



CO₂ Emission and Reduction of Tourist Transportation at Koh Mak Island, Thailand

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Koh Mak Island was promoted as the low carbon destination in Thailand. Transportation represents the main contributor of greenhouse gas (GHG) emissions which is linked to climate change. These GHG emission from surface transport is quite complicated as data is scarce on the distances travelled for tourism purposes. The aim of this study is to estimate the amount of CO₂ emission from energy consumption by tourist transportation in Koh Mak Island, Trat province, Thailand. The methodology of a bottom up approach was observed by using questionnaire surveys. Firstly, the questionnaire design ensured the validity of the questionnaire by calculating the Item-Objective Congruence (IOC) index which was found to be 0.96 which is acceptable. Secondly, CO₂ emission from energy consumption by transportation was calculated by the 2006 Intergovernmental Panel on Climate Change (IPCC) criteria. The CO₂ emission of local transportation was estimated by using the 465 copies of questionnaire that were distributed to the tourists. The tourism demographic information of male and female in Koh Mak Island were 42 % and 58 %. Most of the tourist age was 26-35 years old. The average local transport between beginning of the journey in Thailand and Koh Mak destination was 468 ± 139 km person⁻¹. The total consumption of gasoline and diesel for road transportation of the 465 tourists were 7,954.01 and 15,199.80 L. Gasoline used in boat transportation was 1,357.80 L. The total CO₂ emissions in transportation due to consumption of gasoline and diesel were 20,389.14 and 23,715.83 kg CO₂-eq. The average CO₂ emission was 23.83 kg CO₂ person⁻¹. The alternative to reduce CO₂ emission in transportation by low carbon tourism is to ride bicycles on the island as the distance between landmarks are quite short and there is very good scenery between the roads.

1. Introduction

Global warming and climate change are problems that are faced by all the life around the world. Daily human activities have caused severe environmental impacts which are associated to global warming. The rapid growth in tourism industry in Asia has caused an adverse effect to the environment, especially the transportation sector, which is one of the major causes for energy consumption. It represents the key contributor to greenhouse gas emissions, which are linked to global warming and climate change. Carbon dioxide (CO₂) is the most important greenhouse gas, accounting for 78 % of the global anthropogenic emission (32.3 Gt) in 2011 (WRI, 2012). Recent data reveals that global CO₂ emissions were 150 times higher in 2011 (198 Mt CO₂) than they were in 1850 (32,274 Mt CO₂). Asia's gross domestic product became the largest in the world in 1994. Asia became the largest emitter of CO₂ due to rapid economic growth. In the past, the largest share of global emissions came from Europe and Northern America. By the end of 2011, Asia dominated, contributing more than half of global CO₂ emissions, which are linked to global warming and climate change (WRI, 2012). The GHG emission intensity per capita in Thailand for 2011 was the third in Asia, emitting GHG as high as 103 t CO₂-eq/USD 100,000 (WRI, 2012). The second Thailand's inventory in 2000 of the anthropogenic GHG emission was about 229.08 Tg CO₂-eq. The energy sector is the largest contributor of greenhouse gas emissions, which is equivalent to 159.39 Tg CO₂-eq, and share 69.6 % of the

total national emission. In 2000, the fuel burning from the transportation sector produced GHG emission of about 44.70 Tg CO₂-eq or 28 % of the total GHG emission of energy sector in Thailand. Thailand continues to face the environmental impacts caused by the use of transportation fuels, especially GHG emissions and air pollutants, such as carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NOX), particulate matter (PM), sulphur dioxide (SO₂). Such pollutants are proven to be directly harmful to human health and are considered as a major cause of the urban climate deterioration that is affecting people (Ratanavaraha and Jomnonkwo, 2015). Transportation related air pollution primarily causes the greenhouse phenomena resulting from CO₂. The CO₂ emission from tourism transports are more difficult to calculate because data on the number and length of trips are more scattered and only available for a limited number of countries. The types of vehicle are also important to calculate the CO₂ emission from transportation, which should be calculated separately from fuel consumption. In this analysis, CO₂ emission from domestic tourism transports were calculated for each surface of transports (road and boat transports) by multiplying an estimated average distance travelled per trip by the total number of trip and emission factor separate by vehicle and fuel types. The tourism industry is a significant source of these emissions with its contribution expected to grow considerably in the future as the sector expands. Currently, the tourism industry accounts for more than 30 % of global exports of services, 6 % of total exports and 9 % of global GDP (World Tourism Organization, 2014). Scientists found that it is a good practice to reduce the impact of tourism sector on the environment, especially from energy consumption in transportation.

Tourism is an industry of central importance to Thailand and one which provides employment to a significant proportion of the workforce. The trends of tourism industries in Thailand were increasing with rapid growth in the past decade. The core value of low carbon tourism is to provide a high-quality tourism experience that ensures low carbon emissions and decrease in pollution from tourist activities, especially for the fuel consumption from transportation. GHG emission from surface transport is more complicated as only very scarce data are available on distances, number, and types of vehicle of travelled for tourism purposes. The purposes of this study are to propose a technique to predict the amount of CO₂ emission by bottom-up technique and GHG mitigation options on the tourist transportation in Koh Mak Island, Thailand.

2. Materials and Methods

2.1 Questionnaire Design

Questionnaire was used as the tools to collect data on the CO₂ emission and reduction in tourist transportation in Koh Mak Island, Trat province Thailand. The validity of the questionnaire is ensured by calculating the Item-Objective Congruence (IOC) index, where the test was given to five experts to examine and rate each item so that the content met the objectives of the study. The IOC was calculated by assigning scores to three types of answers: congruent = 1, uncertain = 0, incongruent = -1. The result of IOC was 0.96 which was acceptable.

The sample size of tourisms in Koh Mak Island was calculated based on Yamane's formula (Yamane, 1967).

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

Where; n = the sample size, N = the size of population, e = the error of 5 percentage points.

By using the Yamane's formula of a sample size with an error 5 % and with a confidence coefficient of 95 %, the number size of tourists in Koh Mak Island in 2013 was 130,569 people and the increasing rate of the tourists was about 2 - 5 % per year (DASTA, 2014). The sample size was 400 questionnaires, calculated from the number of tourists in Koh Mak Island in 2013. To account for possible attrition, the number of subjects in this research was increased to 465. Because the increasing rate of tourists in the island had increased up 5 % per year from 2013 - 2016, the sample size was increased following the trend of travellers in the present.

465 samples were selected by accidental sampling from the visitors in Koh Mak Island, Thailand during high season on March - May 2017. Data were analysed using statistical computer program and interpreted as follow;

Section 1: Personal information were analysed in terms of frequency and percentage.

Section 2: The perceptions and feelings on tourism image were analysed in terms of percentage and mean.

Section 3: CO₂ emission of tourism transportation in Koh Mak Island, Thailand was separated by energy consumption follow by type of vehicle.

2.2 Calculation of CO₂ Emission and Reduction in Transportation

A calculation of air pollutant emissions involves the estimation of the amount of CO₂ released from energy used in tourist transportation during the distance between home and Koh Mak Island. CO₂ emission was

calculated from energy consumption multiply by the emission factors of fossil fuel types (IPCC, 2006). The formula was as follows:

$$\text{CO}_2 \text{ emission} = \Sigma (\text{EF}_{\text{Fuel}} \times \text{FC}_{\text{Fuel}}) \quad (2)$$

Where CO_2 emission is the amount of CO_2 released from energy consumption, emission factor of fuel (EF_{Fuel}) is the CO_2 emission factor by fossil fuel types. The EF_{Fuel} of gasoline and diesel fuels for transportation were 2.1896 and 2.7446 $\text{kg CO}_2\text{-eq L}^{-1}$. Fuel consumption (FC_{Fuel}) was calculated by multiple by the distance and fuel consumption rate separated by the vehicle types (Table 1).

Table 1: Fuel consumption rate separate by vehicle type

Vehicle type	Fuel type	Fuel consumption rate (km/L)	References
1. Small car (1,500 cm^3)	Gasoline	17.770	Pollution Control Department, 2012
2. Medium car type 1 (1,600 cm^3)	Gasoline	15.238	Pollution Control Department, 2012
3. Medium car type 2 (1,800 cm^3)	Gasoline	13.796	Pollution Control Department, 2012
4. Big car ($\geq 2,000 \text{ cm}^3$)	Gasoline	12.248	Pollution Control Department, 2012
5. Average truck	Diesel	6.369	API, 2016
6. Van	Diesel	10.204	API, 2016
7. Bus	Diesel	2.850	API, 2016
8. Motor bike	Gasoline	36.625	Pollution Control Department, 2012
9. Big bike	Gasoline	38.655	Pollution Control Department, 2012

3. Results and Discussions

3.1 Demographic Information

The results of demographic information of tourist in Koh Mak Island show that the ratios of male and female were 41.5 % (193 person) and 58.5 % (272 person). Ratios of visitors in this Island between Thai and foreigner were 64.5 % and 38.5 %. European were the most found tourist in Koh Mak Island, especially from Germany and France. The age frequencies of the tourists were 16 – 25 and 26 - 35 years old, which were about 46 % and 26 %. The tourist age indicated that the people was of teenage and working age. The result found that 44 % of the tourists had working experience as government and non-government officer and 20 % were students. Most of the tourist graduated with bachelor's degree (53 %). Table 2 shows the frequency and percentage of visitor's personal information.

Table 2: Frequency and percentage of visitors' personal information

Personal information of visitors		Frequency N = 465	%	Personal information of sample	Frequency N = 465	%
Gender: (Thai)	Male	114	24.52	Occupation: Public Sector/State Enterprise	49	10.54
	Female	172	36.99			
(Foreigner)	Male	79	16.99	Private Sector	40	8.60
	Female	100	21.50	Merchant/Own Business	92	19.78
Age:	Below 15 years	8	1.72	Agriculturist	22	4.73
	16 - 25 years	215	46.24	Student	91	19.57
	26 - 35 years	120	25.81	Others	152	32.69
	36 - 45 years	70	15.05	N/A	19	4.09
	46 - 55 years	19	4.09			
	More than 55	33	7.10			
Education:						
	Elementary school	11	2.37			
	High school	65	13.98			
	Certificated or similar	36	7.74			
	Bachelor's degree	247	53.12			
	Higher Bachelor's degree	103	22.15			
	Others	3	0.65			

3.2 Perceptions and Feelings on Tourism Image

The beautiful island of Koh Mak is situated in the eastern gulf of Thailand close to the Cambodian border. It is one of the 50 islands along the Gulf of Thailand and is the third largest in that area after Koh Chang and Koh Kood. The island is a small tropical paradise, covering an area of 16 km² and a coastline of 27 km. Most of the island is still covered by coconut and rubber plantations which is the island's main export products. Many of the locals also make handicrafts from coconut shells, batik fabrics and furniture. The oil extracted from coconuts can also be refined into medical oil. Koh Mak Island is privately owned by a small group of families who each strive to work together to ensure the island proceeds in a sustainable way by following the ideals of ecotourism. Many of the hoteliers and tourism business operators signed an agreement to treat Koh Mak as a low carbon tourist destination and to continue to limit beach facilities and restrict completely jet skis, banana boats, night clubs and similar disruptive activities. The island markets itself as a laid-back, peaceful location where it is possible to relax in the bosom of nature. The attractions image perceptions of Koh Mak Island visitors were as follows; 23 % of visitors were repeat visitors. About 92 % of the visitor purposes were mainly rest and relaxation. Koh Mak's impressions were beautiful and wonderful place. It had good atmosphere, Landscape and scenery. Many visitors like this place because the calm beach is an appropriate relaxing place for holiday. The seafood is also very fresh, and the area has many nice foods. Tourism activities in Koh Mak Island from the visitors' perceptions were shown in Table 3.

Table 3: Tourism Activity in Koh Mak Island from visitors' perception

Tourism Activity Item	Total (persons)			Percentage (%)		
	Did not participate	Participated Unsatisfactory	Participated Satisfactory	Did not participate	Participated Unsatisfactory	Participated Satisfactory
1) Beach activities	83	36	347	17.81	7.73	74.46
2) Canoe/Kayak	195	54	217	41.85	11.59	46.57
3) Sightseeing	72	50	344	15.45	10.73	73.82
4) Camping	271	49	146	58.15	10.52	31.33
5) Ride bicycle	208	52	206	44.64	11.16	44.21
6) Swimming/Snorkelling	81	64	321	17.38	13.73	68.88
7) Boat trip around the island	186	57	223	39.91	12.23	47.85
8) Trekking	263	64	139	56.44	13.73	29.83
9) Eating local food, example, sea food	27	69	370	5.79	14.81	79.40
10) Local cooking class	274	57	135	58.80	12.23	28.97
11) Spa/Thai massage	244	60	162	52.36	12.88	34.76
12) Visit Luang Prom Pakdi's home	255	52	159	54.72	11.16	34.12
13) Visit Koh Mak museum	188	56	222	40.34	12.02	47.64
14) Visit Koh Mak temple	195	63	208	41.85	13.52	44.64
15) Visit The Kingdom of Somchai's Affection (Art and Sculpture)	272	67	127	58.37	14.38	27.25
16) Visit organic farm, for example, organic vegetables	243	62	161	52.15	13.30	34.55
17) Learning to manage area as a low carbon attraction	257	54	155	55.15	11.59	33.26
18) Souvenir shopping	203	66	197	43.56	14.16	42.27

The popular and please activities of visitor in Koh Mak Island were eating local food (79.40 %), beach activities (74.46 %), and sightseeing (73.82 %). Tourist did not play some activities in Koh Mak Island for example, camping mountain, Thai cooking class, and Visit Kingdom of Somchai's Affection (Art and Sculpture). The tourist does not know the way to go to there but it was the good choice for travelling in Koh Mak Island. The main objective of the traveller's need is to relax by fresh nature such as sleep on the room or beach, read book and play smart mobile on the beach, and slow life. They do not prefer adventure tourism

activity in Koh Mak. According to the group of visitors were small groups or family units and to be visiting Koh Mak as part of multi-destination holiday (Apivantanaporn and Walsh, 2016).

3.3 CO₂ emission and mitigation option in transport sector

The average distances of tourists between home and Koh Mak Island location was 468.23 ± 139.38 km. Total energy consumption of gasoline and diesel in road transportation of 465 tourists were 7,954.01 and 15,199.80 L. Gasoline used in boat transportation was 1,357.80 L. Bus and van were the most popular vehicle for visiting this area because it was difficult to access to transportation between lands and island. It had speed boat for transferring the tourist and luggage. Total CO₂ emissions in both transportations, based on the fuel consumption of either gasoline or diesel, were 20,389.14 kg CO₂-eq and 23,715.83 kg CO₂-eq, (Table 4). The average CO₂ emission was 23.83 kg CO₂ person⁻¹. Jamnongchob et.al. (2017) estimated CO₂ emission of tourist transportation in Suan Phueng Mountain, Thailand. They found that mean CO₂ emissions of tourist transportation was 21.20 kg CO₂ person⁻¹. The CO₂ emission per person of tourist transportation between both areas was quite similar but the average distance was differentiation. Distance of Suan Phueng was shorter than Koh Mak Island around 260 km but the CO₂ emission was higher than the Suan Phueng Mountain because car was the most popular vehicle for visiting in the Suan Phueng, but bus and van was the most popular vehicle in Koh Mak (Table 2).

The CO₂ emission of tourist transportation was depending on type of vehicle, number of tourist and distance. Normally, the GHG emission in tourist activity was produced from transportation sector, according to previous research shown that GHG emission in transportation of Chinese tourism industry was the highest contributor about 48.25 % (Meng et al., 2016). The carbon emissions ratio of transportation was higher than the other activities in tourism. So, the policies should be made concerning this transportation activity, for example more stringent vehicle fuel standards should be developed; energy saving cars and electric vehicles should be encouraged, and at the same time, public transportation should be developed greatly (Meng et al., 2016). The mitigation options of tourist transportation in Koh Mak Island, Thailand were bicycling because the distance between each landmark were quite short and also had the scenic road. The tourism authority of Thailand and Koh Mak Island entrepreneur did the good biking trails around the island. The tourists should ride the bicycle during the sightseeing of this scenic area which will be reducing the CO₂ emission from tourist transportation. Eco-friendly energy use should also be advocated. Biofuel is recognised as an environmentally friendly and renewable source. It is predicted that around 27 % of the transportation fuel would be replaced by biofuel by 2050 in South East Asia (IEA, 2013). Thai government has approved the exemption of excise tax imposed on ethanol, controlling the retail price of gasohol (a mixture of ethanol and gasoline at 10 % (E10) and 20% (E20) to be less than that octane 95 gasoline, within a range not exceeding THB 8 – 10 per litre (Exchange rate THB 33/USD). The policy promoting ethanol for transportation is being supported by its positive effects on energy security and climate change mitigation in the country. Raw material to make ethanol has a high potential in Thailand such as more crop residue in agriculture.

Analysis of energy and greenhouse gas balances was done to evaluate fuel ethanol produced from cassava in Thailand (Nguyen et al., 2007). The results found a positive energy balance of 22.4 MJ/L and the net avoided GHG emission of 1.6 kg CO₂-eq L⁻¹ was found for cassava-based ethanol. The trends of energy use in transportation has a relatively fast growth and affected the increasing GHG emission. Low carbon tourism is the good alternative GHG mitigation of tourism industry in our country by reducing energy consumption, fuel burning, and GHG emission during travelling activities.

Table 4 The energy consumption and CO₂ emission from tourist transportation to Koh Mak Island

Type of Transports	Type of fuel	Total energy consumption (L)	Average energy consumption (L/person)	Total CO ₂ emission (kg CO ₂ -eq)	Total CO ₂ emission (kg CO ₂ -eq person ⁻¹)
Road	Gasoline	7,954.01	16.51	17,416.10	36.15
	Diesel	15,199.80	9.7	23,715.83	28.96
Boat	Gasoline	1,357.80	2.92	2,973.04	6.39
	Total	24,502.61	9.71	44,104.97	23.83

4. Conclusions

Total energy consumption for tourist transportation in Koh Mak Island, including gasoline and diesel in road transportation, were 7,954.01 L and 15,199.80 L. Gasoline used in boat transportation was 1,357.80 L. Total CO₂ emissions in transportations by the fuel consumption, in terms of gasoline and diesel, were 20,389.14 kg CO₂-eq and 23,715.83 kg CO₂-eq. The average CO₂ emission was 23.83 kg CO₂ person⁻¹. The CO₂ emission of tourist transportation was dependent on the type of vehicle, number of tourist and distance. The mitigation options in Suan Phung Mountain transportation were suggested to include a change in behaviours, such as the use of bicycles, clean sources and the use of public transportation.

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