Chapter 3

Transport

March 2017

This chapter should be cited as

ERIA and BNERI (2017), 'Transport', in Kimura, S., R. Pacudan and H. Phoumin (eds.), *Development of the Eco Town Model in the ASEAN Region through Adoption of Energy-Efficient Building Technologies, Sustainable Transport, and Smart Grids*. ERIA Research Project Report 2015-20, Jakarta: ERIA, pp.37-68.

CHAPTER 3

Transport

3.1. Introduction

The transport sector in ASEAN countries accounts for 40–60 percent of the total energy demand. The sector is dominated by oil (gasoline and diesel), of which imports have been increasing rapidly in parallel to the slowing down of domestic production, which affects the security of supply (Kutani, 2013). Increased combustion of oil products has worsened the air quality, which potentially has great socio-economic impacts.

In many cases, there has been a rapid drop in infrastructure for public transport, walking, and cycling due to overbuilt roadways which accelerate more usage of private vehicles. Where the public transport system is inadequate and unreliable, there is often the urge to own a private vehicle or a motorised two-wheel vehicle. This also in turn makes walking and cycling redundant, mainly due to unfavourable and not-public-friendly walking and cycling pathways.

In light of this, efficient and sustainable transport infrastructure is vital for a particular town that aspires to be environment friendly. Sustainable transport offers a more balanced and holistic system for better mobility and more choices among the users.

This chapter first gives an overview of sustainable transport in an eco town as well as an approach to energy saving measures in the transport sector. It also touches upon a case study for Brunei Darussalam in terms of estimation of current and future energy demand and emissions, as well as the corresponding energy savings and emissions reductions achieved through different scenarios applied.

3.2. Sustainable Transport in an Eco Town

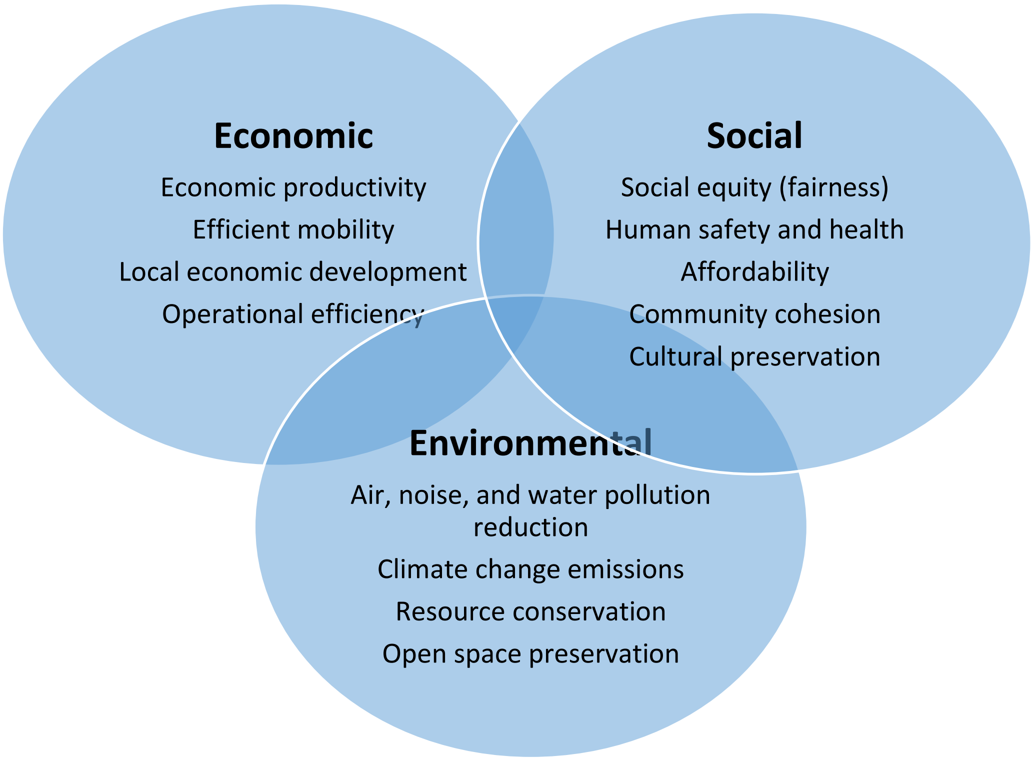
Sustainable transport aims to reduce greenhouse gas (GHG) emissions by switching from conventional vehicles to low-carbon ones, and at the same time encouraging walking and cycling within the town. An efficient and sustainable transport system is the one that (Gilbert and Cormier, 2005):

- allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations;
- operates efficiently, is affordable, can offer various transport mode choices, and supports a vibrant economy; and
- minimises the consumption of non-renewable resources (fossil fuels) while using

renewable resources efficiently and sustainably, reuses and recycles its components, and minimises noise and the use of land.

An efficient transport infrastructure should support the sustainability goals that emphasise balancing economic, social, and environmental goals which often overlap with each other. For instance, GHG emissions from transport (environmental issue) can affect human safety and health (social issue) as well as productivity (economic issue). This is reflected in Figure 12 below.

Figure 12: Sustainable Transport Goals



Source: Author.

3.3. Policy Measures for Energy Savings in Road Transport

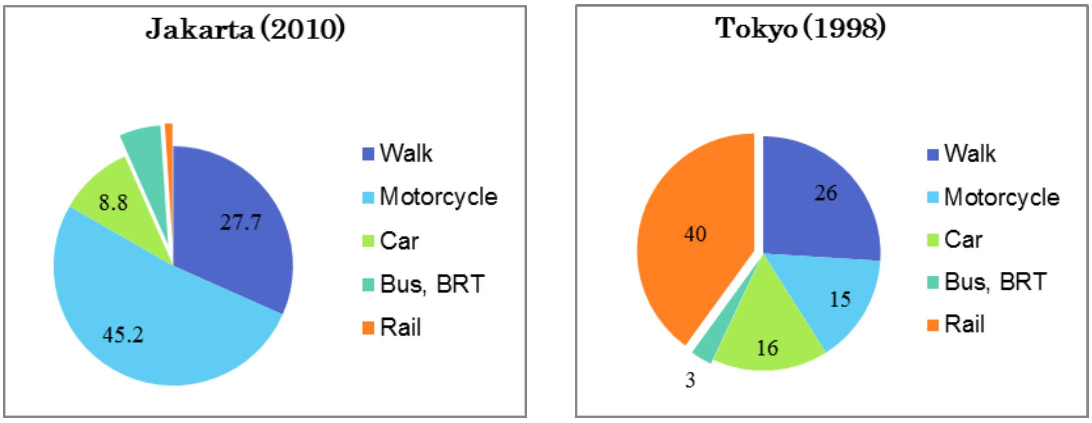
3.3.1. Introduction

Cities, in developed or in developing, face various problems in mobility, including air pollution, accidents, traffic jams, or lack of parking space. The following describes policies for energy savings in developing cities.

A common characteristic of today's developing cities is rapid motorisation with relatively poor public transport infrastructure. In cities like Jakarta and New Delhi, the number of vehicles is increasing at a rate of over 1,000 per week and many people have come to own their vehicles. The pace of motorisation in these cities is about six times as fast as in developed cities in the past (Table 6 – comparing Jakarta and Tokyo), so the public transport systems in the current developing cities are much more inadequate compared with the number of vehicles. Developed cities, on the other hand, tend to possess higher shares in public transport systems than private vehicles. For instance, Tokyo, being a developed city, had rail system as the highest percentage share in 1998 compared to that in Jakarta in 2010 which had the lowest percentage (Figure 13).

Huge traffic jams, caused by rapid private motorisation, may result in deaths due to fatigue or prolonged inhalation of exhaust pollutants. In 2016, a severe traffic congestion from Jakarta to Tegal, a city in Java Island, lasted for about 35 hours in East Brebes toll road (Figure 14). Eighteen people lost their lives mainly due to fatigue and accidents in road crossing.

Figure 13: Trip Mode Share in Jakarta and Tokyo (%)



BRT = Bus Rapid Transit.
Source: SITRAMP - The Study on Integrated Transportation Master Plan for JABODETABEK, JICA, Indonesia.

Figure 14: Traffic Jam in East Brebes

Source: Webb (2016).

Table 6: Comparison of Motorisation in Tokyo and Jakarta

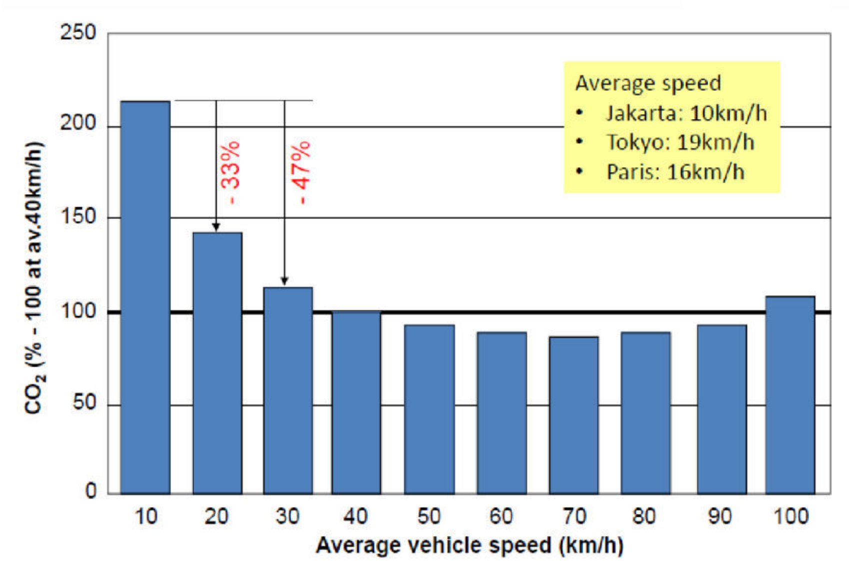
City	Tokyo		Jakarta	
Year	**1970**	**2009**	**2002**	**2009**
Number of Vehicles per Person	7.9	25.3	7.9	22.9
Percentage Growth Rate	3.1%		19.4%	

39 years → 7 years →

Source: Toyota InfoTechnology Center (using official government data).

Problems caused by traffic jams include not only economic losses but also, to the same extent, energy losses and air pollution from wasted energy combustion during traffic jams, which are 'invisible' but serious for cities as these problems cannot be seen through physical observation.

Figure 15: CO_2 Emissions (Fuel Consumption) by Average Speed



Source: Japan Automobile Research Institute (as cited in Maruyama, 2012).

The average vehicle speed on the road is around 10–20 kilometres per hour (km/h) in major cities. The National Institute for Land and Infrastructure Management, a Japanese research institute, has shown that an average speed improvement from 10 km/h to 20 km/h creates energy savings of a third and an improvement to 30 km/h as large as half (Dohi et al., 2012) (Figure 15).

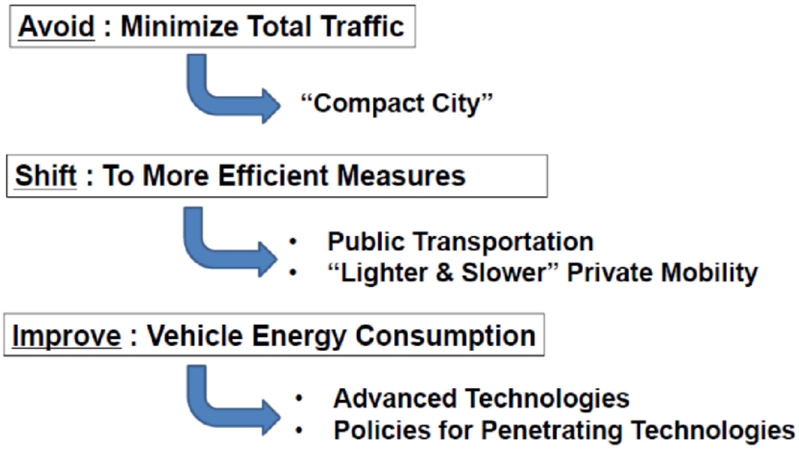
3.3.2. Approaches to Reduce Energy Consumption

3.3.2.1. 'Avoid, Shift, and Improve' Approach

The 'Avoid, Shift, Improve' (ASI) approach is becoming a common approach for policymakers and analysts. The following are some examples and difficulties pertaining to policy making for energy saving measures.

As shown in Figure 16, 'Avoid' means basically reducing traffic through city design or change of lifestyle. 'Shift' means transferring from personal mobility modes like using one's own car to public transport options like using trains with higher efficiency. The concept of autonomous driving with smaller and slower mobility tools like the Google car has recently been gaining attention; and sharing mobility through the use of mobile apps is growing in cities. The emergence of these types of new mobility, not perfectly private nor public, is categorised as 'Shift'. Finally, 'Improve' means applying greener technologies, an approach related not only to the technology itself but also to the necessary policies.

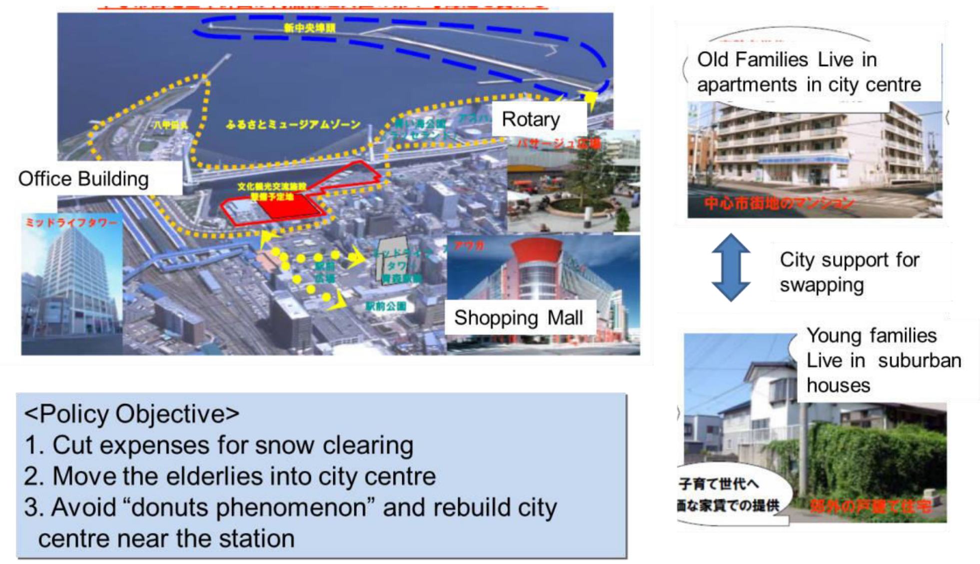
Figure 16: 'Avoid, Shift, Improve' Approach and Measures



Source: Author.

'Avoid': Compact City Approach

Figure 17: Example of a Japanese City



Source: Author's compilations from Aomori City webpage.

Figure 17 is an example of a compact city in Japan. The main objective of Aomori City is to cope with the country's aging society, since many of the elderly who have poorer mobility still live in the suburbs, and to cut city expenses for public services with less tax revenue.

The main policy contents of the compact city approach are to:

- build new offices and shops in the city centre funded by the local government
- move the elderly living in the suburbs into public apartments in the city centre
- provide houses to younger families at reduced prices, using the city budget.

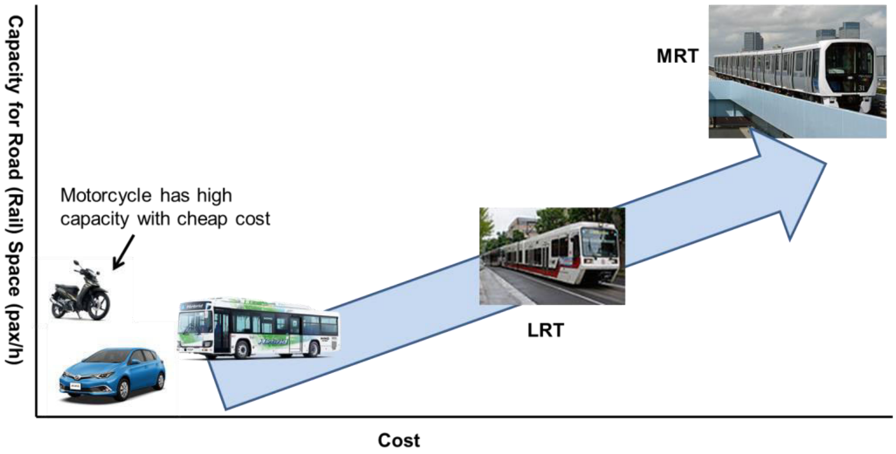
Tenants in city centre buildings have moved out and the number of people moving between the city centre and the suburbs is fewer than originally planned under the compact city. This is, first, because shops in new buildings lack attractiveness compared to mega-malls in the suburbs which have lots of shops, theatres, and various amusement options. As a result, the new buildings cannot absorb the traffic flow of shoppers or of office workers. Second, the city budget does not meet all the needs to move the elderly or acquire new houses.

This example shows that shopping at mega-malls in the suburbs cannot be replaced by shopping in shops in the city centre, because mega-malls occupy huge spaces to house not only shops and supermarkets but also facilities such as cinema complexes. Such huge spaces are easier to acquire in the suburbs than in the city centre. Considering this fact, even if the city government had sufficient budget to meet the needs of moving all the elderly to the city centre, the daily traffic would not change drastically because the attractive mega-malls would still be located in the suburbs. The same would be true for large hospitals where the elderly often go as such facilities also require huge amounts of land. Furthermore, for a community to be attractive, it requires a mix of economically active and elderly population, so the concept of an area like a residential zone for the elderly lacks vitality and is not attractive enough to become and maintain as a community.

City planning would fail without consideration for people's lives or companies like mega-malls, because people's or companies' motivation is not based on 'efficiency for the whole community' but individual efficiency or interest.

'Shift': Shift to Public Transport

Figure 18: Relation between Capacity and Cost by Modes



Source: Author.

Basically, a higher passenger capacity mode requires higher cost, as illustrated in Figure 18. It is often the case that local governments cannot introduce larger infrastructure like railways, even if they know the future growth of traffic demand, considering the deficit during the growth period when the demand does not meet the cost. Alternatively, even after they introduce the rail system, they reduce capacity (reduce frequency, etc.) or raise the fare (reduce demand).

Choosing the 'most fitting' transport system plan is quite difficult, because oftentimes local governments themselves change the capacity or demand from the original plan by changing supply and demand.

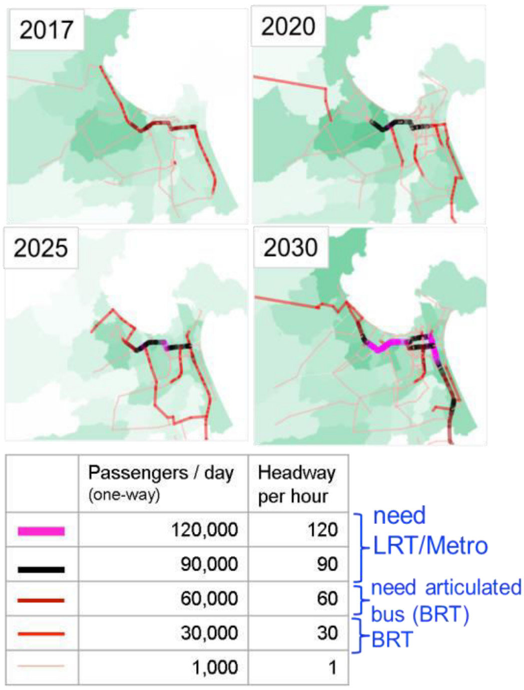
Figure 19 shows the example of future traffic demand in Da Nang City, Viet Nam. The research was conducted by ERIA and another working group in 2016. Da Nang has chosen a bus rapid transit (BRT) system, because its population is not so large and, considering the budget, BRT was considered the "best solution".

The simulation with information from the latest intention survey of the population of Da Nang and with current population projection by area shows that traffic demand in some areas will exceed the BRT's capacity in 2020, only 3 years after it starts operations.

Da Nang's current public transport system is not sufficient and most trips (around 80%) are conducted by motorcycle. As a result, people in Da Nang are not accustomed with the use of the public transport system, especially within the city. It is therefore important for the local government to instil the 'habit' of using public transport before starting operations on a larger scale.

During this early stage, patience is required of the local government. In policy implementation, the most cost-effective measure is often adopted first. However, the time required for people to change their daily behaviour should be considered. This will usually take longer than planned, because of which the introduction of the new transport system may appear to have failed. All new policies and new infrastructure have reached planned capacity only after gaining people's understanding and acceptance.

Figure 19: Example of Demand Simulation in Da Nang, Viet Nam

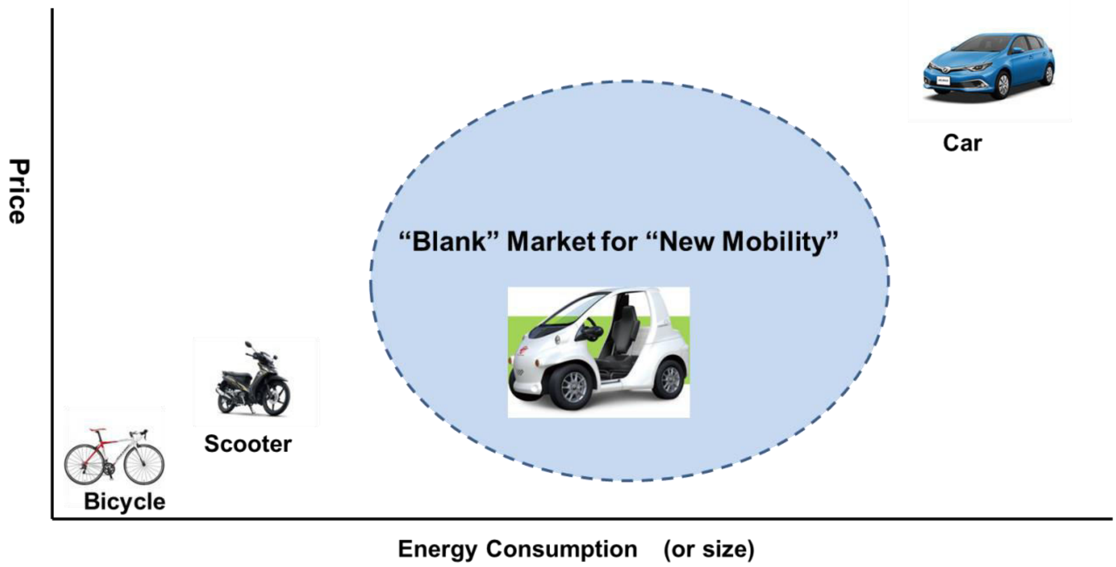


Source: ERIA (2016).

'**<u>Improve': Shift to Smaller and Slower Traffic</u>**

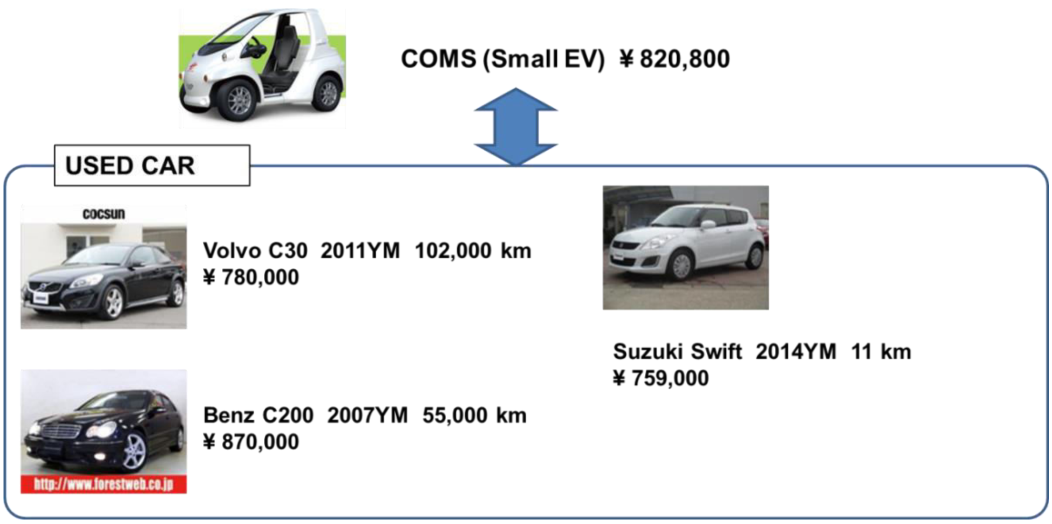
The force necessary to move objects is based on weight and acceleration (speed). To reduce energy use, a possible solution is to shift to smaller (lighter) and slower modes of transport such as bicycles. A lot of cars carry only one passenger (in other words, a 2,000-kilogram (kg) car carries a person of 60 kg) and some may criticise its 'wasted' energy. There are obvious reasons for a car's weight to be as heavy as 2,000 kg for safety and/or comfort. While there are already golf cart style 'small mobility' vehicles, they are unfortunately not so common. There may be a potential 'blank' market between motorcycles and small cars by size and price, and introducing 'new small mobility' solutions into this area could create a new market. Attempts to date have failed, however, as no big market exists in this area. This could be due to the cars being characterised as 'durable, expensive, and consumer goods' which gives rise to a used car market in parallel with new markets.

Figure 20: Typical Marketing Discussions for 'New Mobility'



Source: Author.

Figure 21: Example of the Used Car Market in Japan



EV = electric vehicle.
Source: Author.

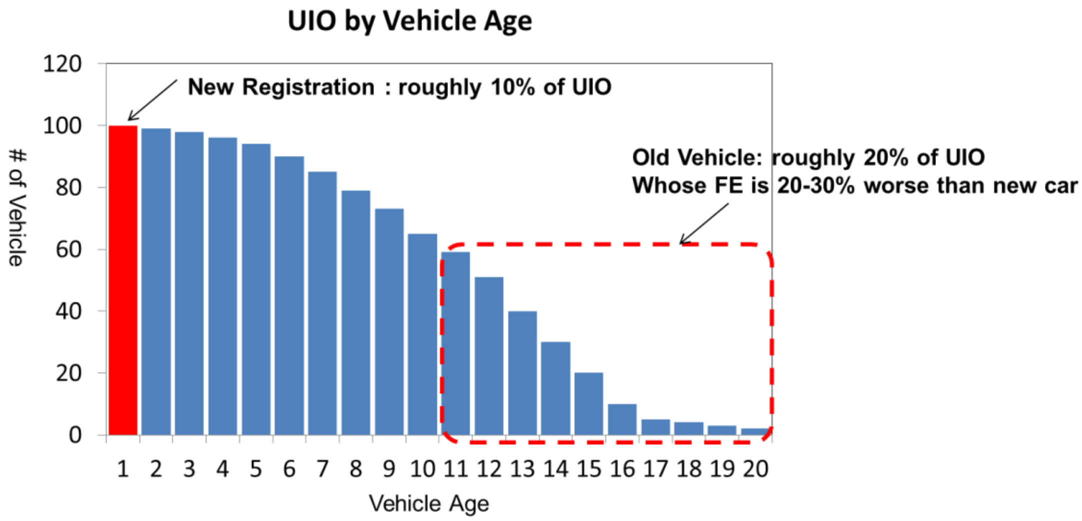
Figure 21 is an example of recent offers in the used car market in Japan. A small electric vehicle (EV) called COMS is priced at ¥821,000 (approximately US$7,000). This is much cheaper than a low-end new car, but considering the used car market, there are a lot of options, like an almost new Suzuki Swift or luxury brands like Volvo or Mercedes Benz. This is a reflection of the image of cars as 'durable' and 'expensive'. As for 'durable', cars can be used even after 10–15 years, and when consumers buy a new car, they often sell their old car for an initial payment of the new one. Additionally, the 'expensive' image of cars creates the used car market, because if the price gap between a new and a used car is not so large, consumers would not feel attracted to buy a used one.

Needless to say, buying a vehicle is a big purchase decision for customers. Even if they are offered a new small EV at a cheaper price, it may be natural for customers to choose a used car because it is much more convenient and far more comfortable.

<u>'Improve': Policy Options</u>

Energy efficiency standards are often adopted as an 'Improve' policy option in the road transport sector not only in developed countries but also in developing ones. It is important to point out, however, that this is not an only option.

Figure 22: Effectiveness of Fuel Efficiency Standards



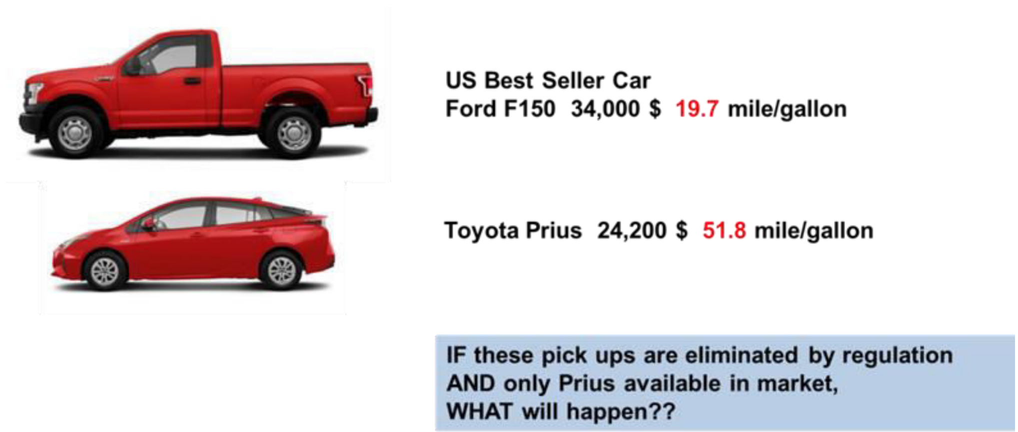
FE = fuel efficiency, UIO = units in operation.

Source: Author.

Figure 22 shows an example of the number of vehicles by vehicle age. The number of vehicles decreases the older they get. This is mainly because of scrappage of vehicles due to accidents or having no market value in the used car market. Roughly speaking, the portion of new vehicle registration is around 10 percent of the total vehicle population; thus, fuel efficiency standards affect only 10 percent. While raising fuel efficiency through regulation is a very important and effective policy, since it covers only 10 percent of the total vehicle population, it may be a policy for a longer time scope. On the contrary, older vehicles, whose fuel efficiency is much worse than newer ones, occupy 20 percent of the total vehicle population. A vehicle naturally lasts 10–15 years; in other words, once a technology is introduced, it lasts for 10–15 years, even if it is not the latest type. To promote better average fuel efficiency, it is also important to shorten the average vehicle age by promoting scrappage of old vehicle (scrap incentive).

It is also important to set the right target. The model mix or deployed technology differs by market, depending on differences in climatic conditions (hot or cold), income level (rich or poor), or fuel price including tax/subsidy. A regulator can easily copy regulation from other markets like the European Union. But without considering the current situation and customer preferences, the regulation cannot meet its target by itself.

Figure 23: Fuel Efficiency Regulation Assumptions in the US Market



Source: Yahoo! Autos.

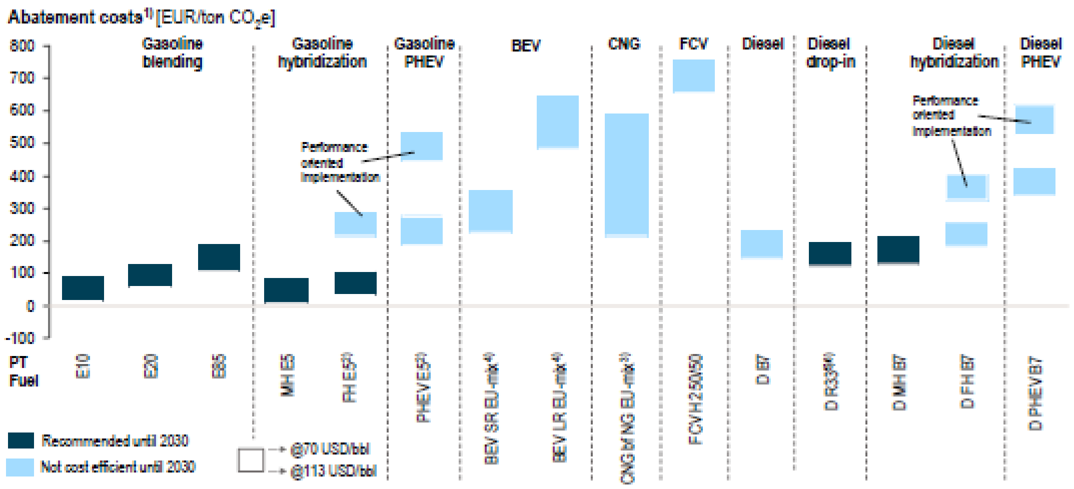
Figure 23 illustrates an example of the regulation in the US market. The best-selling model in the US market for years has been the Ford F150. Besides the F150, other manufacturers like GM or Chrysler sell pickup models to meet customer preferences. The fuel efficiency of the F150 compared with cars like a sedan is not very good. Suppose a US regulator were to introduce a ban on selling pickup trucks and force people to only buy the Toyota Prius. Whatever the regulation says, people's preferences do not change suddenly and they will buy a used F150 rather than a new Prius. Again, this should consider the characterisation of vehicles as goods. The result of unrealistic targets ignoring the market's condition or false measures will slow down the improvement of fuel efficiency, contrary to the policy intention.

<u>'Improve': Vehicle Technology Alternatives</u>

Finally, the following discussion provides a menu of vehicle technologies for better fuel efficiency. First, it should be stated that this refers to vehicle technologies currently developed for conventional vehicles. In other words, mobility tools like the Google self-driving car are not discussed, though it is much smaller in size, its speed is slower, and, as a result, its energy consumption is much lower than 'conventional' vehicles, regardless of the energy source. Several governments and original equipment manufacturers (OEMs) are discussing the way to reduce GHG emissions. Their main arguments are based on the current transport scheme, which is consistent with the current mobility system provided by current market players like OEMs. The autonomous car like the Google car is a kind of revolution for ordinary customers, because for most drivers, driving is a ‘waste of time’ and they might accept the autonomous car as a way to spend ‘more fruitful driving time’. As a result, vehicle electrification may be achieved outside the current GHG mitigation discussion by the electric-powered Google car.

There are various alternatives for vehicles based on ‘cost and effect’ looking toward 2030. Presenting policymakers in each city with alternatives or candidates is quite important, because every city has different problems and different circumstances. Therefore, no single answer exists for this issue.

Figure 24: Abatement Costs by Technology in 2030



Note: Original data for the calculation were provided by vehicle manufacturers including Toyota and the oil industry.
Source: Roland Berger (2016).

Figure 24 analyses various powertrain technologies with cost per tonne of CO_2. The working group members who worked on the analysis have stated that current conventional engine-based technologies (including hybrids) will be cost-effective, including related costs like building energy infrastructure. For example, plug-in hybrid electric vehicles (PHEV) or battery electric vehicles (BEV) will not be cost-effective considering the cost to build battery or charging infrastructure even at an oil price of US$113 per barrel.

The story with ultra-low carbon mobility tools, which will meet future European Commission regulations equivalent to GHG emissions below 40 grams per kilometre, is different. Comparing total (well to wheel) GHG emissions by technology and fuel, all the current cost-effective candidates will not be able to meet future regulation targets other than the internal combustion engine (ICE) with biofuel. This means that using only the ‘Improve’ approach cannot solve the future problem of severe global warming. Some may say that once the regulation is made by regulators, all OEMs should comply with it, and, as a result, all new vehicles will become greener. However, all vehicle technologies will be deployed only when customers buy them. It is also important to say that most customers do not or will not have a strong interest for their vehicles to be 'green' and instead will only consider the cost merit and convenience. If all new vehicles are 'green' but expensive, customers will choose a used car rather than a new one. This will cause slower achievement of the policy goals (greener road mobility) contrary to their original intention.

Others may insist on the importance for a subsidy. It is true that subsidies or incentives are very important policy measures for deploying promising but expensive technologies at an early stage. Still, every budget has a ceiling, so choosing 'promising fast deployment' technologies for GHG mitigation not only for the transport sector but also for all other sectors is quite important considering the preference of people in choosing each product or service.

3.3.3. Conclusion

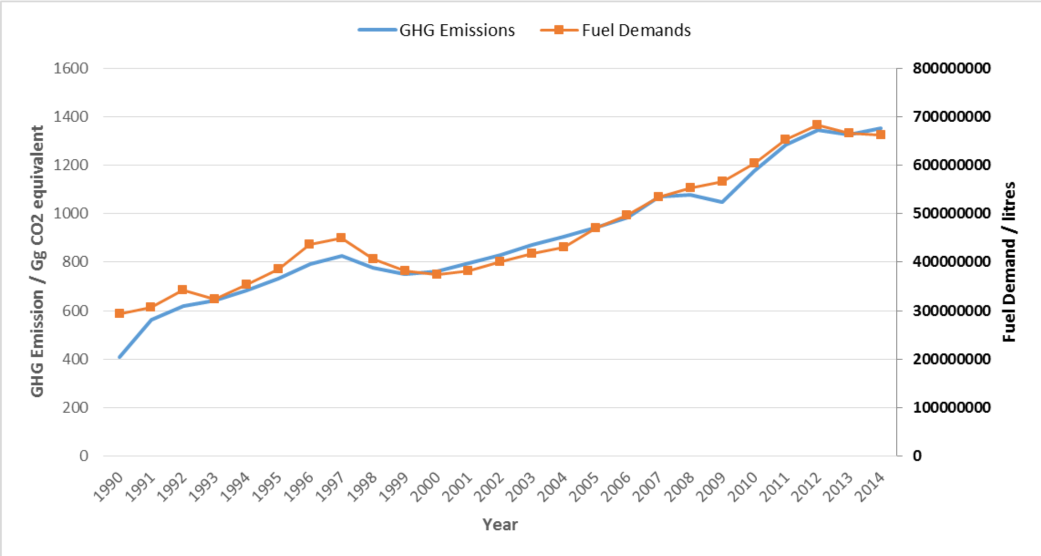
There are policy options to establish greener road mobility by using the 'Avoid, Shift, Improve' approach, but they also have drawbacks. To avoid these 'traps', each country or city has to determine the 'best' approach to improve the current situation or solve problems. Approaches vary and there are also many experiences in other cities. Thus, information sharing of each city's policy goal and concrete actions for the future as well as past successes or failures is important for making progress on the right and shortest way for each different city.

3.4. Brunei Darussalam's Transport Energy Demand and Emissions

3.4.1. Introduction

Road transport in Brunei Darussalam is one of the most energy-consuming sectors in the country, accounting for half of the total national energy consumption with 80 percent nearly consumed by cars alone. In 2010, the sector was the third-largest spender in fuel expenditure, accounting for B$521 million or 25 percent of the total energy expenditure, and it still stands at present. Transport is dominated by conventional gasoline and diesel vehicles, with a negligible share of hybrid vehicles. Statistics from the Land Transport Department (LTD) in 2014 show that 77 percent of the total number of vehicles in Brunei comes from gasoline vehicles, 22.9 percent from diesel vehicles, and the remaining 0.1 percent from hybrid vehicles. According to LTD, as of present only 601 hybrid vehicles have been registered and licensed since 2005. Statistics show that there were 262,649 registered and licensed passenger vehicles in 2014 for a population of 411,900, equivalent to a vehicle ownership of 638 vehicles per 1,000 persons.

Figure 25: Fuel Demand and GHG Emissions from Road Transport in Brunei Darussalam (1990–2014)



Gg = gigagram, GHG = greenhouse gas.

Sources: Fuel demand data from the Department of Economic Planning and Development; GHG emissions data from the Intergovernmental Panel on Climate Change (IPCC) Inventory for Brunei Darussalam.

Figure 25 illustrates the historical trend in fuel demand and its corresponding GHG emissions. Since 1990, the emissions from road transport have increased by about 5 percent, which is due to the increasing population and hence increase in gasoline and diesel demand.

Because of overwhelming use of private vehicles, Brunei's public transport infrastructure is still in its infancy. To provide a more integrated, robust, and efficient transport network, the government introduced the Land Transport White Paper and the Land Transport Master Plan which outline the policies and strategies to improve the country's transport infrastructure. The government is also currently exploring ways to reduce the number of new vehicles every year as part of its efforts to establish efficient and robust public transport.

3.4.2. Objectives

The study aims to forecast passenger vehicle energy demand and emissions and to analyse the potential scenarios of energy saving and implementation of alternative energy sources as well as emissions reductions in Brunei Darussalam. In order to forecast the conventional energy demand and emissions reductions, the vehicle ownership until 2035 is first projected for the whole of Brunei, based on the official statistics from 1979 to 2014. Then, the results are used to forecast the corresponding energy demand and emissions for three different scenarios:

- business-as-usual (BAU) scenario
- fuel economy improvement (FEI) scenario

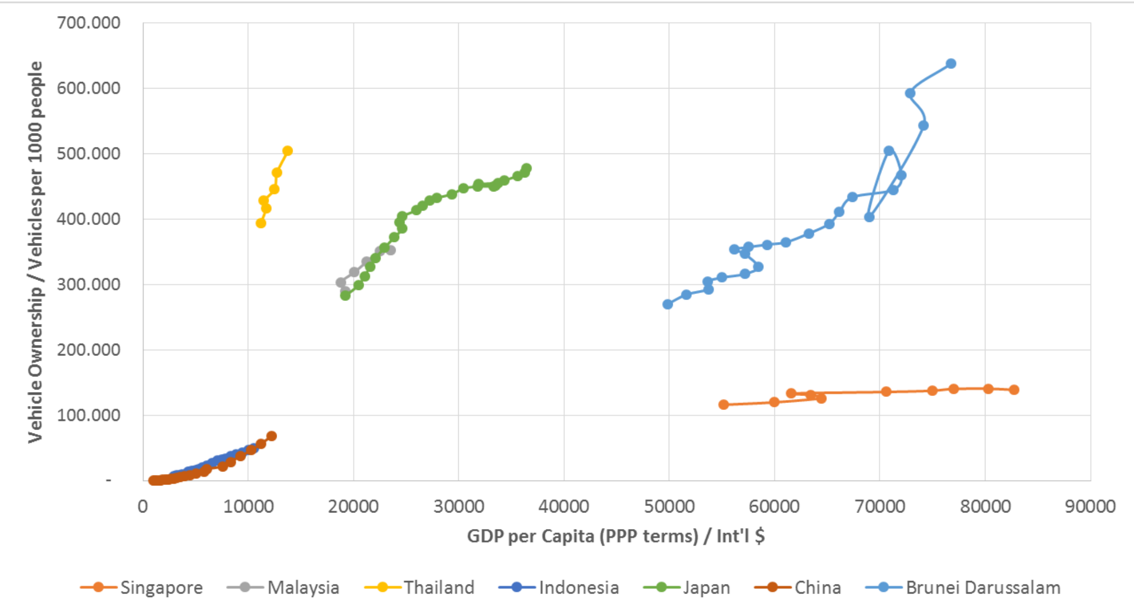
- electric passenger vehicle (EPV) scenario.

3.4.3. Overview of Road Transport in ASEAN and East Asia

3.4.3.1. Trends in Vehicle Ownership

Figure 26 illustrates the trends in passenger vehicle ownership of selected countries in ASEAN and East Asia against their per capita gross domestic product (GDP). There is a general relationship between vehicle ownership and GDP, albeit highly non-linear. Passenger vehicle ownership grows at a relatively slower rate at the lowest level of per capita GDP, then increases until reaching a saturation level at the highest per capita GDP level.

Figure 26: Passenger Vehicle Ownership against GDP per Capita of Selected Countries in ASEAN and East Asia



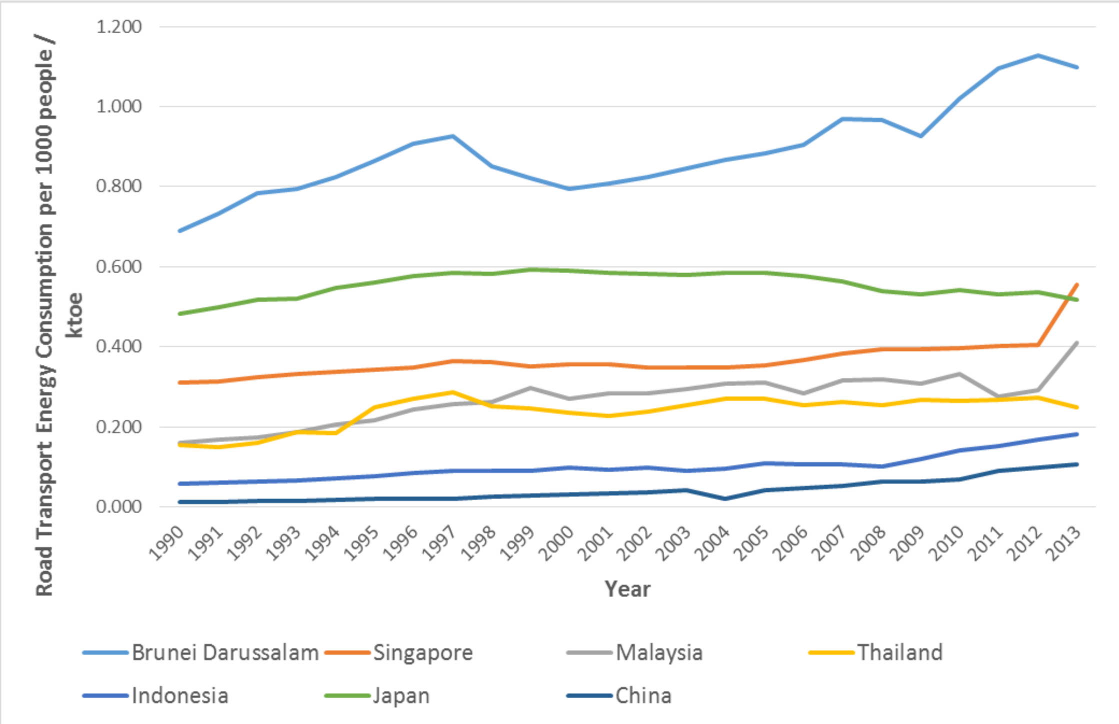
GDP = gross domestic product, PPP = purchasing power parity.

Sources: Data for Singapore from the Land Transport Authority; for Malaysia from the Road Transport Department; for Thailand from the Ministry of Transport; for Indonesia from BPS Statistics Indonesia; for Japan from the Statistics Bureau Japan; for China from the National Bureau of Statistics China; for Brunei Darussalam from the Department of Economic Planning and Development.

3.4.3.2. Trends in Energy Demand

Figure 27 illustrates the trends in energy demand (expressed in fuel consumption per 1,000 people) of seven countries. In general, the energy demand has been following a rising trend, ranging from that of China at 0.01 kilotonnes of oil equivalent (ktoe) to that of Brunei Darussalam at 1.09 ktoe. Despite having the smallest population among the countries, Brunei's energy demand has been the highest from 1990 until 2013, driven by fuel price subsidies.

Figure 27: Road Transport Energy Demand per 1,000 People in Selected Countries in ASEAN and East Asia



ktoe = kilotonne of oil equivalent.
Source: Asia Pacific Energy Research Centre (APERC).

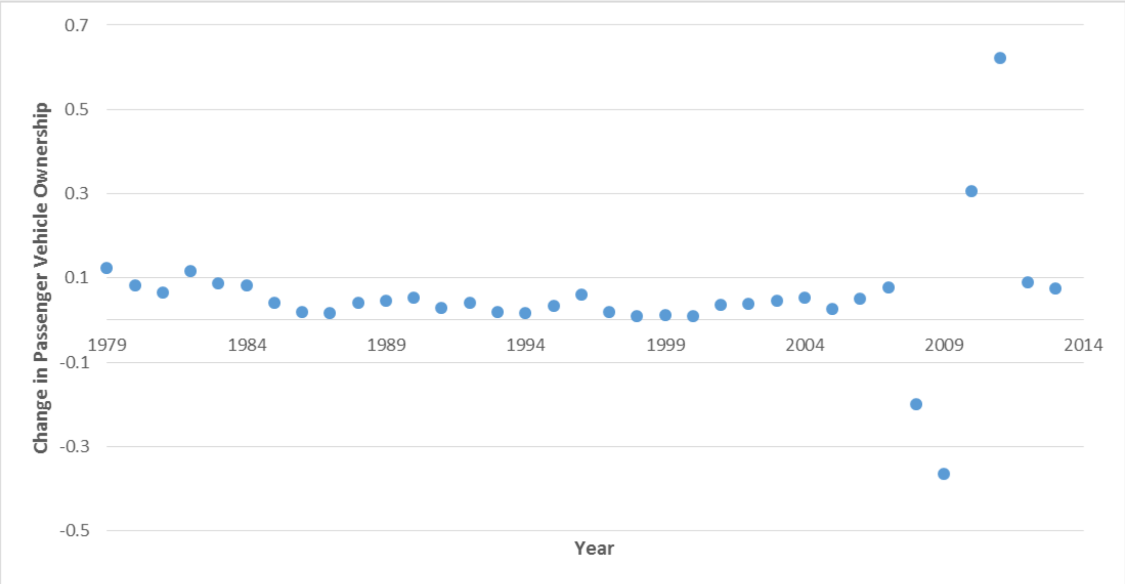
3.4.4. Forecasting Passenger Vehicle Ownership

3.4.4.1. Methodology

The growth in vehicle ownership is typically represented by a sigmoid or S-shaped curve.). This shape implies that ownership slowly increases at the lowest income levels and then grows rapidly as income rises until the curve reaches a saturation level. However, the saturation level must first be estimated either from the S-curve function (Singh, 2000), or by applying a rule of thumb, for instance one car per household (Palelink, 1960) or vehicle ownership per capita (Button, Ngoe, and Hine, 1993; Kobos, Erickson, and Drennen, 2003). The Transport and Road

Research Laboratory (TRRL) devised a statistical methodology, in which they analysed the relationship between the rate of change of vehicle ownership and the actual vehicle ownership in each country. The ownership level at which the rate becomes zero would be the ultimate saturation level in their logistic analysis. Despite the oversimplification of the estimation, the above method has been utilised in the United Kingdom and other countries to estimate the ultimate saturation level. As there are no studies pertaining to the passenger vehicle ownership in Brunei Darussalam, it is assumed that the saturation level is based on the rate of change of ownership.

Figure 28: Growth Change in Passenger Vehicle Ownership in Brunei Darussalam (1979–2014)



Source: Author.

Not taking into account the outliers between 2008 and 2011,[1] it can be shown in Figure 28 that the growth change generally decreases exponentially over time, with the lowest level between 1997 and 2000. Between 2005 and 2013, the growth slightly increased. This suggests that ownership has theoretically almost reached its saturation point. Assuming that the number of private cars is still increasing, 700 vehicles per 1,000 people is estimated as the ultimate vehicle ownership saturation point.

If *VO* denotes the passenger vehicle ownership growth per 1,000 persons at each year and *GDPPC* denoted GDP per capita, the Gompertz model can be expressed as:

$$VO = S \exp[-a \exp(-b\ GDPPC)], \qquad (1)$$

[1] The outliers could be due to statistical discrepancies reported in the National Statistical Yearbook, especially between 2008 and 2011.

where *S* is the saturation level and *a* and *b* are the model coefficients that define the curvature of the function. In order to calculate these model coefficients via regression analysis, equation (1) is further converted into its linear form:

$$ln[ln(\frac{S}{VO})] = \ln a + (b\ GDPPC). \quad (2)$$

Similarly, the logistic function can be expressed as follows:

$$VO = \frac{S}{1+a\exp[-bt+c\ln[(GDPPC)]]}, \quad (3)$$

where *S* is the saturation level, *t* is the time series, and *a*, *b*, and *c* are the model coefficients that define the curvature of the function. Equation (3) can be converted into its linear form:

$$\ln(\frac{S-VO}{VO}) = \ln a + (-bt) + c\ln(GDPPC). \quad (4)$$

3.4.4.2. Results and Discussions

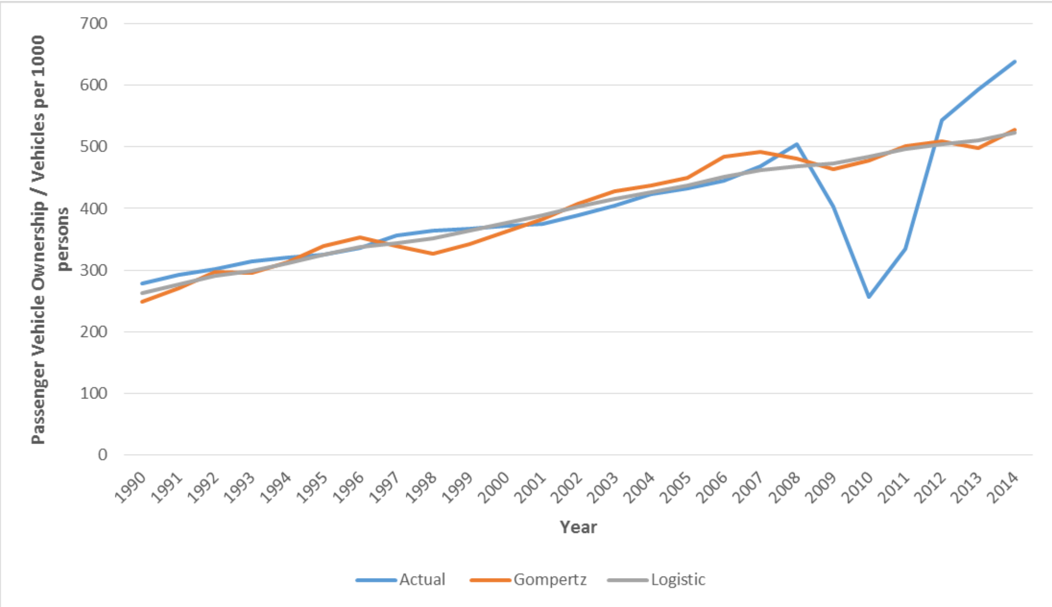
The estimated result of the growth of passenger vehicle ownership is illustrated in Table 7.

Table 7: Estimated Results of Gompertz and Logistic Models

Model	Model Coefficient			R^2	MSE
	ln a	b	c		
Gompertz	3.00	-0.0000557	-	0.554	0.145
Logistic	13.82	-0.0564	-1.205	0.558	0.211

Source: Author.

Figure 29: Graphical Comparisons between the Actual, Gompertz, and Logistic Vehicle Ownership



Source: Author.

As shown in Table 7 and Figure 29, both regression models fit the data relatively well, and the identical R-squared values of 0.55 imply that 55 percent of the variance in the passenger vehicle ownership can be found in the actual data. However, the Gompertz model illustrates a lower mean square error value than the logistic model. Furthermore, the lower range of the confidence intervals in the Gompertz model strengthens the evidence that the Gompertz model is a better fit than the logistic model.

3.4.5. Energy Demand and Emissions

3.4.5.1. Methodology

The energy demand of passenger vehicles per year is determined by the following formula:

$$ED_i = NV.ADT.PF_i.\frac{1}{FE_i}, \qquad (5)$$

where ED_i is the energy demand of fuel type *i* (ktoe), *NV* is the number of passenger vehicles, *ADT* is the average distance travelled per year (km), PF_i is the proportion of passenger vehicles by fuel type *i* and FE_i is the fuel economy of passenger vehicles by fuel type *i* (km/l).

The corresponding emissions are defined by the following formula:

$$EM_{ij} = ED_i.EF_{ij}.GWP_j, \qquad (6)$$

where EM_{ij} is the emission of greenhouse gas *j* from fuel type *i* (kg CO_2 equivalent), EF_{ij} is the emission factor of greenhouse gas *j* from fuel type *i* (kg/TJ), and GWP_j is the global warming potential of greenhouse gas *j*.

In this case, the fuel types *i* considered would be gasoline and diesel, from which carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the main greenhouse gases *j* emitted. Each of the default emission factors of the gases was obtained from the Intergovernmental Panel on Climate Change (IPCC) (see Table 8).[2]

Table 8: Emission Factors of Gasoline and Diesel Fuels

Fuel Type	Emission Factor (kg/TJ)		
	CO_2	**CH_4**	**N_2O**
Gasoline	69,300	33	3.2
Diesel	74,100	3.9	3.9

kg = kilogram, TJ = terajoule.

Source: Intergovernmental Panel on Climate Change.

Each greenhouse gas has its own global warming potential (GWP) value. The global warming potential of a gas is defined as the total contribution to global warming resulting from the emission of one unit of that gas with respect to one unit of the reference gas (CO_2), which is assigned a value of 1. Based on Table 9, 1 gram of N_2O has the highest impact on global warming, about 300 times higher than 1 gram of CO_2.

Table 9: Global Warming Potentials of Greenhouse Gases

Greenhouse Gas	Global Warming Potential
CO_2	1
CH_4	28
N_2O	265

Source: Intergovernmental Panel on Climate Change.

[2] The Intergovernmental Panel on Climate Change (IPCC) is the international body for assessing the science behind climate change.

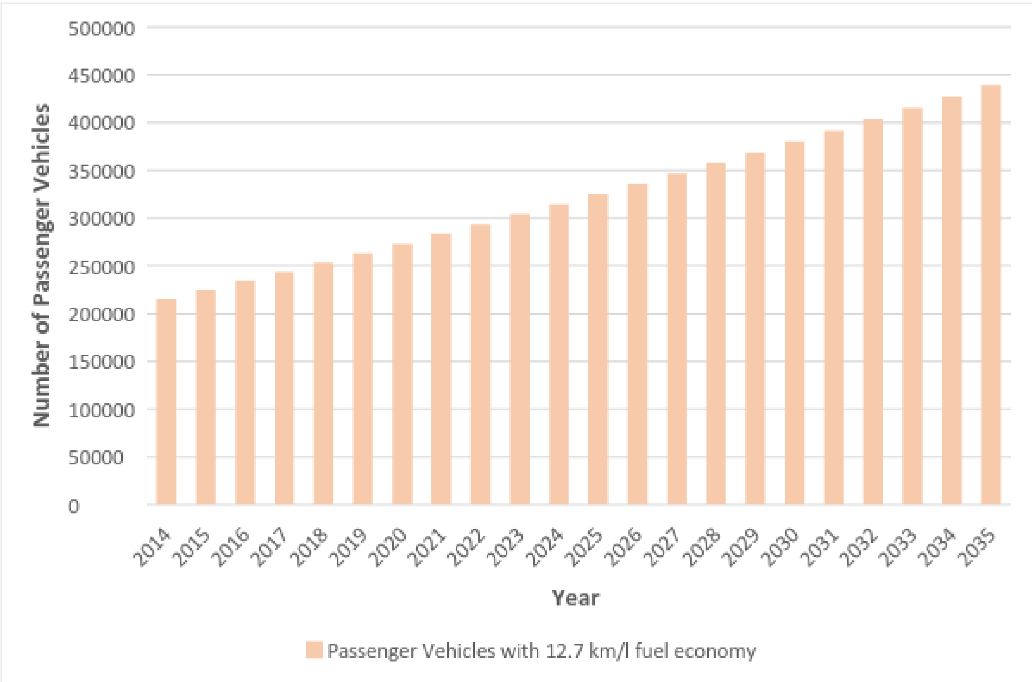
3.4.5.2. Scenarios

In order to analyse the impact of energy demand and emissions in road transport for various alternative scenarios, the business-as-usual (BAU) scenario was used as a base case. For the alternative scenarios, it is assumed that more efficient vehicles with higher fuel economies and electric vehicles will be implemented in the future.

Business-as-Usual (BAU) Scenario

In this scenario, the number of passenger vehicles is forecasted based on the passenger vehicle ownership growth, with the base year 1990. The average present fuel economy value in Brunei is about 12.7 km/l. Between 1990 and 2014, the average ratio of gasoline and diesel vehicles was about 69 percent to 31 percent. Therefore, it is assumed that the present efficiency of vehicles would be unchanged and the policies pertaining to more efficient vehicles would not be implemented in the future. This is illustrated in Figure 30, where all the vehicles are expected to have the average fuel economy value of 12.7 km/l.

Figure 30: Passenger Vehicles in the BAU Scenario in Brunei Darussalam



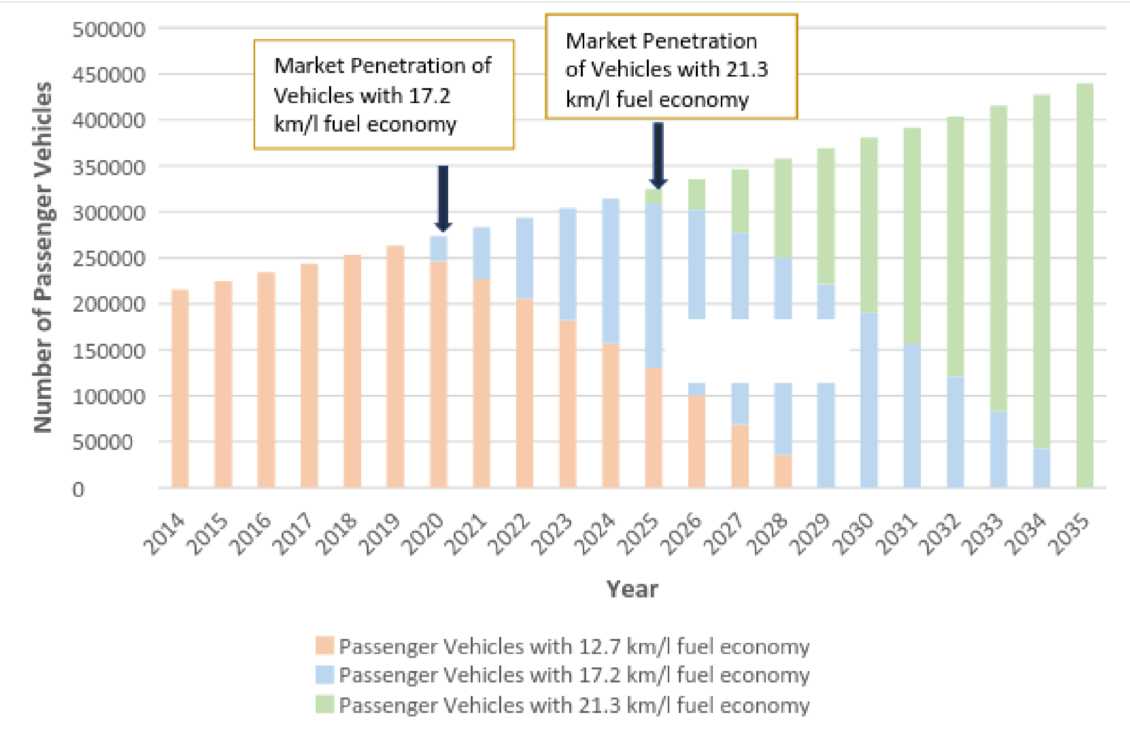
BAU = business-as-usual.
Source: Author.

Fuel Economy Improvement (FEI) Scenario

Fuel economy is one of the important factors in the reduction of energy demand and emissions in road transport. Many countries, including Singapore and Japan, have adopted the fuel economy regulation as a basis for energy efficiency in road transport. Fuel economy is basically an indicator to measure the relationship between the distance travelled by a particular vehicle and the amount of fuel being consumed by the same vehicle. It is generally expressed as kilometres per litre (km/l) and is used in Asia, continental Europe, parts of Africa, and Oceania. Miles per gallon (mpg) is commonly used in the Unites States, Canada, and the United Kingdom. The higher the value, the better the fuel economy of the vehicle.

Brunei is currently in the process of adopting the fuel economy regulation for all new vehicles, which are similar to those in the European Union (EU), for example 17.2 km/l by 2020 (EU 2016 equivalent) and 21.3 km/l by 2025 (EU 2020 equivalent).

Figure 31: Penetration of More Efficient Vehicles in Brunei Darussalam



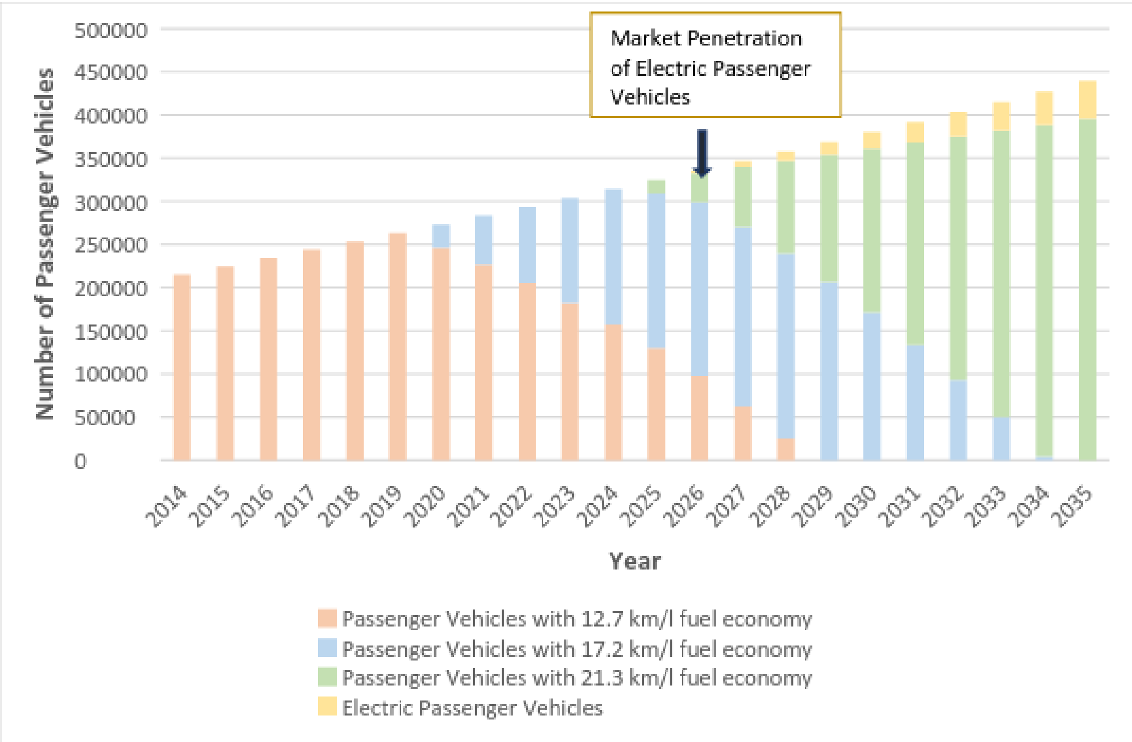
Source: Author.

Based on the above, the methodology in this scenario is devised in such a way that the penetration of more efficient vehicles will begin according to the respective regulations set up by the Government of Brunei Darussalam. As shown in Figure 31, 10 percent of vehicles with 17.2 km/l fuel economy are expected to enter into the market in 2020, while gradually decreasing the penetration of less-efficient vehicles. Similarly, by 2025, vehicles with 21.3 km/l fuel economy will be introduced, eventually phasing out all less-efficient vehicles by 2035.

Electric Passenger Vehicle (EPV) Scenario

An electric vehicle is a relatively new technology which relies entirely on electricity. It releases no tailpipe air pollutants and generates less noise at rest or in motion. Therefore, the adoption of electric vehicles would have significant net environmental benefits as they largely contribute to greenhouse gas emissions reduction.

Figure 32: Penetration of Electric Passenger Vehicles in Brunei Darussalam



Source: Author.

It is assumed that by 2035, 10 percent of the total passenger vehicles in Brunei will be electric-powered. Similar to the FEI scenario, electric passenger vehicles would gradually be introduced in 2026 until the 10 percent target is reached in 2035 (Figure 32).

Despite emitting no tailpipe air pollutants, a great deal of electricity is required to charge the electric vehicles at night or whenever required. If the electricity is sourced from a generic fossil power plant, the problem would be that the power plant itself would cause more emissions than a comparable gasoline or diesel-fuelled car coughed up from its exhaust pipe, as a higher amount of fossil fuel would need to be combusted to meet the demand. This eventually defeats the purpose of having electric vehicles while still relying solely on a thermal power plant for electricity.

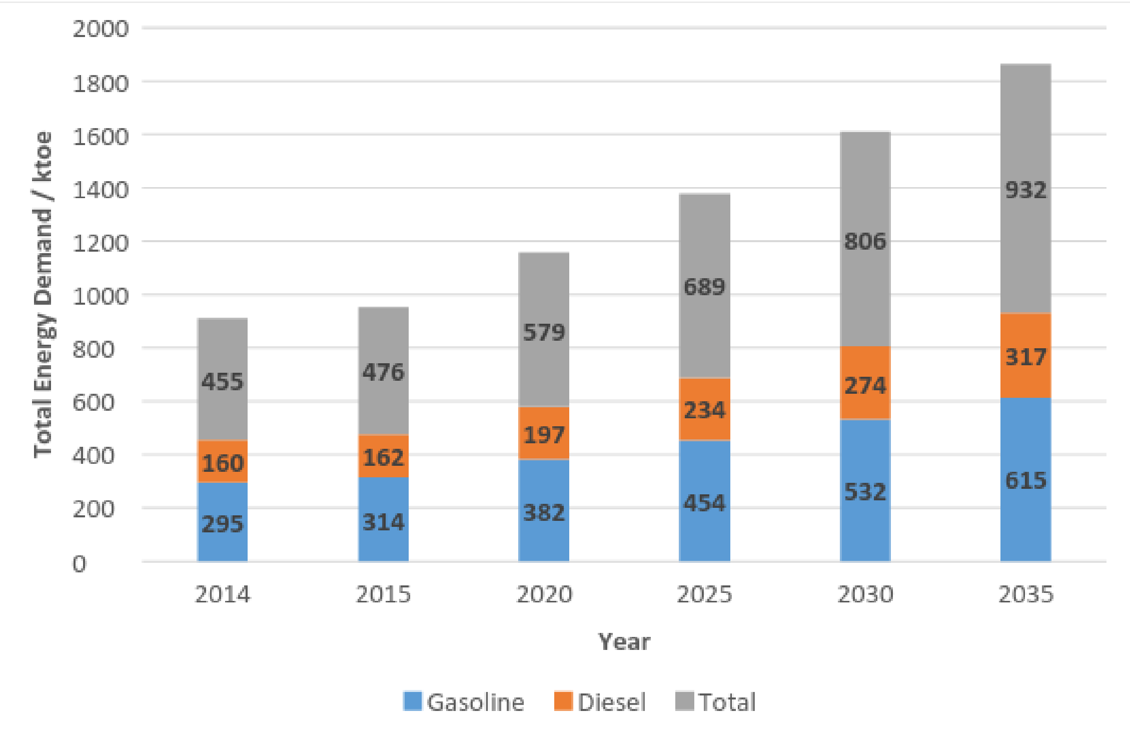
An efficient electric vehicles system requires a robust and reliable smart grid infrastructure with renewable energy integration and storage. By 2026, since Temburong would be the hub for smart grid infrastructure, all the electric vehicles would be supported by electricity coming from renewable energy.

3.4.5.3. Results and Discussions

Business-as-Usual (BAU) Scenario

The following graph in Figure 33 illustrates the energy demand from 2014 until 2035 based on the share of vehicles by fuel type.

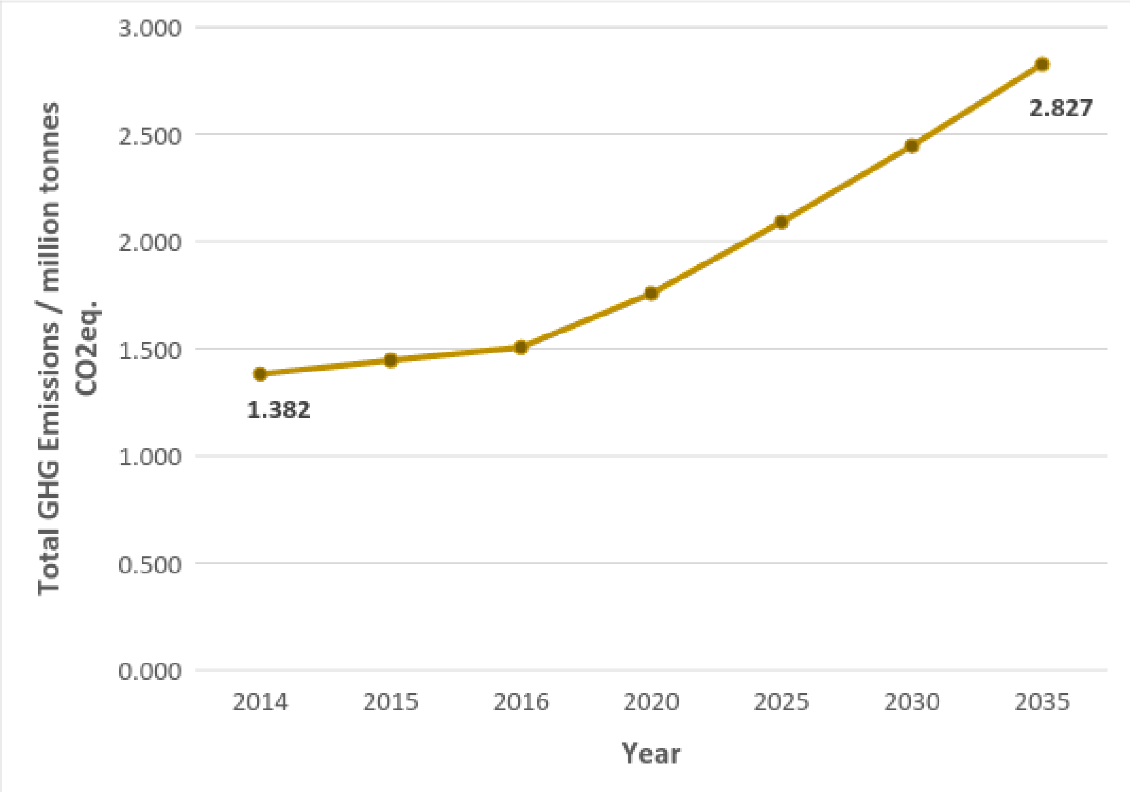
Figure 33: Total Energy Demand with Respect to Share of Vehicles by Fuel Type



Source: Author.

It is envisaged that the total energy demand will increase with an average annual growth of 3.31 percent from 455 ktoe in 2014 to 932 ktoe in 2035. Gasoline vehicles would continue to dominate ahead of diesel vehicles with an annual growth of 3.39 percent and 3.15 percent, respectively.

Figure 34: Corresponding Total GHG Emissions



GHG = greenhouse gas.

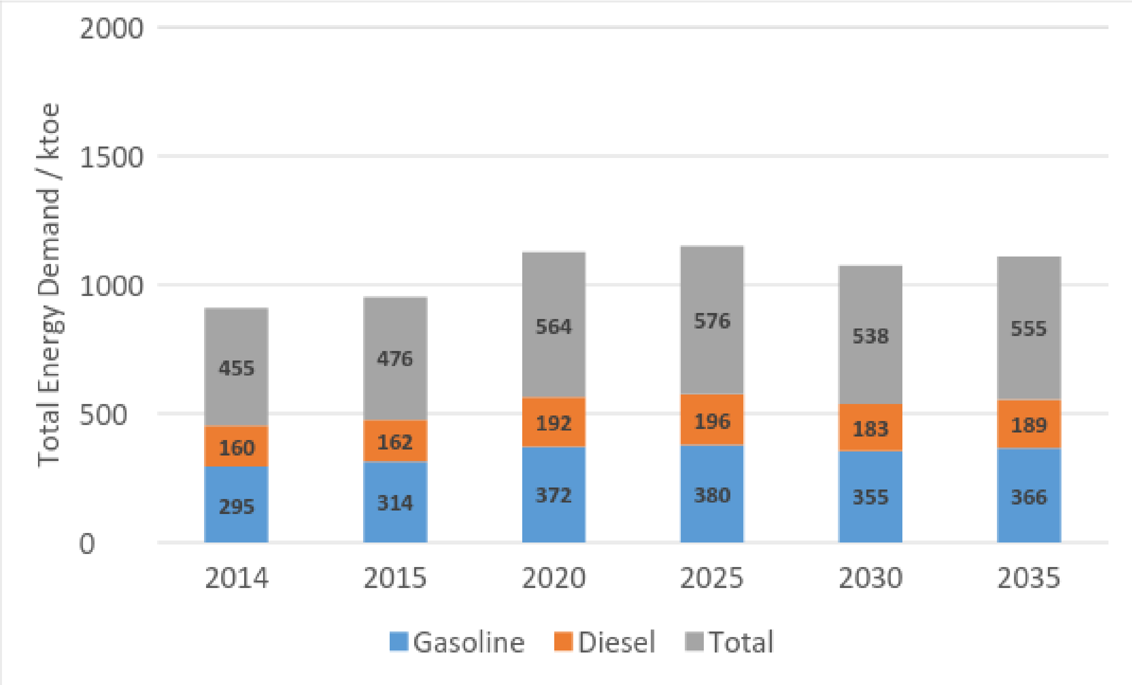
Source: Author.

In terms of the environment, total GHG emissions are expected to increase from 1.38 million tonnes of CO_2 equivalent (tCO_2e) to 2.83 million tCO_2e (Figure 34), corresponding to an average annual increase of 3.31 percent from 2014 to 2035. Since about 99 percent of the total GHG emissions comprise CO_2, the other gases can be neglected.

Fuel Economy Improvement (FEI) Scenario

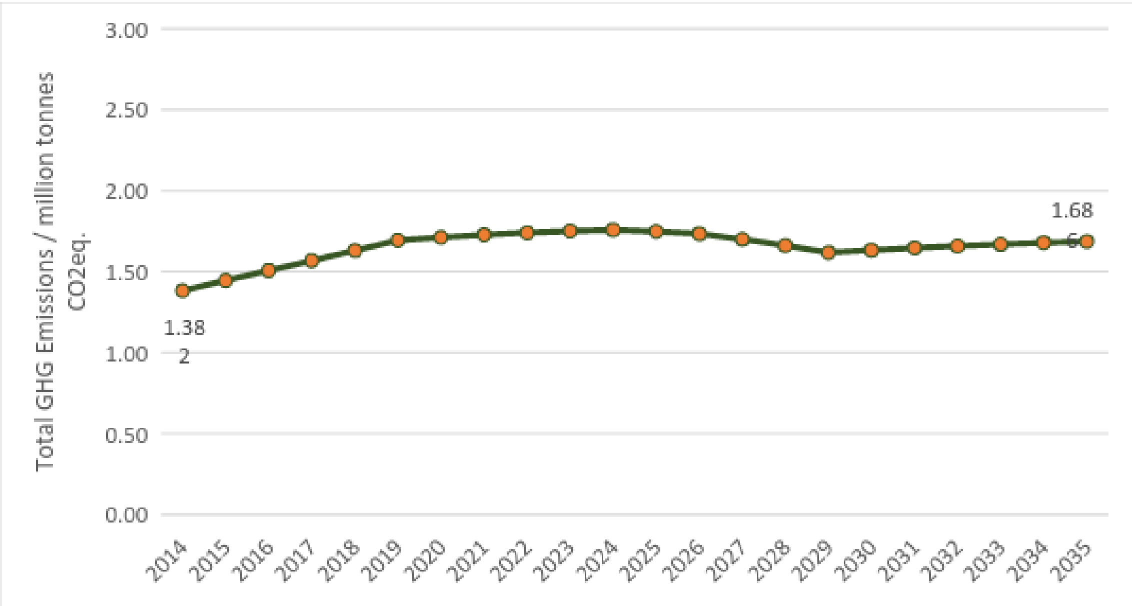
Due to the improvement in the fuel economy of passenger vehicles, the energy demand is expected to increase from 455 kilotonnes of oil equivalent (ktoe) in 2014 to 555 ktoe in 2035 (Figure 35), corresponding to about a 0.9 percent increase. The model predicts that there would be a reduction of about 40.3 percent in the energy demand in 2035 compared to the BAU scenario in the same year. As a result, the corresponding emissions would increase from 1.38 million tCO_2e to 1.69 million tCO_2e (0.9% increase) (Figure 36), with a reduction of 40.3 percent between the BAU and FEI scenarios in 2035.

Figure 35: Total Energy Demand for FEI Scenario



FEI = fuel economy improvement, ktoe = kilotonne of oil equivalent.
Source: Author.

Figure 36: Corresponding Total GHG Emissions of FEI Scenario



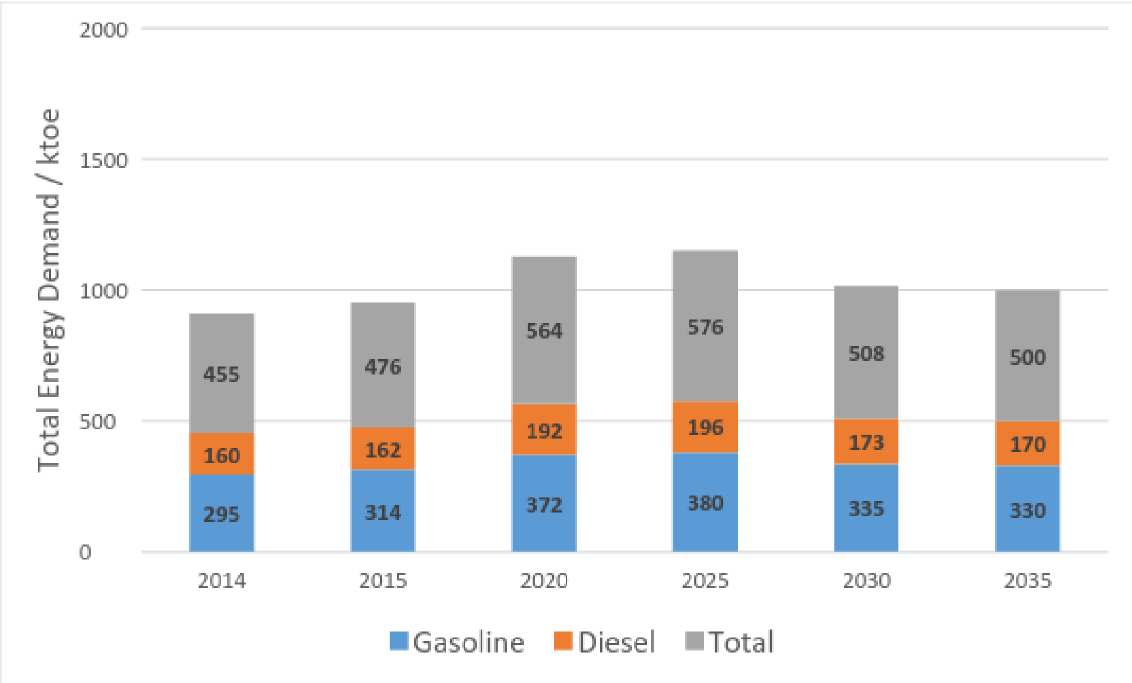
FEI = fuel economy improvement, GHG = greenhouse gas.

Source: Author.

Fuel Economy Improvement (FEI) + Electric Passenger Vehicle (EPV) Scenario

As shown in Figure 37, the inclusion of electric passenger vehicles in the FEI scenario is expected to further reduce the energy demand to 500 ktoe from the BAU and FEI levels of 932 ktoe and 555 ktoe, respectively, by 2035. It is expected that a reduction of about 46.3 percent from the BAU level can be achieved in this scenario by 2035.

Figure 37: Total Energy Demand in the FEI + EPV Scenario

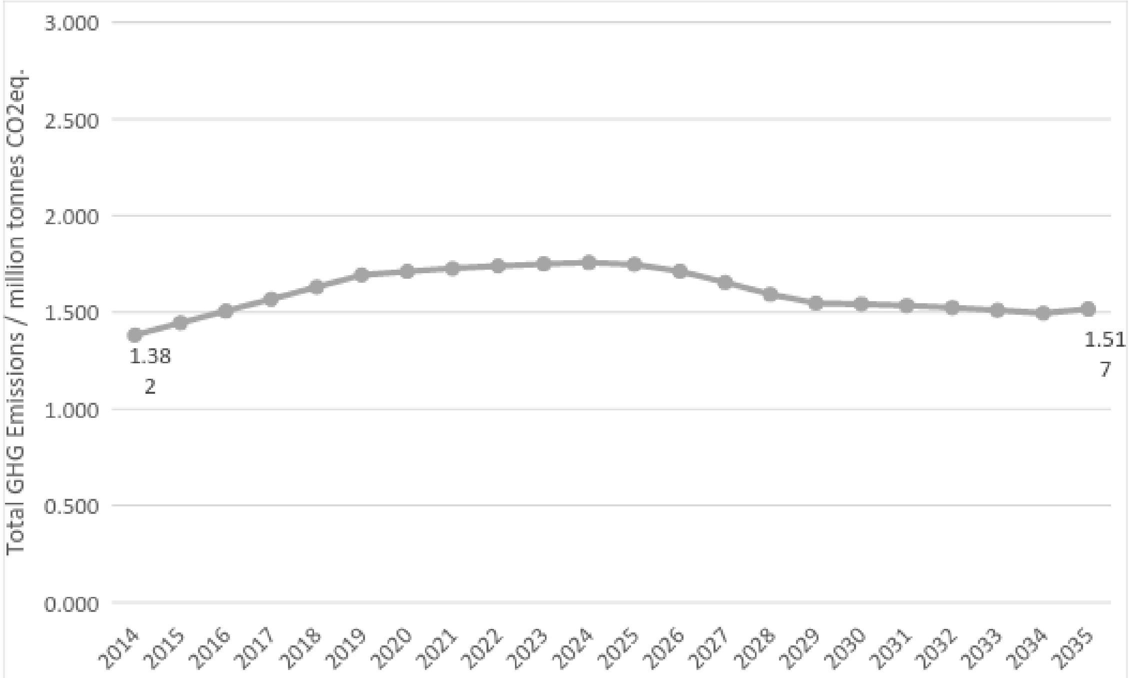


EPV = electric passenger vehicle, FEI = fuel economy improvement, ktoe = kilotonne of oil equivalent.
Source: Author.

The corresponding emissions would increase from 1.38 million tCO_2e to 1.52 million tCO_2e (0.4% increase) (Figure 38), with a reduction of 46.3 percent between the BAU and FEI scenarios in 2035.

The additional fuel savings from the introduction of electric vehicles are quite insignificant since the vehicles only constitute about 10 percent of the total number of passenger vehicles. However, mass production of electric vehicles could bring the overall cost down, potentially making them cheaper than conventional vehicles. In this case, beyond 2035 the fuel demand of 500 ktoe could be further reduced.

Figure 38: Corresponding Total GHG Emissions in FEI + PEV Scenarios



EPV = electric passenger vehicle, FEI = fuel economy improvement, GHG = greenhouse gas.

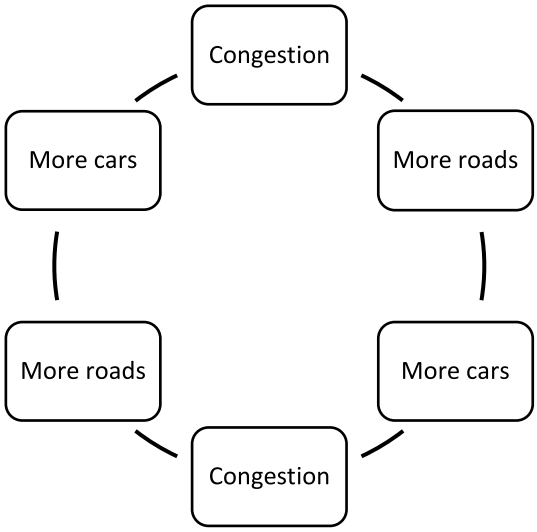
Source: Author.

3.5. Issues, Challenges, and Recommendations

The issues and challenges in achieving an energy-efficient and sustainable transport system are apparent in most countries, particularly in developing Asia, where the public transport system is considered unreliable and unsafe. Rapid increase in private motorisation, coupled with the use of low-quality fuels in relatively old and poorly maintained vehicles, has often resulted in inefficient use of fuels and hence high levels of air pollution.

Given that most developing countries are heavily reliant on roads for transport, they often tend to develop their transport system around road vehicles, by expanding infrastructure to cater to increasing private motor vehicles. Construction of more roads would only alleviate traffic congestions in the short term, however, and these new roads that cater to more vehicles would then give rise to heavier congestion, resulting in a vicious circle, as shown in Figure 39.

Figure 39: Vicious Circle of Vehicle-Oriented Development



Source: Buis (2009).

The real solution to the above cycle is not the expansion of roads and highways, but rather a balanced transport system that houses a variety of travel modes which will provide people with more options. Some possible answers are as follows:

- Provide funding for clean and efficient public transport, which includes fuel-efficient buses and light railways.
- Improve land-use and urban planning.
- Provide funding for cycling and pedestrian pathways. The funding would include incentive-based programmes that encourage walking and cycling, as well as carpooling.
- Limit or reduce funding for possible future road expansions.
- Establish and implement fuel economy regulations that allow for more efficient vehicles to enter the market and reduce the share of low-efficient ones in the market

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