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Passenger transportation sector gasoline consumption due to friction in Southeast Asian countries

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ABSTRACT

Energy demand in the transportation sector across Southeast Asian (SEA) region is rapidly increasing. This poses a challenge to the sector in mitigating greenhouse gas (GHG) emissions because of its heavy reliance on fossil fuels. Decarbonisation efforts tend to focus on the use of low carbon energy, often neglecting frictional losses in vehicles. Therefore, the study aims to determine the fuel cost savings and the environmental impact from reduction of frictional energy losses in passenger cars and motorcycles for selected SEA countries. An energy analysis framework is proposed; estimating a total of USD 42.6 billion/year is wasted through fuel energy loss in moving these vehicles in the selected SEA countries, emitting 109 Mtonne/year of CO_2. By implementing relevant tribological improvement strategies, fuel energy savings of USD 18.3 billion/year could be achieved, leading to 46.6 Mtonne/year of CO_2 emissions reduction. This level of CO_2 emissions reduction, obtained via friction reduction, can contribute between 0.8% and 1.9% towards the committed GHG reduction targets for the selected SEA countries by 2030. It is emphasised that combined effort, from vehicle manufacturers and end-users, is required in implementing relevant friction reduction strategies to avoid backlash from inappropriate use of these strategies.

1. Introduction

Global transportation energy demand is projected to increase up to around 155 quadrillion BTU (163 EJ) in the year 2040 from 104 quadrillion BTU (595 EJ) in the year 2012, representing a growth of 49% [1]. It is also projected that gasoline would remain as the largest transportation fuel at 33% in 2040 [1]. Such projection raises even more concern with regards to the effect of fossil fuel emissions on the environment. Therefore, it is important that countries, which participated in the 2015 United Nations Climate Change Conference (COP21), increase their effort to achieve their Intended Nationally Determined Contribution (INDC) towards green-house-gas (GHG) emissions reduction, in keeping the increase in global average temperature to well below 2 °C when compared with the pre-industrial era.

Most countries in Southeast Asian (SEA) region have announced INDCs relevant to the need of their countries to combat the rise of GHG emissions. The efforts put in by SEA countries are crucial in GHG emissions reduction because this region has a combined population that creates the world's third largest market, after China and India [2]. Besides this, in the year 2014, there are a total of 1.2 billion vehicles in use (excluding motorcycles) in the world [3], with an estimated 33.1% of these vehicles found to be used in countries from Asia, Oceania and Middle East. From this, about 13.5% of the total vehicles in use are found in SEA region [3].

It is only essential that the transportation sector also undertake significant decarbonisation measures, as one of the major contributor towards global GHG emissions (up to 23% global CO_2 emissions from fuel combustion [4]). Decarbonisation in the transportation sector could include, but not limited to: (1) moving towards alternative fuels; (2) improving energy efficiency on vehicles and (3) using alternative lubricants. Such measures could prove to be a challenge to COP21 participating countries' success in achieving the levels of GHG emissions reduction committed in their announced INDCs because of the heavy reliance on fossil fuel products in this sector [5].

One of the common example of decarbonisation effort in switching to alternative fuels include blending of bioethanol with gasoline to be used in internal combustion (IC) engines, which has been shown to significantly reduce life cycle GHG emissions [6]. For IC engines running on diesel fuel, blending of biodiesel, derived from natural feedstocks, such as palm oil, with diesel fuel has been shown to be able to

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reduce life cycle GHG by 1.03 million tonnes in Malaysia [7]. In a separate study, it is estimated that CO_2 emissions in the transportation sector in Malaysia could be reduced between 6.7% and 15.1% by blending 5% biodiesel (B5) in diesel fuel and 10% bioethanol (E10) in gasoline fuel for use in vehicles running on IC engines [8].

Blending of biodiesel (e.g. soybean oil derived) with diesel fuel has been reported to reduce CO_2 emissions when used in IC engines [9]. However, there are also conflicting observations being reported in literature, showing increased CO_2 emissions, when biodiesel blended with diesel fuel is used to operate these engines [10,11]. Other studies have demonstrated that too high an amount of biodiesel blending with diesel fuel in IC engines could lead to significant engine lubricant dilution, generating increased friction and wear [12–14]. Some engine manufacturers even reported of possible premature engine failure as a result of higher levels of biodiesel dilution of the engine lubricant [15]. In addition to these, there are also concerns on corrosion of engine components being in direct contact with such biofuel, affecting durability of the engines [16].

Pongthanaisawan and Sorapipatana [17] found that moving to alternative fuels does have higher GHG mitigation impact in the short term. However, they also stated that improving efficiency of vehicles could have higher GHG mitigation in the longer term, only with the condition that the penetration of high-energy efficiency technologies increases significantly. Therefore, alternatively, the transportation sector can also focus on using higher energy efficiency vehicles. This involves promoting the use of either fuel cell, solar photovoltaic system [18] or electric powered vehicles. In Japan, it is estimated that a reduction of CO_2 emissions by as much as 81% by the year 2050 when compared with the level in the year 1990 could be achieved, if the share of low emission vehicles, such as electric vehicles, reach 90% and 60% in passenger and freight transportations, respectively [19].

Egbue et al. [20] mentioned that increasing the penetration of electric vehicles heavily depends on: (1) the public's willingness to pay for the new technology; (2) the amount of distance that can be travelled using these vehicles; (3) the perception of these vehicles as being good for the environment and (4) the perception of these vehicles' travel speed. It is also essential that appropriate electric vehicle charging strategies be implemented using renewable energy sources [21–23]. However, some still believed that electric vehicles might take a while before being largely used across the globe due to its high vehicle and battery costs [5,24]. A recent study found that existing transportation infrastructure might still favour liquid alternative fuels over electricity or hydrogen [25]. The same study also mentioned that human nature of satisfying their needs with the least effort might also favour liquid fuels over electricity.

In view of these possible scenarios, alternative decarbonisation approaches should also be considered. The analysis by Zhao et al. [26] suggested that conventional powertrain for vehicles still has potential for energy conservation. Fuel economy standards for motor vehicles, where a minimum requirement for the energy performance of the vehicle that manufacturers must meet before it can be legally sold, have been identified as an effective strategy in reducing emissions [26–29]. One of the possible ways to conserve energy in vehicles includes reducing frictional energy losses in improving the vehicle fuel efficiency. Holmberg et al. estimated that one third of available fuel energy is actually being used to overcome friction in passenger cars [30]. By reducing frictional losses in passenger cars worldwide, it is possible to achieve fuel savings of up to 385 billion litres/year and CO_2 emissions reduction of up to 960 million tonnes/year.

In order to determine the impact of various possible decarbonisation efforts, a number of studies employed econometric models for energy planning analysis in estimating energy demand and CO_2 emissions in the transportation sector [17,31,32]. Some researchers adopted optimisation models to facilitate energy planning for this sector [8,33,34]. Typical economic quantities used are type of fuel mix, fuel price, income per capita and fuel consumption. However, such analysis approaches lack the capacity to directly consider the effect of engineering technological advancements towards vehicle energy consumption improvements, such as friction losses reduction. For this, Holmberg et al. proposed a method to calculate energy consumption for passenger cars by breaking down the energy consumption into exhaust and cooling losses and mechanical power [30], allowing for more detailed inclusion of vehicle energy consumption measures.

Table 1
Estimated number of vehicles in use by type in selected Southeast Asian (SEA) countries in 2014.

	Number of vehicles in use (thousand units)			
Country	Passenger cars [3]	Commercial vehicles [3]	Motorcycles	Total
Indonesia	12,595	8278	92,976 [35]	113,849
Malaysia	11,027	1201	11,088 [36]	23,316
Philippines	3099	437	4489 [37]	8025
Singapore	648	179	144 [38]	971
Thailand	8381	7224	19,147 [39]	34,752

In this study, the aim is to determine the financial savings and the environmental impact of frictional losses reduction in the SEA region transportation sector, which is often ignored in most energy analysis. Table 1 shows the breakdown of vehicle types in use in selected SEA countries. The three major types of vehicles include passenger cars, commercial vehicles and motorcycles. Overall, in the selected SEA countries, it can be observed that passenger cars and motorcycles are the two most common vehicles in use. In Fig. 1(a), passenger cars are observed to be the dominant type of vehicle in use in Singapore, which comprises 66.7% of the estimated total vehicles in use in this country. On the other hand, in Indonesia, approximately 81.7% of the vehicles in use are motorcycles. Similar observation can also be made for countries such as the Philippines and Thailand, where motorcycles contribute towards 55.9% and 55.1% of the estimated total vehicles in use in these countries, respectively. However, the number of passenger cars (47.3%) and motorcycles (47.6%) in use in Malaysia are evenly matched.

The information on commonly used fuel type by the transportation sector in SEA region is also critical when conducting the intended energy analysis. It is found that the fuel type typically used for motorcycles in these countries is gasoline. However, the same cannot be said for passenger cars in the selected SEA countries as depicted in Fig. 1(b). The passenger cars in most of these countries are observed to mainly run on gasoline fuels. However, diesel fuel usage for passenger cars in Indonesia, the Philippines and Thailand are shown to also be fairly significant. The other fuel types consumed by passenger cars considered in Fig. 1(b) include Compressed Natural Gas (CNG), electric, combination of gasoline and electric and combination of diesel and electric.

From Fig. 1, it can be surmised that the major types of vehicles in use in the selected SEA countries are passenger cars and motorcycles, predominantly running on gasoline fuel. Hence, the current energy analysis has chosen to focus on determining the gasoline fuel energy consumption by passenger cars and motorcycles in Indonesia, Malaysia, the Philippines, Singapore and Thailand. The financial savings and environmental impact from possible reduction of frictional energy losses for passenger cars and motorcycles are identified by adopting the framework proposed by Holmberg et al. [30].

2. Methodology

The energy analysis in the current study focuses on gasoline fuel energy usage by passenger cars and motorcycles in selected SEA countries. The breakdown of fuel energy consumed by each of these vehicle types has to first be determined in order to ascertain the relevant frictional energy losses. Fig. 2 illustrates the energy analysis framework adopted for the current study. The following sections