Analysis of Transportation Energy Consumption: En Route Towards Carbon Reduction for Sustainable Campus

2017 IOP Conf. Ser.: Mater. Sci. Eng. 226 012055

(http://iopscience.iop.org/1757-899X/226/1/012055)

IOP Conf. Series: Materials Science and Engineering **226** (2017) 012055 doi:10.1088/1757-899X/226/1/012055

Analysis of Transportation Energy Consumption: En Route Towards Carbon Reduction for Sustainable Campus

Nur Sabahiah Abdul Sukor[1], Sitti Asmah Hassan[2]
[1]School of Civil Engineering, Universiti Sains Malaysia
[2]Faculty of Civil Engineering, Universiti Teknologi Malaysia

cesabahiah@usm.my

Abstract. This paper reports the estimation of transportation energy consumption based on the travel behaviour characteristics of the population in the Engineering Campus, Universiti Sains Malaysia. The travel behaviour characteristics include the travel distance, travel speed, number of trips per day, and modal share of the transport, which only focused on the trips that were made inside the campus. The travel behaviour data were collected through online and pencil-and-paper questionnaire survey involving 1000 respondents including staffs and students, which is equivalent to 25% of the total population. The result from the survey showed that a total of 1897 trips per day were made by the motorised vehicle owners including car and motorcycle owners. The total trip length per day was 1056.29 km with an average speed of 45km/h. The average trip for each person was four trips per day. The estimate energy consumption from the motorised vehicles in this campus was reported to be $1.25E^9$ MJ.

Keywords: Transportation energy consumption, sustainable campus, carbon emission

1. Introduction

One of the largest energy consumptions in Malaysia comes from the transportation sector [1]. Factors that could contribute to the transportation energy consumption include travel behaviour characteristics, such as travel trip, travel speed, travel length, travel distance, and modal share of private motorised models (PMM) [2]. This necessitates a transportation study with detailed analysis of a community travel behaviour in order to gain deep understanding of the travel thinking in the transportation sector. It can also be claimed that one of the key elements in a transportation study is influenced by the travel behaviour characteristics. Therefore, it is crucial to understand and identify transportation needs in order to support the making of a sustainable campus for the future.

Nowadays, one of the major contributors to greenhouse gas (GHG) emissions in Malaysia comes from the transportation sector, which also contributes the largest energy consumption [1,2]. Air pollution produced from the transportation sector brings negative impact to the environment [4], and to minimise air pollution, the sustainability concept was introduced. Subsequently, universities worldwide have taken the challenge to make sustainability an important issue [5] because universities are among the contributors to transportation energy consumption following the high usage of private motorised modes (PMM) and less active mode in campuses [6]. Therefore, to enhance the making of a sustainable campus, the first step is to identify the transportation energy consumption in the campus. The travel behaviour characteristics of the population in the campus also need to be identified in order to estimate and calculate transportation energy consumption [3].

A questionnaire survey method is the most widely used method for travel behaviour studies. A questionnaire is typically designed to gain the travel behaviour characteristics of a respondent in order to estimate transportation energy consumption. This study adopted a questionnaire survey as the key method to fulfil the objectives of the study. The purpose of this study is to obtain the value of transportation energy consumption made by the community on campus through an analysis of data collected from a questionnaire survey.

The main point of this study is to estimate the total energy consumption in Engineering Campus, University Sains Malaysia. Various methods can be adopted to estimate transportation energy consumption, but in this research, the estimation involved analyses of travel behaviour characteristics, which include travel speed, travel distance, travel trip number, and modal share. The values of these variables were collected by using an online questionnaire survey and also the typical pen-and-pencil questionnaire form The outcomes from this study can be an initial strategic step to enhance the sustainability of campuses in the future.

2. Literature Review

Sustainability is defined as a subject that can be maintained in a specific state for a very long time, perhaps for an indefinite period [7]. In the other word, sustainability is the property of a thing being sustainable. The Brundtland Report claimed that sustainability is generally acknowledged from the term *sustainable development* (SD) [8].

2.1 Sustainable transport

By referring to the definitions of sustainability, sustainable transportation can be considered as one that is able to meet today's transportation needs without compromising the ability of future generations to meet their transportation needs [9,10]. An example of sustainable transportation is the energy efficient vehicles with clean fuels like biodiesel, electricity, car sharing, and park-and-ride [11,12]. Therefore, all forms of the public transport such as buses, mass transit, and nonmotorised transports (such as walking and cycling) are called sustainable transports. However, sustainable transportation is one of the major challenges faced by universities due to the daily mobility of their population and the growing repercussions for the environment [13].

2.2 Sustainable Campuses

The criteria of a sustainable campus are divided into three categories: ecological, economic, and institutional [14]. The ecological criterion explains food and recycling, green building, and transportation, which focus on alternative transportations for students, faculty, and staff, as well as alternative fuel or hybrid technology for campus fleets. The economic category consists of endowment transparency and investment priorities. The institutional criterion includes administration, student involvement, shareholder engagement, climate change, and energy.

2.3 Sustainable Transport in the Campus

Within the campus, motorised vehicles are more desired than any sustainable transportation system available. However, motorised traffic creates an unhealthy environment to the pedestrians in the campus, particularly in the forms of air and sound pollutions, unhealthy lifestyle, and safety issues. A few sustainable mobility programmes have been applied around the world (including universities), such as transport choice improvement and incentives[6].

2.4 Transportation Energy Consumption in Malaysia

The transportation sector is an important component of globalisation and makes a critical contribution to the economy [15]. One of the key factors for the growth and development of the Malaysian economy comes from the transportation sector [1,2]. Unfortunately, this activity involves major energy consumption and produces a veto impingement to the living environment by using limited nonrenewable energy.

2.5 Efficiency of transportation energy consumption

The efficiency of transportation energy consumption is described as making higher value with lower environmental impact on PMM [3]. Otherwise, it is defined as the ratio between the combination of gross regional domestic product (GRDP), trips by PMM, public modes, and transportation energy consumption. In addition, the government of Malaysia has implemented the energy efficiency programme to ensure the sustainability of energy supply and its consequence to the country's sustainable economic development [16].

2.6 Travel Behaviour Charateristics

Travel behaviour, which is described as how the citizenry travels, also influenced by urban form and land use as well as by socioeconomic and demographic characteristics [12, 17, 18,19,20]. In addition, travel behaviour is defined as the resolution of comprehensive urban-transport natural actions [3]. Travel characteristics studies usually involve trip generation rate, mode shares, and distributions of trip lengths, and departure time profiles [19]. Meanwhile, trip length, trip speed, daily trip number, and model share of PMM are the four main travel characteristics that are usually considered (1) to encourage sustainable behaviours in travel patterns and (2) to identify the need to develop, expand, and improve the services for bus transit, parking management, and TDM.

3. Methodology

The data for this study were collected using questionnaire survey, which targeted all staffs and students in the campus. The first phase consisted of an online questionnaire survey. Nevertheless, the initial response rate was not sufficient for analysis, prompting the researcher to conduct a face-to-face survey hence managed to involve 1000 respondents (equivalent to 25% of the total population of the engineering campus). The questionnaire survey form consisted of several sections. Section A queries about the respondents' sociodemographic factors, such as gender, race, and status (for both staff and students). Section B specifically queries the students' faculty and category of academic. In Section C, the respondents were asked about their vehicle ownership. The answer in section C directed the respondents either to section D or section E. Section D was developed for respondents who own motorised vehicles, such as car or motorcycle. Section E was developed for respondents who do not own any motorised vehicle, who either walk or cycle in the campus. Section F queries the issues with regard to sustainable transportation system in the campus.

The analysis of the travel behaviour characteristics was modelled in order to estimate the transportation energy consumption based on Equation 1[3]

$$E_k = P_k.G_k.Y_k.L_k.e \tag{1}$$

where,

E_k = Transportation energy consumption (MJ)
P_k = Population (Person)
G_k = Average daily trip number (Trip)
Y_k = Modal share of private motorized modes (PMM) (%)
L_k = Average trip length (Km per trip)
e = Intensity of energy consumption (MJ per person Km)

The data for population was based on the students' registration number and staffs' identification number for the current year. For this study, the population of the engineering campus was identified as 4000 peoples. Meanwhile, the data for average daily trip number and average trip length were determined from the questionnaire survey. In this study, the modal share of private motorised modes was determined as 50% of the total population based on the number of vehicles' registration for the lastest two academics sessions.

In order to calculate the intensity of energy consumption, *e*, Equation 2 and Equation 3 were also applied as follows:

$$e = Fc_{(Vk)}.HV \quad (2)$$

and,

$$Fc_{(Vk)} = [829.3/V_k] – 0.8572V_k + 0.007659V_k^2 + 64.09 \quad (3)$$

where,

$Fc_{(Vk)}$ = Fuel efficiency of a vehicle at an average speed (cc per Km)
HV = Average calorific value of gasoline (MJ per L)
V_k = Average vehicle speed (Km per hour)

In addition, to calculate the intensity of energy consumption in the campus, the average calorific value of gasoline in Malaysia was set to be 43.96 MJ/L [21]. To complete Equation 2 and Equation 3, the fuel efficiency of a vehicle at an average speed was determined. Speed limit signs can also influence the drivers, therefore speed limit can be used as the average speed [22]. This study considered 45km/h as the average speed limit in the campus according to the speed limit signage.

4. Result and Discussion

4.1 Descriptive Analysis

Table 1 shows the descriptive analysis of the respondents for this study. Most of the respondents were female (52.2%). The proportion of the respondents according to race shows that Malay respondents were dominant (68%) followed by Chinese (25%), Indian (4%), and others (3.6%). Even though this study targeted all population of the campus, only 14% of the respondents were staffs and the rest (85.9%) were students. From the propotion of the students, 7.8% represented postgraduates and the rest (77.9%) represented undergraduates. The highest percentage of the respondents came from School of Civil Engineering. In terms of vehicle ownership, 55.4% of the respondents have motorised vehicles (32.2% - car, 23.2% - motorcycle) and 44.6% do not own any motorised vehicle but walk or cycle in campus.

Table 1. Table of descriptive analysis for respondents

Variable	%	N	Variable	%	N
Gender			School		
Female	53	522	Civil Engineering	29	247
Male	48	478	Material and Mineral Resources Engineering	25	219
Race			Mechanical Engineering	14	118
Malay	68	677	Electrical and Electronic Engineering	13	116
Chinese	25	249	Chemical Engineering	12	99
Indian	4	38	Aerospace Engineering	7	60
Others	4	36			
Status			Vehicle Ownership		
Student	86	857	Car	32	322
Staff	14	141	None	25	254
Level of Study			Motorcycle	23	232
Undergraduate	78	779	Bicycle	20	194
Postgraduate	9	78			

4.2 Travel Behaviour Characteristics

Figure 1 shows a high number of the car owners who make two travel trips per day. Motorcycle owners made the highest number of travel trip per day as (seven), indicating that motorcycle is a vehicle used regularly in the campus. For those with no vehicle, they make the most two travel trips per day, indicating that those who do not have a vehicle do not do as many travel trips as those who have a car or motorcycle. The same goes with bicycle owners who make just two travel trips the most

IOP Conf. Series: Materials Science and Engineering **226** (2017) 012055 doi:10.1088/1757-899X/226/1/012055

daily. We can conclude here that the bicycle owners have no vehicle to regularly travel to and return from a particular destination per day. However, the car and motorcycle owners tend to make more than two trips per day. Therefore, the road in the campus is regularly used by car and motorcycle owners, compared to bicycle owners and those with no vehicle.

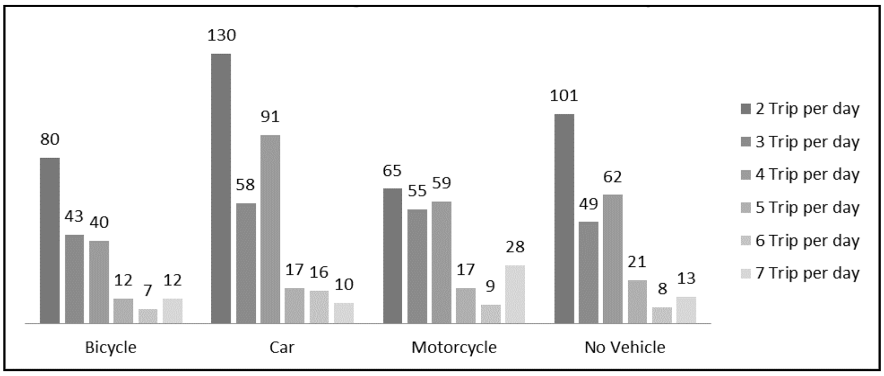

Figure 1. Frequency of travel trip according to vehicle ownership

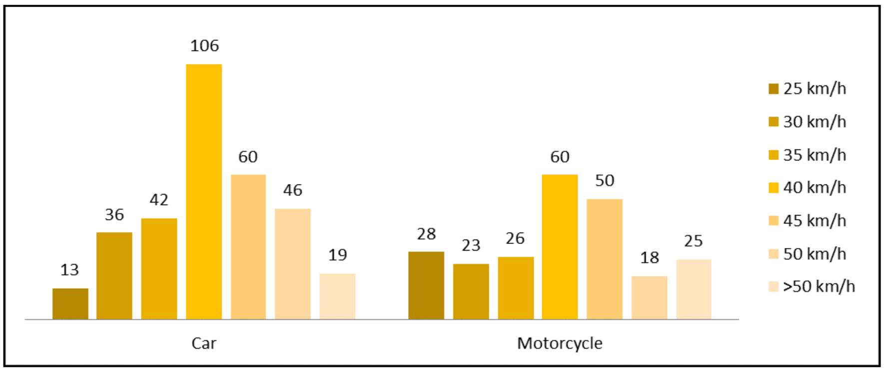

Figure 2. Frequency of travel speed according to vehicle ownership

Figure 2 shows the travel speed of cars and motorcycles in the campus. Both are known as motorised vehicles with a preferred speed 40km/h. As mentioned, the speed limit in the campus is 45km/h, therefore the previous theory which suggests that a speed limit sign is influenced by the speed of vehicle can be accepted [23]. With speed limit shown on the road, all driver prefer to drive more or less of the speed limit. Therefore, the findings support the value of the speed limit as the average speed of vehicle in the campus.

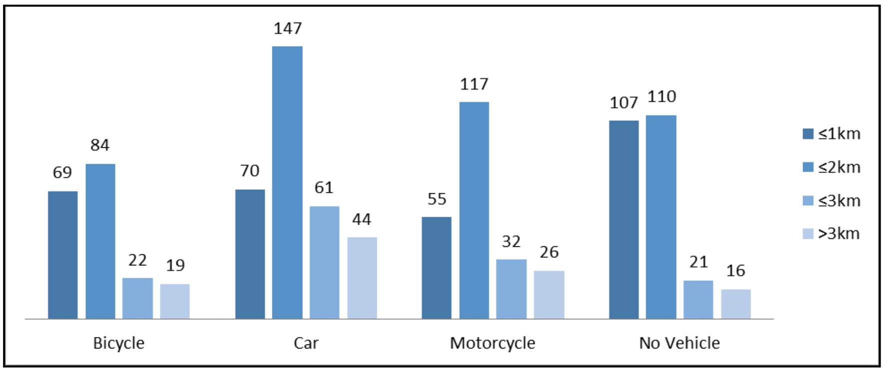

Figure 3. Frequency of travel distance according to vehicle ownership

Figure 3 indicates how far the vehicles tend to move per day in the campus. Cars and motorcycles made the highest number of trips for the longest travel distance (more than 3 km per day) in the campus. The lowest travel distance is made by bicycle owners and those with no vehicle. This indicates that compared to motorised vehicle owners, students who cycled and walked in the campus have travelled in a smaller distance. Table 2 represents the value of each variable that was used in the Equation 1 to estimate the transportation energy consumption in the campus. As a conclusion, the product of the numbers of population in the campus (P_{k}), the percentage of the modal share of PMM (Y_k), the value of average daily trip number (G_k), the average of trip length (L_k), and the intensity of energy consumption (e), would produce the value of transportation energy consumption ($1.25E^9$ MJ).

Table 2. Values used in estimating transportation energy consumption in the campus

Variables	Values
P_k	4000 people
Y_k	55.2%
G_k	4 trips
L_k	0.54km
e	2613.61MJ per person Km

5. Conclusion

The finding from this study shows that the value of transportation energy consumption in the Engineering Campus was $1.25E^9$ MJ, the product of the number of population in the campus (P_k = 4000), average daily trip number (G_k = 4 trips), modal share of PMM (Y_k = 55.4%), average travel distance (L_k = 0.54 km per trip), and the value of intensity of energy consumption (e = 2613.61 MJ/Person.km). This finding indicates that the campus recorded considerably high energy consumption from the transportation system. One reason is that the use of private vehicle still dominated the modal share of the campus. Furthermore, the respondents claimed that weather is one of the main drawbacks that has discouraged them from walking and cycling in the campus. They admitted that although they preferred sustainable campus, they were more likely to use their own vehicle as their main transport.

In order to minimise transportation energy consumption in the campus, the best solution that fits the environment of the campus is to upgrade the pedestrian pathway by providing a roof, which can increase the comfort of pedestrians and protect them from rain and hot weather. A parking policy may also discourage the usage of private motor vehicles, although the policy must be paralleled to the walking and cycling infrastructure in the campus, for example, with sufficient and strategic bicycle parking spaces near the students' residential areas, lecture halls, cafeterias and the library. It will also be more interesting if the university could provide a bicycle sharing programme that allows students to use bicycle facilities in the campus with their identification card.

Travel distance is another obstacle revealed by the respondents in this study. Even though the shuttle bus is not applicable for this campus as it is a very small campus, a shuttle service is still needed especially during hot weather and rainy season. The provision of a shuttle service would likely minimise car and motorcycle usage in the campus. Also instead of ordinary shuttle cars or buggy, it is time to apply solar vehicles to enhance the level of sustainability in the campus.

Acknowledgements
This research is supported by the Delivering Excellence Research Grant , Universiti Sains Malaysia (1002 / PAWAM / 910346) and Transdisplinary Grant (TRGS), Ministry of Higher Education (203/PAWAM/67610002).

References
[1] Al-Mofleh A, Taib S, Salah W A 2010 Malaysian energy demand and emissions from the transportation sector *Transport* 25 448
[2] Mustapa S I and Bekhet H A 2016 Analysis of CO 2 emissions reduction in the Malaysian transportation sector: An optimisation approach. *Energy Policy*, *89*, 171-183.
[3] Choi H, Nakagawa D, Matsunaka R, Oba T and Yoon J 2013 Estimating the efficiency of transportation energy consumption based on railway *International Journal of Railway* 6 33
[4] Miralles-Guasch C and Domene E. 2010 Sustainable transport challenges in a suburban university: The case of the Autonomous University of Barcelona *Transport policy* 17 454.
[5] Beringer A, Wright T and Malone L 2008 Sustainability in higher education in Atlantic Canada.*International Journal of Sustainability in Higher Education* 9 48
[6] Rasool D and Mukherjee M. 2014 Social–Friendly Sustainable Mobility in Indian Campuses *International Journal of Research* 1 860
[7] Heijungs R, Huppes G and Guinee J B 2010 Life cycle assessment and sustainability analysis of products, materials and technologies. Toward a scientific framework for sustainability life cycle analysis.*Polymer degradation and stability* 95 422
[8] Brundtland G H 1987 *The Brundtland Report, World Commission on Environment and Development.*
[9] Black W. R. 1996 Sustainable transportation: a US perspective.*Journal of transport geography* 4 151
[10] Richardson B C 2005 Sustainable transport: analysis frameworks *Journal of Transport Geography* 13 29
[11] Awasthi A, Chauhan S S and Omrani H 2011 Application of fuzzy TOPSIS in evaluating sustainable transportation systems *Expert Systems with Applications* 38 12270
[12] Lu X and Pas E I 1999 Socio-demographics, activity participation and travel behavior *Transportation Research Part A: Policy and Practice* 33 1
[13] Limanond T, Jomnonkwao S, Watthanaklang D, Ratanavaraha V and Siridhara S 2011 How vehicle ownership affect time utilization on study, leisure, social activities, and academic performance of university students? A case study of engineering freshmen in a rural university in Thailand. *Transport Policy* 18 719
[14] Emanuel R and Adams J 2011 College students' perceptions of campus sustainability.*International Journal of Sustainability in Higher Education* 12 79
[15] Ong H, Mahlia Tand Masjuki H 2012 A review on energy pattern and policy for transportation sector in Malaysia *Renewable and Sustainable Energy Reviews* 16 532
[16] Mohamed A. R. and Lee K. T. 2006). Energy for sustainable development in Malaysia: Energy policy and alternative energy *Energy Policy* 34 2388
[17] Boarnet M and Crane R 2001 The influence of land use on travel behavior: specification and estimation strategies. *Transportation Research Part A: Policy and Practice* 35 823
[18] Cervero R 2002 Built environments and mode choice: toward a normative framework.*Transportation Research Part D: Transport and Environment* 7 265
[19] Cervero, R. (2002). *Transportation Research Part D: Transport and Environment*, *7*(4), 265-284.
[20] Curtis C and Perkins T 2006 *Travel Behaviour: A review of recent literature* (Perth, WA: Urbanet, Curtin University of Technology)
[21] Wong K, Kou K and Wan I 2013 Travel characteristics in Macao: a small and gaming-led tourism city. *Asian Geographer* 30 169

IOP Conf. Series: Materials Science and Engineering **226** (2017) 012055 doi:10.1088/1757-899X/226/1/012055

[22] Kainuma M, Matsuoka Y and Morita T 2003 *Climate policy assessment: Asia-Pacific integrated modeling* (Springer Science and Business Media)
[23] Vaughn D. 1996 *U.S Patent No, 5,485,161* (Washington DC, US : Patent and Trademark Office)