Emission Reduction from Transportation Sector Using Carbon Footprint

Christia Meidiana
Regional and Urban Department
Brawijaya University
Malang, Indonesia
c_meideiana@ub.ac.id

Noufal Riziqi N Rohman
Regional and Urban Department
Brawijaya University
Malang, Indonesia
noufalnr@student.ub.ac.id

Deni Agus Setiyono
Regional and Urban Department
Brawijaya University
Malang, Indonesia
deni.agus@ub.ac.id

Adina Khusnudzan Hadid
Regional and Urban Department
Brawijaya University
Malang, Indonesia
adinahadid@student.ub.ac.id

***Abstract*—Sidoarjo urban area is an area with different type of activities, such as settlement, trade, services, government, and also public service such as schools and hospitals. Different type of activities generate high levels of transportation activity resulting in high level of CO_2 emissions. The purpose of this research is to determine the appropriate solution for CO_2 emission reduction from transportation activity. Emission reduction was calculated as a result of different between transportation-borne-CO_2 generation and emission absorption. Absorptive capacity analysis was conducted to calculate the current amount of emissions absorbed by plants. Calculation result showed that CO_2 emissions at weekday is higher than at weekend which is 3,256.15 tons and 2,962.01 tons respectively, while the absorption ability of plant in current green space is approximately only 3.8 kg per hour. With this result the solution is needed to reduce CO_2 emissions from transportation activity. Referring to the result from the above analysis, two strategies were defined, i.e. adding the area of green space and shifting the fuel consumption from diesel and gasoline to biodiesel and bioethanol respectively. Meanwhile, gas is used to substitute gasoline consumption in public transportation. Required area and type of green spaces was defined and calculated to find out the expected absorption capacity. The amount of emission reduction increased as shifting final energy consumption from transportation sector was applied.**

Keywords: emission reduction, transportation, bio-capacity

I. Introduction

Air pollution is the main problem in urban areas caused by increasing urbanization rate and loss of open spaces [1]. This condition leads to air quality degradation having adverse effect on health [2]. Three determinants influencing the air quality in urban areas are increasing population, urbanization, and industrialization [3]. Therefore, measures to reduce the greenhouse gas (GHGs) emission are demanding to avoid health problems in urban areas [4]. Measurement can be determined properly if emission is calculated beforehand. Life cycle assessment (LCA) is a method to calculate the emission once goods (product or service) is produced, consumed and disposed [5]. LCA can describe also the effect of the product on environment during their life cycle [6]. Meanwhile, carbon footprint measures the amount of carbon emission generated by an activity direct and indirectly. The activity sources may an individual, group, government, firms, or organization [7]. One of the activities in urban areas contributing emission is transportation. Transportation contributes emission significantly from fossil fuel burning [8]. Transportation sector is mostly needed for mobilization including goods and services [9]. The sources of emission from transportation includes all light and heavy vehicles [10]. One of the reasonable measures for emission reduction from transportation sector can be implemented in developing countries is traffic controlling and urban landscaping. The concept of bio-capacity has been developed to accommodate the demand of carbon absorption [11].

II. Literature Review

A. Emission Calculation

IPCC 2006 Guidelines for National Greenhouse Gas Inventories is used for emission calculation analysis. Certain formula is used based on the CO_2 generated form transportation activities and thus is used to calculate the CO_2 emission in each grid. Each grid's size is decided with 0.25 km x 0.25 km size [12]. Therefore, there are 36 grids used to cover the whole area of Sidoarjo City. Furthermore the calculation for number of vehicles within the grid area are measured during the peak hour which consists of 4 different sessions, then the calculation of mileage is done with (1).

$$S = l \times n \tag{1}$$

Where:
S = Distance [km]
l = Road length [km]
n = Number of vehicles

The value of mileage (S) is used to calculate the total fuel consumption with (2).

$$C_{tot} = S \times C_e \tag{2}$$

Where:
S = Distance [km]
C_{tot} = Total fuel consumption [liter]

C_e = Energy consumption [liter/km]

TABLE I shows the default values for energy consumption for different vehicle types.

TABLE I. VEHICLE ENERGY CONSUMPTION

Type of vehicle	Energy Consumption [liter/km]
Car/public transportation (angkot)	0.118
Bus	0.169
Mini Bus	0.118
Taxi	0.109
Truck	0.158
Pick-up	0.081
Motorbike	0.027

The result from calculation of total fuel consumption is further used to determine energy consumption value (*Ec*) with (3). Energy consumption value is the result of conversion from fuel consumption using conversion factor (F) based on the types of fuel is used (gasoline or diesel) as it is explained in TABLE II.

$$E_c = C_{tot} \text{ x } F \quad (3)$$

Where:
E_c = Energy consumption
C_{tot} = Total energy consumption [liter]
F = Conversion factor

TABLE II. CONVERSION FACTOR

Fuel Type	Conversion Factor
Gasoline	0.03466
Diesel	0.03868

Energy consumption value is further used to calculate the emission by multiplying total energy consumption with emission factor (EF) as it is explained in (4). The EF value is presented in TABLE III.

$$E_m = E_c \text{ x } EF \quad (4)$$

Where:
E_m = Emission
E_c = Total energy consumption [liter]
EF = Emission factor

TABLE III. EMISSION FACTOR VALUE

Fuel Type	Emission Factor
Gasoline	69.3
Diesel	74.1

B. Biocapacity

Calculation of residue from emission which is not absorbed by the trees is done by subtracting the emission value (E_m) and absorption rate of trees (*Abs)* as it explained in formula (5).

$$\Delta E_m = E_m - Abs \quad (5)$$

Where:
E_m = Emission [kg]
ΔE_m = Residue [kg]
Abs = Absorption [kg/tree]

Value of tree absorption rate (Abs) can be categorized based on the types of tree that further is categorized from both local and its scientific name. The value is referring to the previous study from [13] as explained in TABLE IV.

TABLE IV. ABSORPTION OF CO_2

No.	Local Name	Scientific Name	Absorption of CO_2 (Kg/tree/year)
1.	Trembesi	*Samanea saman*	28448.39
2.	Kenanga	*Canangium odoratum*	756.59
3.	Pingku	*Dysoxylum excelsum*	720.49
4.	Beringin	*Ficus benyamina*	535.90
5.	Krey Payung	*Fellicium decipiens*	404.83
6.	Mahoni	*Swettiana mahagoni*	295.73
7.	Saga	*Adenanthera pavoiana*	221.18
8.	Johar	*Cassia grandis*	116.25
9.	Puspa	*Schima wallichii*	63.31
10.	Akasia (auriculifornis)	*Acacia auriculiformis*	48.68
11.	Flamboyan	*Delonix regia*	42.20
12.	Sawo Kecik	*Manikara kauki*	36.19
13.	Tanjung	*Mimusops elengi*	34.29
14.	Bunga Merak	*Caesalpinia pulcherrima*	30.95
15.	Khaya	*Khaya anthotheca*	21.90
16.	Merbau Pantai	*Intsia bijuga*	19.25
17.	Akasia (mangium)	*Acacia mangium*	15.19
18.	Angsana	*Pterocarpus indicus*	11.12
19.	Dadap Merah	*Erythrina cristagalli*	4.55
20.	Asam	*Tamarindus indica*	1.49
21.	(4) Kempas	*Coompasia excelsa*	0.20

C. Sampling Method

Scope of field study is determined by the number of grids which refer to the guidelines [12]. The rules to determine the number of grids is determined by the size of the city or region of interest as it explained:

- City or region with area > 100 km^2, size of grid is 1 km × 1 km wide
- City or region with area < 100 km^2, size of grid is 0.5 km × 0.5 km or 0.25 km × 0.25 km wide

The area of Sidoarjo City is less than 100 km^2, therefore the size of grid is 0.25 km x 0. 25 km wide and 36 grids in total. Furthermore, the sampling method consists on 3 different subjects, which consists of transportation, trees and household with each rule are described below.

- Transportation sampling method is done by calculating every vehicles across within the grids
- Trees sampling method is done by calculating number of tree based on its types as it is explained within TABLE IV, and located within the public area.
- Household energy consumption is done regardless the types or the criteria of the household, all household is considered has same characteristics.

III. Results and Discussion

A. Green Zone

Greenspace in Sidoarjo City has the area of ± 272 Ha wide which consists of parks, green way, and cemeteries. Green way consists of river borders, railway borders, high voltage air ducts borders, road median, and roundabouts. There are many types of trees that can be planted and further can be used as greenspace with different purposes. The number of trees within the field of study area is explained within TABLE V.

TABLE V. Number of Trees in the Area of Study

No.	Local Name	Scientific Name	Number of Trees
1.	Johar	*Cassia grandis*	30
2.	Kirei Payung	*Fellicium decipiens*	65
3.	Angsana	*Pterocarpus indicus*	284

B. Greenhouse Gas Emission from Transportation

1) Weekday

Emission of CO_2 was calculated from every grid used in this research with the total number of 36 grids. The number of vehicles, types of fuel, road length of every grid, and emission factor value are considered within the calculation of emission. The result shows that motorbike produced the highest emission, while the lowest emission is produced by taxi. Even though larger vehicles such as truck and bus has higher fuel consumption, but their number are too low compared to motorbike, car and taxi. Thus they produce less emission.

Car and motorbike are the main contributor to CO_2 emission in every grids. It indicates that private vehicles is the most favorable transportation mode for people to commute. Mini bus or bus as a mode of public transportation produces few or even no CO_2 emission. The emission is emitted mainly in the morning and the evening because it is the time when people commute at most to start their daily activities or commute back to their home. The distribution of emission during the weekdays is showed in Fig. 1. The calculation comes to the result that total emission during the weekdays is 3256.15 tons/hour.

2) Weekend

Calculation of CO_2 emission during weekends was applied to confirm the difference of CO_2 emitted from vehicles due to the difference in number of vehicles during weekday and weekend. Motorbike still emits the highest CO_2, but the amount is less compared to the emission in weekdays. On the contrary, car produces higher emission in weekends compared to weekday. This result relates with the fact that most people have different destination of commuting during weekday which is mainly related for working or school activities, and weekend which mainly relates with recreation purpose. In weekends, the emission is the highest during afternoon and evening, which is different compared to that of in weekdays. Fig. 2 presents the distribution of emission during the weekends and the total emission is 2962.01 tons/hour.

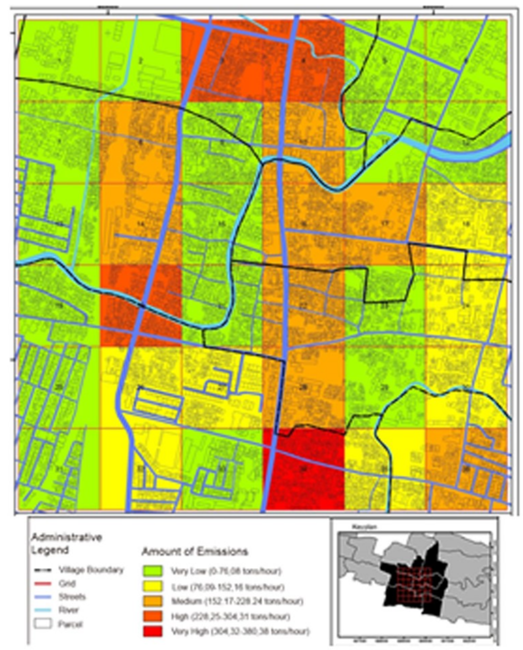

Fig. 1. Emission Distribution on Weekdays.

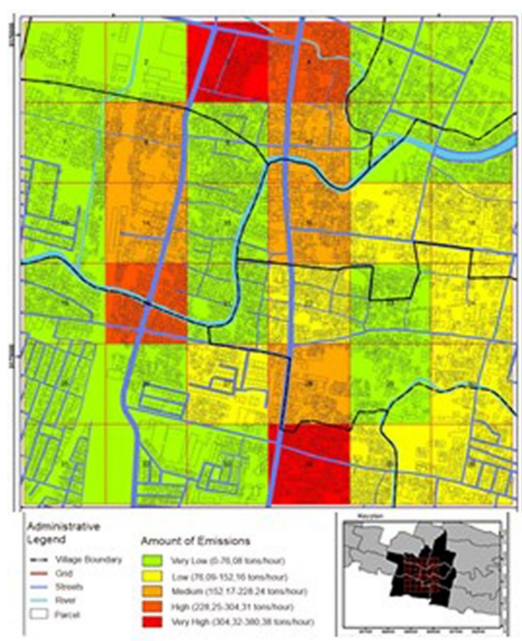

Fig. 2. Distribution of Emission on Weekends.

C. Emission Reduction Calculation Through Absorption

Referring to (5), total absorption of emission was calculated according to the bio-capacity of each tree type showed in TABLE V. Three kinds of tree were used in the calculation, i.e. Angsana tree, Johar tree and Kirey payung tree because these trees are appropriate to be planted in area of study in comply with local regulation.

TABLE VI. CURRENT BIOCAPACITY IN AREA OF STUDY

Cell	Angsana [0.0012 Kg]	Johar [0.0132 Kg]	Kirei Payung [0.046 Kg]	Total Bio-capacity [kg/hour]
1	-	-	-	
2	2	-	-	0.00254
3	2	-	-	0.00254
4	-	-	-	-
5	40	-	-	0.05078
6	30	6	4	0.30256
7	-	-	-	-
8	6	-	-	0.00762
9	-	-	-	-
10	-	-	6	0.27728
11	20	-	18	0.85723
12	6	2	-	0.03416
13	-	-	-	-
14	4	-	-	0.00508
15	-	-	-	-
16	-	-	-	-
17	20	4	4	0.26332
18	18	2	2	0.14182
19	-	-	-	-
20	6	-	2	0.10004
21	-	2	-	0.02654
22	-	-	-	-
23	6	-	4	0.19247
24	24	2	6	0.33429
25	2	-	-	0.00254
26	28	-	-	0.03554
27	-	2	2	0.11897
28	14	-	-	0.01777
29	-	-	-	-
30	10	4	6	0.34306
31	-	-	-	-
32	20	-	-	0.02539
33	6	2	4	0.21901
34	6	2	-	0.03416
35	-	2	6	0.30382
36	10	-	2	0.10512
Total	280	30	66	3.80000

TABLE VI shows that current bio-capacity is too low to absorbs the emission both in weekdays and weekends. It can reduce emission only about 0.1%. Therefore, two measurements are proposed to increase the emission reduction i.e. increasing the bio-capacity by planting more trees and shifting the fuel from fossil to renewable energy.

TABLE VII presents the first measurement and the result shows that it can reduce the emission up to 0.6%.

TABLE VII. BIOCAPACITY AFTER MEASUREMENT

Cell	Trees	Number	Biocapacity (ton/hour)	Total (ton/hour)
1	Kenanga	38	0.0032820	0.0033502
	Tanjung	10	0.0000391	
	Dadap	56	0.0000291	
2	Dadap	48	0.0000249	0.0257898
	Kenanga	22	0.0019001	
	Kenanga	180	0.0155464	
	krey paying	180	0.0083184	
3	Kenanga	34	0.0029365	0.0029365
4	kenanga	10	0.0008637	
	kenanga	14	0.0012092	
5	-	-	-	0
6	kenanga	24	0.0020728	0.0020728
7	kenanga	6	0.0005182	0.0042321
	kenanga	43	0.0037139	
8	kenanga	59	0.0050958	0.0105861
	krey payung	59	0.0027266	
	kenanga	32	0.0027638	
9	-	-	-	0
10	-	-	-	0
11	kenanga	50	0.0043184	0.0043184
12	kenanga	21	0.0018137	0.0101051
	kenanga	96	0.0082914	
13	kenanga	45	0.0038866	0.0125901
	kenanga	82	0.0070822	
	krey payung	22	0.0010167	
	kenanga	7	0.0006046	
14	krey payung	21	0.0009705	0.0068117
	krey payung	18	0.0008318	
	kenanga	18	0.0015546	
	kenanga	40	0.0034547	
15	-	-	-	0
16	kenanga	12	0.0010364	0.0010364
17	kenanga	30	0.0025911	0.0115734
	kenanga	30	0.0025911	
	kenanga	59	0.0050958	
	kenanga	15	0.0012955	
18	-	-	-	0
19	kenanga	7	0.0006046	0.0101983
	kenanga	13	0.0011228	
	kenanga	29	0.0025047	
	kenanga	45	0.0038866	
	krey payung	45	0.0020796	
20	kenanga	24	0.0020728	0.0079065
	kenanga	44	0.0038002	
	krey payung	44	0.0020334	
21	kenanga	26	0.0022456	0.0022456
22	-	-	-	0
23	Kenanga	14	0.0012092	0.0034547
	Kenanga	26	0.0022456	
24	-	-	-	0
25	Kenanga	5	0.0004318	0.5461553
	Kenanga	152	0.0065640	

Cell	Trees	Number	Biocapacity (ton/hour)	Total (ton/hour)
			0.0065640	
	trembesi	164	0.5325954	
26	Kenanga	22	0.0019001	4.9683775
	Kenanga	16	0.0013819	
	Kenanga	26	0.0022456	
	Kenanga	11	0.0009501	
	Kenanga	22	0.0019001	
	krey payung	22	0.0010167	
	trembesi	1527	4.9589831	
27	Kenanga	6	0.0005182	0.0049230
	Kenanga	40	0.0034547	
	Kenanga	11	0.0009501	
28	Kenanga	36	0.0031093	0.0043184
	Kenanga	14	0.0012092	
29	Kenanga	31	0.0026774	0.0154600
	Kenanga	6	0.0005182	
	Kenanga	68	0.0058731	
	Kenanga	74	0.0063913	
30	kenanga	34	0.0029365	0.0185693
	Kenanga	90	0.0077732	
	Kenanga	91	0.0078596	
31	Kenanga	50	0.0043184	3.9142084
	krey paying	50	0.0023107	
	Kenanga	55	0.0047503	
	krey paying	55	0.0025417	
	Trembesi	1201	3.9002873	
32	Kenanga	35	0.0030229	13.8277713
	Trembesi	4257	13.8247484	
33	Kenanga	12	0.0010364	0.0025911
	Kenanga	18	0.0015546	
34	Kenanga	18	0.0015546	0.0015546
35	Dadap	9	0.0000047	0.0168544
	Dadap	15	0.0000078	
	Kenanga	85	0.0073413	
	Kenanga	86	0.0074277	
	Kenanga	24	0.0020728	
36	Dadap	12	0.0000062	0.0000062
			Total bio-capacity	23.4420704

The second measurement can be applied using the following assumption:

1. Gasoline can be substituted with Bioethanol which can reduce the emission up to 48%.
2. Solar can be substituted with Biodiesel which can reduce the emission up to 74%.
3. Public transportation (angkot) can shift the fuel from gasoline to gas generating 30% less emission and gas is cheaper than gasoline.

Calculation using above assumptions comes to the result of the following emission reduction (TABLE VIII and TABLE IX).

TABLE VIII. EMISSION REDUCTION ON WEEKDAYS

Type	Emission	Absorption (Abs)	Reduction [%}	Residue (ΔEm)
Motorbike	1,749.69	839.85	48%	909.84
Car	1,247.69	598.89	48%	648.8
Angkot	135.49	132.53	30%	94.74
Taxi	13.57	6.51	48%	7.06
Pick Up	54.28	52.52	74%	14.11
Mini Bus	56.58	55.11	74%	14.71
Bus	15.26	14.95	74%	3.97
Truck	52.74	51.77	74%	13.71

TABLE IX. EMISSION REDUCTION ON WEEKENDS

Type	Emission	Absorption (Abs)	Reduction [%}	Residue (ΔEm)
Motorbike	1,423.24	683.16	48%	740.09
Car	1,261.37	605.46	48%	655.91
Angkot	128.6	38.6	30%	90.07
Taxi	15.26	7.32	48%	7.93
Pick Up	42.75	31.56	74%	11.11
Mini Bus	49.01	34.91	74%	12.74
Bus	9.44	6.99	74%	2.46
Truck	32.27	23.28	74%	8.39

Shifting the fossil fuel to biofuel and gas can reduce the emission of 49% and 48% on *weekday* and *weekend* respectively.

IV. CONCLUSIONS

The highest emission rate is in cell 34 on weekdays which is 380.38 ton/hour and cell 34 on weekends which is 336.36 ton/hour because there is higher transportation volume caused by the more activities during those times. Totally, the emission rate is approximately 3256.15 ton/hour and 2962.01 ton/hour on weekdays and weekends respectively. Motorbike generates the highest emission both during the weekdays and weekends, while bus emits the least emission at the same period.

The current number of trees in the area of study reduce the emission from transportation insignificantly which is only about 0.01%. By adding the area of the green space and the number of the trees, the emission reduction increases although still low amounting to around 0.6%.

Shifting the fuel from fossil to other alternative fuels, such as bioethanol, biodiesel and gas can reduce more emission up to 49% on weekdays (1840.91 ton/hour) and weekends (1587.49 ton/hour).

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