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To cite this article: M R Muhammad Saifuddin *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **373** 012024

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Addressing GHG emissions from land transport in a developing country

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Abstract. The number of motor vehicles in Malaysia is growing at a significant rate, from around 15 million in 2005 to around 25 million in 2014. Based on the National GHG Inventory as reported to UNFCCC, as a whole the transport sector has consistently remained the second largest GHG emitting sector in the country, accounting for 20% of the country's total GHG emissions in 2014 of which about 18% comes from road transportation. In this paper, a possible approach in addressing the GHG emissions from the land transport sector is presented. The *avoid-shift-improve* strategy is employed to determine the possible measures to deal with mitigating the GHG emissions. Computation of GHG emissions for 2014 revealed that car is the vehicle with the biggest contribution, due to its large numbers and also VKT. Motorcycles, on the other hand, have relatively lower GHG contribution despite its huge numbers, while goods vehicle have significant GHG contribution despite its small number of vehicles. Public transport (both rail and bus) can significantly reduce GHG emission for each passenger-kilometer compared to other alternatives. Opting for smaller vehicle can also reduce GHG emissions. Another potential solution towards lower GHG emission is adoption of electric mobility and alternative fuel.

1. Introduction

Based on the National Greenhouse Gas (GHG) Inventory as reported to UNFCCC, as a whole the transport sector has consistently remained the second largest GHG emitting sector in the country, accounting for 20% of the country's total GHG emissions in 2014 of which about 18% comes from road transportation [1]. As such, one of the important sectors to reduce GHG emissions in order to help meet Malaysia's commitment to the Paris Agreement would be the land transport sector. Under the Paris Agreement, Malaysia has committed to reducing GHG emissions by 45% by 2030 in relation to our 2005 GDP. This target was set with 35% on unconditional basis and 10% on conditional basis upon receipt of climate finance funding, technology transfer and capacity building from developed countries.

According to previous studies [2,3,4,5,6] the contribution to GHG emissions from the land transport sector will be dependent on a number of parameters ranging from land use planning, travel behaviour, vehicle technology and fuel and energy sources.



The magnitude of GHG emissions from road transport vehicles is very much linked to the land use pattern in a city or urban area. Transit-oriented development (TOD) and green urbanisms are two built forms or land use development models that could lead to a more sustainable urban future. Cervero and Sullivan [2] explored synergies that are created when neighborhoods are designed as both green and transit-oriented and how 'Green TOD' can reduce a project's environmental footprint more than each strategy can achieve individually. They estimated that carbon emissions and energy consumption of Green TOD can be nearly 30% less than that of conventional development.

A study by Yang et.al [3] investigates how California, USA may reduce transportation GHG emissions 80% below 1990 levels by 2050. They conclude that although no individual strategy exists that can achieve the goal, the ambitious GHG emission target in California, USA for transport may be achieved if a concerted effort is made to change travel behaviour and the vehicle and fuels that provide mobility.

McCollum and Yang [4] analyses scenarios with multiple options (increased efficiency, lower-carbon fuels and travel demand management) across various subsectors and confirmed the notion that if substantial emission reductions are to be made, considerable action is needed on all fronts. They conclude that in all cases, travel demand management strategies are critical; deep emission cuts will not likely be possible without slowing growth in travel demand across all modes.

The need to reduce GHG emissions from road transport is not only related to climate change but also to health concerns. A study by Woodcock et.al [5] to estimate the health effects of alternative urban land transport scenarios for London, UK, and Delhi, India, found that a combination of active travel and lower emission motor vehicles would give the largest benefits in terms of reduction in the number of years of life lost from ischaemic heart disease. They [5] conclude that climate change mitigation in transport should benefit public health substantially. Policies to increase the acceptability, appeal, and safety of active urban travel, and discourage travel in private motor vehicles would provide larger health benefits than would policies that focus solely on lower-emission motor vehicles.

A study on GHG emissions from the transport sector in Thailand [6] reports that two mitigation scenarios were investigated, namely, fuel switching and energy efficiency options, and it was found that both these mitigation options can reduce the GHG emissions differently. The fuel-switching option could significantly reduce the amount of GHG emissions in a relatively short time frame, whereas the energy efficiency option is more effective for GHG emissions mitigation in the long term. As such, both measures could be implemented simultaneously for both short- and long-term mitigation effects so as to achieve GHG emissions reduction target more effectively.

2. A brief glance on the road vehicles and public transit

Here a brief glance of an overview of some relevant information with regard to the road vehicles and public transport scenario in Malaysia as a developing country.

2.1. Number of registered vehicles

The number of vehicles in the country is growing at a significant rate, from around 15 million in 2005 to around 25 million in 2014. The big majority of the registered vehicles are cars and motorcycles, with a volume share of 45 percent and 47 percent, respectively. Given the trend of an increasing number of vehicles expected to further continue, mitigation measures are needed to enable the country to fulfill its commitment to reduce Greenhouse Gas (GHG) emissions.

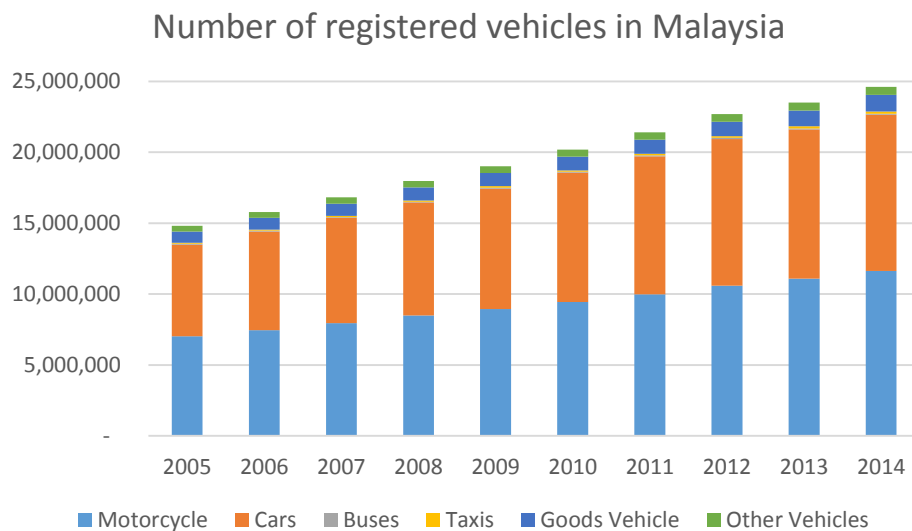


Figure 1. The cumulative number of registered vehicles in Malaysia. Source Data [7]

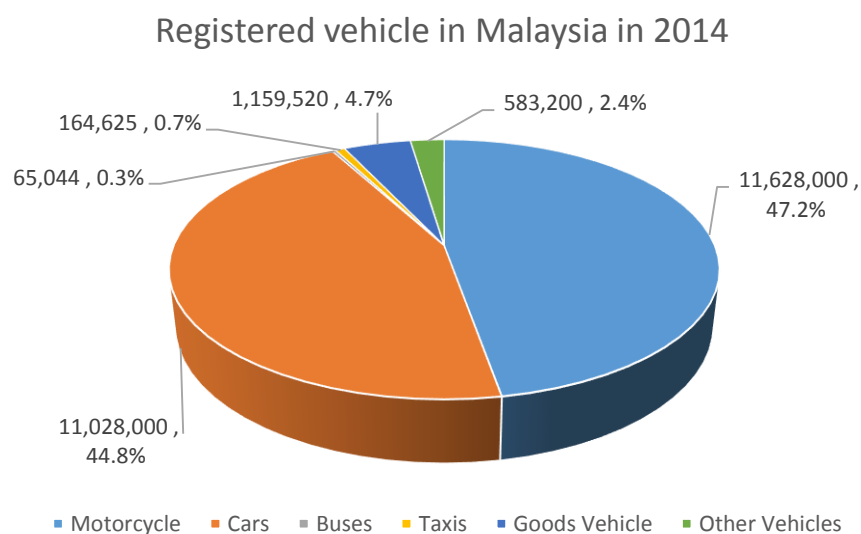


Figure 2. A number of registered vehicles in Malaysia. Source Data [7]

2.2. Public transit capacity, connectivity and accessibility

The rail transit ridership for the two LRT systems has been steadily increasing since 2008 until 2014 when it starts to plateau. Introduction of the MRT in 2017 has a modest impact on other types of public transport modes, only KTM Komuter and KLIA transit registered declining trend in the same year. There are a number of reasons for the KTM ridership decline which actually began in 2015: fare increase and the frequent disruptions of train services due to upgrading works on the rail network. It is not possible to determine how many among the MRT new users are previously private vehicle users, but the overall public transport ridership has increased after 2017.

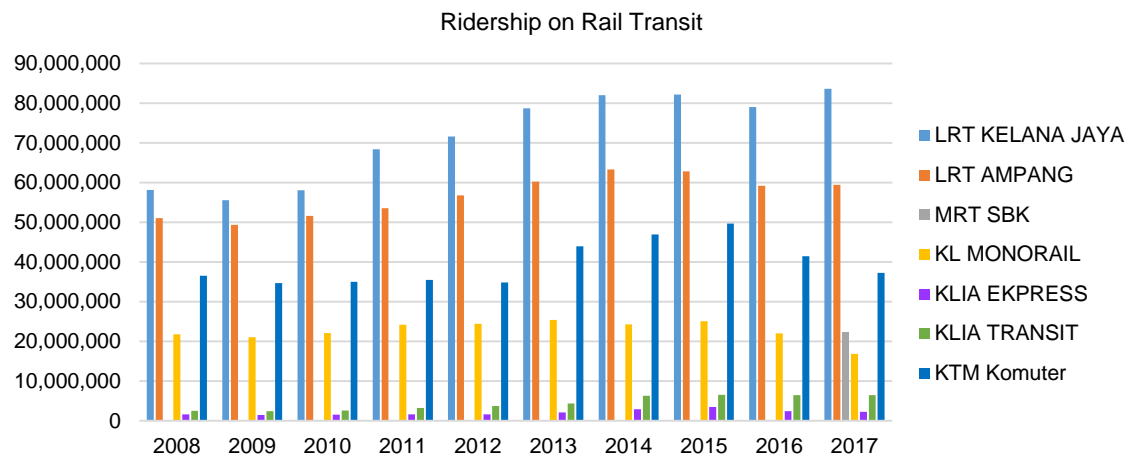


Figure 3. Ridership on rail transit

2.3. Supply and Demand of PT (Rail)

A ridership survey during the morning and evening peak hours at selected LRT stations along the Kelana Jaya Line within the Subang Jaya Municipality were conducted to determine the ridership demand for the LRT rail transit system. Figure 4 shows the actual boarding at each LRT station during the morning peak compared with the actual alighting during the same period at the same stations. Although the demand level varies between the LRT stations, the number of users that board and alight at each LRT station in the morning/evening peak hour appears to be almost similar in numbers. This appears to be the general pattern at the LRT stations which indicates that the LRT is a choice for a sizable number of the commuting public. The varying demand level between the LRT stations during the peak hours would be a tough challenge to handle because the LRT station with the highest demand would be dictating the capability of the LRT to accommodate the actual demand at all stations along the LRT route during the peak hours. Observations during the survey indicate that demand exceeds the train capacity during the peak hours and many users need to wait for the next train before they could continue their journey. A similar pattern is observed in the evening peak hour (Figure 5).

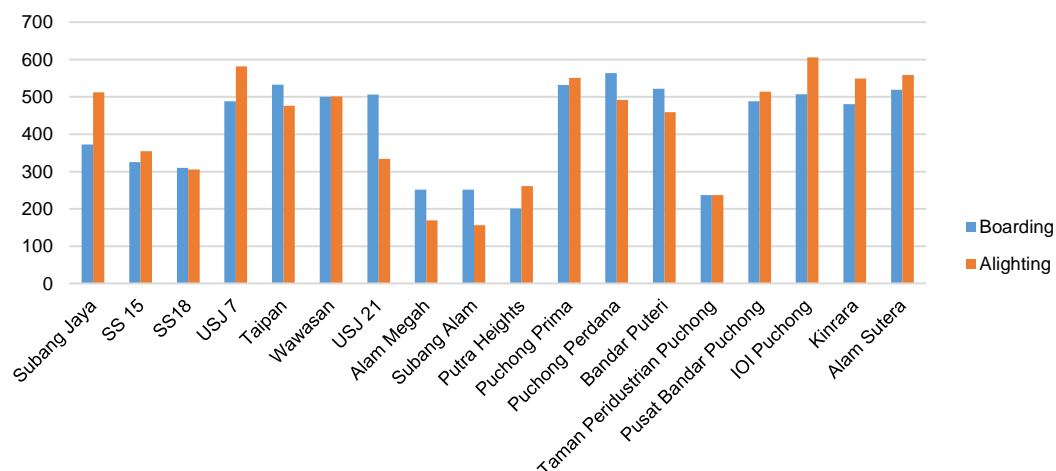


Figure 4. Morning Peak Hour Boarding and Alighting at LRT Stations, 2018

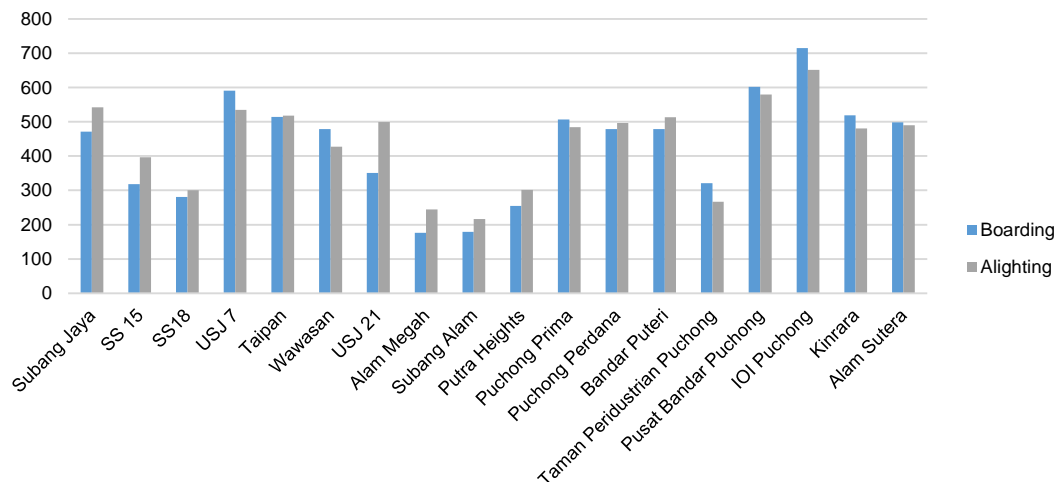


Figure 5. Evening Peak Hour Alighting and Boarding at LRT Stations, 2018

3. GHG emission from land transport

This section will present the baseline data for the analysis, the estimation of vehicle kilometer travel, and the resulting energy consumption and GHG emission produced by each vehicle type.

3.1. Baseline data

The GHG emission will be quantified based on available data on land transport. The aspects that directly affect GHG emission level includes vehicle fuel efficiency, the distance traveled, and the fuel used. The vehicle fuel efficiency and kilometer traveled are listed in Table 1 and Table 2. The emission factor for different fuel is shown Table 3.

Table 1. The fuel efficiency of land transport vehicles. Source of data: [7,8]

Vehicle Type	Fuel Type	Engine Size Range	Fuel Efficiency (km/L)	Fuel Efficiency (L/100km)
			*(km/kwh)	*(kwh/100km)
Motorcycle	Petrol	All	46.53	2.15
Motorcycle	Electricity	-	26.00*	3.85*
Car	Petrol	All	12.24	8.17
Car	Diesel	2000 cc and above	8.74	11.44
Car	Electricity	-	5.36*	18.64*
Bus	Diesel	All	3.56	28.10
Taxi	Petrol	2500 cc and below	10.21	9.79
Taxi	NGV	2000 cc and above	11.90	8.40
Taxi	Diesel	2000 cc and below	8.76	11.42
Goods vehicle	Petrol	2000 cc and below	9.00	11.11
Goods vehicle	Diesel	All	4.63	21.59
Other vehicles	Petrol	4000 cc and below	7.52	13.30
Other vehicles	Diesel	All	5.51	18.14
Rail	Electricity	-	0.31*	322.58*

Table 2. Annual vehicle kilometer traveled for different vehicle type

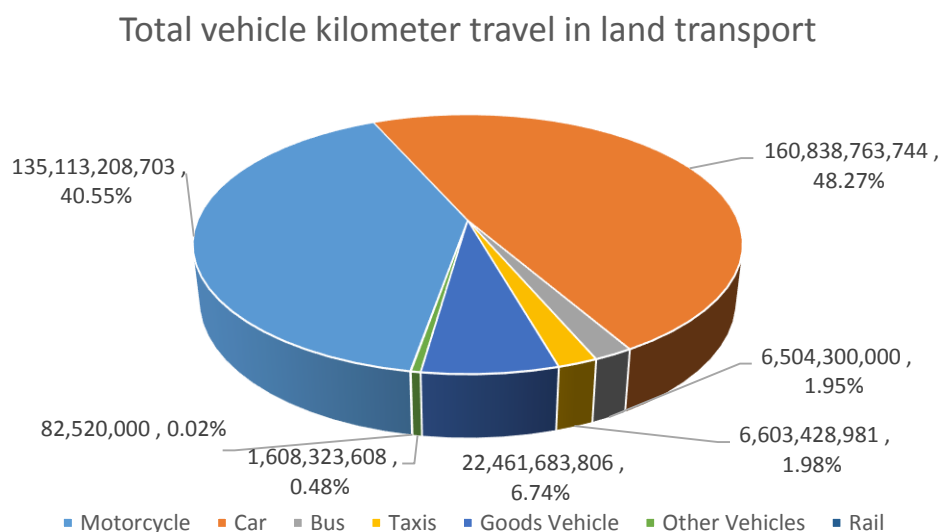
Vehicle Type	Annual Vehicle Kilometer Travelled (km)	Data source
Motorcycle	21,500	Shabadin, A., et al. (2017) [9]
Car	28,000	Shabadin, A., et al. (2017) [9]
Taxi	86,000	Economic Planning Unit (2017) [7]
Bus	100,000	Economic Planning Unit (2017) [7]
Goods vehicles	70,000	Briggs, A., et al. (2016) [10]
Other Vehicles	10,000	Economic Planning Unit (2017) [7]

Table 3. Emission factor for different vehicle fuel

Vehicle Fuel	Emission Factor	Source
Petrol	72.309 t CO _{2eq} /TJ	IPCC (2006) [11]
Diesel (B7)	70.085 t CO _{2eq} /TJ	IPCC (2006) [11]
CNG	59.294 t CO _{2eq} /TJ	IPCC (2006) [11]
Electricity	0.694 kg CO ₂ /kwh (192.7 t CO _{2eq} /TJ)	Greentech Malaysia 2016 [12]

3.2. Vehicle kilometer travel estimation

In computing GHG emission it is noticed that the registered vehicle number cannot be directly used for several reasons. First, the total registered vehicle number of almost 25 million is far larger than the number of licenses issued of 14.3 million [13]. Secondly, it would result in higher calculated values of energy consumption and GHG emission compared to what was reported in the National Energy Balance (NEB) report [14] the Malaysia Third National Communication and Second Biennial Update to the UNFCCC (BUR) report [1], respectively. Hence the calculation uses an estimated vehicle kilometer travel (VKT) that is proportionately adjusted to satisfy these conditions: number of vehicles on the road cannot exceed the number of licenses, and energy consumption and GHG emission values match the values reported in the NEB and BUR reports. The estimated VKT is presented in Figure 6.

**Figure 6.** Total vehicle kilometer travel by different vehicles in land transport for 2014

3.3. Resulting energy consumption and GHG emission for land transport

The resulting energy consumption and GHG emission from the various vehicle types inland transport are illustrated in Figure 7 and Figure 8, respectively. The biggest contributor to energy consumption and GHG emission is car. Relating to the VKT presented in Figure 6, it can be said that this observation is not unexpected as car has the biggest VKT compared to other vehicles. Motorcycle, despite having also a major portion of the total VKT, have significantly lower energy consumption and GHG emission contributions. This relates back to the significant difference in fuel economy between cars and motorcycles. Goods vehicles, despite having only less than 7 percent of the total VKT, contribute around 20 percent of the land transport energy consumption and GHG emission due to the significantly higher fuel consumption per unit vehicle. Buses also have big fuel consumption per unit vehicle, however the number of buses and hence VKT is very small compared to the total number of vehicles and the total VKT, resulting very small share of total energy consumption and GHG emission.

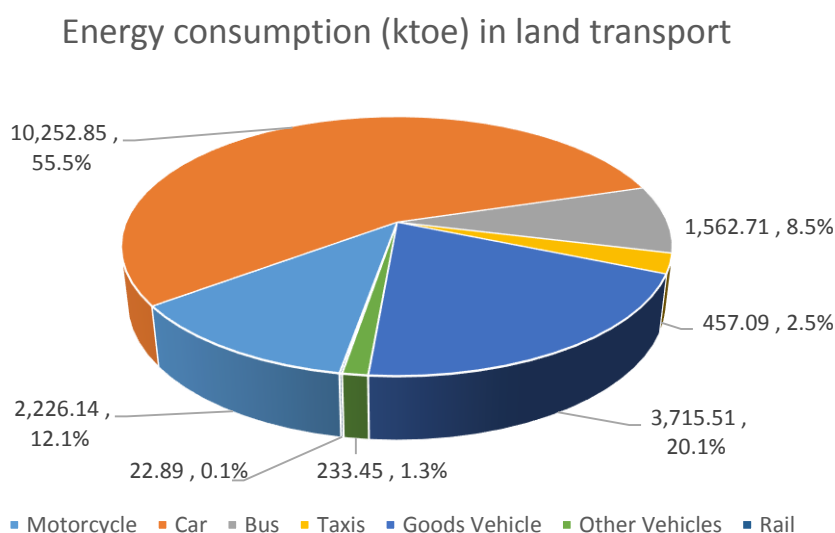


Figure 7. Calculated energy consumption by different vehicles inland transport for 2014

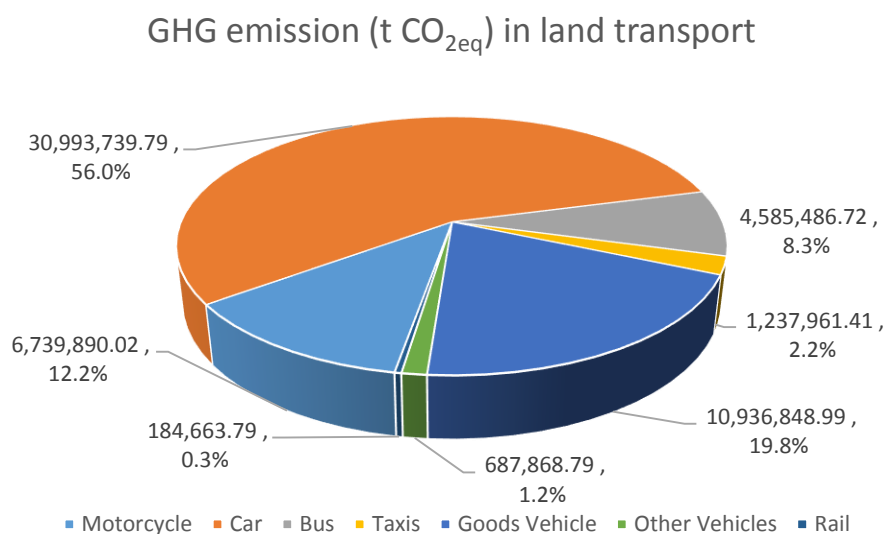


Figure 8. Calculated GHG emission by different vehicles inland transport for 2014

3.4. GHG emission comparison between different vehicle options

The GHG emission for each vehicle kilometer travel and also for each passenger kilometer travel is presented in Table 4. There are a few important notes to be noted about the values presented in the table. Based on the registered vehicle data, certain fuel type is used for car or taxi only for certain engine size. For example, diesel cars and taxis are only available for cars with 2000 cc or higher. As a result, side by side comparison with cars or taxis running on petrol may not give an accurate deduction, as the weighted average fuel efficiency for the vehicles will not be applicable for comparison. For instance, the majority of cars registered in the country are petrol cars below 2000 cc, hence the weighted average fuel consumption for petrol cars will be relatively low, compared to the weighted average fuel consumption for diesel cars will be relatively high. For motorcycle comparison, the electric motorcycle is clearly better than the petrol motorcycle in term of GHG emission.

For bus comparison, the diesel bus category is divided into two subcategories, namely less than 5000 cc and 5000 cc and above, so that a valid comparison can be made with the electric bus data which is based on stage buses and express buses which correlate to diesel buses of 5000 cc and above. Comparing diesel buses from the two subcategories, it is obvious that the smaller buses produce lower GHG emission level than the larger sized buses. Comparing electric bus with diesel bus with 5000 cc and larger engine, the GHG emission is comparable. It should be noted that the emission level of electric vehicles is dependent on the grid connected electricity emission factor, for which the energy source for the electric power generation. Given the commitment of the government to significantly increase renewable energy portion in the energy mix, the corresponding electricity emission factor would be lower, and hence the calculated GHG emission would also be lower.

Between different choices of vehicle for traveling, it can be seen that the GHG emission footprint would be significantly lower if travel by bus or rail is chosen, compared to personal car or taxi. This highlights the importance of mode shift from private cars or even taxi towards public transport of buses and rails, if significant GHG emission reduction is to be achieved. In case where public transport is not an option and personal vehicle need to be used, motorcycle would be the best option.

Table 4. GHG emission comparison for various land transport vehicles in Malaysia. Source data for occupancy rate: [10]

Vehicle	Fuel	GHG emission per vehicle km (g CO _{2eq})	Occupancy Rate (passenger/vehicle)	GHG emission per passenger km (g CO _{2eq})
Motorcycle	Petrol	49.89	1.2	41.57
Motorcycle	Electricity	26.68	1.2	22.23
Car	Petrol	189.63	1.4	135.45
Car (>2000cc)	Diesel	287.12	1.4	205.08
Car	Electricity	129.43	1.4	92.45
Bus (<5000cc)	Diesel	560.68	18.4	30.47
Bus (>5000cc)	Diesel	836.35	18.4	45.45
Bus	Electricity	835.81	18.4	45.42
Taxi (<2500cc)	Petrol	227.34	1.55	146.67
Taxi (<2000cc)	CNG	159.94	1.55	103.19
Taxi (>2000cc)	Diesel	286.52	1.55	184.85
Rail	Electricity	2237.81	36.75	60.89

4. Approach to address GHG emission

The general approach in addressing the GHG emissions from the land transport sector was formulated based on the basic understanding on the factors that influence the emissions of GHGs from the land transport sector itself. GHG emissions are from vehicles on the road that performs the function of moving people and goods from origin to destination for various trip purposes. As such, the trips made by various categories of vehicles on the road network for the specific purposes will determine the extent to which the GHG emissions are produced from the land transport sector.

Addressing the issue of GHG emissions from land transport may be considered as part of pursuing a more sustainable transport system, of which emissions from vehicular traffic affect the environment particularly the air quality within the vicinity. In this respect, the most appropriate approach to address the GHG emissions from land transport would be to utilize the *Avoid-Shift-Improve (ASI)* approach which is universally accepted as the approach to achieve a more sustainable transport system.

Adapting the ASI approach in this study was deemed most appropriate as can be understood from the following discussions. The *Avoid* strategy relates to the efficiency of the land use – transport system and means that the trip may not necessarily be made and can be avoided without jeopardizing the fulfillment of the purpose of the trip. It implies that a person can still perform a certain function without having to make the trip using a motorized vehicle. In this case, a motorized trip will be avoided, hence one less motorised vehicle on the road. As for the *Shift* strategy which relates to trip/travel efficiency implies that a person will choose a less carbon-intensive mode of transport (such as public transit, cycling) instead of the regular private car. Finally, the *Improve* strategy refers to the improvements that can be made on the vehicle technology and fuel efficiency as well as improvement to the traffic control and management system for more optimal traffic flow.

4.1 Focus Areas

Based on the ASI approach this study has identified four focus areas in which strategies and action plans can be developed to address the GHG emissions from land transport, the five focus areas are a modal shift, land use planning, vehicle technology, alternative fuel, and traffic management. The modal shift refers to people who are using private cars shifting to less carbon-intensive modes such as public transport and non-motorised transport. This is an important focus area in terms of GHG emissions reduction not only in terms of carbon reduction per capita for the mode but also the multiple effects on possible congestion reduction as well.

The second focus area is land use planning because the type of land use will impact on the travel pattern and modes to be used. A high-density mixed development would usually encourage higher public transport patronage as compared to low-density development. A transit-oriented development would encourage transit use as compared to urban sprawl. The third focus area is vehicle technology since improvements would lead to higher energy-efficient and environmentally-friendly vehicles. Alternative fuel would be the fourth focus area since the type and quality of fuel will influence the energy efficiency and carbon emission level of the vehicles. Last but not least is the focus on traffic management which aims to optimize the road traffic operations and improve traffic flow in the road network which will result in better energy savings and higher emission reduction.

5. Possible measures for modal shift, land use planning and traffic management

Measures that would encourage mode shift for those who are used to using their private vehicles may be in both ‘*carrot & stick*’ combination to make it more effective. Some of the examples of measures that were considered and analysed include improvements to the public transport system (road and rail) in terms of provision, service characteristics and infrastructure. Couple with this will be the traffic restraint measures (such as parking control, high parking rates, congestion charging) that would discourage private car use in the congested city areas. An increase in the provision of public transit not only involves the expansion of the current stage bus network and rail transit lines but also proposals to consider BRT and Trams in the city areas. The BRT would cater to the commuters from/to city areas, while the trams will provide for inner-city and within city movements. Shared mobility measures and

integration of cycling and pedestrian access to public transport stations and stops are also strongly recommended. Improvements to the First-Last-Mile access modes and infrastructure will encourage further patronage of public transport from amongst the private car users. Promotion of active transport modes for commuters accessing public transport stations/stops as well as those making short trips (such as school trips, shopping trips, lunch trips) would reduce the use of private cars, hence reduce GHG emissions.

As for freight transport, currently more than 95% are carried by road and less than 5% by rail. Since freight carried by rail is much more efficient in terms of per tonne-km, it is also recommended that a reasonable amount of freight carried by road need to shift to rail. As such, certain measures pertaining to rail network expansion and FLM access to rail stations from/to source of freight and terminals need to be considered. The energy savings and GHG emission reductions would be very significant per tonne-km of freight (both cargo and containers).

Promotion of public transport use can be made easier through appropriate land use development (or re-development). The transit-oriented development (TOD) has been proposed around transit stations or in its vicinity to reduce the need to use private transport for those in the TOD and those wanting to access the TOD. Sustainable intensification of land use by local authorities can limit urban sprawl, thus increasing the opportunity for public transport.

GHG emissions from vehicles are also related to the vehicle speed, thus an optimum traffic speed would greatly reduce emissions as compared to very low speed (as in congestion) or to a very high speed. The use of intelligent transport system (ITS) would be appropriate in cities to assist in improving the traffic flow and achieve a more appropriate traffic speed and reduce GHG emissions.

6. Possible measures through vehicle and fuel consideration

In term of vehicle and fuel consideration, comparison of GHG emission level presented earlier in Table 4 do illustrate that improvement of GHG emission level can be achieved by several measures, including having smaller vehicle instead of a larger vehicle, using alternative fuel such as CNG for taxis, and having vehicle technology like electric vehicles. Additionally, as calculated GHG emission is directly related to the fuel consumption of the vehicle, any vehicle technology that can improve fuel efficiency could be considered as possible measures to address GHG emission.

Both ‘*carrot & stick*’ combination may be used in effectively promoting any of the mentioned measures. In term of promoting smaller vehicles or highly energy-efficient vehicles that would require very low fuel consumption, both incentives for the consumer to opt for these vehicles, coupled with taxes that will discourage consumer from going for larger vehicle that consumes significantly more fuel. As for public transport fleet, a study may be performed to evaluate whether there is any route that does not require large buses that are actually served by large buses.

In term of having vehicles run on greener alternative fuel, a more detailed study may be needed to identify which vehicle segment would be ideal or viable for adoption of these fuels. Currently there is initiative by the government in term of increasing the biodiesel blend in the diesel supply for diesel vehicles. As for biogas, given that the country has significant number of oil palm mills, viable use of the biogas for transport may be studied and adopted.

In term of having more widespread adoption of technologies that significantly reduce GHG emission including electric vehicles, generally, the barrier for adoption for the consumer is the price gap between these vehicles and the currently cheaper vehicle options. Measures that can be considered include the adoption of these vehicles in the government fleet and also the public transport fleet. While functioning for its intended purposes, these vehicles should also be used as an advertisement to raise awareness of its viability and benefits. For the private car owners, the buyers of higher price bracket of cars can be targeted as the early adopters, with any tax structure and incentive which makes it appealing for them to opt for electric vehicle, for instance.

7. Conclusion

The transport sector is one of the most important sectors for the country to reduce GHG emission. Given the continuously increasing trend of the number of registered vehicles, mitigation measures are needed for the country to fulfill its commitment to reduce GHG emissions. Baseline information gathered from published data have been presented, and GHG computation has been performed. Passenger car is a significant road transport vehicle category as it contributes towards the biggest portion of total energy consumption and GHG emission.

Several conclusions can be made from the comparison of GHG emission. Firstly, public transport buses and rails can significantly reduce GHG emission for each passenger-kilometer travel. Some mitigation measures are needed for more people to shift towards public transport, given that some rail lines are already at maximum capacity during peak hours. Secondly, energy-efficient vehicles with better fuel efficiency would be a way forward and generally vehicle size does have an impact on GHG emission, where smaller vehicles tend to consume less fuel and hence produce less GHG emission. Opting for smaller cars or buses when possible can reduce GHG emission. Thirdly, electric vehicle does have potential to be one solution for lower GHG emission, especially given the commitment of the government to increase renewable energy portion in the energy mix.

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