A STUDY OF CARBON EMISSIONS IN TRAVELING:
A CASE STUDY OF PHITSANULOK MUNICIPALITY

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Abstract

Pollution caused by transport poses a high percentage of health threats in urban areas which causes serious diseases and leads to death. The purpose of this study was to study the fuel consumption in the transport sector, vehicle selection behavior, and important factors affecting travel in Phitsanulok city municipality. The study consisted of 400 samples by using questionnaires to analyze the statistical results. From the study, it was found that each type of fuel consisted of Benzene, Gasohol 91, Gasohol 95, Gasohol E20 and Gasohol E85 used at 166,155,256.02 liters/year, and diesel fuel consisted of Diesel B7, Diesel B10 and Diesel B20 were used at 3,941,085.20 liters/year. From fuel consumption, it was found that the CO_2 emissions were 326,562.09 tCO_2/year or, representing 0.04% of the whole country. The factors influencing the decision to choose the travel mode of private car users include 1) safety 2) travel time 3) cost 4) accessibility 5) waiting time 6) trips 7) service and 8) routes, respectively, which are different from public traveler consist of 1) cost 2) safety 3) travel time 4) waiting time 5) service 6) accessibility 7) trips and 8) routes, respectively. All stakeholders must jointly campaign to change travel behavior by developing and promoting public transportation in conjunction with using electric vehicles. For better quality and health of citizens in the city, leading to a sustainable low-carbon society.

Keywords: Low-Carbon Society, Carbon Emissions, Travel Behavior

Introduction

Air pollution is an environmental problem that is increasing day by day (Department of Health, 2020), caused by the rapid expansion of the industrial plants, or construction business. In terms of transportation and traffic caused the contaminated air pollution exceeds the standard, and global warming. Which, the main and common air pollution sources are transportation (Pochanaet, 2016). The Office of the National Economic and Social Development Council (Office of the National Economic and Social Development Council, 2011) has reported carbon dioxide (CO_2) emissions in the Thai economy, it found that the electricity generation sector emits the most CO_2 gas followed by the industrial, transportation, and other economic sectors such as business and household.

The relaxing measures to control the pandemic of Covid-19, resulting in business sectors and economy recovering even through Social Distancing measures or guidelines for implementing D-M-H-T-T measures of the Ministry of Public Health (Department of Disease Control, 2021) still be applied. However, the country lockdown, which restricted travel and work from home, has made people want to travel even more (Saenkam, 2021), increasing Thailand's Gross Domestic Product (GDP) in 2021 by 1.6 percent. Moreover, the amount of CO_2 emission in the transportation sector was 28 percent, which increased by 7.4 percent from last year in 2020. Two main types of CO_2 emission in the transportation sector are Natural gas (NGV) and refined oil products. Refined oil product has emitted 66.7 million-tons of carbon dioxide (million-tons CO_2) and Natural gas (NGV) has emitted 2.4 million-tons CO_2 (Office of Energy Policy and Planning, 2021) . Furthermore, there is a tendency to use more fuel, which will also increase the impact on the environment and weather. The proportion of CO_2 emissions in the transportation sector in 2021 is shown in Figure 1.
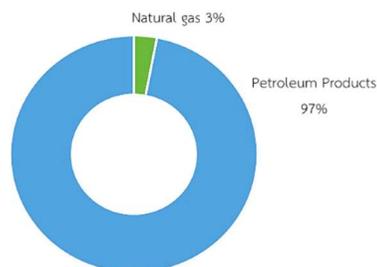

Figure 1 CO_2 emission in transportation sector in 2021

Source: Office of Energy Policy and Planning (2021).

Driving the country toward a low-carbon society, Thailand should study the developed countries as a model for guidelines and management by upgrading the ability to cope, issuing policies to drive it into practice (Activity Project Linking Research and Policy Sector, 2013). So, the campaign to promote environmental preservation awareness is therefore everyone's duty (Small Business Credit Guarantee Corporation, 2019). According to a study by Chinese researchers, green low-carbon behavior are activities related to everyone's interests in society through the participation of 3 main primary stakeholders: government sector, business sector, and public sector (Xiao et al, 2021). The research about the global warming crisis and air pollution said that after considering Greenhouse gas emissions from oil producing countries such as Qatar, Country of Curaçao, Republic of Trinidad and Tobago, and Kuwait which have emitted approximately 46, 39, 30, and 26 tons CO_2 per person, respectively which compares to Sweden where has urban planning and infrastructure management both architecture and buildings to be environmentally friendly, has emitted 4.3 tons CO_2 per person (Faure et al, 2019). Thailand has an average Greenhouse gas emission annually of 5.3 – 5.5 tons CO_2 per person (King Mongkut's University of Technology North Bangkok, 2013), which is necessary for the consideration of environment and society part at the same time, both at the national level and community level to ensure that people are equally aware of this air pollution problem (Raworth, 2012). The 11th National Economic and Social Development Plan (A.D. 2012 – 2016) emphasized climate change and aimed to drive the country to become a "low-carbon economy and society" and also environmentally friendly (Office of the National Economic and Social Development Council, 2021) which caused many provinces valued on carbon dioxide emission amount caused by activities in various sectors, together with reducing the amount of Greenhouse gas emissions within urban areas (Thailand Greenhouse Gas Management Organization, 2018). So, the concept of having a low-carbon society was developed to reduce Greenhouse gas emissions from community life by raising awareness in the community about catastrophic problems due to the intensified climate change and encouraging people in the community to collaborate to reduce the Greenhouse gas caused by their activities (Leknoi, 2017).

The Greenhouse gas emission model can be divided into two models: top-down, which estimates from economic variables and bottom–up, which estimates alternatives

from technology related to climate change. In this research, we collected data by fuel type and subdivided activities by Greenhouse gas emission coefficient technology (Ruengphol, 2016) by calculating the Greenhouse gas emission from transportation sector in the IPCC Guideline for National Greenhouse Gas Inventories by Intergovernmental Panel on Climate Change (IPCC) at level 1 (Thailand Greenhouse Gas Management Organization, 2021) as shown in the equation (1)

$$\text{Emission} = \sum [\text{Fuel}_a \times \text{EF}] \qquad (1)$$

By means of:

Fuel is the amount of energy obtained from fuel combustion,

Emission is the emission (greenhouse gas) from the transportation,

EF is Greenhouse gas emission coefficient, and

a is the fuel type (Benzene, Diesel)

Phitsanulok province is one of the important cities in the lower northern region, located at the Indochina intersection, which can connect the Eastern – Western economy and Northern – Southern economy. There are facilities and infrastructure supporting transportation, i.e., airports, train stations, bus stations, and vehicles on the road. These factors raise volume of patient who affected by the air pollution as shown in 2021 for 142,774 persons which separated into various diseases i.e., Respiratory disease, Cardiovascular disease and Cerebrovascular disease, Inflammatory eye disease, Dermatitis, etc. (Phitsanulok Provincial Public Health Office, 2021) which is caused by the vehicles fuel combustion. Phitsanulok municipality gives priority to to developing low-carbon city projects for a better quality of life such as increasing the number of green spaces in the city, creating a solid waste management polity to be a zero-waste community and Greenhouse gas emission reduction measurement (Phitsanulok City Municipality, 2014). However, the number of registered cars in Phitsanulok province, is increasing every year, with an average of 11,772 new cars, as shown in Figure 2.
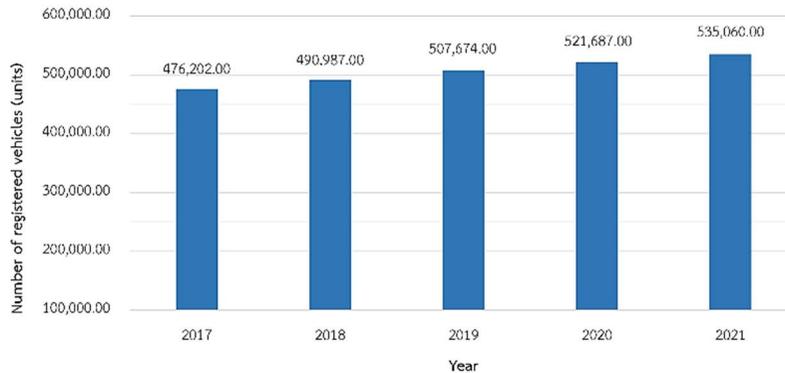
Figure 2 The number of registered cars in Phitsanulok province

(Phitsanulok Provincial Transport Office, 2021)

As of Figure 2, It results in the various problems such as road traffic accidents, traffic jams, air pollution caused by travel activities which create Greenhouse gas emission and affect adversely to physical health, climate change and global warming.

Materials and methods

To drive the livable city to a low-carbon society, besides the collaboration between the public sector and private sector to promote this campaign all citizens have to cooperate and comply which is also essential to know the following various factors:

1) To study the fuel consumption in the transportation sector in Phitsanulok municipality.

2) To study the travel behaviors in Phitsanulok municipality.

3) To study the important factors which affect traveling in Phitsanulok municipality.

Overall, the results of this study can be used as guidelines for setting policies or measures for developing a low-carbon society in local government organizations. The researcher collected the questionnaires by surveying general information, all of travel behavior (private and public transport), and important factors for calculating CO_2 gas emission.

The calculation of Greenhouse gas emission ($kgCO_2$/TJ) and carbon dioxide emission ($kgCO_2$) by using net heat (MJ/Unit) of Benzene, Diesel, Ethanol, and Biodiesel with 31.48, 36.42, 20.90, and 33.30 accordingly which is based on IPCC Guidelines for National Greenhouse Gas Inventories (Intergovernmental Panel on Climate Change, 2006) for consideration of energy consumption (TJ) as shown in the equation (2).

Carbon dioxide emission CO_2 ($kgCO_2$) = Energy consumption (TJ) x Greenhouse gas emission ($kgCO_2$ / TJ)   (2)

Sample

The sample size calculation used in this research is based on a finite population (Khaimook, 2003), and the population in Phitsanulok Municipality is 63,978 people (Phitsanulok City Municipality, 2021). These can be calculated using Yamane's formula (Yamane, 1973) which was suitable for Municipality study (Muekhuntod, 2016) and survey research (Sakworawich, 2016) at a confidence level of 95% as shown in the equation (3).

$$n = \frac{N}{(1+Ne^2)} \qquad (3)$$

By means of: n is the sample size

N is the total of population size

e is the acceptable tolerance

As of equation (3) can calculate the sample size for 397.5 sets or use for the random questionnaire 400 people according to the proportion of Phitsanulok municipality area divided into four zones as follows 1) Zone 1 has 18 communities with population of 14,995 people, representing 27.75% with the number of 111 sets of questionnaires, 2) Zone 2 has 14 communities with population of 10,558 people, representing 19.5% with the number of 78 sets of questionnaires, 3) Zone 3 has 15 communities with population of 13,586 people, representing 25.25% with the number of 101 sets of questionnaires, and 4) zone 4 has 17 communities with population of 14,432 people, representing 27.5% with the number of 110 sets of questionnaires which shown in Figure 3.
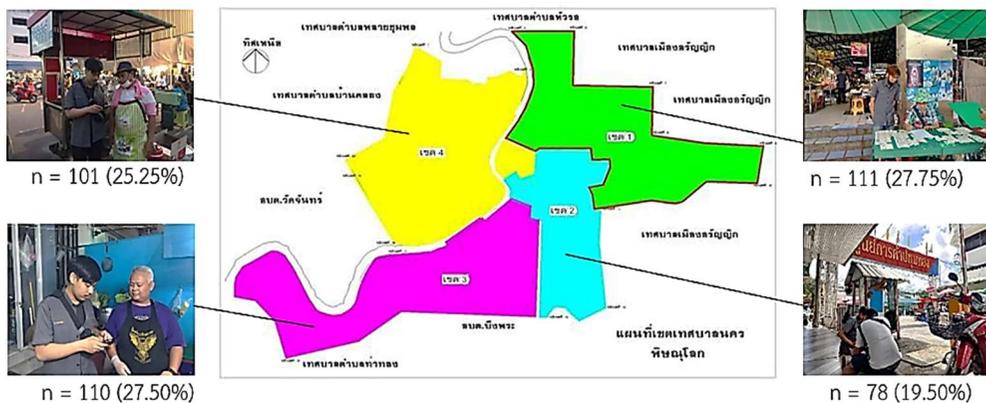

Figure 3 Field surveys in Phitsanulok municipality (Zone 1 - 4)

Data collection

The researcher conducted the data survey during the relaxation of disease prevention measures for COVID-19, which was issued under section 9 of Emergency Decree on Public Administration in Emergency Situations A.D. 2015 (Phitsanulok City Municipality, 2021) with the Closed-ended questions form (Closed Form) and Open-ended questions form (Open Form). The contents are divided into 3 parts as follows:

Part 1 is respondents' general information;

Part 2 is traveling behaviors with trip generation and trip distribution about origin/destination, purpose to travel, travel time, traveling cost, distance, vehicle, type and fuel consumption;

Part 3 is the important factors affecting travel. Type of the questions is the Likert Scale which can be considered an interval scale, the mean was 0.8 and will interpret the score as follows:

> 4.21 – 5.00 will be equal to very satisfied,
>
> 3.41 – 4.20 will be equal to satisfied,
>
> 2.61 – 3.40 will be equal to neutral,
>
> 1.81 – 2.60 will be equal to dissatisfied, and
>
> 1.00 – 1.80 will be equal to very dissatisfied.

Results

The survey questionnaire of 400 people from Phitsanulok municipality studied travel behavior, gender, age, occupation, income, family members and vehicle ownership in each household which are important factors affecting carbon dioxide emission consumption as shown in Table 1.

Table 1 Respondents' general information

Information	Amount	Percentage
Gender		
Male	222	55.50
Female	178	44.50
Age range		
20 - 30	187	46.75
31 - 40	124	31.00

Table 1 Respondents' general information (cont.)

Information	Amount	Percentage
41 – 50	64	16.00
up to 51	25	6.25
Occupation		
Unemployed	2	0.50
Students	111	27.75
General employee	78	19.50
Merchant / Business owner	73	18.25
Housewife	43	10.75
Agriculturalist	11	2.75
Government official / State enterprise employee	65	16.25
Retired / Pensioner	11	2.75
Others	6	1.50
Income / month (baht)		
No income	6	1.50
< 5,000 (less than 5,000)	47	11.75
5,001 - 10,000	111	27.75
10,001 - 15,000	105	26.25
15,001 - 20,000	73	18.25
20,001 - 25,000	41	10.25
25,001 - 30,000	9	2.25
> 30,001 (less than 30,001)	8	2.00
Family members (person)		
1 – 2 persons	70	17.50
3 – 4 persons	186	46.50
up to 4 persons	144	36.00
Possession of vehicles (cars)		
Bicycle	53	7.75
Motorcycle	370	54.09
Sedan	144	21.05
Pickup	117	17.11
Multi-purposes vehicles	20	2.92

Travel behaviors

The traveling journey from one place to another reflects traveling needs of the respondents by surveying information from the sample and the researcher classified the places and dates of traveling during weekdays (Monday – Friday) and weekends (Saturday – Sunday) is be shown the proportion in Figure 4.
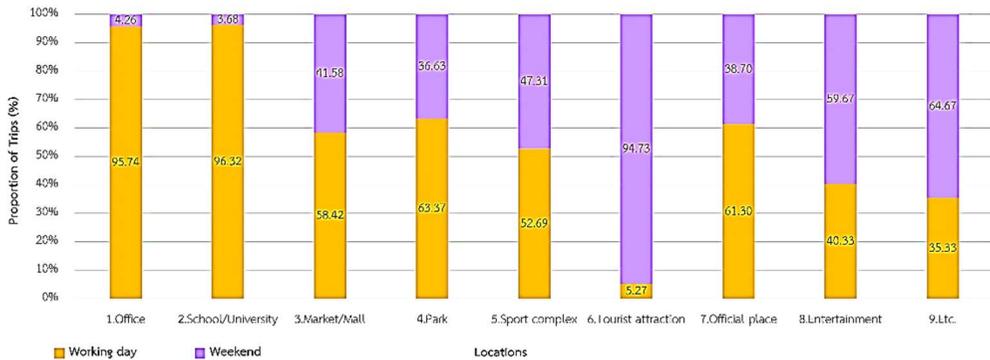

Figure 4 The difference of traveling purpose

The traveling journey on weekdays, the respondents in Phitsanulok municipality had the top 3 highest purposes of traveling as follows: travel for work with 282 persons, representing 34.39%, followed by going to school with 187 persons, representing 22.80%, and travel to the market or department store with 118 persons, representing 14.39%. In part of the traveling journey during weekend, also had top 3 highest purposes of traveling as follows: travel for leisure with 127 persons, representing 17.61%, followed by travel to the market or department store with 117 persons, representing 16.23%, and travel to the entertainment venue with 52 persons, representing 7.22%.

The respondents' fuel consumption in Phitsanulok municipality has various types of fuel selection. The researcher classified the fuel into two types which are Benzene and Diesel. For the Benzene type, the most chosen from the correspondents were Gasohol 95, Gasohol 91 and Gasohol E20, while the Diesel type was Diesel B20, Diesel B7 and Diesel B10 as shown in Figure 5.

The researcher chose to survey the travel journey respondents divided into two groups: traveling by their private vehicle and traveling by public transportation. And the three most chosen vehicles were the bus, minibus, and taxi.
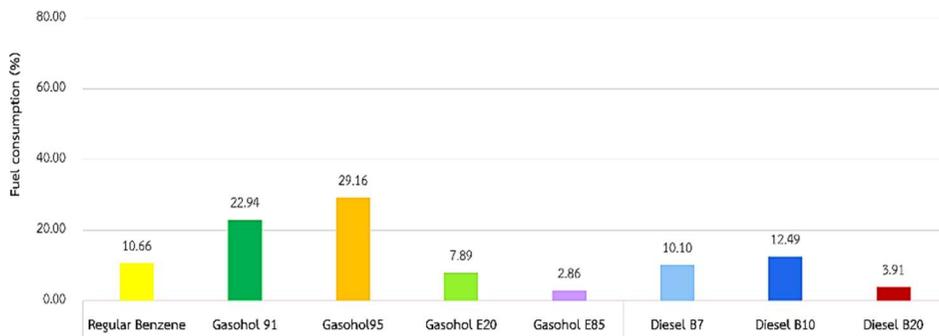
Figure 5 Type of used fuel

The departure time during weekdays in the morning is mostly around 06.01 – 08.00 o'clock for traveling to work and going to school, and in the afternoon, it will be around 16.01 – 18.00 which is the period of returning home. During the weekend, the departure time will be around 11.01 – 12.00 and 16.01 – 18.00 which are for chill out time, having family lunch or dinner time.

The duration and travel distance shown that the respondents spend the travel time during weekdays approximately 10 – 20 minutes/day, representing 46.50%, a short trip. Moreover, spending time during the weekend, approximately 21 – 30 minutes/day, represents 30.25%. Moreover, the data also shows that during the weekend, the respondents spend even more time on the road (more than 1 hour). This may cause more toxic pollution in that area as shown in Table 2.

Table 2 The duration of traveling

Duration (minutes)	Weekday		Weekend	
	Amount (person)	Percentage	Amount (person)	Percentage
< 10	33	8.25	32	8.00
10 – 20	186	46.50	91	22.75
21 – 30	142	35.50	121	30.25
31 – 40	30	7.50	56	14.00
41 – 50	5	1.25	29	7.25
51 – 60	2	0.50	10	2.50
> 1 hour	2	0.50	61	15.25
Total	400	100	400	100

The respondents' travel distances differed between weekdays and weekends. From this survey, it found that during weekdays most of the respondents got their travel distance between 10.1-20.0 kilometers, representing 45.75%. This is followed by travel with a distance of less 10 kilometers, representing 45.25% which has almost a similar number. Whereas the respondents who traveled a distance of 10.1-20.0 kilometers, representing 37.25% and who traveled a distance of 20.1-30.0 kilometers, representing 15.50%, qually got the travel distance with more than 50 kilometers. This indicates that respondents have traveled more distance or even traveled outside of Phitsanulok municipality as shown in Table 3.

Table 3 The respondents' travel distance

Distance	Weekday		Weekend	
(kilometers)	Amount (persons)	Percentage	Amount (persons)	Percentage
≤ 10.0	181	45.25	92	23.00
10.1 – 20.0	183	45.75	149	37.25
20.1 – 30.0	25	6.25	62	15.50
30.1 – 40.0	5	1.25	19	4.75
40.1 – 50.0	3	0.75	16	4.00
> 50.0	3	0.75	62	15.50
Total	400	100	400	100

Important factors which affect the travel behavior

The study of travel behavior found the top 3 factors that affect travel with their private vehicle were 1) travel time, 2) safety concerns during traveling, and 3) traveling cost. These factors will be a guideline for improving infrastructure and public transport networks according to travel demand and reducing carbon dioxide emissions, as shown in Table 4.

Table 4 Important factors which affect travel behavior.

Factors	Private vehicle			Public transport		
	$\overline{x}$	S.D.	Result	$\overline{x}$	S.D.	Result
Traveling time	4.41	0.73	very satisfied	4.04	0.91	satisfied
Traveling cost	4.26	0.75	very satisfied	4.21	0.93	very satisfied
Traveling Service	4.01	0.82	satisfied	3.92	0.88	satisfied
Traveling demand	4.04	0.76	satisfied	3.88	1.03	satisfied
Traveling route	3.96	0.76	satisfied	3.88	0.80	satisfied
Traveling waiting period	4.10	0.80	satisfied	4.04	0.91	satisfied
Safety concern while traveling	4.39	0.75	very satisfied	4.08	0.97	satisfied
Convenience and accessibility	4.24	0.74	very satisfied	3.92	0.88	satisfied

Carbon dioxide emissions

Bottom – up model of the carbon dioxide calculation of each vehicles (King Mongkut's University of Technology Thonburi, 2017), vehicles in the survey i.e., motorcycle, sedan, pickup, or multi-purposes (SUV) vehicle, can be divided into two fuel types which are Benzene and Diesel as shown in the average distance data in Table 5 and the proportion of fuel consumption in Figure 7.

Table 5 An average distance data by vehicle

Vehicle type	Amount (cars)	Average distance (km/year)
Motorcycle	370	1,054,872
Sedan	144	2,196,504
Pickup	117	1,474,300
SUV	20	355,131

The calculation of vehicle travel distance by fuel type will be divided into Benzene engine vehicles and Diesel engine vehicles as shown in Table 6 for travel distance and amount of vehicle consumption in Table 7.
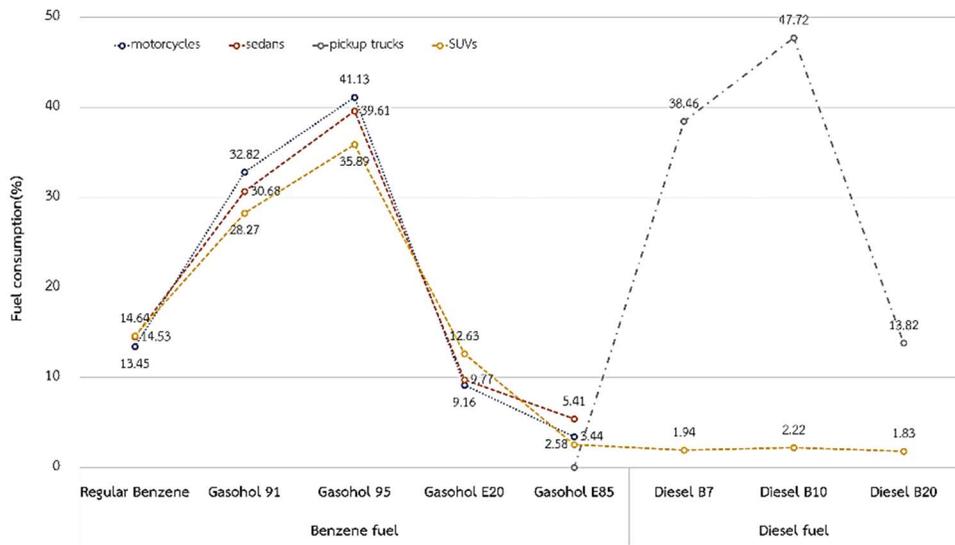
Figure 7 Proportion of fuel consumption by vehicle

The calculation of carbon dioxide emission from traveling can be analyzed from two parts of oil which are 1) the proportion of Ethanol and Benzene to be used to calculate the amount of energy from Benzene, and 2) the proportion of Biodiesel and Diesel to be used to calculate the amount of energy from Diesel as shown in Table 8.

Table 6 Travel distance by fuel type (100,000 km/year)

Vehicle type	Benzene					Diesel		
	X1	X2	X3	X4	X5	X6	X7	X8
Motorcycle	112.39	242.01	307.57	83.22	30.14	n/a	n/a	n/a
Sedan	234.03	503.93	640.44	173.30	62.76	n/a	n/a	n/a
Pickup	n/a	n/a	n/a	n/a	n/a	148.91	184.06	57.68
SUV	37.83	81.47	103.54	28.01	10.14	35.86	44.33	13.89

Remarks X1 = Benzene, X2 = Gasohol 91, X3 = Gasohol 95, X4 = Gasohol E20

X5 = Gasohol E85, X6 = Diesel B7, X7 = Diesel B10, and X8 = Diesel B20

Table 7 Fuel consumption classified by vehicle (100,000km/year)

Vehicle type	Benzene					Diesel		
	X1	X2	X3	X4	X5	X6	X7	X8
Motorcycle	3.74	8.06	10.25	2.77	1.00	n/a	n/a	n/a
Sedan	18.62	40.09	50.95	13.79	4.99	n/a	n/a	n/a
Pickup	n/a	n/a	n/a	n/a	n/a	12.10	14.96	4.69
SUV	3.07	6.62	8.41	2.27	0.82	2.91	3.61	1.12

Remarks X1 = Benzene, X2 = Gasohol 91, X3 = Gasohol 95, X4 = Gasohol E20

X5 = Gasohol E85, X6 = Diesel B7, X7 = Diesel B10, and X8 = Diesel B20

Table 8 Quantity and proportion of fuel

Fuel type		Quantity (liter)	Fuel proportion (liter)	
			Ethanol	Benzene
Benzene	Benzene	24,086,041.33	-	24,086,041.33
	Gasohol 91	51,862,412.31	5,186,241.23	46,676,171.08
	Gasohol 95	65,911,661.20	6,591,166.12	59,320,495.08
	Gasohol E20	17,835,651.44	3,567,130.29	14,268,521.15
	Gasohol E85	6,459,489.73	5,490,566.27	968,923.46
	Total	166,155,256.02	20,835,103.91	145,320,152.10
Diesel	Diesel B7	1,502,215.70	105,155.10	1,397,060.60
	Diesel B10	1,856,946.83	185,694.68	1,671,252.15
	Diesel B20	581,922.67	116,384.53	465,538.13
	Total	3,941,085.20	407,234.32	3,533,850.88

From the above calculation and the following equation (3), it found that the energy consumption of Benzene, Diesel, Ethanol, and Biodiesel is equal to 4,574.68 TJ, 128.70 TJ, 435.42 TJ, and 13.56 TJ, respectively, which in total for 5,152.40 TJ. Moreover, when considering carbon dioxide emission in Phitsanulok municipality will be equal to 326,562,093.41 $kgCO_2$ per year or approximately 326,562.09 tCO_2 per year.

Discussions

The case study of Carbon dioxide emission consumption from traveling in Phitsanulok municipality, and the case study of traveling behaviors data for leading to a low-carbon society at Phitsanulok municipality, the main objective was to study the traveling behavior by using the vehicle with the random questionnaire of 400 people. It

was found that mostly traveled by motorcycle which was an average travel distance of 10 – 20 kilometers per day both during weekdays and weekends and the main purpose of traveling was for working and going to school while during weekend there was a longer distance of traveling and took longer of traveling time, the main purpose was for traveling to the department store and tourist attraction places. We make some important observations.

Related to this study, we found carbon dioxide emissions in Phitsanulok municipality, which would likely increase emissions in the future. Especially, Central Business Districts have high traffic density. Theaenleh (2013) studied the CO_2 emission from Hat Yai municipally , and the travel demand was about 240,599 tCO_2 per year. Thus, the impact of driving conditions would be one of the causes of pollution. Chatterton (2014) uses data from annual vehicle check-ups to estimate CO_2 emissions from personal vehicles. These still cannot be discerned what areas are producing transportation emissions. However, most people struggle to understand and concerns about climate change differ among individuals (Waygood & Avineri, 2016). Therefore, public transportation and renewable electricity policies have been considered by the government organization. (Prasad & Munch, 2012).

Conclusions

Phitsanulok municipality is where the government centers, military camps, schools, and hospitals are located not far from each other, which makes people travel by private vehicle more than public transportation , which is the main concern for travel time, safety, and cost/expenses. And for carbon dioxide calculation the by bottom – up method of each vehicle type showed CO_2 emission for 326,562,093.41 $kgCO_2$/year in Phitsanulok municipality or about 326,562.09 to CO_2 per year which is equivalent to 21 million planted trees per year or 1.8 million of planted trees per month, so it would help to absorb CO_2. So, those who are involved and responsible for environmental works urgently need to conduct the campaign, issue the policies, and find the solution to prevent danger from pollution caused by the transport sector.

Therefore, the development of Phitsanulok province leads to a low-carbon society that should promote non-motorized vehicles and the use of electric vehicles instead, including issuing the policy of using public transport, which will help make the

city become a sustainable and livable city. Also, if people can change their behavior to be a short distance traveling and change the type of engine, this could help to reduce the amount of CO_2 emission that cause pollution is harmful to the respiratory system. The encouragement of a public bicycle for short distances traveling also for exercise. The use of electric scooters in conjunction with the consideration of safe travel routes will gain more interest from the public.

Acknowledgement

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