Eco-driving Techniques for road freight transport in Ecuador

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Abstract *— This study concisely describes the current situation of road freight transport in Ecuador and presents the advantages and benefits of eco-driving in this transport mode. Eco-driving techniques have been developed worldwide; however there is not draft implementing these techniques in Ecuador since at present day there is no public policy that specifically addresses such driving techniques. The implementation of Eco-driving as an instrument to reduce fuel consumption, emissions of greenhouse gases and improve driving safety, in the heavy road transport segment, is validated and techniques addressed by other studies are contemplated. The article considers specific characteristics of Ecuador since it is difficult for heavy trucks to maintain a constant velocity, due to the geographical conditions. Finally it is important for drivers to carefully follow the recommendations proposed in this article to reduce fuel consumption, emissions of greenhouse gases and improve driving safety while transiting roads with pronounced slopes and tight turn his document gives formatting instructions for authors preparing papers for publication in the Proceedings of an IJETT Journal. The authors must follow the instructions given in the document for the papers to be published. You can use this document as both an instruction set and as a template into which you can type your own text.*

Keywords *— Ecuador, Eco-driving, Road freight transport, Fuel consumption***.**

I. INTRODUCTION

Energy Efficiency (EE) in the transport sector is the combination of processes and actions that allow for the optimization of the relationship between fuel consumption and distance travelled [1]. It is determining for transport companies, to start promoting energy efficiency best practices within their business logistics, particularly in the operative ones. Such implementation will allow for a reduction in the national energy demand and will also allow for an expansion in the company´s operational margin [1].

The transportation of goods and passengers is essential in order to guarantee economic and social development; in the year 2014, the contribution from this sector to the Gross Domestic Product (GDP) was approximately 7%.

Fuel economy is a relevant parameter that is used to measure energy efficiency in transportation and it can be expressed in terms of gallons/km or Joules/km [2].

An alternative indicator is the Greenhouse Gas Emissions (GHG), and it is proportional to fuel consumption, hence, an improvement in the energy efficiency of the sector will result in an abatement of GHG emissions [2].

Energy Efficiency is a subject that has drawn much concern, mainly due to a combination of three issues:

- The rising tendency in fossil fuels and its impact in the supply chain.
- Raising awareness regarding energy security.
- The impact of fossil fuel emissions over global warming issues

Energy efficiency levels can be enhanced through effective actions focused in four particular stratums:

- Technology
- Transportation systems operation
- Infrastructure
- Policy

This study is centered in the field of transportation systems operation. Factors, that are pertinent to driving habits, are identified and analyzed in contrast to fuel consumption with aims to obtain significant energy savings.

A. CURRENT SITUATION

Transport is the sector responsible for the highest energy demand in the country. According to the latest National Energy Balance (based on 2014), Transport represent 42% of the total energy consumption [3]. The annual growth rate in energy consumption from the sector is approximately 7%, with respect to the two latest reported years (2014/2013) and 4% with respect to the latest decade reported [3].

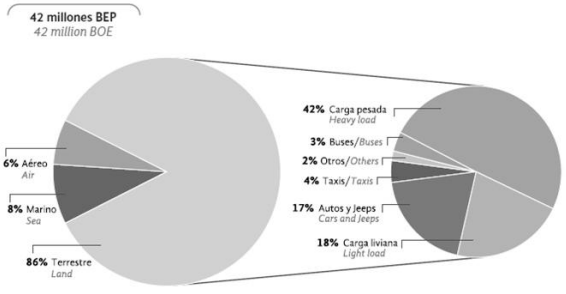

Fig. 1 Energy consumption by mode of transportation [3]

On the other hand, fuel consumption is not only associated to energy use and emissions, but it also represents economic costs that can be reflected in the price of transported merchandise.

These results suggest the need to develop technologies and promote initiatives that allow for an accretion in energy efficiency of road freight transport and consequently abatement in energy consumption, which will further improve the sector´s competitiveness and sustainability.

Nowadays, there is a variety of mathematic models that are being applied throughout the world, which are destined to achieve potential energy savings. They are based on features such as the mechanical design of the vehicle and urban development matters. Nonetheless, there is a third alternative focused on fuel use diminution, which appoints driving behaviors [4].

Eco driving is a technique that contributes to the abatement of energy use and GHG Emissions and to the amelioration of road safety. It is an integral method for a vehicle´s operation, oriented towards improving fuel economy. Additional benefits of eco-driving include, extending the lifetime of mechanical components [5].

It has been reported that eco-driving has the potential to achieve a 14% reduction in fuel consumption [6]. Other authors have performed experimental tests in which a vehicle travelled a distance of 120 km and savings have been quantified to be around 3.5% [7].

Driving habits can be substantially reflected through vehicle´s fuel consumption, and they can also signify in the accelerated deterioration of vehicle parts. The driver´s attitude for instance may be a correlated qualitative variable affecting energy use and emissions from an automobile [4].

II. METODOLOGY

A Eco-driving techniques for road freight transport, addressed by several sources, are proposed.

Eco-driving can be defined as a combination of effective driving techniques and habits, that attempt to achieve potential fuel savings.

Some benefits and recommendations that can be applied to road freight transport in Ecuador are presented.

A. ADVANTAGES OF ECO-DRIVING:

- Improves driving comfort and reduces stress.
- Economic savings associated to a reduction in fuel consumption.
- Abatement of GHG Emissions. Improves air quality.
- Advance in road safety.
- Reduced costs associated to vehicle maintenance.

B. CO-BENEFITS OF TRUCK ECO-DRIVING

Eco-driving has demonstrated to save fuel and reduce GHG emissions. It can also reduce pollutant emissions as a result of smoother driving with milder acceleration and better vehicle maintenance. In addition, many of the truck eco-driving tips go hand in hand with safe driving practices so there can be safety benefits from eco-driving as well. Thus, the quantification of these co-benefits of truck eco-driving is an important research topic [8].

C. IMPACTS OF TRUCK ECO-DRIVING ON TRAFFIC FLOW

There are many impacts which have eco-driving those are climate, air quality and safety benefits and the most important save fuel. Better traffic flow reduces rolling resistance due to they will not have many stops and stars, consequently the fuel saving and emission reduction benefits for individual trucks may decrease. In consequence, investigation is needed to evaluate the latent impacts of large-scale adoption of truck eco-driving under a variety of roadway and traffic scenarios, taking Ecuador geography into consideration [8].

D. EFFICIENT DRIVING RECOMMENDATIONS

The following recommendations should not be considered as a manual from driving school, instead they are intended to be employed by experienced drivers. These recommendations will allow improving a driver´s habits and consequently reducing vehicle´s fuel consumption:

II.D.1 BEFORE YOU LEAVE

- Plan your trip

An efficient driver is not only concerned about his/her driving habits, but also takes other aspects into account, which will have a direct influence over the fuel, consume don each trip. The first thing to consider is to plan the trip and to diligently follow a schedule.

It is important to consider some planning time in order to study a map and identify the shortest routes. This task will allow to optimize the trip.

Fuel consumption and travel time can be optimized if the driver chooses routes that have less traffic and more appropriate departure times, that is, avoiding peak traffic hours. This task will result in avoiding the vehicle from consuming energy while standing still. Additionally, travelling through a route with low traffic will imply cruising at a constant speed, which results in better vehicle performance.

If there are several clients or places to be attended, it is better to plan the trip ahead in order to deliver the products in the least number of trips. The main objective of this recommendation is to avoid trips without cargo.

Make use of current GPS technology in order to plan the route. Some state of the art software

applications not only guide the driver through the trip but also display information regarding traffic and alternative routes.

- Prepare ahead the vehicle for the route.

A heavier load hints a higher energy demand. The heavier the load carried by the vehicle, the more amount of fuel it will demand. The driver should check the load and verify that all the cargo and accessories that will be carried have a specific purpose.

The load should be attached firmly and the external contour should be as uniform as possible, so as to avoid empty spaces, between the cabin and the load, that may increase the aerodynamic drag. Special care should also consider the weight limits per axle.

- Tire pressure control.

When a tire has less air than the required by the manufacturer, the vehicle requires more energy in order to move from one point to another. One can imagine riding a bicycle with flat tires, the rider will require more physical energy in order to get around.

The tire pressure has to be regularly monitored. Se tiene que revisar la presión de los neumáticos regularmente. It is advisable to check the pressure either every 5000 km, every two weeks or before the start of a long trip. According to the Chilean Agency for Energy Efficiency, it has been estimated that a pressure level of 14% below the optimal may result in 1% to 2% additional fuel consumption.

The optimal operating pressure is determined either by the vehicle manufacturer or by the tire manufacturer, the information can be found in the vehicle´s manual. Usually, the pressure starts to fall after two weeks of a fine tuning procedure. This is a normal behavior, since air particles are very small, and it leaks at a very slow rate. Excessive pressure levels can also be counteractive factors with negative consequences as the following:

- Tire shock absorbing properties are diminished, external impacts are transmitted with higher intensity to passengers and the trip becomes less comfortable.
- Overloading of springs and shock absorbers, which may diminish their lifetime or cause permanent damages..
- Road safety may be reduced since traction is reduced.
- Accelerated tire wear.

- Proper engine maintenance

A deteriorated filter may increase 0.5% in energy consumption [9]. The fuel pump has to develop additional effort in order to send fuel to the engine and eventually, fuel supply will not match air flow and the combustion process will become will be inefficient.

A clogged air filter can reduce 1.5% of the efficiency of the vehicle [8]. It can reduce the amount of air in the combustion chamber, hence affecting the stoichiometric balance. Having a non-stoichiometric reaction implies that fuel is not being combusted efficiently, so the engine is not taking full advantage of the fuel being delivered, and part of the fuel mass will not be converted into heat, instead it will be converted into soot and other elements that will end up in the exhaust.

II.D.2 ON THE ROAD

- Keep a safe distance

Keep a safe distance with the surrounding vehicles, will prevent the driver from accelerating or braking constantly. Frequently accelerating leads to a repeated power exigency to the engine, which signifies more energy consumption in contrast to maintaining the speed as constant as possible. The definition of a safe distance can be interpreted by the driver taking into account, the overall speed of all vehicles in the road, traffic levels, load carried and the vehicle´s braking capacity.

- Avoid abrupt braking.

It is advisable to anticipate a stop where possible, in order to reduce the time that the foot unnecessarily pushes the gas paddle. Also, consider if possible downshifting gears as a braking mechanism. It has been reported that this anticipating behavior can reduce approximately 98 grams of fuel per event [10].

Use momentum in gear in order to reduce the speed of the vehicle. Speed will decrease due to frictional forces within the gear box. Some vehicles have fuel cut off modes, so it is advisable to make use of this technique on such vehicles. Otherwise, down shifting as a braking mechanism may result in high RPM´s, hence higher fuel consumption. Strictly utilize the braking pedal when needed in order to avoid getting too closer to the vehicle in front.

An efficient driver should release the foot from the gas pedal when he/she anticipates a nearby stop, so that the reduction in speed is taken care by frictional forces applied to the vehicle, such as aerodynamic drag, rolling resistance and internal frictional forces between mechanical components.

- Drive at high gears.

It is preferable to reach higher gears (3rd, 4th, 5th or higher) because the engine operates at lower RPM´s which implies less energy consumption. Higher gears also allow the vehicle to travel at constant speeds. Cruise control can be advisable for extra urban driving. For instance, a light truck can travel at a constant speed of 70 km/h at a higher gear. A not so efficient alternative is to travel at the same average speed with more frequent shifts in gears.

- Pull out smoothly.

Deep accelerations cause an excessive consumption of fuel. A driver that is used to abrupt accelerations may use 10% or 15% more fuel tan a moderate driver [9]. It is always recommendable to avoid abrupt accelerations even from a safety point of view.

- Ignition without stepping on gas pedal.

In most modern vehicles the driver does not need to press the gas pedal. Pressing the gas during ignition signifies that additional fuel is being used for no purpose whatsoever.

- Turn off engine during prolonged stops.

It is common to have prolonged and unexpected stops due to traffic conditions, accidents or weather conditions. In these occasions and as a general rule it is better to turn off the car when the stopping time is more than two minutes. From an economic perspective, it is better to turn off the car and turn it on again whenever the car is allowed to move again rather than waiting with the car on. In general, stop lights last less than a minute, so it is not convenient to turn off the car under these circumstances.

II.D.3 HIGHWAY SPEED CONTROL.

In the highway it is convenient to keep the speed below 90 km/h. If a vehicle travels at a speed of 100 km/h, it may arrive at its destination 15 minutes earlier than a car travelling at a speed of 90 km/h. However the difference in fuel consumption will be more significant [9].

- Exceeding and emergency situations.

Security has precedence over economy, that is, eco-driving techniques can be ignored in order to avoid situations that may threaten the security of the passengers. Nonetheless, exceeding is recommended whenever there is an adequate distance which does not require excessive forcing of the engine and, of course, can be carried out in a safe manner.

- Minimize use of heating and air conditioning

Decrease use of the air conditioner can help you save 10-15 % of fuel. Park your vehicle in the shade [8].

II.D.4 ECO-DRIVING IN STEEP ASCENDING AND DESCENDING SLOPES

Ecuador has particular geographic conditions and land configurations; there is a high variety in altitudes since the territory covers different weather zones ranging from tropical valley regions to moderately cold mountain ranges. The following criterions are considered in order to classify the most characteristic slopes.

- Flat land.- slope less than 2%.
- Wavy – flat land.- Slopes ranging from 2-8%. Small hills and mountains that are the result of young fluvial networks that gently shape the contour of valleys.
- Wavy land.- Slopes ranging from 8-16%. Associated to relatively old fluvial networks with moderate river encasements.
- Wavy – Mountainous land.- Slopes ranging from 8-16%. Not eroded surfaces from ancient folding geological events which have deeply defined waters streams.
- Mountainous land.- Slopes greater than 30%. Considerable differences in elevation between valleys and summits. Slow erosive process over a strong geological folding.
- Highly mountainous land.- Slopes greater than 30%. Pronounced differences in elevation between valleys and summits. Slow erosive process over a strong geological folding.

According to information from the Strategic Mobility Plan from the Ministry of Transport and Public Works in Ecuador (MTOP), 24.8% of the roads are located in wavy and mountainous land, and more than 50% of the roads from the National Road System are located over irregular surfaces (wavy-mountainous, mountainous and highly mountainous land) [11]. The following recommendations are proposed and based on the geological conditions aforementioned.

When travelling uphill, if the speed can be kept constant by pressing the gas pedal, the current gear should not be shifted. If the RPM´s do not decrease or slowly decrease, then the current operation mode should remain unchanged until the car reaches the top of the hill, the power demand decreases and the car starts increasing its speed [12].

If the RPM´s start dropping when travelling uphill at a moderate slope, the driver should step over the gas pedal to the extent necessary. If the RPM´s continue to fall, the driver should shift down half gear, allowing the engine to develop enough RPM´s in order to operate at a maximum torque regime [12].

If the slope is very steep and the RPM´s start to fall dramatically, the driver should shift down one gear in order to achieve more torque. If a significant change in slope can be anticipated, the driver should shift down two gears at once. Careful attention should be focused on maintaining if possible low RPM´s [12]. In general, the time of ascent between high RPM´s and low RPM´s regimes is insignificant in comparison to the time that it takes to complete the complete trip [12].

When travelling downhill at a pronounced slope, engine brake should be employed as possible, avoiding vehicle acceleration through gear down shifting. In this case, increasing RPM`s do not represent a major issue as long as they remain below

a critical zone that can cause damage to the engine [12].

III.CONCLUSIONS

The main eco-driving techniques applied to road freight transport have been described. They can be promoted and applied in Ecuador since at present day there is no public policy that specifically addresses such techniques.

As we know there are benefits for the government and for trucking industry because thusly they will reduce GHG emissions from trucks at the same time the y will improve fuel efficiency. To sum it up we suggest those choices for achieving these goals side with one of the 25 energy efficiency policy recommendations made by the International Energy Agency.

Even though sustainable transportation is a global concern, a specific methodology should be defined according to the reality and features of each region.

In Ecuador, it is difficult for heavy trucks to maintain a constant velocity, due to the geographical conditions. Therefore, it is important for drivers to carefully follow the recommendations proposed in this article with respect to driving techniques while transiting roads with pronounced slopes.

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REFERENCES

[1] ACEE. (2015). Transporte De Carga Opta Por La Eficiencia Energética. Retrieved from http://www.acee.cl/transporte-de-carga-opta-por-la-eficiencia-energetica/

[2] Trentadue, C., & Hugo, C. (2014). La eficiencia energética en el transporte.

[3] MICSE. (2015). Balance Energético Nacional 2015. Retrieved from http://www.sectoresestrategicos.gob.ec/wp-content/uploads/downloads/2016/01/Balance-Energe%CC%81tico-Nacional-2015.pdf

[4] Villeta, M., Lahera, T., Merino, S., Zato, J. G., Naranjo, J. E., & Jiménez, F. (2012). Modelo para la Conducción Eficiente y Sostenible basado en Lógica Borrosa. *ScienceDirect*.

[5] Correa, A., Cogollo, J., & Salazar, J. (2010). Evaluación del efecto de la conducción eficiente en el consumo de combustible en vehículos de transporte de carga pesada usando diseño de experimentos.

[6] Fonseca, N., Casanova, J., & Espinoza, F. (2010). Influence of Driving Style on Fuel Consumption and Emissions in Diesel-Powered Passenger Car.

[7] Hellström, E. (2007). *Look-ahead Control of Heavy Trucks utilizing Road Topography*. Retrieved from http://www.diva-portal.org/smash/get/diva2:23829/FULLTEXT01.pdf

[8] IRU. (2009). Eco-Driving Safely for Trucks.

[9] AChEE. (2013). Guía de Conducción Eficiente de Vehículos de Carga.

[10] Thijssen, R., Hofman, T., & Ham, J. (2013). Ecodriving acceptance: An experimental study on anticipation behavior of truck drivers. *El Sevier*.

[11] MTOP. (2013). Plan Estratégico de Movilidad - República del Ecuador.

[12] IDAE. (2005). Manual de conducción eficiente para conductores de vehículos industriales.