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Overview on the Effects of Eco-Driving Strategies on Greenhouse Gas Emissions and Road Safety

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Abstract: ***The increasing number inurbanfatalities and energy consumptions caused major challenges in many countries.Minimizing fatalities and improving safety is one of the top priorities in different countries. Eco-driving has received increasing attention in the past years as one of the effective ways that aim to improve safety, reduce fuel consumption and greenhouse gas emission. This paper presents an overview on the effects of eco-driving strategies on greenhouse gas emissions and road safety.***

Keywords: Driving Behavior, Eco-driving, Greenhouse Gas Emissions, GHG Emissions, Safety

1. Introduction

Driving is one of the necessary tasks in most of daily peoples' life, and at the same time it is considered as association with quality of life in different cases [1]. The number of vehicles usage on road is increasing due to the increasing in population. According to the report of Malaysian Institute of Road Safety Research (MIROS), the population number and registered vehicles number are increasing year by year [2]. Hence, the accidents number is increasing.

The increasing number of car accidents is a major challenge in many countries[3]. The consequences of accidents can harm individuals and governments in term of social and economic loss which impact the society. Traffic road accidents are causing more than a million deaths per year over the world, and it is predicted to be the fifth leading cause of death by 2030 [4]. According to the Department of Statistics of Malaysia, transports accidents recorded the fourth highest cause of death in 2016 [5]. According to MIROS report conducted on Malaysian motorcyclists, the age group between 16 – 25 years old is involving in more than 40% of the total fatalities [6]. Improving traffic safety today is one of the top priorities list of different countries around the world[7]. Understanding the main causes of accidents will assist finding solutions to prevent or reduce traffic accidents. According to [8], human errors, road conditions, and vehicle failure are the main contributing factors to road traffic accidents. Human error (e.g. lack of attentions, incorrect control, aggressive driving) is the most influential factor in contributing to traffic accidents. As stated in [9], human error is causing around 90 percent of traffic accidents. Thus, analyzing and understanding driver behavior is the key factor to prevent or reduce traffic accidents. The term of driver behavior can be defined as different concepts related to driving mannerisms and driving actions of a driver which introduce everlasting variables [10]. Studying driving behavior not just assist in road safety improvement, it also assist in safe environment by finding solutions to reduce fuel consumptions and gas emissions.

According to the department of environment in Malaysia, the increasing number of air pollution due to the increasing trend of industrial sources and numbers of vehicles. Vehicles' emission is the major source of the air pollution especially in the urban areas [11]. Based on the environment's department of Malaysia, the overall air pollutant's accumulation emission load in 2018 was 2,210,634 metric tons of carbon monoxide (CO), 95.6% of the emission source was from motor vehicles; 889,890 metric tons of nitrogen oxides (NO_2), 25% of the emission source was motor vehicles; 257,457 metric tons of Sulphur dioxide (SO_2), 6% of it from motor vehicles; and 26,789 metric tons of particulate matter (PM), 15% of the emission load was from motor vehicles [11]. Based on Global GHG and CO2 Emissions report, carbon dioxide (CO_2) emissions in 2018 reached up to 257.84 metric kiloton (kt) in Malaysia, 24.69% of the emission load was from transport sector [12].

Reducing fuel consumption and gas emissions are primary goals in different countries [13]. The increasing number of vehicles is one of the main causes of environmental pollutions due to the gases emissions from the vehicle engine while burning the fuel such as carbon dioxide (CO2) and acid rain, as well as these greenhouse effects increase the possibility to be infected with some lung diseases such as lung cancer [14]. Hence, it is necessary to minimize the usage of fuel in order to reduce the impact of vehicles on the environment. According to a study [15], the rate of greenhouse gas emissions is rapidly growing in Malaysia due to the growth in industrial and transportation sectors, with a total of 194 million tons in 2011 to predicting to reach over 285 million tons in 2020. Practicing economic driving (eco-driving) strategies is one of the best solutions in minimizing fuel consumption, greenhouse gas emissions, and improving traffic safety [16]. The term of eco-driving can be defined as applying set of rules during driving aimed to minimize fuel consumption and improve safety [17]. Based on this definition, it can be found that modifying driving style could improve the efficiency of driving which leads to improve safety and reduce energy consumption. The following table 1 illustrates the potential impact of practicing eco-driving on different areas of activities. Encouraging

drivers to adopt eco-driving strategies can be through different ways such as prior education, post-drive statistics, or real-time in-vehicle feedback. Among these ways, it has been found that real-time in-vehicle feedback is working well [18].

Table 11: The potential impact of eco-driving [16]

Activity area	*Potential Impact*
Safety	• Road safety improvement • Driving skills improvement
Environment	• Greenhouse gas emission reduction • Reduction of noise
Economic	• Fuel consumption reduction • Reduction of maintenance costs • Reduction of traffic accidents costs
Social	• Driving awareness improvement • Reduction of stress during driving • Increasing ride comfort

Measuring and understanding behavior of driver while driving can be achieved through deploying in-vehicle sensors. These sensors aimed to measure different aspects of daily activities in vehicle operation [19]. In the last decades, the technology has been rapidly advanced especially in the areas of smartphone and wearable devices. Smartphone and wearable devices are low cost, widely available, and easily accessible [20]. The improvement of the capabilities of smartphone devices by the variety of embedded powerful sensors included such as global positioning system (GPS) and accelerometer opened the opportunity to measure driving behavior using these devices instead of the high cost installation of external hardware in the vehicles [21]. Additionally, On Board Diagnostics (OBD) adapters provide an access to read the status of different in-vehicle sensors such as fuel rate and oxygen, and at the same time OBD adapters enable a transparent connectivity between the smartphone device and electronic control unit (ECU) of the vehicle [22].

It has been mentioned in a study that eco-driving is a very cost-effective strategy aimed to reduce fuel consumptions up to 7%, reduce NOx emissions up to 5%, reduce PM2.5 emissions up to 7%, and reduced CO2e around 700 metric tons per year. In a transit service bus, the amount of fuel savings around 208,200 Liters of diesel per year [23].It has been stated in another study collected different studies' results that eco-driving contributed to less accidents up to 35% during the test drives [24].

Eco-Driving

Eco-driving stands for economic driving and it was identified as different sorts of decisions associated with driving techniques that aiming in improving driving style with immediate impacts on fuel consumption and greenhouse emission by adopting appropriate driving style [13], [25]. Eco-driving associated with three decisions' levels; operational decisions (e.g. driving style), tactical decisions (vehicle loading, route selection), and strategic decisions (vehicle maintenance, vehicle selection) [25]. Eco-driving could be considered as a better and more efficient driving way that uses optimally modern technologies' possibilities while increasing traffic safety at the same time. The environment is impacted by the vehicles in terms of CO2 emissions and fuel consumptions by the interaction determination of vehicles' technical elements and driving modes [16]. Any small reduction in fuel consumption may increase fuel economy and reduce greenhouse gas emissions significantly [16]. Eco-driving includes different sets of practices, such as driving within the speed limit, gentle acceleration, avoiding harsh braking, shifting up the gear early, driving with the traffic flow, and limiting idling in order to reduce fuel consumption [13], [23], [26]. As stated in [16], the stages of eco-driving modes can be divided into pre-trip stage and during the trip stage. Different recommendations are provided within each stage to ensure efficient driving. A formula was developed for the relevant efficient eco-driving methods. The following equation 2-1 presents the different factors that influence eco-driving efficiency.

Equation 1: factors influence eco-driving efficiency

$$E = f(S,T,O,P,U,R,I,B)s,t$$

Where, 'E' is eco-driving efficiency; 'S' is standard vehicle maintenance according with the manufacturer; 'T' is reducing the amount of transported cargo; 'O' is proper tyre pressure maintenance; 'P' is gentle acceleration and braking with maintaining safe distance between vehicles; 'U' is slight deceleration using car engine; 'R' maximum minimizing of using the air condition (heating and cooling); 'I' is avoiding idling while driving; and 'B' is closing windows at high speeds.

The methods provided in the above equation 2-1 is describing the both eco-driving stages, where S,T, and O factors represent the before-the-trip stage, while P, U, R, I, and B factors represent the during-the-trip stage [16].

The benefits of eco-driving were discussed and evaluated through simulation driving, real field driving, or a combination of both. As an example of evaluation eco-driving in real field driving, a study was conducted with the aim of evaluating the effectiveness of eco-driving on fuel consumptions and CO2 emissions by using smartphone and OBD2. In their study showed that the fuel consumption was reduced by 22.78% and the CO2 emission was 16.33% less after following eco-driving strategies [16]. Another study was conducted to evaluate the impacts of eco-driving on public services through implementing eco-driving strategies in two different public urban (local and express) services. The results of the study showed a reduction in both fuel consumption and CO2 emission by 7% in express bus service and 5% in local transit service [23].

Evaluating eco-driving using simulator was conducted in previous studies from different perspectives. For instance, a simulator-based eco-driving support system was developed in a study to evaluate the impacts of eco-driving strategies. The results achieved a reduction in fuel consumption and CO2 emission by 5% [27]. Another study developed a simulation-based eco-driving strategy for hybrid vehicles operating on

rolling terrain, and the results presented a fuel efficiency improvement on steep slopes from 15.7% to 16.9% and 5% to 8.9% on mild slopes [28]. Further, a study developed a data-based Bayesian approach to identify and modify the speed to optimize fuel consumption for conventional vehicles. To validate the proposed approach, a software simulator and a real vehicle were used. The results indicated a reduction of fuel consumption by 8.2% overall [29].

2. Conclusion

In this paper, different concerns regarding the lack of road safety and increasing greenhouse gas emissions were presented. Applying eco-driving strategies by drivers can contribute to reduce road accidents, reduce fuel consumptions, reduce greenhouse gas emissions and improve driving efficiency. This paper provides an insight on eco-driving strategies to inspire other researchers to conduct more studies on this field in order to contribute to both improve road safety and save the environment.

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