady speed

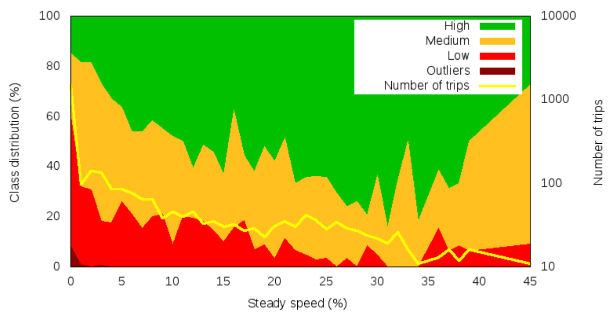

Figure 14. Class distribution of percentage in periods of steady speed

speeds. The odly similar values are due to speed only being recorded as integers. Again, the amount of fuel consumed per km increases as the speed increases but instances at low speeds also show a high fuel consumption per km. Accelerating at high speed is also expensive in fuel as seen in Figure 9. The higher the starting speed, then higher the fuel consumption per second and the slope of the curves also increases as the speed increases. High speeds hence results in higher fuel consumption.

Figure 17 shows how often the four vehicles breaks the speed limit and by how much. The y-axis plots the number of records with the corresponding speed breach normalised by the total number of records for that vehicle. Table IX lists the percentage of records where the vehicles breaks the speed limit. Vehicle 2 and 4 breaks the speed limit in about 13 % of his records and most of these are with small breaches below 10 km/h. Vehicle 3, on the other hand, breaks the speed limit on more than 25 % of the records and at much higher speeds. The highest breach is at 79 km/h above the speed limit. Vehicle 1 rearly breaks the speed limit, and when he does it, it is with small breaches.

As seen, driving too fast will reduce ones fuel efficiency, and the most fuel inefficient vehicle breaks the speed limit much more than the other vehicles. High speeds may contribute to this.

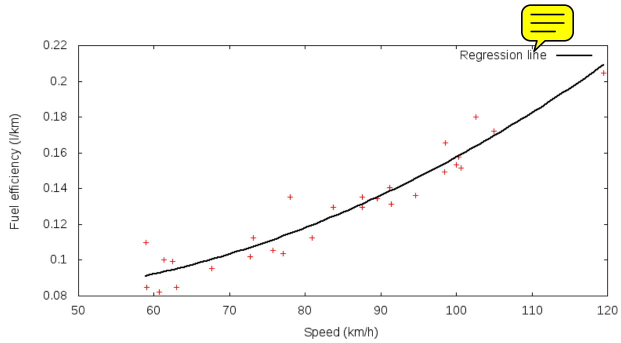

Figure 15. Fuel efficiency at different speeds

vid	Speed breach(%)
1	6.96
2	13.13
3	25.71
4	13.11

Table IX. SPEED BREACHES

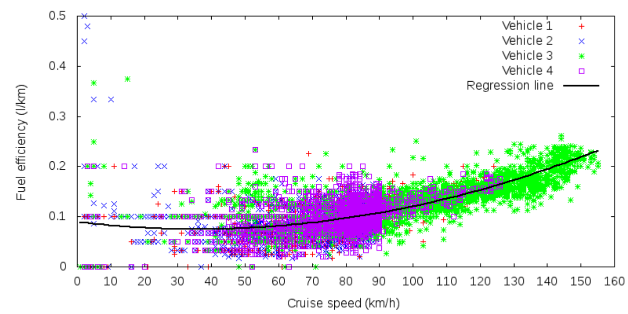

Figure 16. Fuel efficiency at different cruise speeds

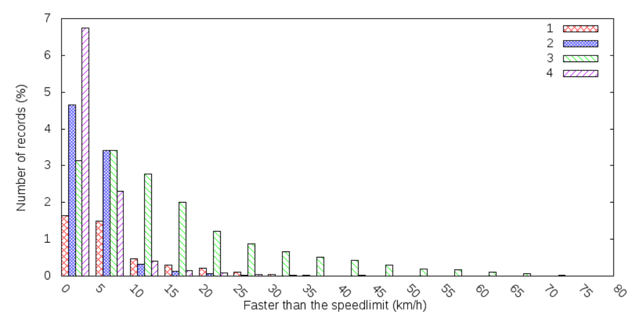

Figure 17. Breaking the speed limit

X. ANTICIPATE TRAFFIC FLOW

Anticipating traffic flow is a key factor for maintaining a steady speed and avoiding unnecessary accelerations. Avoiding stopping at traffic lights and adjust the speed to the expected phases of the light is one part of anticipating the traffic flow [12].

A. Avoid Traffic Lights

Traffic light data is collected from open street map, that contains a fair number of traffic lights but not all, especialy the smaller traffic lights are missing. Algorithm 4 details the procedure for counting traffic lights in a trip where $TLInRange$ finds the closest traffic light within range and returns null if none is found. Line 1 orders the records of the trip on its timestamp. Line 2-4 setup initial variables. Line 5 loops the individual records in chronological order on timestamp. Line 6-8 test if the record are within a 25 meters radius of a traffic light and if so, add one to the counter and sets the variable inL indicating that the vehicle are now inside the area of a traffic light. Line 9-11 test if the vehicle have left the traffic light and then resets the variable inL. Line 12-15 test if while the vehicle are inside a trafficlight if the record have a speed of zero then we count it as a full stop and increment the counter $redCounter$. To avoid favouring shot trips, the number of traffic lights visited is divided with the length of the trip. This is done on line 17.

This results in traffic lights overlapping only being counted once and is a neccesary limitation as OpenStreetMap provides multiple identifiers for the same traffic light.

The 25 meter radius is determined from the graph in Figure 18. It is clear that the average number of traffic lights a vehicle crosses stablises after 25 meters . Hence, vehicles crossing a trafficlight without being counted is very unlikely.

Algorithm 4 $countTrafficLights(\textbf{trip})$

```
R = trip.timeOrderRecords
TL = all traffic lights
inL, red = False
counter, redCounter = 0
while r = R.popFirst() do
    if not inL and TLInRange(TL, r, 25) then
        inL = True
        counter+ = 1
    else if not TLInRange(TL, r, 25) then
        inL = False
    end if
    if not red and inL and r_speed = 0 then
        red = True
        redCounter+ = 1
    end if
end while
return counter/trip.kmcounter
```

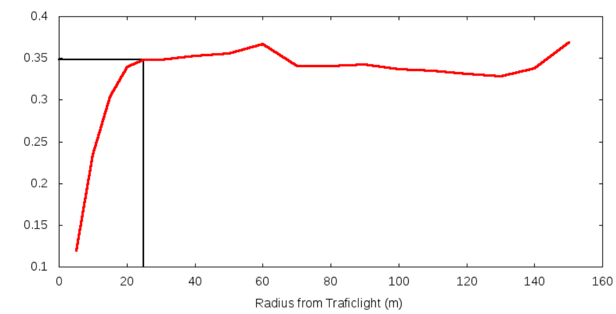

Figure 18. Size of traffic lights

Figure 19 plots the percentage of trips in the four classes driving through different concentrations of traffic lights. From this graph it is clear that the trips in class ‘high’ with a high km/l are mostly driving in areas with few traffic lights, whereas trips driving in areas with many traffic lights mostly are in class ‘medium’ or ‘low’.

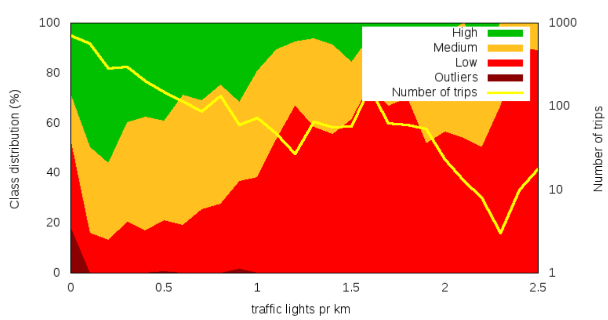

Figure 19. Traffic lights per kilometer

Figure 20 shows 16 trips driving a 0.7 km straight road containing a single traffic light and few small side roads. All trips are driving in the timespan from 9:00 to 15:00. From 20 to 46 seconds some of the trips stop, presumably because of a red light. The graph shows the time each trips takes to drive the 0.7 km road, there speed and the fuel cost. It is clear that the trips that stop are using more fuel than the other trips. Defining a traffic light related stop as in Algorithm 4 we get the average fuel consumption for the 0.7 km road section from these 16 trips as in Table X. A similar example can be seen in Figure 21.

Vehicle id	Time span of trips s	$days$
1	2,154,336	24.93
2	2,198,987	25.45
3	1,159,756	13.42
4	2,224,390	25.75

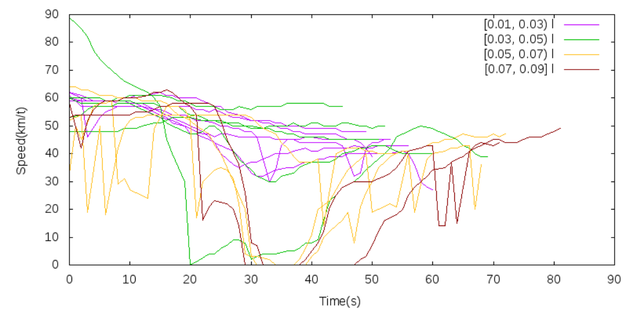

Figure 20. Cost of stopping at a traffic light

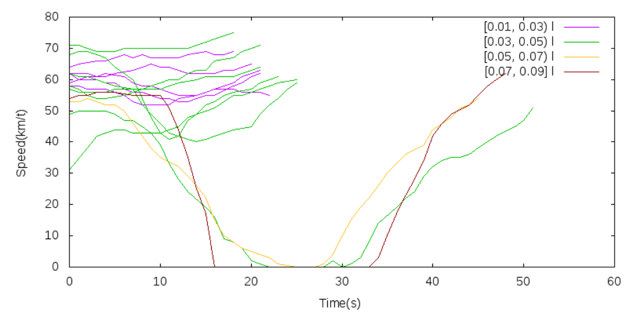

Figure 21. Cost of stopping at a traffic light

B. Road Types

Road categories are devided into three groups based on the Open Street Map (OSM) road categories as show in Table XI.

Motorways are unidirectional roads with no traffic lights and no crossing traffic. They also usually have higher speed limits from 110-130 km/h. Main roads contains all main roads both in and outside of the cities. They usually have a speed limit from 50-80km/h. Small roads are mostly found in residential areas or connecting smaller cities. The speed limit can vary from 10 to 80 km/h. Figure 22 shows the distribution

Figure	With stop		Without stop	
20	$64ml$	$72.2s$	$33\ ml$	$53s$
21	$60\ ml$	$48s$	$31\ ml$	$21.3s$

Table X. FUEL CONSUMPTION AND TRAVEL TIME AT A TRAFFIC LIGHT

Road categories	OSM categories values
Small	32-63
Main	13-31
Motorway	11-12

Table XI. ROAD CATEGORIES FROM OSM

of trips with different percentage driving on the small roads. It is clear that the ‘low’ trips have a high percentage driving on small roads and the ‘high’ group are avoiding the small roads. In contrast Figure 23 shows that the ‘high’ group drive more on the normal roads.

XI. Avoid Idling

Avoiding idling or minimising idle time is a factor in eco-driving as fuel is still consumed when the engine is running even though the vehicle is not moving. The driver is hence consuming unneccesary fuel when idling.

We say a vehicle is *stopped* iff. the RPM i above zero and the speed is zero for at least 2 consecutive recordings.

$$\begin{aligned}\mathbf{r}_{i+1}.\mathbf{stop} = true \text{ iff.}\\ &\mathbf{r}_i.\mathbf{RPM} > 0 \wedge \mathbf{r}_{i+1}.\mathbf{RPM} > 0 \wedge\\ &\mathbf{r}_i.\mathbf{speed} = 0 \wedge \mathbf{r}_{i+1}.\mathbf{speed} = 0\\ &\mathbf{r}_{i+1}.\mathbf{kmcounter} - \mathbf{r}_i.\mathbf{kmcounter} = 0 \quad (1)\end{aligned}$$

A vehicle is hence stopped when for example waiting at a red light, in a queue or parked with the engine turned on. A *stopped period* is a sequence of records where $\mathbf{r}.\mathbf{stop}$ is true as per Section V-B. But when looking at idling, we are not interesseted in all stopped periods. All stops near traffic lights is not idling and short stops are neigher.

Figure 24 shows the total number of stopped periods with different minimum durations of the periods. The curve flattens around 250 s, a little over 4 minutes. An *idle period* is therefore a stopped period that longer than 250 s and not near a traffic light. Involuntary stopped periods such as queues~~, duty to give way and alike~~ are thereby reduced.

Figure 25 and Figure 26 show~~s~~ the sum how often the veliceles are stopped outside traffic lights and for how long. The periods are combined into ranges of 100 seconds and displayed on the x-axis, e.g. 100.0 indicates the time range 100-199 seconds. Most of the stops are short stops of 100 seconds or less. This correlates with the longest circulation times of traffic ligths[16]. The longer stops of more than 100 seconds does not occur as often, but sums up to almost the same amount of time as spent in the short stops at or below 100 seconds. Vehicle 3 do not spend as much time with short stops as the other vehicles, but, on the other hand, also spends more time with longer stops that the others. This might be because vehicle 3 drives more outside of the cities.

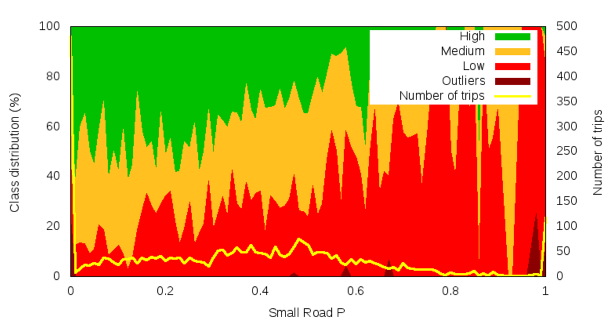

Figure 22. Class distribution of driving on small roads

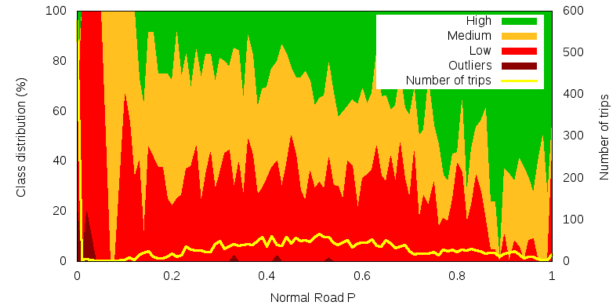

Figure 23. Class distribution of driving on normal roads

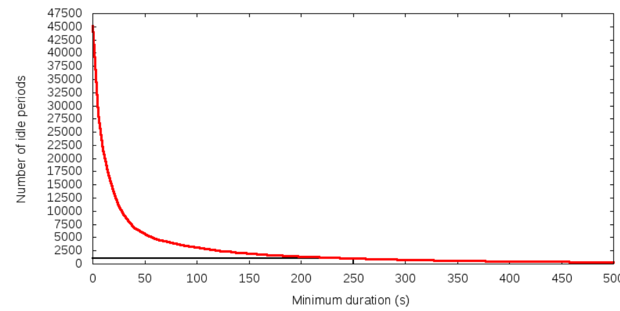

Figure 24. Minimum idle duration

Figure 27 shows how much fuel is consumed in the idle periods. Fuel consumption is shown on the y-axis and the number of seconds of the idle period is shown on the x-axis. A linear regression line has been plottet for each vehicle We see that few idles for more than 1300 seconds ($\sim$ 21 minuts) but that these use between 0.5 and 2 liters of fuel each time. Following the regression lines it can be estimated that between 0.85 and 1.25 liters of fuel are used per idling hour.

Table XII shows how much each vehicle idles and how much fuel is used using the driving times from Table IV. The numbers should therefore be read as if the vehicles drives 24 hours a day. Vehicle 3 idles the most (15 % of the time) and consumes about 4 and a half liter of fuel a day on idling. This corresonds well with the fact that vehicle 3 is the most fuel ineffcient vehicle. Vehicle 4 idles the least and consumes least fuel on idling, but vehicle 2 and 3 are close. Vehicle is the most fuel efficient vehicle of the four, but these results suggest that other factors than idling contributes to this.

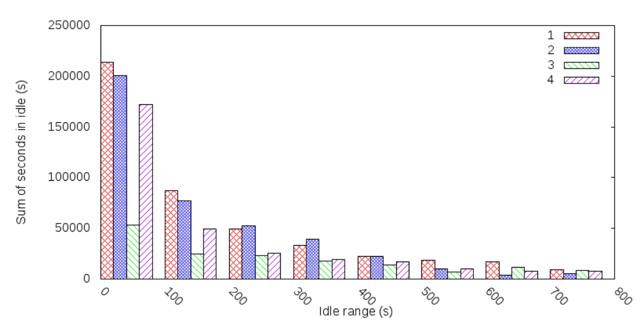

Figure 25. Number of idle periods at different ranges below 800 s

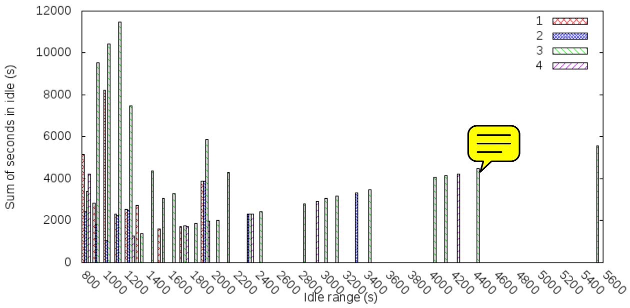

Figure 26.   Number of idle periods at different ranges above 800 s

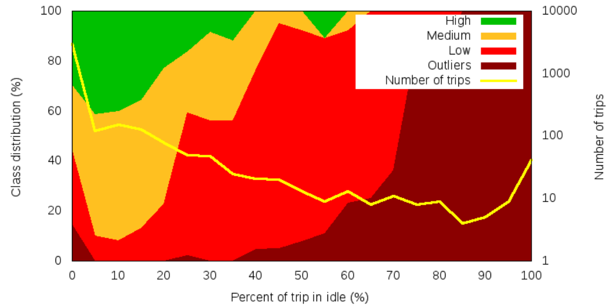

Figure 28.   Class distribution of percentage in idle periods

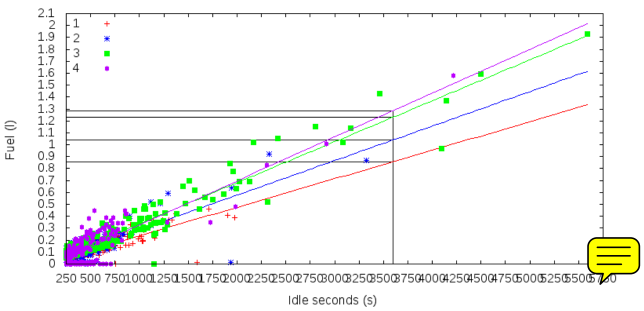

Figure 27.   Fuel comsumption when idling

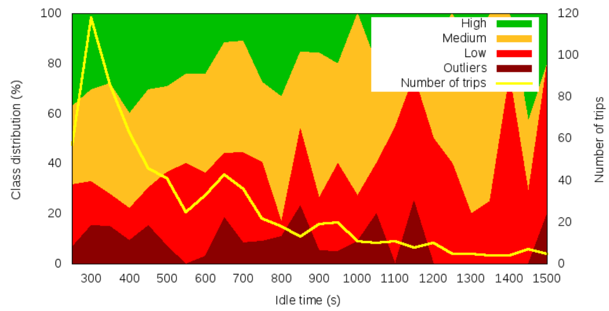

Figure 29.   Class distribution of time in idle periods

It will also be interesting to investigate whether how much of a trip is in an idle state has an infulence on the trips km/l. Figure 28 shows the class distribution of all trips grouped by how much of the trip is in an idle period. The yellow line indicates the number of trips on a logaritmic scale. We clearly see that of the trips with a small idle percentage are mostly in the class 'high' and vice versa. The classes 'low' and 'outliers' consists of trips that idles most of the time. This strongly suggests that there is a correlation between idle and fuel efficiency. Figure 29 shows the class distribution over the length of the pure idle periods split into ranges. We do not see the same clear distinction in this plot as for Figure 28. This might indicate that the trips from class 'outliers' and 'low' do not necesarily idle for long periods but idles more often.

XII. Recapitulation

A treemap over the four vehicles. Pinpointing where they could improve. What are the expected savings?

An interesting remark about Figure 7 is that vehicle 40 tends to become more fuel efficient over time and that vehicle 67 becomes slight less fuel efficient over time. The reason is unknown.

	Idle			Fuel	
Vehicle id	s	%	min/day	l	l/day
1	150,763	6.10	104.70	35.12	1.46
2	122,890	5.59	81.93	35.12	1.40
3	176,522	15.22	226.31	59.21	4.55
4	90,919	4.09	60.61	26.27	1.05
Average	135,273.5	7.97	118.39	38.93	2.12

Table XII.   Time and fuel consumption in idle

A. Are the Vehicles Compareable

It has been assumed until now that the vehicles are comparable. This assumption is challenged in this section.

Statistics over the RPM of the four vehicles when idling can be see in Table XIII. The RPM is around 852 and we believe that, even though the deviations are different, the vehicles are comparable on this parameter. Similar data for the fuel consumption per second when idling can be seen in Table XIV.

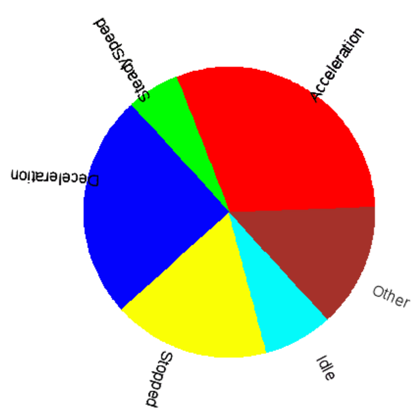

Figure 30.   Summary of the behaviour of vehicle 1

Figure 31. Summary of the behaviour of vehicle 2

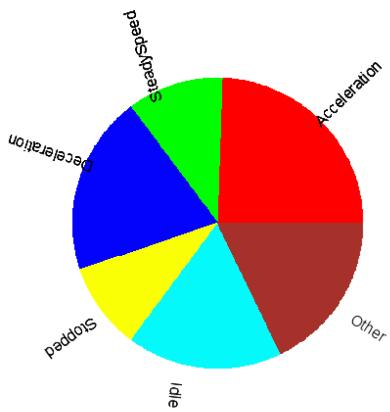

Figure 32. Summary of the behaviour of vehicle 3

XIII. Experience with data

We have found that there are certain requirements to the GPS and CANBus data before usable and precise analyse of the driving behaviour can be made.

Speed data is used in many connections and has a great infuence on the results. The speed values are only recorded as integers, which results in inprecise calculations of for example acceleration. The speed values are sometimes also incorrect

Vehicle id	RPM Min	Avg.	Max	Std. deviation
1	79	852.67	3067	54.81
2	54	851.95	3413	37.10
3	42	851.86	4149	29.95
4	51	852.34	3204	36.57

Table XIII. RPM when idling

Vehicle id	Fuel consumption (ml/s) Min	Avg.	Max	Std. deviation
1	0	0.23	0.41	0.07
2	0	0.28	0.56	0.10
3	0	0.33	0.59	0.09
4	0	0.26	0.83	0.19

Table XIV. Fuel consumption when idling

Figure 33. Summary of the behaviour of vehicle 4

when the GPS device looses signal (See Table XVI). The speed can be set to zero or some interpolation can be made. The fact that speed erroneously can be set to zero has resulted in the last requirement of the property of stopped periods (See Definition 1). It can be difficult to detect some of these errors, due to the interpolation, and the errors create false accelerations. One way to handle these errors could be to compare speed values from the GPS with the read-out from the speedometer which is a CANBus value. The GPS speed will on many occations be the most correct value, but errors might be easier to detect if data from the speedometer where avaiable as well. This was not the case in the available data set.

The fuel consumption will have to have a certain percision. The original data set contained six vehicles of which two only has a precision of $500ml$ in fuel consumption. The remaining four has a precision of $10ml$. A precision of $500ml$ will result in very inaccurate calculations as the amount of fuel consumed often is a few liters per kilometer, especially when idling or driving slowly. The fuel consumption of small periods will often randomly either be $0ml$ or $500ml$. This is not usable in these analysis, and we chose to descard the two vehicles with too inprecise fuel measurements.

The mileometer only meassures kilometers with one decimal point, i.e. $100m$ precision. In many cases this is enough, but it will result in inaccurate calculations over short periods especially at slow speeds. More precision on the mileomter will be required in these cases.

The gears were not available, and prevented us in analysis some of the eco-driving advices. For more detailed analysis, gears and other measurements will be required. These might be position of the throttle, road gradients make and model of the vehicle, and others.

The available data set contained an acceleration value with is not used in the analysis. The nature of the values indicate that it might be meassurements from an accelerometer, but the units are unknown. An acceleration of 50 were also often recorded eventhough the vehicle was maintaining the same speed. Due to many unanswered questions about this acceleration value, we chose to disregard it in the analysis.

XIV. Conclusion

XV. Future Work

The next steps in this process will be to expand the analysis to a larger data set with more vehicles recorded over a longer time period. This will allow more detailed analysis and hence conclusions.

More data values will also be necessary in order to evaluate all of the eco-driving advices. Gears, for example, are essential for several of the advises, but other information such as the gradient of the road might also provide usable data.

XVI. Acknowledgement

We would like to give our thanks to ProTracking[3] for providing data for this project.

Ove for map-matching the data set.

???

XVII. Appendix

Figure 34 shows a map of a road segment 0.7 km long indicated by the arrow. It is located 12 km south of Herning city denmark and has a slight curve. Vehicles first exit the roudaboud and then accelerate along the road. The speedlimet on the road is 80 km/h.

Figure 34 shows a map of a road segment 0.8 km long indicated by the arrow. It is located 2 km east of Herning ~~city~~ denmark and is ~~completely~~ straight. Vehicles first exit the roudaboud and then accelerate along the road. The speedlimet on the road is 80 km/h.

Figure 34 shows a map of a selected road segment 0.8 km long indicated by the arrow. It is located in Tjøring 1 km north of Herning ~~city~~ denmark and is completely straight. Only a sigle trafficligt exist on the selected road segment and 2 small dead end side roads. The remaning side roads are closed off. The speedlimet on the road is 50 km/h.

Figure 37 shows a map of a selected road segment 0.4 km long indicated by the arrow. It is located 1 km west of Herning city denmark and is completely straight. Only a sigle trafficligt exist on the selected road segment and a few small side roads are connected. The speedlimet on the road is 60 km/h before the traffic light and 80 km/h after.

Figure 38 shows the speed of 39 trips accelerating and the associated fuel cost for a road segment as a function over time. The road segment can be observed in Figure 34.

Figure 38 shows the speed of 85 trips accelerating and the associated fuel cost for a road segment as a function over time. The road segment can be observed in Figure 35.

Figure 40 shows the distribution of trips with from 0% to 10% records driving on the motor moterways. It is clear that there is insufficient data of trips driving on moterways.

Figure 41 shows the fuel consumption at different average accelerations with a plot for different starting speeds including

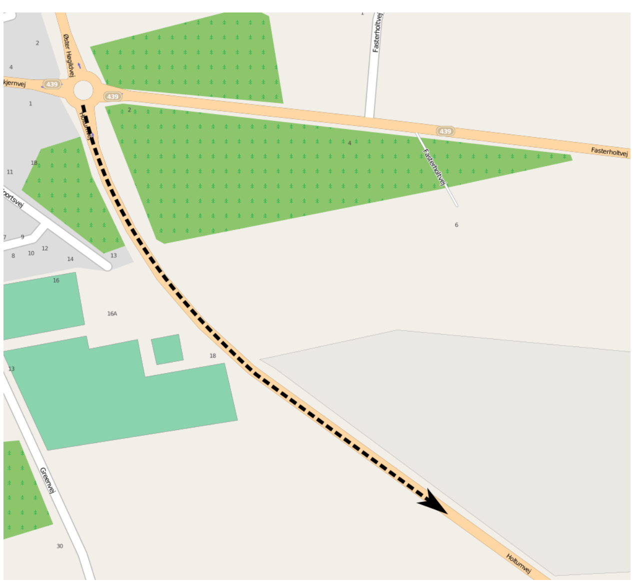

Figure 34. Road segment where trips are accelerating. 12 km south of Herning city

Figure 35. Road segment where trips are accelerating. 2 km east of Herning city

Figure 36. Road segment where trips are driving through a traffic light represented by the black dot. 1 km north of Herning city

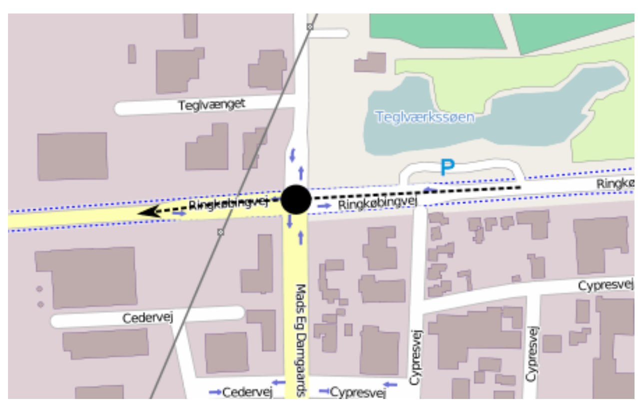

Figure 37. Road segment where trips are driving through a traffic light represented by the black dot. 1 km north of Herning city

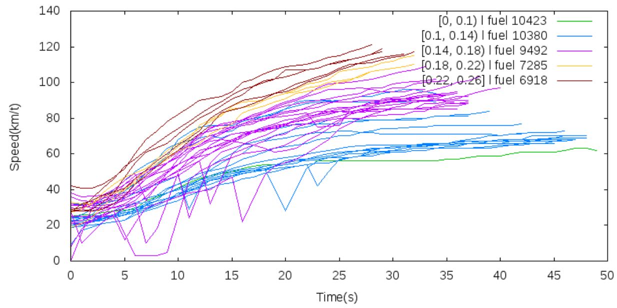

Figure 38. Trips driving the same road segments with diffrent accelerrations

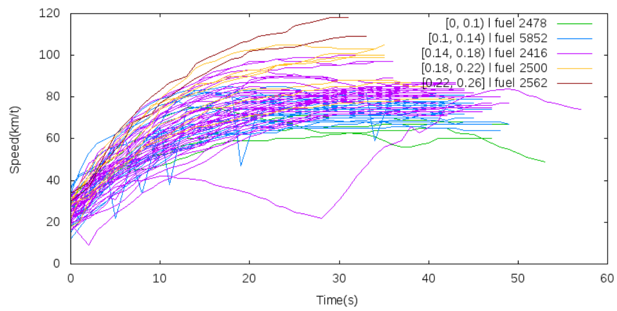

Figure 39. Trips driving the same road segments with diffrent accelerrations

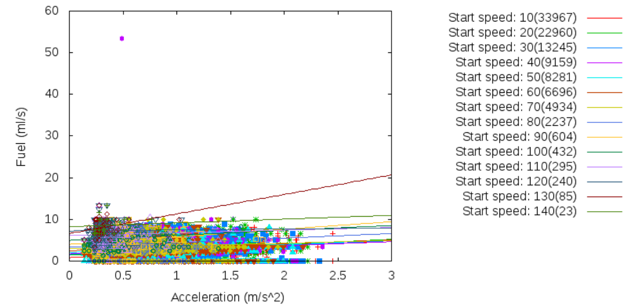

Figure 41. Fuel consumption at different accelerations and starting speeds

Timestamp	Speed	Modified speed	RPM	Acceleration
2013-02-01 12:13:14	89	89	2253	39.2
2013-02-01 12:13:16	89	89	2248	39.6
2013-02-01 12:13:17	89	89	2251	40.4
2013-02-01 12:13:18	6	60	2247	41.2
2013-02-01 12:13:19	30	27	2248	41.2
2013-02-01 12:13:20	47	30	2251	40.4
2013-02-01 12:13:21	30	30	2247	42
2013-02-01 12:13:22	30	30	2246	44
2013-02-01 12:13:23	74	57	2245	45.6
2013-02-01 12:13:24	83	83	2250	44.8
2013-02-01 12:13:25	87	87	2251	44
2013-02-01 12:13:26	88	88	2251	44
2013-02-01 12:13:28	89	89	2249	43.2
2013-02-01 12:13:29	89	89	2252	41.6
2013-02-01 12:13:30	89	89	2244	42

Table XV. EXAMPLE OF ADJUSTING SPEED VALUES

the regression lines. Values above $90km/h$ are based on very few data points and this might be the reason for their respective regression lines to be different from the rest.

Table XVI show the data records for a part of a trip where the data apersIt can be seen how Speed is ajusted to the Modified speed to repair some of the errors caused by the recording equipment. RPM show the engine rounds per minute. Accelerration show the vehicle accelerration calculated from Modified speed.

Figure 42, 43, 44 and 45 plots the cost of fuel per second for acceleration m/s^2 and the initial speed km/h for vehicle 1,2,3 and 4 respectively.

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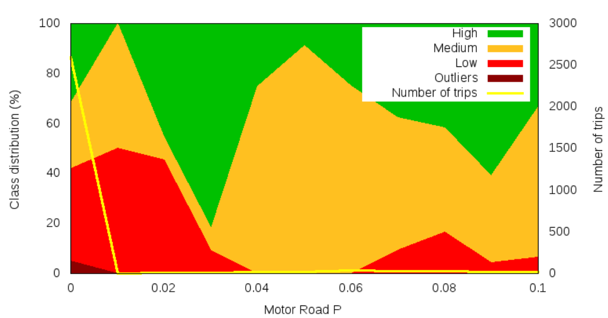

Figure 40. Class distribution of driving on motorways

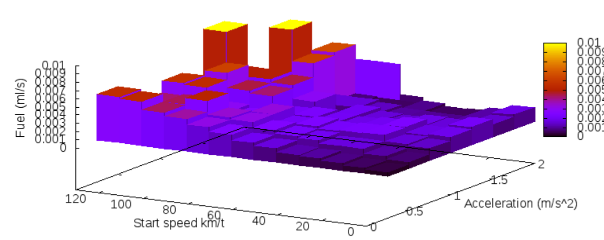

Figure 42. Fuel efficiency at start speed and acceleration for vehicle 1

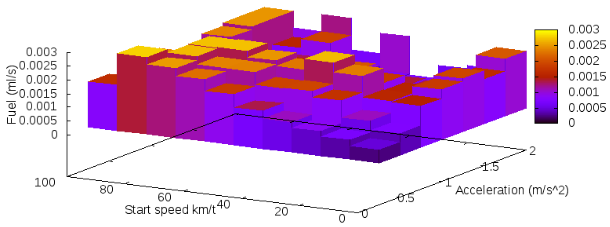

Figure 43. Fuel efficiency at start speed and acceleration for vehicle 2

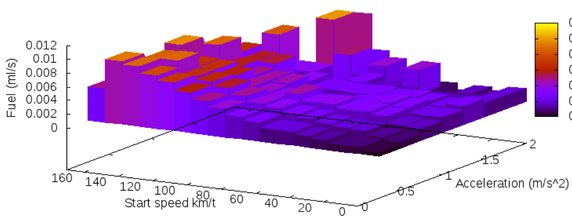

Figure 44. Fuel efficiency at start speed and acceleration for vehicle 3

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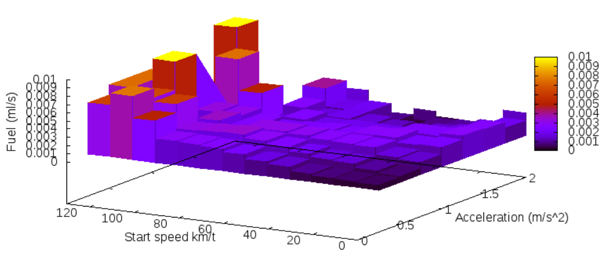

Figure 45. Fuel efficiency at start speed and acceleration for vehicle 4

Timestamp	Speed	Acceleration	Fuel
2013-02-21 16:28:56	46	0	2845.41
2013-02-21 16:28:57	45	-0.277777777778	2845.41
2013-02-21 16:28:58	39	-1.66666666667	2845.56
2013-02-21 16:28:59	45	1.66666666667	2845.41
2013-02-21 16:29:00	45	0	2845.41
2013-02-21 16:29:01	46	0.277777777778	2845.41
2013-02-21 16:29:02	48	0.555555555556	2845.57
2013-02-21 16:29:03	50	0.555555555556	2845.57
2013-02-21 16:29:04	52	0.555555555556	2845.57
2013-02-21 16:29:05	52	0	2845.57
2013-02-21 16:29:06	53	0.277777777778	2845.57
2013-02-21 16:29:07	54	0.277777777778	2845.58
2013-02-21 16:29:08	54	0	2845.43
2013-02-21 16:29:09	55	0.277777777778	2845.43
2013-02-21 16:29:10	56	0.277777777778	2845.43
2013-02-21 16:29:11	51	-1.38888888889	2845.58
2013-02-21 16:29:12	56	1.38888888889	2845.44
2013-02-21 16:29:13	55	-0.277777777778	2845.44

Table XVI. EXAMPLE OF ERRONOUS FUEL MEASSUREMENTS