Carbon Footprint Reduction in Transportation Activity by Emphasizing the Usage of Public Bus Services Among Adolescents

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Abstract: Transportation is one of the sectors that contributes to the Greenhouse Gases (GHGs) emissions. In terms of carbon footprint, transportation is among the major contributors of high carbon intensity in the urban area. This study was conducted to reduce the carbon footprint contributed by the transportation sector in Penang Island by emphasizing the use of public buses. Secondary school students were the target group for this study. They were asked to report their daily travel behaviour and fuel consumption in a travel journal. The fuel consumption data from the travel journal were used to calculate each individual's carbon emission level. After the analyses, the value of carbon emissions was revealed to the students. Next, they were encouraged to use public transport in a motivation session and were asked to record their fuel consumption in the travel journal once again. The results showed that there was a significant difference in fuel consumption before and after the motivation session, as the students preferred to use public buses instead of private vehicles after the motivation session. This indicates that the motivation programme had been successful in creating the awareness towards carbon footprint reduction among the adolescents.

1. Introduction

Carbon Footprint (CF) is widely used to measure the impact of human activities on global warming [1]. Even though the definition of carbon footprint is very wide and varied, most concepts of CF define GHG emissions as direct or indirect emission from activities that include all relevant sources including consumption and production which are represented in carbon dioxide equivalents (CO2-e) [2-5].

The Kyoto Protocol had identified that the typical six main causes for the greenhouse gases (GHGs) effect such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) were contributed from human activities [6]. Amongst the six GHG, CO_2 is the GHG with the largest annual proportion of gas emitted globally [7]. Meanwhile, it is also claimed that the developing countries are responsible for the increase in CO_2 emission especially from the transportation activities [8].

The emissions from road transport vehicles were identified as a serious threat to the air quality and has caused worldwide concern due to its rapid growth in the release of greenhouse gases (GHGs) [9]. The harmful pollutants derived from the use of fossil fuels which is burned during the chemical

process of engine combustion before the GHG is released into the atmosphere depends on the vehicle condition as well as the natural background levels of chemical compound [7,10]. These GHGs have the ability to trap excessive sunlight energy which in turn warms up the Earth's atmosphere. As human activities continue to emit GHGs, the global temperature has also been increasing and this leads to the situation of unstable atmospheric equilibrium and extreme climate change [11].

Therefore, efforts in promoting the awareness on carbon footprint reduction can be achieved by changing individual routine choices including travel behaviour. Getting more people to choose the low carbon lifestyle such as shifting their transportation mode of choice to public transport can be done through behaviour modification approaches such as motivation and awareness programmes. A study in Japan successfully reduced 35% of CO_2 emission from private vehicle usage, with 100% of the participants in the programme switching their transportation mode to public transport [12]. Meanwhile, 25% of public transport patronage had increased in South Perth after motivation and awareness programmes were conducted [13]. The aim of this study is to investigate the carbon footprint differences among adolescents before and after the motivation programme. The hyphothesis is, if there is a reduction in the carbon footprint values, it shows that the programme is successful in creating the awareness towards carbon footprint reduction.

2. Methodology

In order to recruit the participants for the motivation programme, the selection of the schools was mainly based on those that have a good access to the nearest bus stops with a radius distance of 200 metres or less. Out of forty-eight schools which are categorised as public secondary schools in Penang Island, eight schools had met the required criteria. The selection also depended on the permission obtained from the Ministry of Education, Penang Education Department, and the respective schools' principal before conducting the experiment. The study had targeted 200 students from various secondary schools. However, only 176 students had participated until the end of this study. This programme is a joint programme with bus operators to encourage the school students to use the public buses. The participants were given a travel journal to record their carbon footprint for a period of one week. A travel journal or diary is a preferred method in conducting travel behaviour survey for the purpose of transportation planning. The participants had to return their travel journal to the researchers after 7 days of recording their travel patterns. Subsequently, they needed to attend a motivation and awareness session and were asked to fill in the travel journal again by considering the possibilities to reduce their private vehicle usage and hence reduce their carbon footprint.

In this study, the travel journal was developed to determine the travel characteristics and carbon production of the participants on weekdays (Monday to Friday) and weekends (Saturday and Sunday). In Section A of the travel journals, the participants were asked to fill up their student identification, school address, home address, and the details of the main vehicles used for their household travel activities including the mode of transportation, vehicle engine displacement (cc), year of production, choice of fuel type, and fuel consumption (in litre/100km).

According to GHG Protocol [14], emission calculation requires the data on vehicle type, distance travelled and distance-based emission factor. These information can also be extracted from the adolescent's travel journal. The outline equation in calculating the emission based on the distance travelled method is shown in Equation 1.

$$C = \sum D_j \text{ - } EF_j \quad (1)$$

where

C = carbon dioxide (CO_2) emission from transportation (kg CO_2)
D_j = distance travelled (km)
EF_j = emission factor of CO_2 measure (kg CO_2/100km)
J = based on transportation mode choice

The value of individual CO_2 emission produced can be determined by multiplying the length of trip by the appropriate emission factor. The travel distance D_j had been identified from the travel information reported by the adolescent in each trip. The unit for distance used for this study must be kilometre. It is also important to note that the value emission factor expressed in kilogram CO_2 per 100 km unit varies based on the type of vehicle used in every trip.

$$C = FC - f \quad (2)$$

where

FC = Fuel consumption of vehicle used (L/100km)

f = Fuel-base emission factor (kg CO_2/L)

3. Results and Discussion

The results show that the transportation choice of the adolescents is divided into six classifications namely car, motorcycle, van, bus, walking and bicycle. Figure 1 illustrates the mode of travel with respect to the observed trips for weekdays and weekends before the motivation programme. For weekday travel, most of the travel activities were dominated by car and motorcycle which were 38.6% and 27.5% of total travel activity respectively. It was noted that car use is about about one-third of total trips followed by motorcycle. The high proportion of travelling by car indicates that most of the adolescents travel in the company of their parents or guardian especially for school commuting.

As the majority of the students possess driving license, the automobile appears to be the dominant mode of transport. It is also similar with motorcycles, where the students who possess the riding license are most likely to use the motorcycle for their trip to school and other activities. Bus usage and walking only account for 16.7% and 12.7% of total trips during weekdays respectively. Meanwhile, it was found that van and bicycle are the least preferable transportation mode of choice accounting for only 3.2% and 1.3% of trips respectively. The share of trips made by sustainable transport (bus and walking) reveals that the adolescents have the ability to travel independently.

For weekends, the percentage of car usage increased and covered about 56.7% of the weekends' total trips, followed by the reduction in the usage of other modes of transport. This shows that the adolescents highly depend on their parents for the trips made on weekends compared to weekdays. Moreover, the percentage of motorcycle usage accounted for about 24% of the total trips. The increase in private motor vehicle usage corresponds to the increasing ability to drive and license ownership among teenagers [15].

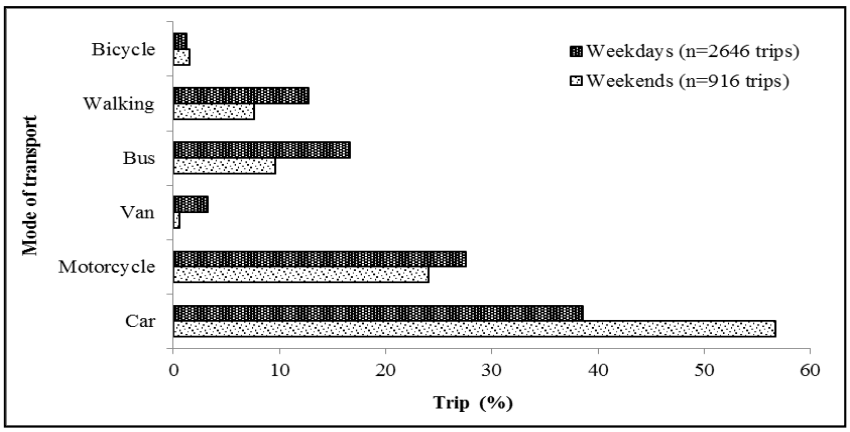

Figure 1. Adolescents'transportation of choice before the motivation programme

Furthermore, public transportation such as bus and active transport mode only account for 9.6% and 9.1% of total trips respectively. Even though the usage of bus and walking were not the most preferred mode of transportation, it reveals that the respondents have freedom in mobility. The least preferred travel mode of transportation during weekends is van which accounts for only by 0.5% of total trips. Hence, it is reasonable to assume that the provision of van services is only for the designated schedule of school travel.

Meanwhile, Figure 2 illustrates the variation in CO_2 emission resulting from the adolescents' daily travel within a seven day time frame. The highest amount of carbon emission recorded during weekdays was 127.07 kg CO_2 and the lowest was 114.65 kg CO_2. Meanwhile, the amount of CO_2 emission on Saturday and Sunday were 280.07 kg CO_2 and 261.79 kg CO_2, respectively. Further analysis of the figures found that the substantial increment in the amount of CO_2 emission occurs during weekend travel. These data represents the results in the previous subsection where the increase in trip distance and the larger share of private vehicle usage contributed to the emission production; especially during weekends. It is common for adolescents to spend the off-school days to travel for longer distances and duration; especially with their family as they are not tied down to the routine activities on weekdays.

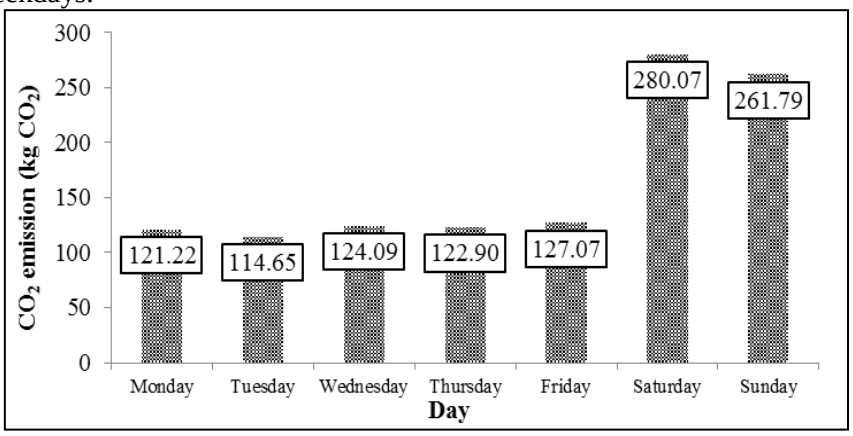

Figure 2. Weekly CO_2 emission from adolescents' daily travel before motivation programme

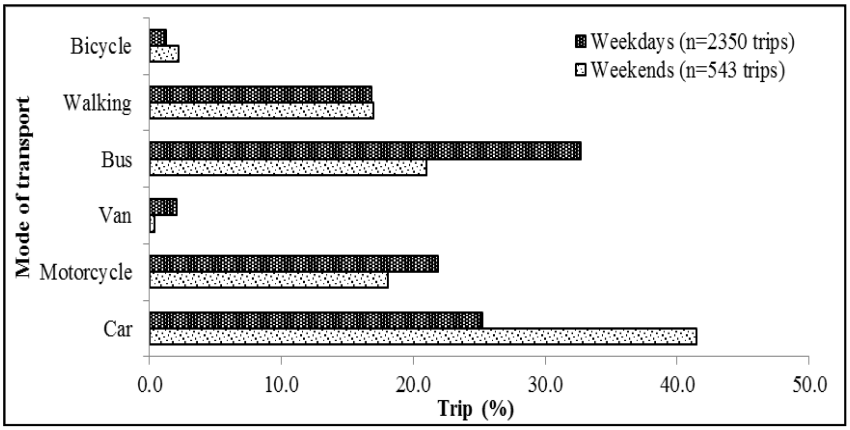

Figure 3. Adolescents'mode choice after the motivation programme

Figure 3 presents the preferred mode of transportation for weekdays and weekends after the motivation programme. Interestingly, the usage of bus has contributed the highest propotion of the total trips during weekdays covering 32.7% of trips, followed by car (25.2% of trips), and motorcycle (21.9% of trips) after the interventions. These results imply the occurence of a switch in the mode of transport from private vehicles to public transport. Walking contributed about 16.9% of the total trips.

This indicates that the active mode of transport can serve as one of the alternatives for trips that can be completed within a walking distance in order to preserve the environment. The trips by van and bicycle were less likely to be used with 2.0% and 1.3% of the total trips, respectively.

On the other hand, the car still appears to be the dominant mode of transportation covering 41.4% of total trips during weekends followed by bus (21% of trips), motorcycle (18% of trips) and walking (16.9% of trips). Bicycle and van seems to be less preferable similar as during weekdays. The high dependency on private vehicles implies that the travels during weekends might still be involving family activities. For example, the adolescents tend to travel with their parents or family when trips are made for the purpose of visiting distant relatives. However, the public transport has become the second most preferable mode of transport which suggests that some adolescents obtained parental permission to travel alone.

The variation of the travel-related CO_2 emissions from adolescents' daily travel within the seven day time frame after the intervention programme is shown in Figure 4. After the implementation of the motivation programme, the largest amount of kg CO_2 that was recorded by the adolescents during weekdays was 64.74 and the lowest was 50.51. Meanwhile, the amount of CO_2 emission on Saturday and Sunday were 72.58 kg CO_2 to 68.29 kg CO_2, respectively. Based on the results from the figure, the production of CO_2 emission was found to be increasing day by day. However, the production of CO_2 emission between weekdays and weekend in this post-intervention stage was not substantially different. This implies that the adolescents tried to give their commitment in this programme. It also proves that the intervention techniques could have influenced the adolescents in reducing individual CO_2 emission through their travel behaviour. Perhaps the adolescents' propensity to spend more time for indoor activities or switching to the other alternative modes of transport such as public transport or active transport mode may also be among the reasons for low emission production.

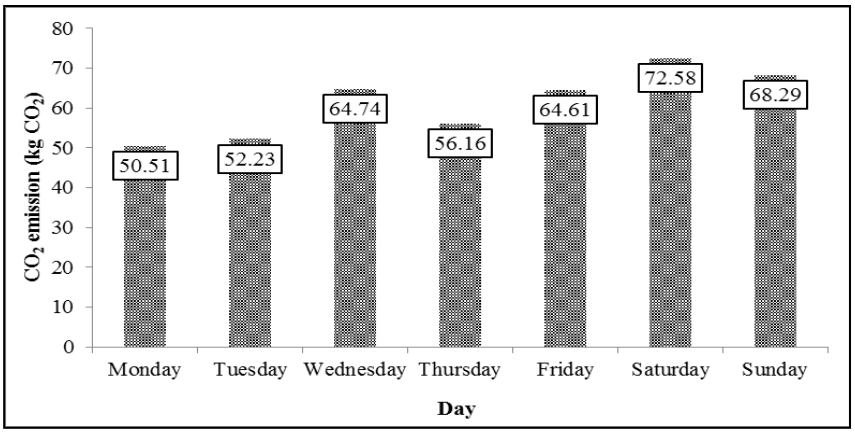

Figure 4. Weekly CO_2 emission from adolescents' daily travel after motivation

Table 1 compares the travel-related CO_2 emission in the time frame of seven days with respect to pre-post interventions. Overall, it was observed that the pre-post mean difference of CO_2 emission were statistically significant from Monday to Sunday. The mean differences for regular school-days (Monday to Friday) vary in the range of 0.335 kg CO_2 to 0.402 kg CO_2. The most significant difference of CO_2 emission production was on Wednesday ($t = 6.128$, $df = 175$, $p < 0.001$) while the lowest was on Friday ($t = 5.380$, $df = 175$, $p < 0.001$). Meanwhile, the mean differences for off school-days (Saturday and Sunday) were 1.179 kg CO_2 and 1.099 kg CO_2, respectively. The strongest significant difference of CO_2 emission production during weekends was on Sunday ($t = 4.665$, $df = 175$, $p < 0.001$) while the lowest was on Saturday ($t = 3.949$, $df = 175$, $p < 0.001$). The findings denote that the production of CO_2 emission has significantly declined

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Table 1. Paired t-test of CO_2 emission for pre-post interventions

Day	Pre-post mean, M_{diff} (kg CO_2)	SD	t-value	p-value
Monday	0.402	0.911	5.854	0.000
Tuesday	0.355	0.780	6.035	0.000
Wednesday	0.337	0.730	6.128	0.000
Thursday	0.379	0.823	6.115	0.000
Friday	0.355	0.875	5.380	0.000
Saturday	1.179	3.353	4.665	0.000
Sunday	1.099	3.694	3.949	0.000

4. Conclusion

This study explores the potential of motivation and awareness programmes in encouraging the usage of public bus. The experiments in this study were implemented through the travel journal method by recruiting secondary school students. The results indicate that providing the awareness through a convincing way of communication to the participants increased the positive perception towards public transport services and can induce the intention to reduce travel related carbon footprint. In the future, additional intervention techniques such as providing a one-month free bus ticket to the targeted respondents should be explored. The analysis shows that after the motivation and awareness programme, the values of carbon emission have significantly reduced and the comparison between the data in the first and second travel journals indicate a notable difference. The evidence of statistical differences in carbon footprint values combined with effective motivation techniques have increased the likelihood for students to travel in a sustainable way in order to protect the environment from the adverse impact of the transportation sector. Therefore, it can be concluded that motivation programmes could help to persuade the participants to focus on ways to reduce the emission from the transportation sector either by using alternative modes of transport or reducing trips. It is suggested that in the future these projects should be continued, with the support from committed participants and the cooperation from schools in order to provide a wider and more effective impact.

Acknowledgements

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