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Carbon Emission Pinch Analysis: An Application to Transportation Sector in Iskandar Malaysia 2025

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Energy sector had growth significantly over the year which cause serious global warming issues. This problem arises from the results of carbon emission. Thus, a proper mitigation strategies are needed to tackle this issues. This paper is aim to apply carbon emission pinch analysis (CEPA) for transportation sector in Iskandar Malaysia (IM). The modified method is applied to study the minimum requirement of electricity need to be generated to implement electric vehicle (EV) based on current policy available and to reach the new emission target by year 2025. The road transportation and rail transportation were considered in the transport composite curve. The alternatives available to reduce emission in IM are by increasing public transport modal share, fuel switching from petrol and diesel to natural gas and biofuels, and increase transport efficiency by plug-in hybrid and EV. As a results, the estimated total amount of 0.25 TJ of electricity is needed for EV to be implemented.

1. Introductions

Carbon dioxide (CO_2) is one of the greenhouse gas (GHG) emission that cause the global temperature to increase. GHGs production and global warming phenomena not only impact on environment and economy but also have conspicuous effects on the human health (Hosseini et al., 2013). CO_2 is emitted mainly from the burning of fossil fuels.Carbon emission level is still at risk although a lot of alternatives had been proposed. Without proper mitigation strategies, the numbers are expected to increase significantly. Transportation is one of the major contributor to this statistics since most of vehicles on the road are still depend on fossil fuels. The number of vehicles on the road increase linearly with the population in the country. Energy planning is an importance aspect in managing transportation growth. Renewable energy plays an importance role in this case since it is categorized as zero emission fuel source which can replace the conventional fossil fuels. Many researchers have widely investigate the potential of reducing carbon emission in electricity sector. Recent study by Walmsley et al. (2015) had investigate the amount of biofuels need to be produced in order to achieve 1990 emission level in New Zealand. But, his study does not include cost analysis. Thus, further study is needed to analyse the impact of renewable energy i.e. biofuels and electric vehicle towards the carbon emission level in transportation sector with cost analysis.

2. Carbon Emission Pinch Analysis

Carbon Emission Pinch Analysis (CEPA) is a novel technique developed by Tan and Foo (2007) which demonstrate the graphical approach of optimisation between set of energy supply and demand. Then, many researchers apply this technique in various field. For instance, Crilly and Zhelev (2008) used CEPA in Irish electricity generation sector. They suggested improvements to the CEPA methodology which include forecasting adaptation and the time pinch adaptation. Similar to Atkins et al. (2010), they also apply CEPA in electricity sector for New Zealand. They found that, 90 % of renewable energy can be installed by fuel switching thus reducing carbon emission. Ooi et al. (2013) using pinch analysis for planning of carbon capture and storage to reduce carbon emission intensity in the air and known as carbon storage composite curves (CSCC). This graphical tool can be used for selection and allocation of CO_2 storage capacity with power plants that implement carbon capture (CC). Ho et al. (2015) had extended the CEPA and apply it in waste management which known as Waste Management Pinch Analysis (WAMPA). WAMPA is capable of identify waste management strategies

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and examine the capacity of each strategy groups through graphical while reducing the carbon emission. But, the limitation of this method is it cannot select the type of technology and its corresponding capacity to be implemented.
In this work, the CEPA method is applied based on Walmsley et al. (2015). Figure 1(a) shows the generic example of transport system. The overall transport emission is set to 1,000 kt CO_2-e. The transport demand and supply is plotted based on different transport class which is transport A', transport B', and transport C' associated with fuel A, fuel B, and fuel C. Two options for emission reduction target are proposed in Figure 1(b) and Figure 1(c). The first option in Figure 1(b) show how emission can be reduce by improving fuel efficiency transport of B' with fuel C. The second option in Figure 1(c) consider fuel switching from fuel C to fuel A in transport B'.

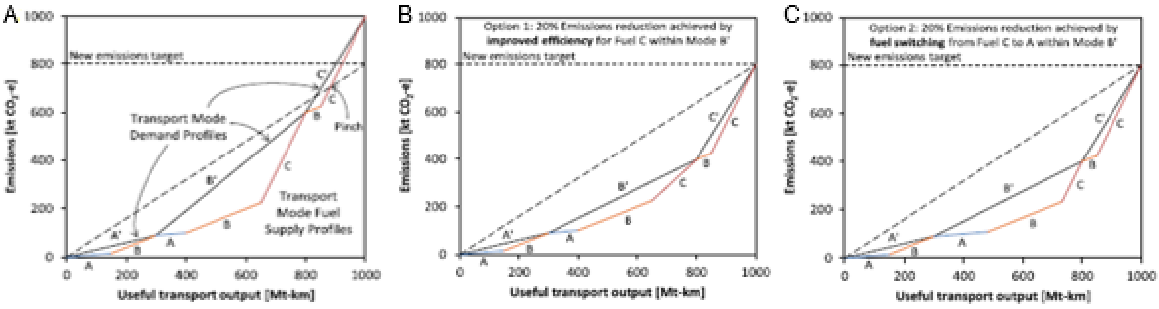

Figure 1: General method for reducing emission in transportation sector (A) supply and demand profiles by transport mode (B and C) two option for reducing emission (Walmsley et al., 2015)

3. Case Study

For the purpose of this study, IM had been chosen as a case study IM include 5 local authorities and first city to be a low carbon region. It covers an area of about 2,216.3 km^2, which is about 3 times the size of Singapore (Ho et al., 2009). IM is centrally located within South East Asia's new economic zone. It had strategic location and space for business expansion. IM is rapidly transforming the socio-economic landscape of Johor. There are five key economic zones in IM from A to E. Zone A (JB city centre), Zone B (Green-field Nusajaya), Zone C (Western Gate Development), Zone D (Eastern Gate Development), and Zone E (Senai-Skudai) (Iskandar Malaysia, 2014). Iskandar Malaysia is already attracting an influx of foreign and high level coporate investments.

3.1 Data Collection

The data collection is performed in three steps. The first step is the searching for relevant data. Then, the second step is data screening. The third step is the data selection. The data mainly collected from literature and report. These are the forecasted data based on the assumption "business as usual" scenario. IM aims to reduce overall carbon emission by 40 % based on 2005 emission level.
Table 1 shows the projected population growth and energy demand in IM until year 2025. Transportation in IM is mainly divided into 4 modes which are land, rail, marine and air. For the purpose of this study, only land and rail transport mode are considered since the data only limit to these type of transportation and only focus for passenger transportation. The detail data for transportation are shown in Table 2. The land transportation involve motorcar, motorcycle and bus while rail transportation involve train. The current fuel sources used for transportation in IM are gasoline, diesel and NG.

Table 1: Projected data for IM (Ho et al., 2009)

	2005	**2025 (BAU)**
Population	1,353,202	3,005,815
Passenger transport demand (mil pass-km)	3,816	8,677
Energy demand passenger (ktoe)	359	790
GHG emission passenger (kt CO_2)	1,015	1,672

Table 2: Transportation data by mode and fuel type for IM in 2025 (Ho et al., 2009)

Type of Transportation	Fuel Type	Total Fuel Usage (TJ)	Transport Demand (mil passenger - km)	CO_2 emission factor ($t\ CO_2$ / TJ)	Total CO_2 emission ($kt\ CO_2$)
Motorcycle	Gasoline	1076.00	910.15	68.60	73.82
	Diesel	661.51	559.80	73.33	48.51
	NG	12.56	10.63	55.82	0.70
Motorcar	Gasoline	13657.34	3342.63	68.60	937.03
	Diesel	8373.60	2051.48	73.33	614.65
	NG	150.72	36.89	55.82	8.41
Bus	Gasoline	452.17	609.12	68.60	31.02
	Diesel	276.33	372.24	73.33	20.26
	NG	4.19	5.64	55.82	0.23
Railway	Electricity	37.68	222.00	0.00	0.00

4. Results and Discussion

For the purpose of this study, four scenarios are constructed to clearly show how transportation policy can affect the total fuel usage, total emissions and total cost for transportation. The first scenario. The first scenario (S1) is based on business as usual where no policy is implement. Second scenario (S2) is the counter measure scenario which is the current scenario that proposed by the government. Third scenario (S3) only considered the usage of EV in the transportation fuel mix. Fourth scenario (S4) is the combination of all options to reduce CO_2 to target. By using CEPA method, different options to reduce emissions to the target are obtain.

4.1 Transport growth in IM for 2025

For the S1, the demand for the passenger transportation in year 2025 based on transportation type is illustrated in Figure 2. This scenario is based on business as where no policy is implied. The total transportation demand and emissions for IM in 2025 were 8,121 mil passenger-km and 1,734.63 kt CO_2 respectively. It can be seen in Figure 2 that the demand of motorcar based on population is about 67 % and follow by motorcycle which is 18 %. Then, bus and rail are 12 % and 3 %. To reduce this huge amount of CO_2 emission, government had proposed counter measure scenario

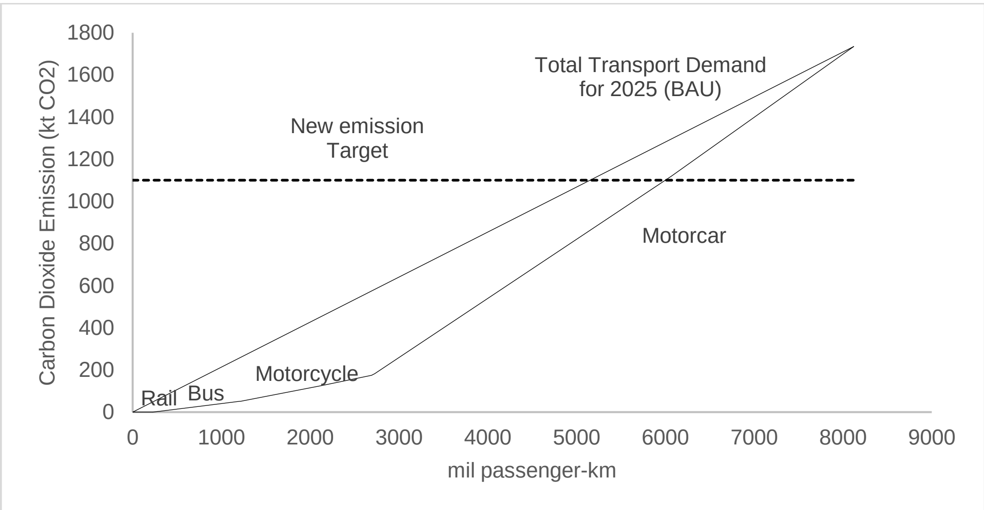

Figure 2: Transportation demand in year 2025 for business as usual scenario

Figure 3 shows the transport composite curve for counter measure scenario which represent as S2. This is based on current government policies suggested need to be implement for IM in 2025. These include 39 % transport management, 36 % fuel shifting, and 13 % efficiency improvement (Ho et al., 2009). As a results, the total emission is being reduced up to 74 % which is from 1,560 to 478.60 kt CO_2. This already far beyond the government target which is 40 % based on 2005 emission level (1,100 kt CO_2).

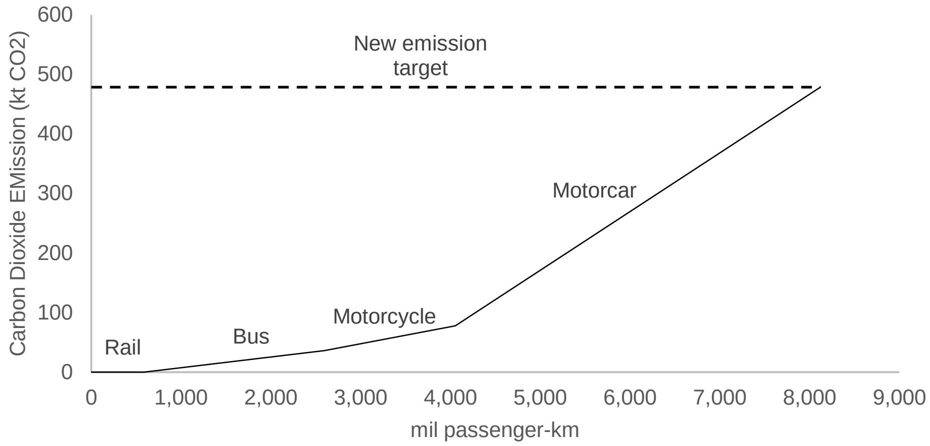

Figure 3: Transportation demand in year 2025 for counter measure scenario

4.2 Effect of EV in the transportation sector

EV currently still in development stage. Motorize industry always find a better solution to produce a reasonable cost EV to compete with the ICE vehicles. With current high price of EV, it will only affordable by higher income people. In IM, the demand of EV in fact not very satisfy. Only a few models of EV already been commercialize in Malaysia. But, this can be one of the option to reduce carbon intensity in IM since the previous solution did not provide EV policy. Figure 4 which represent the S3 shows how EV can affect the composite curve of the transportation demand in 2025.

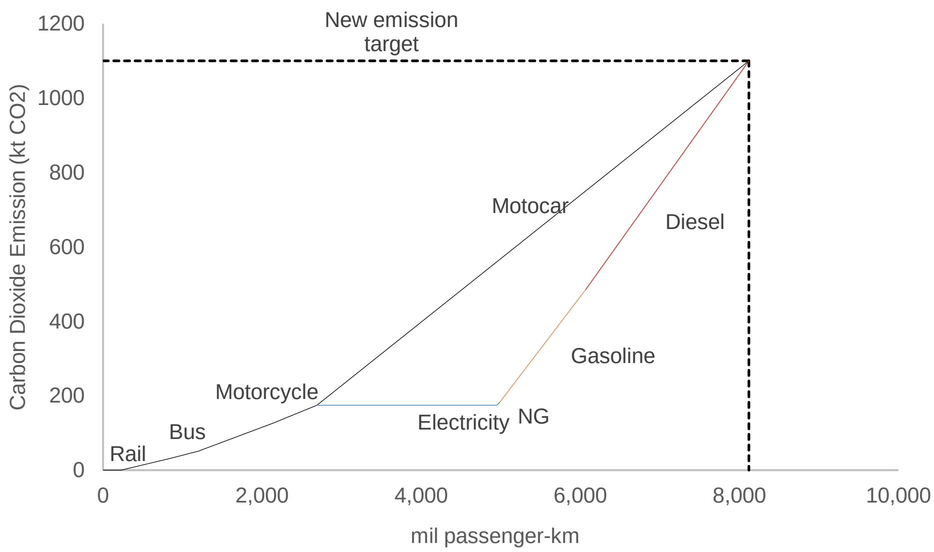

Figure 4: Transportation demand in year 2025, minimum amount of EV required

The scenario in the Figure 4 only consider switching to EV in the composite curve. A lot of scenarios and policy mix can be made in this case study. The EV policy can be integrate with the current government policy to produce a reasonable solution. Thus, the new fuel supply mix for motorcar will comprises of electricity, biofuels, NG, gasoline, and diesel. So, instead of switching from gasoline and diesel to NG and biofuels, now, EV will be one of the options.

Figure 5 which represent S4 shows the full integration of EV policy with the 2025 transportation policy. This include shifting to public transport, fuel shifting, increase fuel efficiency, and electrification of vehicles. From Figure 5, to achieve 40 % of reduction of emission intensity in the year 2025, the NG will increase by 45 times based on current demand in 2025. By increasing the transport management and fuel shifting, the petrol and diesel is being reduced by 36 % and being replace by biofuel. The total energy for biofuel required is about 0.14 TJ. Since the shifting to biofuel only required 36 %, thus the balance is the minimum electricity required for EV to fulfill the demand. The additional of 0.25 TJ is required for the EV.

Based on the four scenarios above, it can be seen that, S4 from Figure 5 which involve the integration of all fuel sources is the best option for IM since, the electricity required for EV is less compared to the S3 from Figure 4. The second option (S2) from the Figure 3 does give good impact to the environment since it can reduce up to 74 % but it is not the minimum requirement to achieve the target. Second scenario and third scenario is construct based on the minimum requirement to meet 2025 passenger demand and emission target.

Figure 6 compared the total fuel cost for all scenarios. S1 shows the most expensive option since it is based on ‘business as usual’ scenario where no policy is implied. S4 meanwhile provide the cheapest option and less fuel usage compared to others. S2 is the second cheapest option but the CO_2 emission is already far from the minimum reduction target. S3 indicate slightly higher compare to S2 and S4 since it only considers the implementation of EV in the transportation system.

Overall, CEPA is able to identify the minimum requirement of EV to be included in transportation sector. However, this method only applicable for early stage of transportation planning since it cannot includes all the constraints. Thus, a mathematical modelling is needed to further analyse the detail effect of fuel mix for the transportation sector.

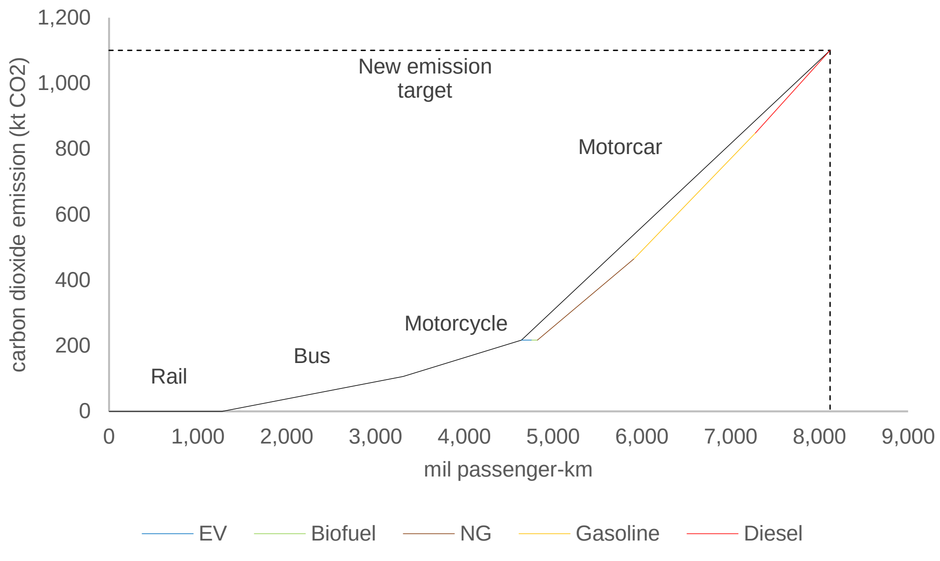

Figure 5: Transportation demand in 2025, integration of all policies

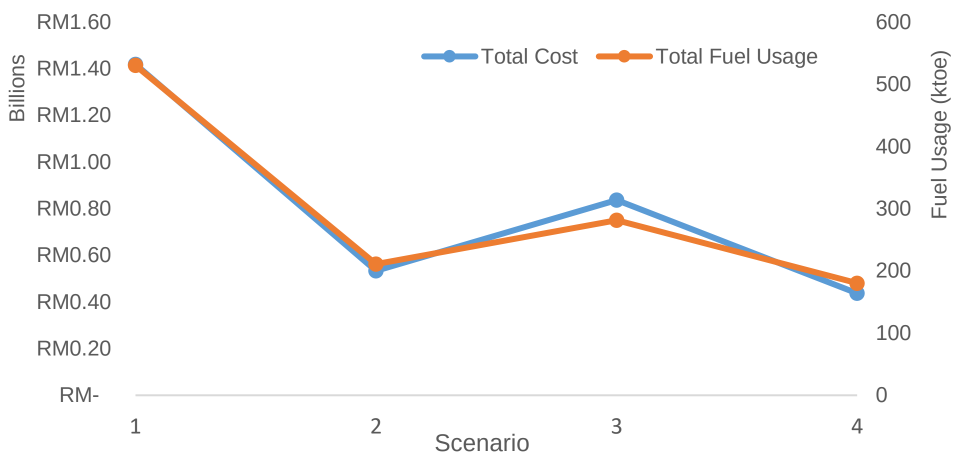

Figure 6: Cost analysis and total fuel usage for 4 different scenarios

5. Conclusions

As summary, CEPA is able to illustrate the minimum amount of energy need to be reduced for each type of vehicles to achieve the new transportation demand and emission target. This amount can vary dependent on the policy maker. Based on the case study, the optimal scenario is the fourth option, S4 which include RM 436 million, where all the policies are included. Total amount of 0.25 TJ of electricity need to be generated to implement EV in IM for the year 2025.

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