The Techno-Economic Impact of Petrol- Ethanol Fuel blends on light duty vehicles: Case Study- Zimbabwean Petrol Vehicle Fleet.

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Abstract

The Government of Zimbabwe has been promoting ethanol as a renewable, homegrown alternative vehicle fuel to gasoline. Ethanol is a form of alcohol that is combustible and can power engines easily. In Zimbabwe, it is made primarily from sugar cane.

This alternative fuel has resonated with consumers who are concerned with Zimbabwe’s dependence on foreign oil as well as pump-price volatility. The main advantages of ethanol to the Zimbabwean government are that it can be produced in large quantities, and it requires fewer technological breakthroughs and less infrastructure development than is needed to support electric vehicles and fuel cell vehicles.

However university scientists and consumers are raising questions about ethanol's viability as a fuel source and are arguing that it is (i). Unethical to produce fuel from a food crop, especially if it drives up food prices.(ii) Ethanol contains less energy than gasoline, and it takes a lot of energy to produce.(iii) A variety of conflicting studies have shown that producing ethanol may or may not increase emissions of carbon-dioxide, a gas linked to global warming.

To better judge ethanol’s strengths and weaknesses, a large fleet of petrol vehicles from different government departments and individuals from the 10 provinces of Zimbabwe were used to gather data for the fuel consumption, vehicle performance/drivability and environmental effects. The research was carried out at different fuel blends of increment of 10% up to 100% and under different weather and road conditions. A control set up of mounted bench engine was put at University of Zimbabwe Mechanical Engineering Workshop.

The main objectives of this research was to investigate the optimal ethanol/petrol blend and determine cold start and hot start exhaust emission.

The research revealed that most of the vehicles are non-flexi-vehicles and have a lower fuel economy at higher blends compared with conventional fuel. The exhaust emission were below the recommended levels by the Environmental Protection Agency.

Keywords: Flexi-vehicle, ethanol, blend
1.0. Introduction

There has been a sharp increase in international oil prices from US$12 at the beginning of 1999 to US$61 per barrel by July 2005, against the background of reduced global supply and increased demand. There are indications that oil prices may escalate to around US$120 per barrel within the next few months. However, currently, the world demand for fuel is lower than the initial projections due to a lower forecast in world economic growth of around 4% which is below the 2004 level of over 5%. Against expected annual export proceeds of around US$1.9 billion, this indicates that about 25% of the Zimbabwe’s export earnings will be absorbed by fuel imports.

![Graph showing the trend of fuel imports to total exports in Zimbabwe](image)

Fig. 1. Percentage of fuel imports to total exports in Zimbabwe

International oil price hikes directly transmit themselves into higher production costs, and ultimately into rising general price levels in Zimbabwe, as is currently being experienced in the Zimbabwean economy. To mitigate the effects of this undesirable development, the supply side of the Zimbabwean economy must be made to rapidly expand as this will dampen fuel price-induced inflationary pressures. Optimal and efficient use of fuel would also stabilize import volumes, and, minimize the negative effects of this latest round of fuel price increases and any future upward adjustments.

Recently there have been a sharp increase of fuel demand in Zimbabwe due to the following factors:

- The influx of privately owned public transport operators especially commuter omnibuses, to cater for the increased number of people in urban areas following the deregulation of the transport sector;
- New entrants in the haulage transport sector
- The liberalization of trade which has seen a huge increase in the importation of relatively cheaper and affordable second hand vehicles, particularly from Japan;
The shift in company policies whereby most employees within managerial grades are accorded company vehicles as part of their total employment package;
Growth in the urban population due to rural-urban migration, which has put pressure on the urban transport system;
The proliferation of small-scale farmers and miners who largely rely on diesel-powered equipment;
Suboptimal pricing of Zimbabwe’s fuel saw a significant number of foreign truckers refueling locally as the price was heavily discounted.
The growth of an urban elite class whereby some families have a minimum of 3 motor vehicles each which they utilize at the same time.

Against this background of fuel consumption, Zimbabwean economy currently requires 900 million litres of diesel and 730 million litres of petrol per annum to operate at full capacity. Taking 1996 as the base year when the economy was operating at close to full capacity, the sectoral breakdown of the annual diesel requirements are as follows; transport sector requires 413 million litres (46%); commerce and services, 236 million litres (26%); agriculture, 122 million litres (14%); manufacturing 89 million litres (10%); and mining 40 million litres (4%) per annum.

1.2. Fuel Consumption patterns of vehicles in Zimbabwe

According to ZIMRA records, there were 1,200,123 vehicles registered in Zimbabwe as at April 2005. Over the past decade, there has been an increase in vehicles within the net mass range of 2300-4600 kilogramme and 4601-9000 kilogramme. These ranges of vehicles generally consume more fuel as compared to smaller vehicles weighing less than 2300 kg.

In 1995, vehicles weighing between 2300-4600 kilogrammes and 4601-9000 kilogrammes accounted for 2.3% and 4.6% of the total vehicle population, respectively. As at 30 April 2005, these classes of vehicles accounted for 4% and 7%, respectively, which indicates a significant increase in large vehicles. Smaller vehicles, which accounted for 74% of the total vehicle population in 1995, now account for fewer than 70%. This indicates that there has generally been a decrease in smaller vehicles, which have smaller engine capacities and are more fuel efficient. Motor vehicles with a net mass of over 4 600 kilogrammes increased by 80%. The latter category comprises of vehicles that consume more fuel.
Table 1. Zimbabwe National Vehicle Population by class

<table>
<thead>
<tr>
<th>YR</th>
<th>1</th>
<th>1*2</th>
<th>2*2</th>
<th>2*3</th>
<th>3*1</th>
<th>3*2</th>
<th>4*1</th>
<th>4*2</th>
<th>5</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>384,044</td>
<td>11,815</td>
<td>23,860</td>
<td>2,258</td>
<td>6,582</td>
<td>28,516</td>
<td>35,623</td>
<td>20,622</td>
<td>9,362</td>
<td>522,682</td>
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<tr>
<td>1996</td>
<td>422,448</td>
<td>12,997</td>
<td>26,246</td>
<td>2,884</td>
<td>7,240</td>
<td>31,368</td>
<td>39,185</td>
<td>22,684</td>
<td>10,290</td>
<td>575,342</td>
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<tr>
<td>1997</td>
<td>464,693</td>
<td>14,297</td>
<td>28,871</td>
<td>3,172</td>
<td>7,964</td>
<td>34,505</td>
<td>43,104</td>
<td>24,952</td>
<td>11,328</td>
<td>632,886</td>
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<tr>
<td>1998</td>
<td>520,989</td>
<td>19,374</td>
<td>32,589</td>
<td>4,789</td>
<td>9,819</td>
<td>41,002</td>
<td>48,014</td>
<td>30,141</td>
<td>14,510</td>
<td>721,227</td>
</tr>
<tr>
<td>1999</td>
<td>534,577</td>
<td>19,975</td>
<td>33,522</td>
<td>4,966</td>
<td>9,846</td>
<td>41,731</td>
<td>48,649</td>
<td>30,967</td>
<td>15,309</td>
<td>739,543</td>
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<tr>
<td>2000</td>
<td>544,490</td>
<td>28,418</td>
<td>34,197</td>
<td>5,077</td>
<td>9,912</td>
<td>42,306</td>
<td>48,970</td>
<td>31,313</td>
<td>15,506</td>
<td>760,191</td>
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<td>2001</td>
<td>556,280</td>
<td>29,072</td>
<td>45,797</td>
<td>5,247</td>
<td>10,069</td>
<td>42,912</td>
<td>49,889</td>
<td>31,915</td>
<td>15,641</td>
<td>786,322</td>
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<tr>
<td>2002</td>
<td>570,866</td>
<td>31,301</td>
<td>47,429</td>
<td>5,726</td>
<td>10,204</td>
<td>43,675</td>
<td>49,882</td>
<td>32,538</td>
<td>15,881</td>
<td>807,502</td>
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<tr>
<td>2003</td>
<td>584,714</td>
<td>32,390</td>
<td>61,330</td>
<td>5,960</td>
<td>10,383</td>
<td>44,404</td>
<td>50,216</td>
<td>33,721</td>
<td>15,926</td>
<td>839,044</td>
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<tr>
<td>2004</td>
<td>597,676</td>
<td>33,665</td>
<td>62,806</td>
<td>6,118</td>
<td>10,484</td>
<td>44,949</td>
<td>50,404</td>
<td>34,385</td>
<td>15,945</td>
<td>856,432</td>
</tr>
<tr>
<td>Apr-05</td>
<td>599,979</td>
<td>34,041</td>
<td>63,024</td>
<td>6,172</td>
<td>10,531</td>
<td>45,039</td>
<td>50,424</td>
<td>34,456</td>
<td>15,957</td>
<td>859,623</td>
</tr>
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</table>

Government, Security, Diplomatic & Other Vehicles April 2005

<table>
<thead>
<tr>
<th>Total Number of Vehicles for April 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>300,500</td>
</tr>
</tbody>
</table>

Notes:
1= 1-2300kg net mass
2*1=2300-4600kg net mass
2*2 = 4601-9000kg net mass
2*3 = 9001 and above kg net mass
3*1 = 1-70cm engine capacity
3*2 = 70cm and above engine capacity
4*1 = 1550 kg factory load capacity
4*2 = 1550 kg and above factory load capacity
5= Tractors and farm equipment

1.3. Alternative Fuel Sources

Petroleum Oil is a finite resource, which is only available in a few countries in the world. Against the background of rising international oil prices and modest foreign exchange inflows, Zimbabwe should exploit alternative sources of fuel. The Zimbabwean government has been promoting use of ethanol for decades as a renewable, homegrown alternative to gasoline. This alternative fuel’s usage has resonated with consumers who are negatively concerned with compulsory blending of petrol with ethanol.
Though the near-term advantages of ethanol as vehicle fuel look promising to government scientists, because it can be produced in large quantities, and it requires fewer technological breakthroughs and less infrastructure development than is needed to support other fuel sources there still exist questions on the viability of its use as fuel in Zimbabwe.

This study was conducted on 15 vehicles, which were provided by government departments and individual stakeholders. These vehicles were running on two blends of ethanol fuel: 10% ethanol content (E10) and 30% ethanol content (E30). The goal of the study was to compare the fuel economy (on-road and dynamometer), emissions, driveability characteristics, oil analysis, and material compatibility of the sample vehicles on each fuel.

All vehicles used in this study were tested for performance at the University of Zimbabwe Automotive Research Workshop before and after they were dispatched.

2.0. Methodology
To carry the study the following activities were carried out.

2.1. Vehicle Selection: Vehicles that use petrol and not more than three years old were selected. And these were of the make Mazda, Toyota, Nissan, Ford, Isuzu, Suzuki, Peugot, Mitsubishi, Honda. Of main interest during the selection was the absence of misfiring and if it was misfiring its ignition was tuned. Once satisfactory ignition performance was demonstrated, each vehicle’s emissions were checked using an infrared exhaust gas analyzer. This was followed by changing engine oil & filter, and fuel filter. The odometer was then checked for each vehicle to ensure accurate fuel economy data.

2.2. Training of the participants
The participants in the study, who were the drivers of the vehicles chosen, were asked to attend a training seminar, which was to eliminate some of the variables that could result due to the type of data each participant was asked to supply. This was also done to insure the tests were repeatable from vehicle to vehicle.

The seminar involved a description of the participants’ part in the study, the procedures that were done in the University of Zimbabwe Automotive Workshop and the tests run in workshop. The participants’ part of the study included the collection of the following data:
• An accurate description of maintenance performed on their vehicles.
• An accurate description of fuel mileage on the road
• All driveability complaints.
• An accurate sample of engine oil collected and sent in for laboratory analysis.

For each of the procedures the participants were given the appropriate form to fill out and a self addressed stamped envelope in which to return their results to the researchers. The participants were also requested to use a specified fuel and continue on the same fuel for the duration of the study.

2.3. Baseline Study.
Before the vehicles were tested, a sample of the fuel was taken from the fuel tank and the percentage of ethanol determined. It was found that in most cases the ethanol content was not
correct. In such cases the fuel was drained and the correct fuel was added. The vehicle was then run for 160 km checking variations in engine oil, tyre pressure, start up and emissions.

2.4. Vehicle Road Tests
After the first set of tests, fuel was switched in each vehicle. The vehicles were driven on a designated test route that was 160 kilometers long. The route included highway driving and urban driving. After the 160-kilometer drive, vehicles were brought back to the University of Zimbabwe Automotive Workshop for testing on the new fuel.

On arrival at the workshop the following activities were carried out on vehicle:
- Fuel samples were taken and analysed for ethanol content
- The ignition system was checked
- Engine oil samples were taken for analysis
- The tyre pressure was checked
- Analysis of emissions was carried out
- The driver’s sheets were collected for analysis

![Fig. 1. Researchers at University checking the technical status of the vehicle](image)

Formulas used to calculate on-road fuel economy data are:
- \( \text{km/liter} = \text{averaged total mileage and total fuel} \)
- 0.765 Kg/l was used for the density of gasoline and 0.79 was used for the density of ethanol.
- 42.7 MJ/Kg was used for the specific caloric value of gasoline and 26.8MJ/Kg was used for the specific caloric value of ethanol.
- Cost/km = cost/ liter divided by km/ liter.

3.0 Results and Discussion
The on-road fuel economy was calculated using the mileage and volumetric values as recorded in the driver logbooks. The on-road fuel economy data was then compared using:
- \( \text{km per liter} \)
- Equivalent \( \text{km per liter gasoline} \)
- Cost per km
- kW per km
As shown on table 2.0.
Table 2. On Road Fuel Economy analysis

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Make</th>
<th>Model</th>
<th>Year of Manuf.</th>
<th>Initial Odometer Milage (km)</th>
<th>Engine Capacity (cc)</th>
<th>Fuel Consumption (km/Ltr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>E30</td>
</tr>
<tr>
<td>Toyota</td>
<td>Corolla</td>
<td>2010</td>
<td>82900</td>
<td>1.5</td>
<td>16.88</td>
<td>18.96</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>Bora/Jetta</td>
<td>2011</td>
<td>33550</td>
<td>2.0</td>
<td>16.00</td>
<td>18.16</td>
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<tr>
<td>Hyundai</td>
<td>103789</td>
<td>1.6</td>
<td>10.14</td>
<td>11.20</td>
<td>10.80</td>
<td>11.20</td>
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<tr>
<td>Nissan</td>
<td>March</td>
<td>2012</td>
<td>71163</td>
<td>1.2</td>
<td>18.36</td>
<td>20.60</td>
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<tr>
<td>Ford</td>
<td>Fiesta</td>
<td>2011</td>
<td>107673</td>
<td>1.59</td>
<td>10.76</td>
<td>12.12</td>
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<tr>
<td>Peugot</td>
<td>406</td>
<td>2010</td>
<td>135665</td>
<td>2.0</td>
<td>9.94</td>
<td>11.20</td>
</tr>
<tr>
<td>Honda</td>
<td>CRV</td>
<td>2010</td>
<td>37169</td>
<td>2.0</td>
<td>13.74</td>
<td>17.40</td>
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<tr>
<td>Fiat</td>
<td></td>
<td>2010</td>
<td>210567</td>
<td>2.6</td>
<td>10.84</td>
<td>12.18</td>
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<tr>
<td>Mazda</td>
<td>Familia</td>
<td>2013</td>
<td>11911</td>
<td>1.2</td>
<td>16.38</td>
<td>18.44</td>
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<tr>
<td>Renault</td>
<td></td>
<td>2010</td>
<td>2012</td>
<td>1.5</td>
<td>12.00</td>
<td>13.42</td>
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<tr>
<td>Suzuki</td>
<td>Swift</td>
<td>2011</td>
<td>76525</td>
<td>1.5</td>
<td>28.86</td>
<td>32.48</td>
</tr>
</tbody>
</table>

3.1. Analysis fuel economy
By analyzing the fuel economy of E10 and E30 it was clear that E10 had an advantage over E30 in volumetric fuel consumption. Fuel economy values on E30, in km per liter, ranged from 1.28% to 14.66% lower for the vehicles in this study. The average decrease in km per liter was 8.83% when this sample used E30. As a result of consuming more fuel volumetrically per km travelled, the cost per km increased when the vehicles used E30. This was not a surprising outcome to the researchers.

3.2. Analysis of emissions
The results of the emission testing reveal that there was no definite pattern identified relating to the emissions differences between the vehicles running on E10 vs. E30. It was noted that in almost every case the emission levels were low, and well below national standards.

3.3. Driveability analysis
Driveability data was recorded for the purpose of analyzing the performance of each fuel in “real world” conditions. During the duration of the test there were no driveability complaints during the spring, winter and summer months. There were no reports of cold starting, vapor lock, or hard starting conditions that might have been associated with higher concentrations of ethanol. The cars all seemed to start with no long duration of cranking. There were also no reported cases of hesitation with the E30 blend of fuel.

3.4. Oil analysis
The results from the oil analysis showed that there was no noticeable wear on engine components due to the E30 blend of fuel.
3.5. Material compatibility
Fuel compatibility was tested using the driveability complaint forms from the participants. There was no conclusive data showing harm as a result of running on the higher blend of ethanol. The data collected from the general maintenance forms showed no fuel system damage during the duration of this study. No apparent danger to any engine or fuel system components by running on the E30 blend of fuel was found.

4.0. Conclusion
There was a reduction in volumetric fuel economy on E30. No apparent trend in vehicle emissions was identified. Almost all emissions were below national standards. There was no driveability problem reported during the study as well as there were no fuel system compatibility problems experienced by any participants.

Recommendation.
The research should be carried with higher fuel blends and also consider the issue of safety, storage and transportation of the fuel blends.

References