

INVESTIGATION OF CARBON FOOTPRINT AWARENESS USING TRAVEL DIARY METHOD

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ABSTRACT: In this study, 100 university students were recruited to complete a seven day travel diary that described their use of privately owned motor vehicles in order to discover their underlying psychological factors that affected the production of individual carbon footprints through travel patterns. The diaries were collected and the respondents were given a motivation session related to carbon emissions caused by motor vehicles. They were then asked to record their travel patterns for a further seven days and encouraged to change their travel patterns to be more pro-environment. A statistical analysis was performed to examine the differences of these individual's carbon footprints; before and after the motivation session. The results revealed significant differences in carbon footprints between first and second travel diaries. The structural equation modeling demonstrated that among the psychological variables, pro-environment attitude was the most significant factor affecting the respondent's intention to reduce their usage of motor vehicles; thus influencing the respondents' behavior to be more pro-environmentalist. As a conclusion, this study suggests that individual carbon footprint can be measured through travel diary method.

Keywords: Carbon Footprint, Travel Diary, Theory of Planned Behavior, Pro-Environment

1. INTRODUCTION

The continuous rise in the number of vehicles, together with increasing mileages of travelling on roads, has triggered the serious issue of air pollution from these motor vehicles. In fact, since the 1960's, the worldwide number of motor vehicles, as opposed to the population, has been growing rapidly. Since 1950, 3.5 billion people having 50 million cars has grown to over 600 million cars for 6.7 billion people. It has been estimated that about a billion cars will be produced by 2020 [1].

Stern [2] reported in his book that the transportation sector accounts for 14% of total global greenhouse gas (GHG) emissions, in which the road transport sector contributes to three-quarters of these emissions. In addition, the World Energy Outlook project claimed that global transport demand appeared to be growing to 45% by 2030 [3]. Therefore, GHG emissions resulting from the transportation sector are undoubtedly posing a serious concern and requires serious attention because of its grievous consequences towards global warming.

The impact of human activities on global warming usually measured via a Carbon Footprint (CF) calculation [4]. Nowadays, there are numerous carbon calculators available online, as well as consultants that regard voluntary carbon footprinting [5]. Wright, Kemp and Williams [6] stated that an individual carbon footprint calculator is used to calculate individual GHG emissions, in order to link them to more pro-environment lifestyles and activities.

However, according to Wiedman and Mix [7], there is still no common consensus about how to measure the carbon footprint; whilst its definition remains intangible. Several studies exist that introduce the carbon footprint concept by measuring CO₂ with other greenhouse emissions in units of carbon dioxide equivalents (CO₂-e) [8-12]. However, the United States Environmental Protection Agency [13] stated that greenhouse emissions, such as CH₄ and N₂O, are complex to calculate; due to their dependency to control equipment, vehicle miles travelled, maintenance, and operational practices.

Meanwhile, the GHG Protocol – mobile guide v1.3 [14] states that either fuel-based or distance-based methods can be used to directly calculate CO₂ emissions for all transportation sources. The Fuel-based Method's calculations are based on aggregate fuel consumption data and the distance-based method's calculations are based on the distance travelled and other distance based emission factors.

1.1 Lifestyle-travel pattern and psychological impact towards carbon emissions.

Individual lifestyle is also claimed to be one of the factors that contributes towards an individual's carbon footprint; including the individual's travel patterns. Vanderbergh, Barkenbus and Gilligan's [15] study reported that the use of private cars was usually related to idling of the vehicle's engine. This can be a source of increased CO₂ emissions. In addition, Susilo and Stead [16] found that young individuals with a high income, that were members of smaller households with privately owned vehicles, were more likely to travel further. These indicators led to unfortunately high carbon emissions that were

instigated by their travel patterns and lifestyles. They also revealed that some proportion of their respondents were in favour of this suggestion; that in order to reduce CO₂ emissions, public transport systems should be strategized and promoted. Several studies also suggested that one way to improve the environment is through planning green cities with fewer motor vehicles [17-18].

Moreover, in order to promote pro-environment lifestyles, Stern [19] suggested that psychology could contribute to a reduction of carbon emissions through developing an understanding of climate that is relevant to households, individuals, and organizational behaviors. For example, voluntary actions to reduce carbon emissions (by reducing the use of cars) were always directed towards an awareness and knowledge of environmental issues [20]. In a psychological and behavioral study, the Theory of Planned Behaviour (TPB) is renowned in explaining the diversity of human behavior through the prediction of intention, attitude, subjective norms and perceived behavioral control (Fig.1).

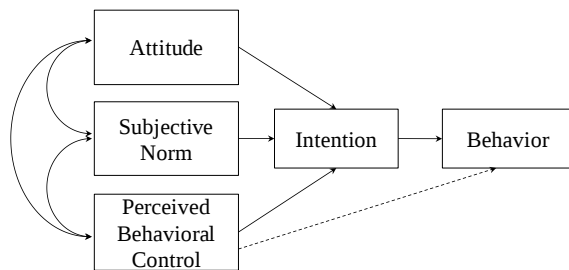


Fig. 1 Theory of Planned Behaviour [21]

An extended TPB was also used to measure psychological effects towards pro-environment travel behaviour. For example, Anable [22], in her study to promote alternative modes for car users, found that the voluntary behaviour of switching to more pro-environment modes of transports was affected by psychological factors, such as attitudes and beliefs. She stated that a person who was a die-hard driver, was likely to create a reluctant attitude towards switching their travel mode.

On account of believing that psychology could give positive impact in reducing emissions caused by private vehicles, Fuji and Taniguchi [23] implemented a motivational approach towards groups of people in different counties in Japan, in order to promote a pro-environment travel behavior. Their study resulted in a reduction of CO₂ emissions and car use; and increased public transport use.

1.2 Study Objective

The objective of this study is to discover the underlying psychological factors of individual

carbon footprints, based on an altered Theory of Planned Behaviour, after a motivation session on carbon emissions. This research applies the distance-based method (obtained from the travel diaries) to calculate CO₂ emissions. For this purpose, this study performed several analyses based on the respondents' travel diary surveys. This paper is organized as follows: Section 2 describes the travel diary, questionnaire, and how the survey was implemented; Section 3 presents the results of the analysis data; and finally, Section 4 is devoted to discussion and the conclusion from the results.

2. METHOD

2.1 The sample and travel diary

This study focuses on the factors affecting university students' carbon footprints; through their use of private motor vehicles. One hundred students from the School of Civil Engineering, Universiti Sains Malaysia, were recruited and asked to complete a seven day travel diary that reported their daily activities and travel patterns. Information from the diaries was used to indicate each individual carbon footprint. After they finished the seven day diary, they were asked to attend a motivational session, which was aimed at increasing their awareness of carbon emissions and environmental issues. At the end of the session, they were requested to answer a questionnaire survey pertaining to psychology. Next, they were asked to fill in another seven day travel diary, in order to check any behavioral changes towards their travel methods.

2.2 Carbon footprint calculation

Data of distances traveled was collected through the travel diary survey and included vehicle and fuel types. The distances estimated from the each individual travel diary were converted into CO₂ emissions by multiplying with a distanced-based emissions factor. In this study, the distanced-based emission factor used was sourced from the GHG Protocol - mobile guide v1.3 [14]. The equation to calculate CO₂ emissions, which was based on the distance traveled method, is presented below.

$$CO_2 = \sum \text{Distance}_j \times d_j \quad (1)$$

$$d = b \times f \quad (2)$$

Where,

d = distance based emission factors (kg/100km)

j = different modes of transportation

b = litres per 100km (litre/100km)

f = fuel based emission factors (kg/litre)

In this study, all respondents used RON95 fuel for their motorized vehicles.

2.3 Questionnaire survey

Table 1 Questionnaire statements for psychological variables

The questionnaires, which were used to measure psychological effects, were given to respondents after the motivation session. Since Ajzen [19] suggested that the TPB is open to expansion, the questionnaire was constructed according to the TPB variables; with the addition of moral obligation and opinion. The questionnaire statements measuring psychological variables are shown in Table 1. The data for all psychological variables listed below were examined through Structural Equation Modeling (SEM).

Statement	Psychological variables	Answer scale
It is an obligation for each individual to reduce the usage of private motor vehicles to reduce the carbon emissions.	Moral obligation	1= Strongly Agree 2= Agree 3=Disagree 4=Strongly Disagree
In my opinion, an attempt to travel without using private motor vehicles is one of the best ways of reducing carbon emissions.	Opinion	1= Strongly Agree 2= Agree 3=Disagree 4=Strongly Disagree
I do not attempt to travel by private motor vehicles to reduce the consequences of carbon emissions.	Attitude	1= Strongly Agree 2= Agree 3=Disagree 4=Strongly Disagree
It is hard for me to travel by not using private motor vehicles.	Perceived Behavior Control	1= Strongly Agree 2= Agree 3=Disagree 4=Strongly Disagree
The people that are close to me do not support me reducing the usage of private motor vehicles.	Subjective Norms	1= Strongly Agree 2= Agree 3=Disagree 4=Strongly Disagree

3. RESULTS

3.1 Descriptive analysis

The results of frequency analysis (shown in Table 2) reveal that the age range for the recruited sample was between 19 and 33 years old. Male and female categories were almost balanced at 52% males and 48% females. 36.7% of the respondents possessed a car, 17.3% owned a bicycle, 8.2% owned a motorcycle, and 31.6% did not own a vehicle. However, in this study, students with a bicycle but no vehicle were included in the same group as students without motor-vehicle ownership.

Table 2 Descriptive statistic of respondents

Variable	% (N)	Mean (S.D)
Age	-	23.08 (2.82)
Gender		
Male	52 (52)	0.56 (0.502)
Female	48 (48)	0.37 (0.489)
Vehicle ownership		
At least one motorized vehicle ownership	49 (49)	0.49 (0.502)
No motorized vehicle ownership	31.6 (52)	0.52(0.502)

3.2 Individual Carbon Footprint (CF)

Table 3 Statistical t-values for carbon footprint before and after motivation session; according to gender and vehicle ownership

Variable	CF before	CF after	t-stat (p-value)
Gender			
Male	17.02	9.72	1.825 (0.035)
Female	16.82	12.11	2.169 (0.074)
Vehicle ownership			
Motorized vehicle ownership	26.35	16.78	2.176 (0.035)
Non-Motorized vehicle ownership	7.88	5.18	1.665 (0.102)

T-test statistical analyses were undertaken in order to examine the carbon footprint value differences between travel diaries 1 and 2. The

results in Table 3 show that there were significant individual carbon footprint emission differences before and after the motivational lecture sessions; according to gender and motor vehicle ownership. This demonstrates that the motivation session was a success in terms of increasing students' awareness towards carbon emission issues. The findings also show that after the lecture session, 62% of the respondents had an intention to reduce their usage of motor vehicles. However, the respondents who did not own a motor vehicle demonstrated no significant difference of carbon footprint between travel diary 1 and 2. This indicates that they maintained a low carbon footprint.

3.3 Psychological Effect

Table 4 presents the estimation results of psychological factors based on structural equation modeling. These results are presented in terms of estimated parameters, standard error, and critical ratio, that corresponds with the t statistics. The overall maximum likelihood estimation of the model yields a Chi-square value of 2.799 with 4 degrees of freedom. A review of the Goodness of Fit Index (GFI) statistics for this model shows a reasonably good fit to the data; particularly the RMSEA value for this model, which is lower than 1. The Chi-square/d.f. of 0.67 is well below the recommended value of 3.00. The (GFI), Normed Fit Index (NFI), and Comparative Fit Index (CFI) values seem probably acceptable and exceed the cutoff value of 0.90. These results show that only attitude has a significant effect, with $p < 0.001$, towards the intention to reduce car usage. The other variables showed no significant impact towards intention. Meanwhile, intention shows a significant effect towards behavioral change to be more pro-environmental, with $p < 0.001$, compared to subjective norm and opinion of being pro-environmental.

These results are congruent with the path diagram shown in Figure 2. The path diagram illustrates the relationship between variables by considering the variations of the students' individual carbon footprint in travel diaries 1 and 2 were as per the dependent variable. These results indicate that attitude was the only important psychological factor related to the intention of reducing the individual carbon footprint; whereas, other psychological variables were not that significant. In addition, attitude also delivered the strongest coefficient value amongst all psychological variables associated with the behavioral intention of respondents. The negative coefficient of attitude indicates that the respondents who were not willing to travel by private motor vehicles to reduce their carbon footprint were most probably on the verge of making

a plan to change their travelling behavior to be more pro-environment; after the lecture session.

Table 4 Estimated causal effects (standardized) among variables

Path To	Path From	E.P	S.E	C.R
Intention	Att	-0.205 ***	0.071	-2.123
Intention	PCB	0.143	0.061	1.497
Intention	SN	-0.138	0.059	-1.467
Intention	MO	-0.146	0.082	-1.531
BC	SN	-0.052	2.827	-0.534
BC	Intention	0.197 ***	4.542	2.002
BC	Opinion	-0.160	3.419	-1.646

Note: Att = Attitude, PCB = Perceived Behavior Control, SN = Subjective Norm, MO = Moral Obligation, BC = Behavior Change, E.P = Estimated Parameters, S.E = Standard Error, C.R = Critical Ratio, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

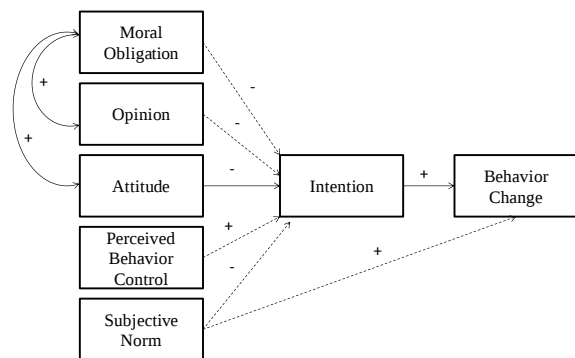


Fig. 2 Estimated model of relationships among psychological variables towards individual carbon footprint behavioral changes.

Note: N = 100; Cmin = 2.799; d.f.=4; Cmin./d.f.= 0.670; CFI = 1.0; GFI = 0.992; AGFI=0.945; 90% confidence interval.

These results also indicate that intention was an extremely important variable associated with respondents' behavioral change. The positive coefficient showed that respondents who had an intention to be pro-environment were likely to demonstrate some changes in their individual carbon footprint; after the lecture session. In the correlation between the psychological variables, moral obligation was found to be significantly related to the respondents' opinion and attitude. It also showed that respondents who felt it was an obligation to avoid using privately owned vehicles to reduce carbon emissions, were expected to decrease their usage. However, the respondents with a moral obligation were also likely to agree that travelling

without using motorized vehicles would be one of the best options to be pro-environment.

4. DISCUSSION

This study emphasized on the effectiveness of a motivation session in order to increase the awareness of the carbon footprint that caused by the individual's pattern of travel. The individual carbon footprints were collected through two time frames (each time frame constitutes 7 days) and interspersed by a motivation session that was related to environmental awareness. At the end of the motivation session, the respondents were required to answer the psychological questionnaire.

Our findings reinforced existing evidence for the importance of attitude and intention in predicting changes towards pro-environmental travel behavior. Among the psychological factors, the attitude displayed significantly stronger effect than the intention. However intention was statistically noteworthy towards the behavioral changes. Other psychological antecedents were found to be not that significant.

The differences of carbon footprint value between diary one and diary two revealed that the motivation sessions have delivered a positive impact on the respondents' attitude towards carbon emission issues that instigated by human travel patterns. Male students were found to be more committed with the reduction of their carbon footprint value as compared to female students. This is because most of the male students owned motor vehicles and the motivation session seemed managed to convince them to reduce the use of their private motor vehicle. It is consistent with the t-test findings where the students who owned a motor vehicle were significantly found had reduced their carbon print. Meanwhile even t-test results show there are not significant different for the students who did not owned a motor vehicle, their carbon footprint showed a little reduction. This also confirms the effectiveness of motivation session in order to influence the respondents' daily travel patterns.

However, this study did not confirm whether the motivation session will affect the students' behavior in the long term. It is suggested to assess the respondents' behavior at 6 months interval after the motivation session. Furthermore, other psychological variables except for attitude and intention were not found to be significant that might be due to the small sample size for this study. This might have an impact on the SEM results. Nonetheless, the aim of this study is also to examine the capability of travel diary to gain the carbon footprint data. This is because the travel diary survey is less concerned to be implemented in Malaysia. Therefore, for future research it is aimed to increase the number of samples to gain more accurate results.

5. CONCLUSIONS

As a conclusion, this study suggested that a travel diary survey can be used to collect the data for carbon footprint. In addition, this study also confirmed that motivational sessions are effective for increasing awareness on individual's carbon emission, thus affecting the individual's way of travelling.

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