Emission Reduction from Transportation Sector
Using Carbon Footprint

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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 CO₂ emissions. The purpose of this research is to determine the appropriate solution for CO₂ emission reduction from transportation activity. Emission reduction was calculated as a result of different between transportation-borne-CO₂ generation and emission absorption. Absorptive capacity analysis was conducted to calculate the current amount of emissions absorbed by plants. Calculation result showed that CO₂ 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 CO₂ 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 space 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 directly 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 CO₂ generated form transportation activities and thus is used to calculate the CO₂ 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).

\[ S = l \times n \] (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).

\[ C_{tot} = S \times C_e \] (2)

Where:
- \( S \) = Distance [km]
- \( C_{tot} \) = Total fuel consumption [liter]
Energy consumption \([\text{liter/km}]\)

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

| Type of vehicle                | Energy Consumption \([\text{liter/km}]\) |
|-------------------------------|------------------------------------------|
| 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.

\[
Ec = C_{tot} \times F \tag{3}
\]

Where:
- \(Ec\) = Energy consumption
- \(C_{tot}\) = Total energy consumption \([\text{liter}]\)
- \(F\) = 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.

\[
E_m = E_c \times EF \tag{4}
\]

Where:
- \(E_m\) = Emission
- \(E_c\) = Total energy consumption \([\text{liter}]\)
- \(EF\) = Emission factor

| 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).

\[
\Delta E_m = E_m - Abs \tag{5}
\]

Where:
- \(E_m\) = Emission \([\text{kg}]\)
- \(\Delta E_m\) = Residue \([\text{kg}]\)
- \(Abs\) = Absorption \([\text{kg/tree}]\)

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.

| No. | Local Name       | Scientific Name   | Absorption of CO\(_2\) \((\text{Kg/tree/year})\) |
|-----|------------------|-------------------|-----------------------------------------------|
| 1.  | Trembesi         | Samanea saman     | 28448.39                                      |
| 2.  | Kenanga          | Canangium odoratum| 756.59                                        |
| 3.  | Pingku           | Dysoxylum excelsum| 720.49                                        |
| 4.  | Beringin         | Ficus benjamina   | 535.90                                        |
| 5.  | Krey Payung      | Fellicium decipients| 404.83                                   |
| 6.  | Mahoni           | Swettiana mahagoni| 295.73                                        |
| 7.  | Saga             | Adenanthera paroiana| 221.18                                    |
| 8.  | Johar            | Cassia grandis     | 116.25                                        |
| 9.  | Puspa            | Schima wallichii   | 63.31                                         |
| 10. | Akasia (auriculiformis) | Acacia auriculiformis | 48.68                                    |
| 11. | Flamboyan        | Delonix regia     | 42.20                                         |
| 12. | Sawo Kecik       | Manikara kauki    | 36.19                                         |
| 13. | Tanjung          | Mimosops eleganti | 34.29                                         |
| 14. | Bunga Merak      | Caesalpinia pulcherrima| 30.95                                   |
| 15. | Khaya            | Khaya anthotheca  | 21.90                                         |
| 16. | Merbau Pantai    | Intsia bitjuga    | 19.25                                         |
| 17. | Akasia (mangium) | Acacia mangium    | 15.19                                         |
| 18. | Amsana           | Pterocarpus indicus| 11.12                                        |
| 19. | Dadap Merah      | Erythrina cristagalli | 4.55                                       |
| 20. | Asam             | Tamarindus indica | 1.49                                          |
| 21. | Kempas           | Coimopsis 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 \(\times\) 1 km wide
- City or region with area < 100 km\(^2\), size of grid is 0.5 km \(\times\) 0.5 km or 0.25 km \(\times\) 0.25 km wide

The area of Sidoarjo City is less than 100 km\(^2\), therefore the size of grid is 0.25 km \(\times\) 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.

| 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\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{2} emission during weekends was applied to confirm the difference of CO\textsubscript{2} emitted from vehicles due to the difference in number of vehicles during weekday and weekend. Motorbike still emits the highest CO\textsubscript{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.
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    | -                   | -                 | -                       | 0.00254                     |
| 2    | 2                   | -                 | -                       | 0.00254                     |
| 3    | 2                   | -                 | -                       | 0.00254                     |
| 4    | -                   | -                 | -                       | -                           |
| 5    | 40                  | -                 | -                       | 0.05078                     |
| 6    | 30 6 4              |                   | 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              |                   | 4                       | 0.26332                     |
| 18   | 18 2 2              |                   | 2                       | 0.14182                     |
| 19   | -                   | -                 | -                       | -                           |
| 20   | 6                   | -                 | 2                       | 0.10064                     |
| 21   | -                   | 2                 | -                       | 0.02654                     |
| 22   | -                   | -                 | -                       | -                           |
| 23   | 6                   | -                 | 4                       | 0.19247                     |
| 24   | 24 2 6              |                   | 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              |                   | 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 absorb 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. BIOCAPACITY AFTER MEASUREMENT

| Cell | Trees | Number | Biocapacity [ton/hour] | Total [ton/hour] |
|------|-------|--------|------------------------|-----------------|
| 1    | Kenanga | 38     | 0.0032820              | 0.0033502       |
| 2    | Kenanga | 10     | 0.0008637              |                 |
| 3    | Kenanga | 14     | 0.0012092              |                 |
| 4    | Kenanga | 24     | 0.0020728              | 0.0020728       |
| 5    | Kenanga | 6      | 0.0005182              | 0.0042321       |
| 6    | Kenanga | 43     | 0.0037139              |                 |
| 7    | Kenanga | 59     | 0.0050958              | 0.0105861       |
| 8    | Kenanga | 32     | 0.0027638              |                 |
| 9    | -       | -      | -                      | 0               |
| 10   | -       | -      | -                      | 0               |
| 11   | Kenanga | 50     | 0.0043184              | 0.0043184       |
| 12   | Kenanga | 21     | 0.0018137              | 0.0101051       |
| 13   | Kenanga | 45     | 0.0038866              | 0.0125901       |
| 14   | Kenanga | 82     | 0.0070822              |                 |
| 15   | Kenanga | 22     | 0.0010167              |                 |
| 16   | Kenanga | 45     | 0.0038866              | 0.0125901       |
| 17   | Kenanga | 7      | 0.0006046              |                 |
| 18   | Kenanga | 21     | 0.0009705              | 0.0068117       |
| 19   | Kenanga | 18     | 0.0008318              |                 |
| 20   | Kenanga | 18     | 0.0008318              |                 |
| 21   | Kenanga | 15     | 0.0012955              |                 |
| 22   | -       | -      | -                      | 0               |
| 23   | Kenanga | 12     | 0.0010364              | 0.0010364       |
| 24   | Kenanga | 30     | 0.0025911              | 0.0115734       |
| 25   | Kenanga | 30     | 0.0025911              |                 |
| 26   | Kenanga | 59     | 0.0050958              |                 |
| 27   | Kenanga | 15     | 0.0012955              |                 |
| 28   | -       | -      | -                      | 0               |
| 29   | Kenanga | 7      | 0.0006046              | 0.0101983       |
| 30   | Kenanga | 13     | 0.0011228              |                 |
| 31   | Kenanga | 29     | 0.0025047              |                 |
| 32   | Kenanga | 45     | 0.0038866              |                 |
| 33   | Kenanga | 45     | 0.0020796              |                 |
| 34   | Kenanga | 24     | 0.0020728              | 0.0079065       |
| 35   | Kenanga | 44     | 0.0038002              | 0.0079065       |
| 36   | Kenanga | 44     | 0.0020334              |                 |
| 37   | Kenanga | 26     | 0.0022456              | 0.0022456       |
| 38   | Kenanga | 26     | 0.0022456              |                 |
| 39   | Kenanga | 14     | 0.0012092              | 0.0034547       |
| 40   | Kenanga | 26     | 0.0022456              |                 |
| 41   | Kenanga | 5      | 0.0004318              | 0.5461553       |
| 42   | Kenanga | 152    | 0.0065640              |                 |

TABLE VII presents the first measurement and the result shows that it can reduce the emission up to 0.6%.
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 (Abs) | 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%           | 13.71         |
| Bus       | 15.26          | 14.95            | 74%           | 2.71          |
| Truck     | 52.74          | 51.77            | 74%           | 13.71         |

Totally, the emission rate is approximately 23.4420704 ton/hour.

### TABLE IX. EMISSION REDUCTION ON WEEKENDS

| Type      | Emission (Abs) | Absorption (Abs) | Reduction [%] | Residue (ΔEm) |
|-----------|----------------|------------------|---------------|---------------|
| Motorbike | 1,423.24       | 683.16           | 48%           | 740.09        |
| Car       | 1,247.69       | 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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