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Comparison of Emission Levels of Passenger Transport Modes in Sri Lanka

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Abstract During last eight years' total vehicle population in the country has been doubled according to the statistics of Department of motor traffic resulting in an increase of emissions. Road transportation have the highest vehicular emissions in terms of Greenhouse gases (GHG) in Sri Lanka. In a global perspective the emissions of multi modal vehicle fleet stand at 61%, 24%, 6%, 6% and 3% of GHG's emits from buses, private vehicle, railways, para-transits and trucks respectively. According to the Sri Lankan department of motor traffic statistics, motor bicycles, motor tricycles and motor cars are the highly used vehicle types in Sri Lanka. In moving towards emission reduction through modal shifts to reduce, it is required to quantify the potential emission reduction gained through different modal shifts. Using the vehicle emission database, this research attempts to quantify emission reductions gained through different transportation strategies. All vehicle emissions were measured emissions per maximum seat occupancy in order to find per capita emissions in each vehicle category. It was found that motor bicycles (4.3% v/v per seat of CO_2 & 850 ppm per seat of HC) and motor tricycles (300% v/v per seat of CO) have the highest emission rates per passenger. Dual purpose vehicles (1.25% v/v per seat of CO_2) and buses were identified as the lowest emitters. Motor cars have slightly high emission levels comparative to buses. (350 ppm per seat of HC & 1.75% v/v per seat of CO_2). But still motor cars can be identified as a better mode than motor cycles and motor tricycles. Results of this study can be used to identify potential vehicle shifts which can be implemented to reduce emission growth in the country.

Keywords: *greenhouse gases, vehicle emissions, vehicle shifts*

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1. Introduction

Air pollution is considered as one of the key environmental isses for most of the busy cities like Colombo and Kandy. Rapid increment of vehicle fleet is the major source of air pollution. It state that 2 stroke engine light vehicles produce 20 – 50% of unburnt fuel (Carbon monoxide & hydrocarbons) while diesel vehicles produce most of nitrogen oxide with lower levels of other emissions. [1] Increasing traffic congestion, overcrowded buses and other vehicles contribute importantly to the air pollution [2]. With the economic growth, job opportunities increase along with the commuter travel distance which is 9 - 12 Km per day in present [3]. The higher commuter distance, will contribute to higher energy consumption. It will lead to poor air quality in urban areas. Smart urban designs have to be implemented in order to minimize the travel distance between residential area and offices or occupational places [3]. Present focus of world is to move away from car dominant development era by avoiding building of more infrastructure for private vehicles. This will enable the allocation of more space for public transportation and non-motorized transportation [4]. Sustainable transportation policies also can cut down vehicular emissions moderately. Aappropriate multi modal mix (such as rail-road, public-private and non-motorized-motorized) which is compatible with economy of a country would contribute positively to reduce vehicular emissions [5].

2. Objective of the Study

The main objective of the study is to identify the emission rates of vehicles corresponding to its maximum seat occupancy rate and thereby compare the emission levels of different vehicle categories to identify low emission modes of transportation.

3. Literature Review

In a study conducted to identify the trends of transport sector emissions, shows the effect of fuel price, vehicle import tax variation on vehicle fleet in Sri Lanka [6]. It was found that import tax change was an influential contributor to increase of vehicle registration while fuel price variation was not much correlated. They also observed a significant growth of hybrid vehicles over the recent past. In comparing the emission levels of hybrid cars against conventional petrol cars, the authors found out carbon monoxide emissions are ten times and hydro carbon emissions are five times lower in hybrid vehicles [6]. But authors found that there was no significant difference in carbon dioxide emissions between hybrid and petrol vehicles [6]. From the analysis results, higher age of vehicle with respect to manufactured year may burn much fuel increasing the CO and HC emissions. At the same time CO_2 emissions will be reduced due to poor fuel consumption.

Catalytic converters can reduce CO and HC emission levels of petrol motor cars where catalytic converters convert HC into CO_2 [7]. It also produces higher emission of CO_2 in petrol motor cars as a secondary product. Furthermore, motorcycles and tricycles were found to emit higher CO and HC content and lower CO_2 content due to absence of catalytic converters. Due to the currently practiced less stringent average emission standards in Sri Lanka , even those vehicles with substantial emission levels are accepted through the emission test procedures. Emission of petrol vehicle in Sri Lanka can be minimized by introducing catalytic converters to all non-catalytic vehicles. Furthermore, researchers [7] state that the emission standards can be made more strict while controlling total emissions significant values through the introduction of catalytic converters.

According to a previous study on Sri Lankan emissions [2], most significant vehicle types in air pollution are two stroke three wheelers, motor bicycles and diesel vehicles. Increasing traffic congestion, overcrowded buses and other vehicles significantly increase the air pollution.

Promoting non-motorized transport is one of the emission reducing strategy. World is now trying to recover from car dominant development era by avoiding the building of more infrastructure for private vehicles and provide more space for public transportation and non-motorized transportation.

4. Methodology

As the transportation mode choice vary with the human needs, different travel modes were identified. Emission levels per head were compared to quantify the emission development with the mode choices. Only CO_2, CO and HC emissions were considered in this study which were taken from the vehicle emission test results of both petrol and diesel vehicles. The emission test data for diesel vehicles are available as a k-factor, and the emission levels were calculated based on a formula derived in a previous study by the authors. K-factor was converted to emission levels of CO_2, CO and PM as detailed in [8]. Vehicle emission data (from 2011-2015) were obtained from Department of Motor traffic Sri Lanka catogorised by vehicle type and fuel type. Maximum seat occupancy rates of vehicle types were judged by authors to calculate per head average emissions per each vehicle type. Different modes of transportation were analyzed irrespective of the fuel type. Afterward per seat emission rates were compared between selected vehicle categories. Analysis was carried out for a selected sample of vehicles from the Vehicle emission test database as detailed in Table 1.

Table 1. Sample sizes of vehicle categories

Vehicle Category	Sample Size
Motor Car	5534 (D) + 492 (P)
Motor Bicycle	94489 (P)
Motor Tricycle	7478 (D) + 40127 (P)
Dual Purpose vehicles	30833 (D) + 789 (P)
Buses	1236 (D)
D – Diesel Vehicle, P – Petrol vehicles	

5. Results and Discussion

From the multimodal vehicle fleet in the Sri Lankan road network, following vehicle types were identified as the highly demanded vehicle types. During past six years vehicle population had grown as in Table 2 and Figure 1.

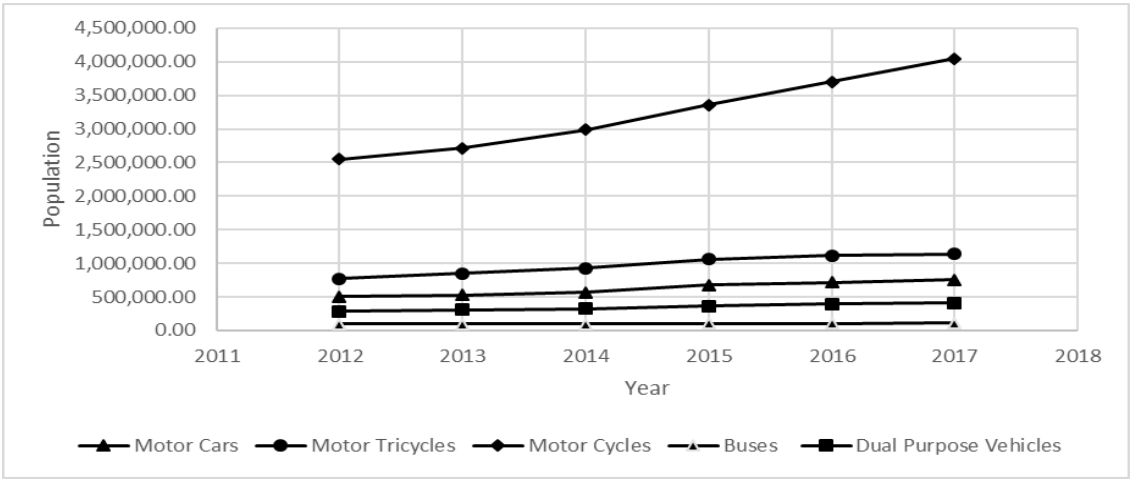

Figure 1. Annual Vehicle population growth

Table 2. Vehicle Population Growth

Year	2012	2013	2014	2015	2016	2017
Motor Cars	499,714	528,094	566,874.00	672,502.00	717,674.00	756,856.00
Motor Tricycle	766,784.00	850,457.00	929,495.00	1,059,042.00	1,115,987.00	1,139,524.00
Motor Cycles	2,546,447	2,715,727	2,988,612.00	3,359,501.00	3,699,630.00	4,044,010.00
Buses	91,623.00	93,428.00	97,279.00	101,419.00	104,104.00	107,435.00
Dual purpose vehicles	280,143	304,746	325,545.00	365,001.00	391,888.00	408,630.00

Table 3 represents the maximum seat occupancy rate of each vehicle category.

Table 3. Maximum seat occupancy

Vehicle Type	Number of seats.
Motor car	5
Motor cycle	2
Motor Tricycle	4
Dual purpose	12
Bus	40

From the database of vehicle emission test data from 2011 to 2015, the average emissions of above selected vehicle categories were calculated as stated in Table 4 to Table 6.

Table 4. Average HC (ppm) emission rates per seat by petrol vehicle category

Year	Motor car	Motor cycle	Motor tricycle	Dual purpose
2011	0.038	1.138	0.525	0.014
2012	0.026	1.076	0.536	0.011
2013	0.018	1.084	0.541	0.010
2014	0.011	0.889	0.484	0.010
2015	0.010	1.066	0.457	0.050

Table 5. Average CO (% v/v) emission rates per seat by petrol vehicle category

Year	Motor car	Motor cycle	Motor tricycle	Dual purpose
2011	2.918	4.272	2.252	1.239
2012	2.908	4.227	2.210	1.234
2013	2.976	4.154	2.233	1.239
2014	2.995	4.329	2.324	1.244
2015	2.957	4.312	2.327	1.185

Table 6. Average CO_2 (% v/v) emission rates per seat by petrol vehicle category

Year	Motor car	Motor cycle	Motor tricycle	Dual purpose
2011	13.512	916.051	270.052	7.249
2012	10.130	881.139	276.696	5.999
2013	6.357	871.306	295.083	5.719
2014	7.987	816.620	299.646	5.287
2015	6.249	830.983	293.941	13.062

Above calculated results had been plotted between manufactured year and emission level, to identify trend of per seat emissions for different vehicle categories were observed as shown in Figure 2 to Figure 4.

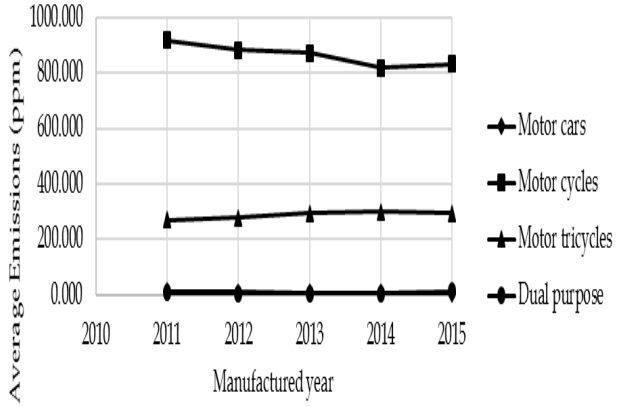

Figure 2. Average HC emission rates per seat by petrol vehicle category

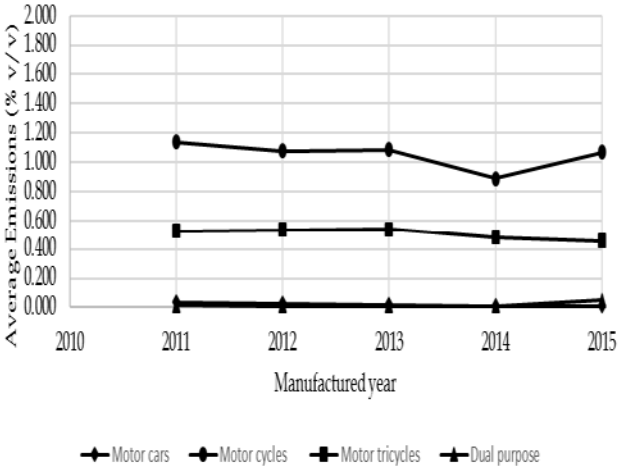

Figure 3. Average CO emission rates per seat by vehicle category

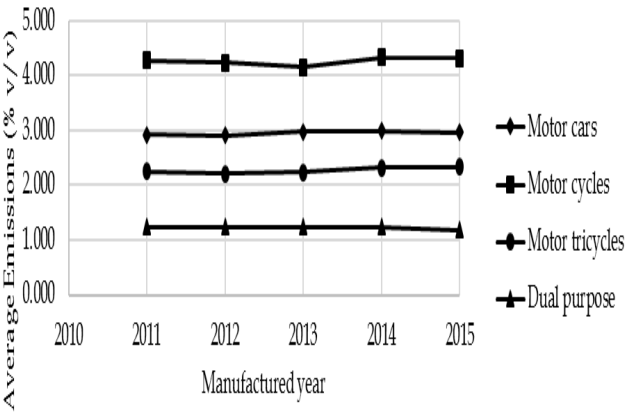

Figure 4. Average CO_2 emission rates per seat by vehicle category

Approximately 10% of the Sri Lankan vehicle fleet is fueled with diesel. Therefore, the average emissions for the diesel fueled vehicles are as Table 7 to Table 9.

Table 7. Average CO (% v/v) emission rates by diesel vehicle category

Year	Motor car	Buses	Motor tricycle	Dual purpose
2011	0.029	0.067	0.062	0.063
2012	0.027	0.050	0.061	0.065
2013	0.020	0.033	0.049	0.061
2014	0.021	0.040	0.052	0.055
2015	0.020	0.023	0.052	0.052

Table 8. Average CO_2 (% v/v) emissions by diesel vehicle category

Year	Motor car	Buses	Motor tricycle	Dual purpose
2011	0.508	1.165	1.081	1.093
2012	0.469	0.863	1.056	1.121
2013	0.343	0.573	0.849	1.057
2014	0.371	0.696	0.892	0.960
2015	0.346	0.391	0.901	0.907

Table 9. Average PM (ppm) emissions by diesel vehicle category

Year	Motor car	Buses	Motor tricycle	Dual purpose
2011	0.114	0.262	0.243	0.246
2012	0.105	0.194	0.237	0.252
2013	0.077	0.129	0.191	0.238
2014	0.083	0.156	0.200	0.216
2015	0.078	0.088	0.203	0.204

From the results it was observed that motor tricycles emit more CO pear seat compared to the other modes of transportation. The motor cycles emit most of the CO_2 and HC per seat and motor tricycles emit highest CO emissions per seat. Dual purpose vehicles have low HC and CO emissions per seat and 3rd lowest CO_2 emissions per seat. Motor cars have the 2nd lowest HC emissions per seat and 2nd highest CO_2 emissions per seat. Buses represent the lowest CO_2 & CO emissions per seat compared with the other vehicle categories. According to the previous work by authors, it had found that overall diesel emissions are lower compared to petrol vehicles. But the disadvantage is the emission of particulate matters (PM) which is carcinogenic. Special consideration was done towards hybrid motor cars which is the trending automobile fuel technology in the country. According to [9], Hybrid vehicle emissions are negligible compared to existing emission standards of Sri Lanka. Author had stated an average CO emission rate of 15.52 (ppm) of HC and zero of CO emissions for hybrid vehicles. Figure 5 to Figure 7 represent the variation of emission rates of motor cars per seat with the different fuel types.

Emission rates of motor tricycles and motor cycles were higher due to the poor fuel combustion and the engine technology of the vehicles. In general, the emission levels per seat are lower with the higher seat occupancy rate. According to [10] it has been further shown that the per seat emission difference between public transport to car is approximately 1:7 in Great Britain. This confirms the need for more long term solutions such are Electric powered Rails or LRT some of which are envisaged by the Megapolis Master plan for Western Region. However, the findings of this study can equally be applied for solutions in the short run by discouraging the growth of motor bicycles and motor tricycles. Sensitivity of vehicle buyers to the tax variation as confirmed by past tax revisions [6] could be used to operationalize this.

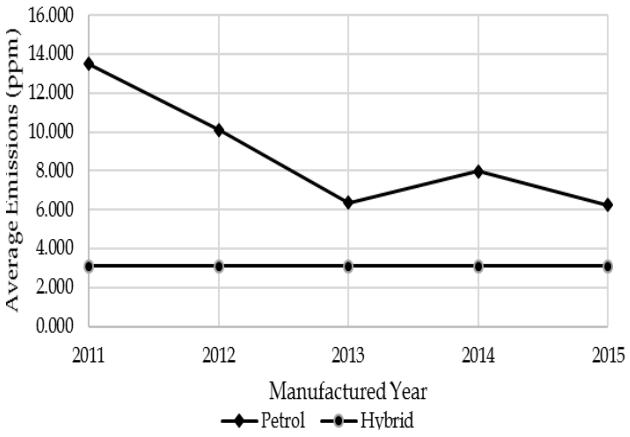

Figure 5. Average HC emission rates per seat for Motor cars

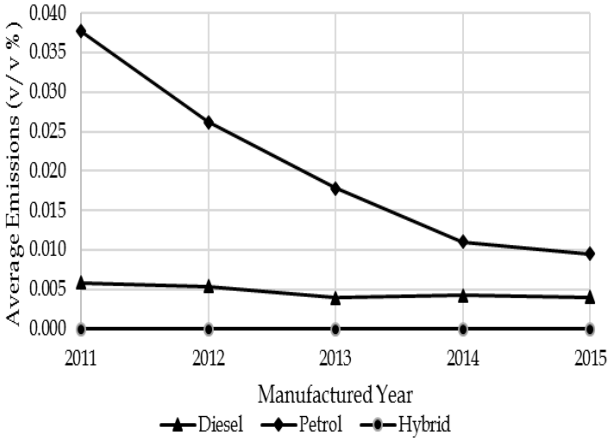

Figure 6. Average CO emission rates per seat for Motor cars

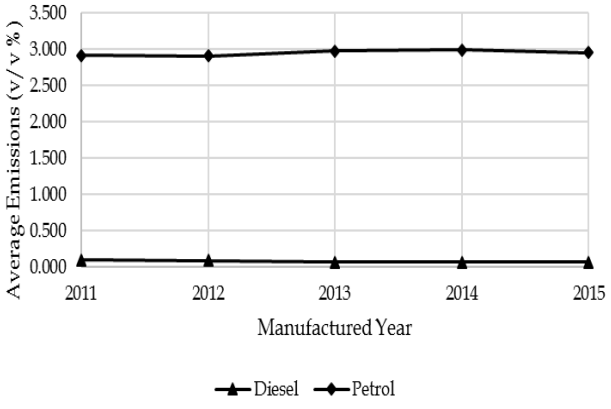

Figure 7. Average CO_2 emission rates per seat for Motor cars

6. Conclusions

Transportation mode choice shall vary with human needs, travel patterns and economy of individual. Mostly Sri Lankan public tends to move towards individual vehicles due to inefficiency of the public transportation system in the country without thinking on its environmental and economic impact.

But usage of public transportation, shared transportation and shuttle services enables to reduce per seat emission generation within the road network. As well as it improves the economy by optimum usage of resources in the transportation sector. Transportation modes like buses and dual purpose vehicles with full seat occupancy rate are the most reliable modes of transportation to reduce emissions. Electrification of transport modes (Ex: Electric Trains) may save a bulk of emissions to the environment. Therefore, travel mode shifting from private vehicles to public and shared transportation modes would be an eco-friendly long term transportation solution in terms of emissions. Encouraging motor cars instead of motor cycle or motor tricycle would lead to massive emission reduction. Government can directly control over the vehicle imports via import tax changes. Even though, extreme casualties on vehicle emissions are not caused up to date, promoting on green transportation (Low emissions) shall be a definite investment to the future.

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