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URBAN METABOLISM AND TRANSPORTATION ASSESSMENT OF KUALA LUMPUR, MALAYSIA

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Abstract

Carbon dioxide, a major greenhouse gas has become an indicator in global warming and climate change. Meanwhile, cities are a medium whereby the source of carbon dioxide is released due to the urbanization and transportation sector. This situation leads to unpredictable impact to the environmental, social and economic condition of the city. Kuala Lumpur is a capital city that experiences rapid growth and was chosen for input-output analysis while Bukit Bintang road and Tunku Abdul Rahman road were chosen for ambient air monitoring due to traffic congestion problems in the city centre. The ambient air quality monitoring was measured on Saturday, Sunday and Monday for 8 hours. The sampling started at 7.00 a.m until 3.00 p.m. with a 5-minute log interval. The study found that carbon dioxide emission from both roads in Kuala Lumpur contributed to 376 ppm of carbon dioxide showing that transportation was a massive source of greenhouse gas emission in the city. Meanwhile, the input-output analysis in Kuala Lumpur showed a significant increase between 2010 and 2016 where electricity consumption, food consumption input, water consumption, gas emission and wastewater output rise due to urbanization and increasing population in the city. In contrast, the enforcement of mandatory waste management by the government has resulted in the decrease of solid waste output in Kuala Lumpur. The greenhouse gas released output in terms of Global Warming Potential from the input-output analysis was 5.88 $MMtCO_2eq$. The study showed that the impact of urbanisation such as ambient air pollution is closely related to energy consumption and greenhouse gas emission.

***Keywords**:* material flow, input-output analysis, urbanization, Kuala Lumpur

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INTRODUCTION

Urban areas are domains for the majority of the global human population. The concept of urban metabolism is similar to an organism that consumes resources from its surroundings, excretes waste products and thus the interaction of various systems in the urban areas are the impression of the metabolism. Therefore, urban metabolism enables studies on the city's function and to understand how the cities operate (Chrysoulakis et al., 2013; Dinarès, 2014). The massive development within the cities to meet the population growth increases the resource use such as fossil energy for human activities (Pincetl, Bunje, & Holmes, 2012).

Any human activity that releases greenhouse gases to the atmosphere warms the earth's atmosphere thus contributing to global climate change. The changes in the earth's climate is caused by various activities which include fossil fuels burning and industrial practices due to urbanisation (Hoornweg et al., 2012; Mustafa, Kader, & Sufian, 2012). The increase of temperature of the surface-troposphere system is caused by the increase of greenhouse gas concentration. The rise of global temperature and sea level are the impacts from carbon dioxide emission concentration in the atmosphere which is the main greenhouse gas emission (Hosseini, Wahid, & Aghili, 2013; IPCC, 2014).

Identification of input-output flows can evaluate direct and indirect environmental impact such as greenhouse gas emissions (Dias et al., 2014; Zhang, 2013). In addition, the material flow of the inputs to the city such as energy, water and food consumption while the outputs such as gas emission, wastewater and solid waste can be examined in order to study the economic and environmental aspect of urban metabolism (Pincetl et al., 2012; Piña & Martínez, 2014; Shafie et al., 2016). These urban materials can be used to calculate greenhouse gas emissions related to climate change. The estimation of carbon dioxide emissions associated with the consumption of input in the urban area can be determined by using input-output analysis.

The urbanization of the city is a result in increased population and rapid development within the city. As the city flourished, transportation within the city also expanded to accommodate the increasing population and facilitated the movement of people from one place to another. The problem arises when hotspot sectors such as transportation are intensified within the city to fulfill the mobility needs of the people thus causing carbon dioxide emission to increase (Dias et al., 2017). In Malaysia, the number of vehicles on the road increases every year which is one of the major sources of air pollution in urban areas (DOE, 2014).

Cities are main critical sites for addressing climate change due to increasing populations and high levels of economic and cultural activity. This is because carbon dioxide per capita emission is higher when there is a high resource use and wealth in the cities (Lee & Meene, 2013). Activities in urban areas cause 70% of greenhouse gas emissions and it becomes a source of environmental problems to the world (Chen & Chen, 2015). The increase of pollutants in ambient air is also due to high density of the human population and growth of industries through urbanization. This showed that many large cities in the world are the major contributors to the global greenhouse gas emission due to compact urban structure such as heavily industrialized cities and high vehicular traffic (Mabahwi, Leh, & Omar, 2015).

MATERIAL AND METHODS

Study location

Kuala Lumpur is a capital city that experiences rapid growth in terms of both economic and population (Han et al., 2014). Kuala Lumpur is a 100% urbanized area where the total land area is 243.7 km^2 (Ling et al., 2010). It is the most popular city in Malaysia with complete transport facilities with an estimation of total population which is about 1.79 million people (Department of Statistics Malaysia, 2016). Therefore, the input and output components (Figure 1) were determined for this city based on a few urban components. Furthermore, traffic congestion due to the increasing transportation sector in cities shared a big portion in among the greenhouse gas emission globally (Grote et al., 2016).

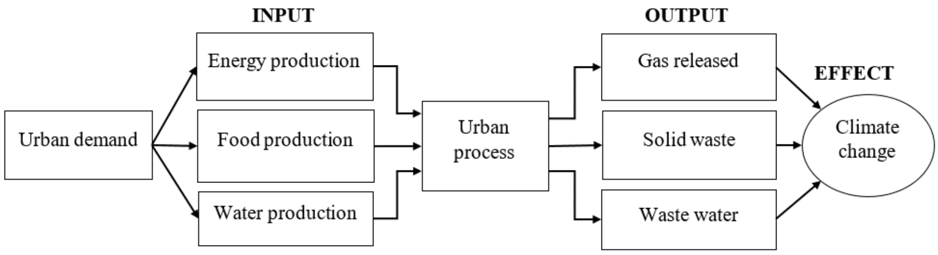

Figure 1. The urban input-output components of Kuala Lumpur

Study procedure

The study was conducted at Kuala Lumpur (Figure 2) where input and output data in Kuala Lumpur were obtained from established secondary sources. The ambient air quality monitoring was conducted at Kuala Lumpur's commercial roads; Bukit Bintang road and Tunku Abdul Rahman road to measure the carbon dioxide level.

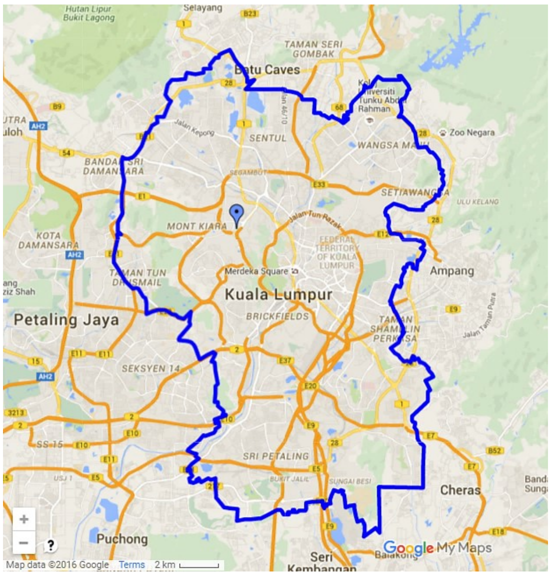

Figure 2. The map of input-output analysis boundary. Source: Google Maps (2018)

Material flow for the urban input and output components of the city was established. The ambient air quality monitoring was conducted to determine carbon dioxide level in Bukit Bintang road and Tunku Abdul Rahman road. The level of carbon dioxide emission was measured using Environmental Monitor EVM-7 Quest Technology to measure level of carbon dioxide at both roads. Both roads contributed to the release of carbon dioxide emission in Kuala Lumpur due to its major traffic congestion (Das et al., 2013; Shamsuddin et al., 2014). Vehicle emissions from the road transportation sector is associated with carbon dioxide emission in the city (Abam & Unachukwu, 2009). The duration of sampling was three days for each road which was on Saturday, Sunday and Monday. Meanwhile, the duration for each sampling point was eight hours; from 7.00 a.m. to 3.00 p.m. The air sampling equipment were placed at the curbside with the distance of 5 meters from the main road. The air sampling method used in this study was adapted from Abam and Unachukwu (2009). The sampling point 1 was at Bukit Bintang road while sampling point 2 at Tuanku Abdul Rahman road. The coordinates of sampling point at Bukit Bintang road and Tuanku Abdul Rahman road were 3°08'53.0"N, 101°42'52.4"E and 3°09'28.7"N, 101°41'46.8"E respectively (Figure 3).

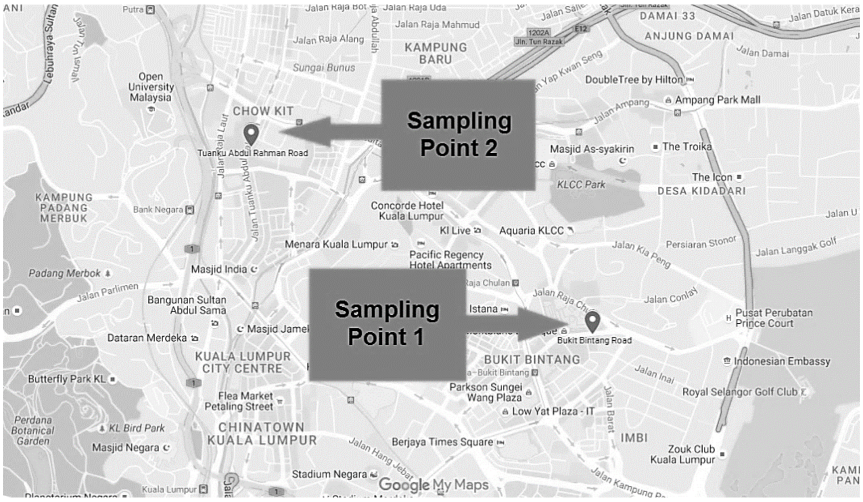

Figure 3. The sampling points for ambient air quality monitoring. Source: Google Maps (2018)

RESULT AND DISCUSSION

Carbon dioxide emission of roads in Kuala Lumpur

For the ambient air quality monitoring, the parameters measured were carbon dioxide emission level, particulate matter (PM_{10}) and temperature. The unit used for carbon dioxide emission was part-per million (ppm) while the unit for PM_{10} was microgram per cubic meter (µg/m^3). The monitoring on Monday showed higher traffic congestion because it was the first working day of the week compared to the monitoring on weekends. Besides, carbon dioxide emission level was high on Mondays due to large number of vehicles on the road which causes traffic congestion that leads to an increase of carbon dioxide emission (Abam & Unachukwu, 2009; Almselati et al., 2011; Ghadimzadeh et al., 2015). The overall result of average level for ambient air monitoring was tabulated in Table 1.

Table 1: The average level of parameters for ambient air quality monitoring

Parameters	Road	8-hour Average			3-day average
		Day 1	Day 2	Day 3	
CO_2 (ppm)	Bukit Bintang	369.70	379.42	379.96	376.36
	Tunku Abdul Rahman	368.90	376.33	381.78	375.67
PM_{10} (µg/m^3)	Bukit Bintang	41.04	108.08	54.90	68.01
	Tunku Abdul Rahman	77.51	96.38	51.65	75.18
Temperature (°C)	Bukit Bintang	30.2	29.1	28.8	88.1
	Tunku Abdul Rahman	29.8	29.9	31.0	30.23

Both roads gave the same reading pattern during the monitoring. The level of carbon dioxide emission was the highest between 1.00 pm until 2.30 pm at both roads and the reading was above 400 ppm. The emission of carbon dioxide tends to be higher in the afternoon and peaks hours due to high traffic on the roads (Ueyama and Ando, 2016). They also pointed out that the level of carbon dioxide emitted was significantly higher during the daytime in the urban areas. This was also for Kuala Lumpur. The minimum and maximum reading of parameters in Bukit Bintang road and Tunku Abdul Rahman road were shown in Table 2.

Table 2. The minimum and maximum level of carbon dioxide emission and PM_{10}

Parameters	**Road**	**Minimum**			**Maximum**		
		Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
CO_2 (ppm)	Bukit Bintang	341	345	333	419	441	472
	Tunku Abdul Rahman	342	354	349	342	425	411
PM_{10} (µg/m^3)	Bukit Bintang	14	45	24	14	45	140
	Tunku Abdul Rahman	43	43	16	160	330	240

The Malaysia Ambient Air Quality Standard is used as a standard for ambient air pollutants criteria such particulate matter, carbon monoxide, nitrogen dioxide, sulfur dioxide and ground level ozone to control air quality and to prevent pollution. The highest average level of PM_{10} was recorded in the second day of monitoring at Bukit Bintang road which is 108.08 µg/m^3 while the lowest level of PM_{10} recorded on the first day of monitoring also was at the Bukit Bintang road which was 41.04 µg/m^3. Throughout the day of monitoring, all the levels of PM_{10} complied with the standard.

The input-output analysis of Kuala Lumpur

The data of input and output analysis in Kuala Lumpur were taken from established secondary sources. In the situation where the material data at city level was not available, the data was downscaled from the national data. The population of Malaysia and number of days in a year were divided from the national figures in order to obtain consumption or production per capita per day. The secondary sources and the main data of input-output analysis were summarized in Table 3.

Table 3. The urban input-output components for Kuala Lumpur

Material	Unit	Total Consumption / Production in a day Kuala Lumpur Population: 1,790 000	Sources (Year)
Input			
Energy (Electricity)	koe/day	3 436 800	Energy Commission of Malaysia (2016)
Water	million liters/day	503	Syarikat Bekalan Air Selangor Sdn. Bhd. (SYABAS) (2016)
Food (Rice)	kg/day	447 500	Food and Agriculture Organization of the United Nations (FAOSTAT) (2013)
Output			
Gas (CO_2)	tonnes/day	16 110	International Energy Agency (IEA) (2016)
Wastewater	m^3/day	515 520	Mat, Shaari and How (2013)
Solid Waste	kg/day	2 219 600	Solid Waste Management and Public Cleansing Corporation Malaysia (SWCorp) (2016)

The collected data were then outlined as an average of individual consumption and production in a day by taking into account the current total population in Kuala Lumpur in order to present the input and output analysis of the city of Kuala Lumpur (Table 4)
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Table 4. Individual consumption in Kuala Lumpur

Input / Output	Unit	Average individual consumption / production in a day Kuala Lumpur
	Input	
Energy (Electricity)	koe/cap/day	1.92
Water	kg/cap/day	281.01
Food (Rice)	kg/cap/day	0.25
	Output	
Gas released (CO_2)	kg/cap/day	9
Wastewater	kg/cap/day	288

Solid Waste	kg/cap/day	1.24

*koe – kg of oil equivalent

The determination of input and output at Kuala Lumpur produced a material flow analysis (Figure 4) where the consumption of inputs by the population through urban processes will produce waste and emissions.

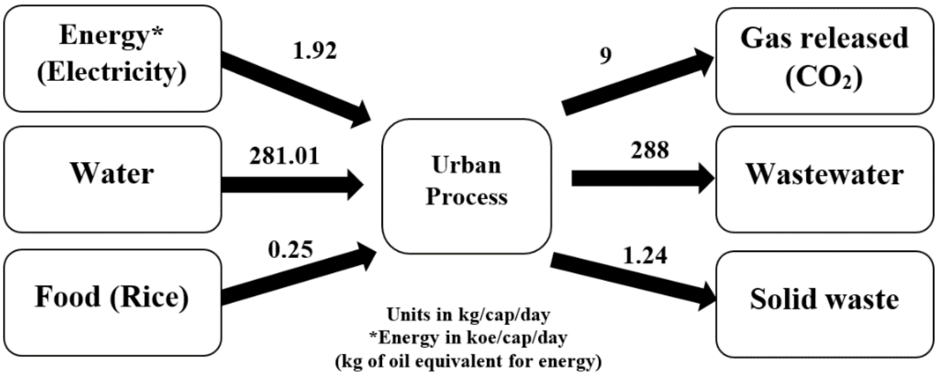

Figure 4. The material flow analysis for Kuala Lumpur

Global Warming Potential (GWP) for Kuala Lumpur

The output component of greenhouse gas emission in this study is carbon dioxide. The data regarding carbon dioxide emission was obtained from the International Energy Agency, 2016. Kuala Lumpur generated 5.88 million metric tonnes of carbon dioxide ($MMtCO_2$) per year for 2016.

The release of 5.88 $MMtCO_2eq$ in Kuala Lumpur were equivalent to greenhouse gas emissions from 1.87 million tons of waste recycled instead of landfilled or driving 1.24 million of passenger vehicles for one year. It is also equivalent to carbon dioxide emissions from 868,281 of annual home's electricity use. The determination of greenhouse gas output in terms of GWP is very useful as it will provide an alternative way to reduce carbon dioxide emission by putting equivalence of the emission with other greenhouse gas. Thus, the strategy will not only focus on the reduction of electricity to reduce carbon dioxide emission, but some other ways such as reducing passenger vehicles on the road or intensifying waste recycling programs in Kuala Lumpur.

The relationship between carbon dioxide emission and climate change impact in Kuala Lumpur

The urbanization of the city causes changes in the environment. Cities are the main contributors to environmental problems and the main contributor to greenhouse gas emission. The massive development of building and infrastructure in the city increases vulnerability to natural disaster and long-term alteration climate (Hoornweg et al., 2012). The emission of carbon dioxide in Kuala Lumpur can contribute to the impact of climate change. The expansion of Kuala Lumpur and its neighboring areas cause traffic congestion and increase the greenhouse gas emission from vehicles. The continuous release of high amounts of carbon dioxide to the atmosphere can accelerate the climate change in Kuala Lumpur thus causing an impact to the economy, social and environment in the city.

The result of input-output analysis shows an increasing input consumption and output production in Kuala Lumpur. The rise of this inputs and outputs is due to the increasing population and massive development in Kuala Lumpur to meet the demand of the populations (Piña & Martínez, 2014). The input consumption such as electricity shows notable changes resulting from the release of a high amount of carbon dioxide and the carbon dioxide equivalent in terms of global warming potential which also shows various ways carbon dioxide can be emitted to warm the earth. The city becomes a critical site in addressing climate change where the population is rapidly growing, and high levels of economic and anthropogenic activities are going on.

CONCLUSION

In conclusion, greenhouse gas emission in the city is the main cause of current climate change in the manifestation of global warming effect and extreme weather condition. Carbon dioxide, the major greenhouse gas has become an indicator to address global warming potential. Understanding the city's input and output flows due to urbanization and its anthropogenic activities can provide an overview on the environmental performance in a controlled setting.

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