

Energy Saving and Eco Driving Behaviour: Empirical Evidence from Ibadan, Nigeria

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Abstract
This study empirically examined the impacts of eco-driving behaviour on energy saving. The descriptive method of analysis was complemented with the OLS estimation technique for robustness check. Results from the two methods reinforced each other. 68.1% of the commercial transport operators affirmed that they were aware of driving styles/behaviour that can help reduce the quantity of fuel their vehicle consumes daily. Despite this, 69.2% of them declared their willingness to learn new driving skills/styles. Our study revealed that 81.3% of the transport operators carry overload and that 85.7% of them do not make use of AC when it is functional. Markedly, we found that traffic hold-up is the most factor that hinders 81.3% of the operators from applying eco-driving skill/behaviour. The results of the empirical model indicated that car fuel consumption (CFC) varies positively with model, number of stoppages, idling, over load, air condition and negatively with engine tuning and tire gauge. Based on our findings, we recommend that the stake holders in the road transport business should intensify practical efforts towards increasing awareness on how car fuel consumption could be reduced using of the eco-driving options.
Keywords: Energy Saving, Eco-Driving, Empirical Analysis.
JEL Classification: B21, R4.

1. Introduction

The United Nations World Commission on Environment and Development (WCED) in its 1987 report defines sustainable development as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable energy is the sustainable provision of energy that is clean and lasts for a long period of time. Sustainable energy technologies guarantee fuel economy and are clean sources of energy that have a much lower environmental impact than conventional energy technologies. They do not emit any greenhouse gases making the world a cleaner and safer place. Studies have shown that increased energy consumption results into increased CO_2 emissions (Liu, 2005; Ang, 2007; Apergis et al., 2009; Payne, 2010 and Arouri et al, 2012).

In terms of petroleum consumption, figures from the weekly loading plan for 17-22 February 2010 released by the NNPC (2010) indicates that a total of over 8,788 truck load of Premium Motor Spirit (PMS) the equivalent of over 290 million litres was made available to filling stations across the country by the NNPC and the major oil marketers. The outline shows a daily average dispatch of over 1255 trucks the equivalent of over 41.4 million litres of fuel. The IES (2012) documents that total petroleum consumption in Nigeria substantially increased from 170 thousand barrels per day in 1980 to 286 thousand barrels per day in 2011. Specifically, data from the WDI (2013) shows that the road[1] sector energy consumption in Nigeria rose from 819 kiloton in 1970 to 8125 kiloton in 2012. Similarly, the percentage of road sector energy consumption in total energy consumption increased from 2.27% in 1970 to 7.65% in 2012. Expectedly, CO_2 emissions from transport in Nigeria have mirrored the aforementioned. For instance, it increased from 21.6 million metric tons in 2006 to 28.2 million metric tons in 2012 (WDI, 2013).

Eco driving is the practice of driving in such a way as to minimize fuel consumption and the emission of carbon dioxide. Among other, it offers numerous benefits, including GHG emissions reductions, fuel cost savings, as well as greater safety and comfort. Stillwater and Kurani (2012) observe that eco driving, is the adoption of energy efficient driving styles and practices (primarily moderating acceleration, top speed, increased coasting, and improved maintenance practices). They assert that eco driving has long been recognized as a potential source of reductions in transportation energy use. According to them, estimates of energy savings attributed to eco driving range widely, from less than 5% to as high as 20% depending on the driving and experimental context. Given that eco driving is capable of delivering a number of benefits, it becomes expedient

[1] Road vehicles dominate global oil consumption, consuming as much as 80% of transport energy and are one of the fastest growing energy end-uses. As a result, transport sector's share of oil consumption has been increasing steadily at around 0.5% per year. In the mid-2000s, some 60% of oil was consumed in this sector worldwide (WDI, 2013).

to carry out a study to ascertain if it does same in Ibadan.

The broad objective of this study is to examine the effects of eco driving behaviour on energy saving. The remainder of this paper is structured as follows. Section 2 presents review of related literature whereas Section 3 briefly describes the Methodology adopted in the study. Section 4 presents and discusses the empirical results while section 5 concludes the study.

2. Literature Review

Energy saving[1] refers to any mechanism designed to make economical use of energy. Alternatively expressed, saving energy means decreasing the amount of energy used while achieving a similar outcome of end use. It allows for a greater percentage of total energy input to a machine or equipment to be consumed in useful work and not wasted as useless heat. This has some benefits, at least, it can result into money saving and help to sustain the environment. It has been well argued in the literature that if people save energy, there will be less pressure to increase the available supply of energy, for example by constructing new power plants, or by importing energy from a different country. Generating energy requires precious natural resources, for instance coal, oil or gas. Thus, using less of it helps to preserve these resources and make them last longer in the future. There have been many efforts[2] in documenting ideas of what can be done to save energy. Here are a few of the ideas:

- Change travel behaviour, think more in terms of public transportation, if possible, walk or ride bicycle instead of taking the car
- Reduce house heat, keep the windows closed while heating, dress warmly
- Choose products that come with lightweight packaging
- Turn off lights and appliances when they are not in use, use energy-saving light bulbs
- Reuse plastic bags for shopping and storage
- Use a microwave instead of a stove to reheat food
- Use rechargeable batteries instead of disposable batteries

In terms of potential for fuel savings, Barkenbus (2010) documented that there is broad consensus from prior research that vehicle fuel savings of 10% are possible through modified driver behavior. Such savings can be attained through reasonably moderate behavior modification without resorting to extreme “hyper-miling” techniques. He estimated that if a third of all U.S. drivers adopted eco-driving techniques, it would result in an annual savings of 33 million metric tons of carbon dioxide (CO2) and a cost savings of $7.5-$15 billion. Barkenbus (2010) proposes that achieving significant fuel savings through driver behavior changes requires substantial investment in a multi-faceted approach involving:

- Public education
- Driver feedback
- Regulatory actions
- Economic and policy incentives
- Social marketing.

During a trip, a driver is required to start, accelerate, brake, jerk, ease off the accelerator, switch gear. Those actions will be repeated several times during one tour. The timing and duration of every action and time between two actions are very important. The sequence of these actions over the time and their durations represent the driving behaviour. This behaviour should change from one driver to another. But also for the same driver, that behaviour should change from one circuit to another (Chaari and Ballot, 2012).

According to Gonder et al (2012) adopting efficient driving behaviors can result in fuel savings on the order of 20% for aggressively driven trips. Even starting from more moderate driving styles, efficient behaviors can reduce fuel consumption by 5%-10%. Wide-spread penetration of such efficiency improvements could result in significant aggregate fuel savings. However, unlike efficiency technologies inherently integrated into a vehicle, realizing such aggregate fuel savings requires first motivating drivers to change how they drive. Important driver behavior influences include the actions of surrounding vehicles, the general flow of traffic, anxiety over trying to get somewhere quickly and the power/ torque available from the vehicle. For many drivers, the perceived value of a fractional reduction in their fuel budget may be insufficient (relative to these other influences) to trigger them to make a concerted behavior change (Gonder et al, 2012).

It is well established that individual variations in driving style have a significant impact on vehicle energy efficiency. Kolman (2009) noted that in road freight transportation, there are three fundamental factors that influence vehicle fuel consumption: the vehicle, the driving conditions and the driver operations. He is of the view that in driver operations “speed and acceleration has the largest impact on vehicle’s fuel economy. Driving

[1] Energy efficiency which is synonymous with energy saving means "using less energy to provide the same service".
[2] Visit for example, futurenergia.org

behaviors that affect fuel economy are well documented in existing studies (Evans; 1979, van der Voort et al; 2001, Brahmadevan et al; 2012, Gonder et al; 2012 and Birrell et at; 2014). Those behaviors include:

- Speed during highway driving.
- Frequency and intensity of braking and acceleration.
- Frequency of stops - faster acceleration is acceptable if it means that a stop is avoided.
- Timing of gear changes not a focus in the present study due to the current market dominance of automatic transmission vehicles.
- Time to Collision (TTC) values metric defined as the following distance from one car to another divided by the speed difference (when the second car is overtaking the first). The studies observed that drivers following an efficiency regimen tended to have fewer instances of small TTC values.

Ericsson (2001) found that eco-driving in high density traffic flow is extremely affected by accelerating smoothly, decelerating gradually and also changing gear as early as possible at a modest engine speed. Accordingly, aggressive driving based on sudden acceleration and deceleration results in fuel wastage of approximately 33% at high speeds on the highway and about 5% around towns (Thew, 2007). Maintaining an efficient speed is an effective means of keeping mileage up. Further, optimal energy efficiency can be expected while cruising with no stops, at minimal throttle and with the transmission in the highest gear. Therefore, acceleration should be quite gentle (Chaari and Ballot, 2012).

In general terms, eco-driving is a set of rules that has been developed to decrease fuel use. It involves both efficient driving practice and vehicle maintenance. IRU (2011) observed that there are two stages to eco-driving: before the journey and during the journey. Before the journey, drivers are advised to:

- maintain the vehicle properly according to the manufacturing standards,
- consolidate trips to bypass congested routes,
- unload as much as possible as soon as possible, and
- keep the tyres properly inflated.

During the journey, the drivers should:

- drive at a steady speed by using the highest gear possible,
- accelerate and break smoothly by allowing a safe distance between vehicles,
- decelerate smoothly using the retarder and the engine break,
- close windows at high speeds,
- minimize the use of heating and air conditioning,
- decrease the speed to a maximum legal limit to avoid unnecessary overtaking of other vehicles on the road,
- avoid idling altogether,
- avoid driving through the city center, and
- drive off from a standstill - but always try to avoid stopping (IRU, 2011).

Ericsson (2006) estimated the potential for reducing fuel consumption and thus the emission of CO2 through a navigation system where optimization of route choice is based on the lowest total fuel consumption (instead of the traditional shortest time or distance). Further the supplementary effects if such navigation support could take into account real-time information about traffic disturbance events from probe vehicles running in the street network were revealed. He finds that for 46% of trips in Lund the drivers' spontaneous choice of route was not the most fuel-efficient. According to his findings, these trips could save, on average, 8.2% fuel by using a fuel-optimized navigation system. This corresponds to a 4% fuel reduction for all journeys in Lund.

Saboohi et al (2009) developed a model of optimal driving strategy. The model has then been applied to identify the optimal driving strategy of a vehicle in different traffic congestions based on eco-driving rules. In the model, vehicle speed and gear ratio served as control variables. However, new methods of eco driving strategy are emerging. Barth et al (2009) examined the concept of dynamic eco driving. This dynamic strategy takes advantage of real-time traffic sensing and telematics, allowing for a traffic management system to monitor traffic speed, density, and flow, and then communicates advice in real-time back to the vehicles. The result was approximately 10-20% in fuel savings and lower CO2 emissions are possible without a significant increase in travel time. Based on simulations, it was found that in general, higher percentage reductions in fuel consumption and CO2 emission occur during severe compared to less congested scenarios.

Birrell et al (2014) examined the association between eco-driving parameters and fuel economy. Their analysis showed how three differing independent studies looking at the same factor (that is, the influence of driver behaviour on fuel efficiency) can be evaluated, and, despite their notable differences in country, environment, route, vehicle and drivers, can be compared on broadly similar terms. The data was analysed in two ways; first, using expert analysis and the second a purely data driven approach. The various models and experts agreed that a combination of at least one factor from the each of the categories of vehicle speed, engine speed, acceleration and throttle position were required to predict the impact on fuel economy. They considered the identification of standard deviation of speed as the primary contributing factor to fuel economy, as identified by both the expert and data driven analysis, an important finding of their study.

3. Methodology

The targeted respondents in this study are the commercial vehicle users. A multi-stage sampling technique was used to select the respondents. A purposive sampling technique was used to select six major routes in the city: Ojoo to Iwo-Road, Ojoo to Mokola, Mokola to Apete, Dugbe to Apata, Iwo Road to Toll Gate and Iwo Road to Gate. 100 commercial vehicle users were selected in each of the routes using the random sampling technique (RST).

Following Birrell et al (2014), we also operationalize the impact of eco-driving parameters on energy saving. The model includes measures of energy saving proxied by weekly car fuel consumption (CFC) as the dependent variable and presents explanatory variables that capture the impact of eco-driving on the dependent. This is algebraically expressed in equation (1);

$$CFC = f(TUN, STP, IDL, OVL, AC, TIRE, MODL) \quad (1)$$

Equation (2) is the estimable version of (1)

$$CFC_j = \Omega_0 + \Omega_1 TUN_j + \Omega_2 STP_j + \Omega_3 IDL_j + \Omega_4 OVL_j + \Omega_5 AC_j + \Omega_6 TIRE_j + \Omega_7 MODL_j + \varpi_j \quad (2)$$

$$\Omega_2, \Omega_3, \Omega_4, \Omega_5, \Omega_7 > 0 and \Omega_1, \Omega_6 < 0$$

Where

CFC	=	weekly car fuel consumption
TUN	=	Tuning
STP	=	Stoppage
IDL	=	Idling
OVL	=	Overload
AC	=	Air condition
Tire	=	Tire gauging
MODL	=	Model of car

The Ordinary Least Square estimation technique was used to estimate the energy saving function.

4. Empirical Results

Table 1 captures the general information of the respondents. The age distribution clearly shows that 64.8% of the respondents fall within the age bracket of 26 – 35. This goes to show that taxi driving job is more of a job for the youths. From Table 1, we see that about 63.8% of the respondents have primary education and Senior Secondary Certificate Education (SSCE). It is also obvious from the same Table that 75.8% of our targeted audience are married.

In terms of the make of vehicles used by the respondents in their commercial transport businesses, we discovered that 46.2% of them use Nissan Micra, 35.2% - Suzuki, 13.2% - Toyota whereas only 5.5% of them use Volkswagen. Our probe into knowing the quantity of litters of fuel each one of them uses each day he operates revealed that 50% use 20 litters, 27% - 12 litters and 22% make use of 8 litters. In the same vein, we found that in a day, 50% of the commercial transport operators who constituted our surveyed sample make 20 trips in a day, 27% - 12 trips in a day while 22% make just 8 trips in a day (Table 2).

Information obtained on the Eco – driving behaviour of the respondents is presented in Table 3. First in this regard, we tried to find out if the commercial transport operators are aware of driving styles/behaviour that can help reduce the quantity of fuel their vehicle consumes daily. 68.1% answered in the affirmative while 26.4% said they are not aware. In addition, 69.2% of them declared their willingness to learn new driving skills/styles that can reduce the quantity of fuel their vehicle consumes daily. The remaining 30.8% responded in the opposite. On the number of times our respondents tune/service the engine of their cars in 3 months, 39.6% said two times, 26.4% - once, 26.4% - three times and 7.7% do not at all (Table 3). Literature has shown that vehicles that their engines are less tuned/serviced consume more fuel (IRU, 2011).

Concerning the number of times commercial transport operators stop on a particular trip, we got the following responses; 34.1%, 0 to 4 times, 41.8%, 5 to 8 times and 24.2%, 9 to 12 times (Table 4). Again, from the point of literature, we note that frequent stoppages positively relate with vehicle fuel consumption (Ericsson, 2001; Thew, 2007 and Chaari and Ballot, 2012). Driving in the highest gear possible without labouring the engine is a fuel-efficient way of driving. Further, 71.4% of them informed us that they leave their vehicle on while waiting for passengers whereas the remaining 28.6% said they do the reverse (Table 4). The idea of leaving vehicle on while waiting for passengers has been referred to in the literature as 'idling'. For the commercial transport operators to improve on the fuel economy of their vehicle, they have to avoid idling. More so, idling pumps needless CO2 into the atmosphere. The modern engine consumes less fuel turning off and re-starting than idling for extended periods.

On whether they carry overload, 81.3% said yes while 18.7% said no (Table 4). IRU (2011) advised vehicle users to unload as much as possible and as soon as possible. Vehicle users are generally advised to lighten their load, think carefully about what they need on a journey. If you do not need something, do not pack it. Remove roof racks if not needed, as they create wind drag. The lighter the load, the lower the fuel consumption and emissions. Thus, carrying excess weight wastes fuel. Regarding comfort and luxury, we asked our respondents if they make use of the air condition (AC) of their car all the times when it is functional. Only 14.3% of them responded yes while a greater percentage number of 85.7 said no (Table 4). Those who said no explained that their reason is because it takes more fuel and that the passengers are reluctant to pay any extra charge that could emanate from such usage. Expert opinion has it that when the AC of a car is turned on, it uses energy supplied to it by the alternator. This energy comes from the engine, which is using the fuel in the gas tank. The consensus in the literature is that driving with the AC off and windows up is the most fuel efficient way to operate an automobile.

The respondents were asked to use figures 1 to 5 to rank the factors that can hinder them from applying eco-driving skill/behaviour. What emerged is that 81.3% of them declared that traffic hold-up is their most hindrance. Eco-driving in high density traffic flow is extremely affected by accelerating smoothly, decelerating gradually and also changing gear as early as possible at a modest engine speed. Accordingly, aggressive driving based on sudden acceleration and deceleration results in fuel wastage of approximately 33% at high speeds on the highway and about 5% around towns (Ericsson, 2001; Thew, 2007). In addition, 5.5% and 2.2% respectively stated that traffic light and quality of the roads hinder them most. Traffic light reduces unnecessary stopping and starting of traffic which in turn reduces fuel consumption. None of the respondents choose level of education and round about to be the most hindrance (Table 5).

The OLS estimates of the impact of eco-driving behaviour on car fuel consumption (CFC) are presented in Table 6. Most of the coefficients are statistically significant, with expected signs. CFC varies positively with model, number of stoppages on a particular trip (stp), idling (idl), over load (ovl), and air condition (ac). On the other hand, number of times car engine is tuned (tun) and number of times the amount of air in car's tires are gauged (tire) negatively impact on CFC. More empirically, cars whose engines are tuned at least two times in a month save about 2.5% of their fuel whereas drivers that maintain regular tire gauge reduce their car fuel consumption by 1.2%. Further, our findings revealed that the more cars stop on a particular trip, the more liable they are to consume additional fuel.

5. Conclusion and Policy Recommendation

In general, this study examined the impacts of eco-driving behaviour on energy saving. The descriptive method of analysis was complemented with OLS estimation technique for robustness check. Our results from the two methods are not just robust but also striking in many instances. 68.1% of the commercial transport operators reported that they are aware of driving styles/behaviour that can help reduce the quantity of fuel their vehicle consumes daily. Despite this, 69.2% of them declared their willingness to learn new driving skills/styles. Our study revealed that 81.3% of the operators carry overload and that 85.7% of them do not make use of their car AC when it is functional. Markedly, we found that that traffic hold-up is the most factor that hinders 81.3% of them from applying eco-driving skill/behaviour.

The results of the empirical model showed that CFC varies positively with model, number of stoppages on a particular trip (stop), idling (idl), over load (ovl), air condition (ac) and negatively with engine tuning and tire gauge. Based on our findings, we recommend that the stake holders in the road transport industry should intensify practical efforts towards increasing awareness on how car fuel consumption could be reduced using of the eco-driving options.

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Table 1: General Information

AGE		
	Frequency	**Percent**
18 – 25	24	4.4
26 – 35	354	64.8
36 – 45	144	26.4
46 – 55	24	4.4
Total	**546**	**100.0**
Highest Education Qualification		
no formal education	120	22.0
Primary	246	45.1
SSCE	102	18.7
Tertiary	78	14.3
Total	**546**	**100.0**
Marital Status		
Single	84	15.4
married	414	75.8
divorce	48	8.8
Total	**546**	**100.0**

Table 2: Information on make of vehicles, litters of fuel used each day and trips made in a day

	Frequency	**Percent**
Make of vehicle		
Nissan Micra	252	46.2
Suzuki	192	35.2
Volks wagen	30	5.5
toyota	72	13.2
Total	**546**	**100.0**
How many litters of fuel do you use each day you operate?		
8.00	120	22.0
12.00	150	27.5
20.00	276	50.5
Total	**546**	**100.0**
In a day how many trips do you make?		
8.00	120	22.0
12.00	150	27.5
20.00	276	50.5
Total	**546**	**100.0**

Table 3: Eco–driving behaviour

	Frequency	Percent
Are you aware that there are driving styles/behaviour that can help reduce the quantity of fuel your vehicle consumes daily?		
Yes	372	68.1
No	144	26.4
no response	30	5.5
Total	**546**	**100.0**
Are you willing to learn new driving skills/styles that can reduce the quantity of fuel your vehicle consumes daily?		
Yes	378	69.2
No	168	30.8
Total	**546**	**100.0**
How many times in 3 month do you tune/service your engine?		
0	42	7.7
1	144	26.4
2	216	39.6
3	144	26.4
Total	**546**	**100.0**

Table 4: Information on number of stoppages, idling and usage of car air condition

	Frequency	Percent
On a particular trip, how many times do you stop?		
0-4	186	34.1
5-8	228	41.8
9-12	132	24.2
Total	**546**	**100**
Do you leave your vehicle on while waiting for passengers?		
Yes	65	71.4
No	26	28.6
Total	91	100.0
Do you carry overload?		
Yes	444	81.3
No	102	18.7
Total	**546**	**100.0**
When the air condition of your car is functioning, do you use it all the times?		
Yes	78	14.3
No	468	85.7
Total	**546**	**100.0**

Table 5: Rank of factors that can hinder the applications of driving skill/behaviour

Using figures 1 to 5, rank the following factors that can hinder you from applying driving skill/behaviour (Number 1 is most ranked)		
	Frequency	**Percent**
Quality of the roads	22	2.2
Traffic hold-up	444	81.3
Level of education	0	0
Round about	0	0
Traffic light	30	5.5

Table 6: The regression results of the impact of eco driving behaviour on energy saving

CFC	Coef.	t
model	0.015	2.290
tun	-0.025	-1.970
stp	0.037	1.982
idl	0.077	2.700
tire	-0.012	-0.050
ovl	-0.101	-2.840
ac	0.061	2.530
cons	10.753	3.210
Adj R-squ.	0.71	
F(7, 76)	26 (0.000)	