The development of software for calculating green open space adequacy to absorb CO₂ in Bangkalan city

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Abstract. Bangkalan Regency, located at the west of Madura Island covering the area 1,260.14 Km², has developed tremendously in some recent years, particularly in the post-development of Suramadu Bridge. To anticipate detrimental effects on the environment due to Bangkalan Regency improvement, the researchers developed software for calculating total CO₂ emissions of vehicles that could be absorbed by Green Open Space (GOS) in this city. The software was developed through Hypertext Preprocessor (PHP) based on the results of empirical study upon emission load and total trees calculation required for absorbing emission residue of vehicles. The software yielded from this research was successfully developed as indicated by the appropriateness of results between manual calculation and software one.

1. Introduction
The rapid development in Bangkalan Regency, not only gives positive effects to many sectors, but also contributes negative ones to the environment. If the Local Government is considered unable to prepare strategies to anticipate the existing changes, particularly the environmental management at the city area, the detrimental effects will vividly exist. One of development effects is the increasing activities of transport, industry, service, and others which eventually raise the emission residue of those activities in the air and cause air pollution.

Air pollution signified by high content of CO₂ will enable unhealthy environment and decrease people’s health. Therefore, reducing CO₂ by developing Green Open Space (GOS) belongs to one of solutions to decrease total emission of carbon dioxide.

This research aimed at designing software for calculating: (a) total CO₂ emissions of vehicle fumes that could be absorbed by Green Open Space in the urban area, and (b) the coverage adequacy of urban Green Open Space.

1.1 Literature Review

1.1.1 Green Open Space. Green Open Space (GOS) refers to a stretched area or path and/or a clumped area for open use, a place where trees grow naturally or consciously planted [1]. Zhang, Biao et al. [2] revealed that GOS was proven to have ability in lowering air temperature and mitigating hot regions due to urbanization process, particularly in Beijing.
The Regulation of Minister of Public Works Number 05/PRT/M/2008 concerning The Principles of Green Open Space Provision and Utilization in the city areas mentioned several functions of GOS as follows.

1. Ecological Function, GOS belongs to a part of air circulation system (lungs of city); as the regulator of micro climate so that the circulation system of water and air can last naturally; as shady maker; and as the oxygen producer and rain water absorber.
2. Socio-cultural function, GOS depicts local cultural expression, interpersonal communication media, recreation site, and media as well as object of education, research, and training for learning nature.
3. Economic function, GOS refers to the sources of products that can be sold such as flower, fruit, vegetable, and it can be a part of businesses in agriculture, plantation, forestry, and so on.
4. Aesthetic function, GOS improves convenience, beautifies city environment, both micro-scale in terms of house yard and housing environment, but also macro-scale such as whole city landscape; stimulates the creativity and productivity of city people; as the factor shaping architectural beauty; and creates harmonious and balance between developed area and no-developed one.

1.1.2 Calculation of Green Open Space. Factor of Emission (FE) is defined as value/score representing the unit/quantity of pollutants emitted to the atmosphere by a certain activity. FE value is stated in pollutant mass per weight unit, volume, and distance or duration of a certain activity emitted the pollutant. In several conditions, FE represents facilities having air pollution controller that has been mounted. However, the yielded value must be considered as a value reflecting a condition when the pollutant controller is attached and functional. To get estimation that can be applied in general and representing emission in the long term, a regular monitoring is indispensable.

This approach provides better estimation value compared to temporary emission measurement. The approach of material balance will be used when the material percentage released to the atmosphere is great enough (for instance sulphur content of fuel). However, data will get high if the material is consumed, reacts chemically within the process, or if the emission released in the atmosphere covers only a small part of total materials being used. Factor of emission can be obtained through modelling, for example empirical model based on the existing data format.

Based on the data of SAMSAT (Sistem Administrasi Manunggal Satu Atap or One-stop Administration Services Office) at Bangkalan Regency in 2015, total vehicles in this city around 125,482 units consisting of 115,813 motorcycles, 123,491 gasoline cars, and 1,991 solar cars.

The load of emission is calculated based on the following equation [3].

\[ E_{\text{miti}} = (n \times L \times f \times \rho) \div FE \]  

Notes:
Emission : CO₂ emission load (tons/year)
n : total vehicles (vehicles/hour)
L : road length (km)
f : factor of emission
FE : fuel economy (km/L)
ρ : gasoline density 0.63 kg/L and solar 0.7 kg/L

Meanwhile, the absorption capacity of CO₂ employs the following equation:

The absorption capacity of trees = the absorption capacity of CO₂ x total trees

The projection of vehicles would be based on the calculation of correlative coefficient. According to Ribka [4], the equation became:
\[ P_n = P_0 (1 + r)^{dn} \]  

Notes:
Pn : total vehicles at the end of period
Po : total vehicles of initial projection
r : average annual population growth
dn : projection period

The calculation of emission residue would be based on the equation:

\[ \text{CO}_2 \text{ emission residue} = A - B \]  

Notes:
A : Total emissions of \text{CO}_2 (g/hour)
B : Total absorption capacity of \text{CO}_2 by GOS of road(g/hour)

1.1.3 Review of Related Studies. Ribka Regina Roshintha and Sarwoko Mangkoedihardjo [4] conducted a study concerning The Analysis of Green Open Space Adequacy as Carbon dioxide (\text{CO}_2) Gas Emission Absorber at Campus Area of ITS Sukolilo Surabaya. This research calculated total existing vehicles and vegetation at campus area of ITS Sukolilo Surabaya as the bases for determining GOS adequacy to absorb \text{CO}_2 emission. The results of analysis indicated that five zones had satisfied GOS adequacy in 2021 and three zones had not yet.

Sukentyas Estuti Siwi [5] revealed that the reduction of GOS area ensued in Depok City for 11 years (in 2000 - 2011) based on the data of Landsat 7 ETM+ and SPOT 4. The data were analysed by referring to radio metrical and geometrical corrections upon by applying Normalized Difference Vegetation Index (NDVI) algorithm, specifically to separate vegetation objects from non-vegetation ones.

Moreover, Rulli Pratiwi Setiawan [6] has proven that to review the comparison of carbon dioxide emissions resulted from the settlement uses at urban and urban fringe areas in Gerbangkertosusila. In the case, urban areas comprised the cities of Surabaya, Mojokerto, and Sidoarjo, whereas urban fringe areas involved the regencies of Gresik, Bangkalan, Mojokerto, and Lamongan. The results of research depicted that the use of settlement area in urban fringe area gave high contribution toward carbon dioxide emission though the housing areas and total households in urban fringe area were extremely fewer than the ones in urban area.

The research of Nurhayati Abdul Malek, et al. [7] was successful in validating the pattern scales of GOS uses in Malaysia including the patterns of passive and active activities. The results indicated that unsuitability between every pattern and theory. The patterns were used consistently for measuring the aspect of people’s participation along the green path.

The paper of Collins Adjei Mensah, et al. [8] justifies that green space bestows social, economic, and environmental benefits which then ultimately improves welfare in terms of physical, psychological, social, and individual material so that the living standard can automatically be increased. Unfortunately, the efforts to actualize all of them are often focused on the social-economical phases by restricted consideration on the green space aspect. This research aimed at bridging the research gap in tracking the relationship between green space and life quality. It also was dedicated to investigate how that relationship could inform the development of policy for assisting the government to obtain positive outcomes.

2. Method
This research was carried out in Bangkalan City exactly in Burneh and Bangkalan Districts. The former district consisted of one urban village and two villages, while the later one had seven urban
villages and one village. The data were meant to calculate total motorcycles, gasoline and solar cars, trucks, and buses which were collected for one week at 07.00-08.00; 12.00-13.00; and 16.00-17.00. To calculate GOS adequacy, the researchers inputted the area data for determining the zone of software being developed. The process of inputting the data of plants and their absorption capacity toward CO\textsubscript{2} was addressed to calculate the plant capacity for absorbing emission. Data of vehicles, total vehicles, road length, emission factor, fuel economy of vehicles, and fuel density were inputted to gain emission load. The inputs of total vehicles at the end of period, total vehicles at the initial projection, average population growth, and projection duration were necessary to count the projection of vehicles. Meanwhile, the inputs of total CO\textsubscript{2} emission and total CO\textsubscript{2} absorption were fruitful to evaluate GOS.

3. Findings and Discussions
The results of field measurement demonstrated total vehicles per week in Burneh District in Table 1 and the ones in Bangkalan District in Table 2.

| Table 1. Total Vehicles per Week in Burneh District |
|-----------------------------------------------|
| No   | Location | Motorcycle | Car (Gasoline) | Car (Solar) | Truck | Bus |
|------|----------|------------|----------------|-------------|-------|-----|
| 1    | Langkap  | 184,544    | 6,688          | 8,696       | 2,108 | -   |
| 2    | Burneh   | 327,656    | 40,352         | 39,504      | 4,732 | 2,388 |
| 3    | Tunjung   | 310,752    | 37,248         | 38,096      | 4,444 | 2,388 |

| Table 2. Total Vehicles per Week in Bangkalan District |
|-----------------------------------------------|
| No   | Location | Motorcycle | Car (Gasoline) | Car (Solar) | Truck | Bus |
|------|----------|------------|----------------|-------------|-------|-----|
| 1    | Martajasah | 2,808      | 880            | 0           | 0     | 0   |
| 2    | Mlajah    | 641,160    | 91,224         | 80,560      | 5,340 | 0   |
| 3    | Kemayoran | 616,400    | 76,568         | 68,664      | 5,340 | 0   |
| 4    | Pengeranan| 162,976    | 16,848         | 15,072      | 476   | 0   |
| 5    | Pejagan   | 417,464    | 45,600         | 49,904      | 1,576 | 0   |
| 6    | Kraton    | 269,720    | 36,360         | 19,352      | 420   | 209 |
| 7    | Demangan  | 282,288    | 45,120         | 24,904      | 688   | 241 |
| 8    | Bancaran  | 208,832    | 16,368         | 12,696      | 0     | 0   |

The total vehicles in Tables 1 and 2 were dominated by motorcycles and some regions had no bus. The biggest number of vehicles passed through Burneh Village, whereas Mlajah and Kemayoran Urban Villages were also the areas mostly crossed by many motorcycles.
Table 3. Total Emissions in Burneh and Bangkalan Districts

| No | Location          | Motorcycle | Car (Gasoline) | Car (Solar) | Truck | Bus | Total Emissions (kg/week) |
|----|-------------------|------------|----------------|-------------|-------|----|----------------------------|
| 1  | Langkap Village   | 13,204     | 1,136          | 1,700       | 1,064 | 0  | 17,104                     |
| 2  | Burneh Village    | 23,444     | 6,857          | 7,721       | 2,388 | 1,515 | 41,925                     |
| 3  | Tunjung Urban Village | 22,234 | 6,329         | 7,446       | 2,243 | 1,515 | 39,767                     |
| 4  | Martajasah Village | 201        | 150            | 0           | 0     | 0   | 350                        |
| 5  | Mlajah Urban Village | 45,875   | 15,501         | 15,746      | 2,695 | 0   | 79,817                     |
| 6  | Kemayoran Urban Village | 44,103   | 13,011         | 13,421      | 2,695 | 0   | 73,230                     |
| 7  | Pengeranan Urban Village | 11,661 | 2,863         | 2,946       | 240   | 0   | 17,710                     |
| 8  | Pejagan Urban Village | 29,870   | 7,749          | 9,754       | 795   | 0   | 48,167                     |
| 9  | Kraton Urban Village | 19,298   | 6,178          | 3,782       | 212   | 1,333 | 29,604                     |
| 10 | Demangan Urban Village | 20,198  | 7,667          | 4,868       | 347   | 153 | 33,232                     |
| 11 | Bancaran Urban Village | 14,942   | 2,781          | 2,482       | 0     | 0   | 20,205                     |

The biggest total emissions occurred in Mlajah and Kemayoran Urban Villages as presented in Table 3.

Table 4. The Absorption Capacity of Trees (kg/week) per Urban Village

| No | Location                      | Total Trees | Total absorption capacity of trees per week (kg) |
|----|-------------------------------|-------------|-----------------------------------------------|
| 1  | Langkap Village               | 255         | 4,299.1                                       |
| 2  | Burneh Village                | 58          | 624.0                                         |
| 3  | Tunjung Urban Village         | 81          | 679.1                                         |
| 4  | Martajasah Village            | 63          | 948.1                                         |
| 5  | Mlajah Urban Village          | 109         | 10,228.8                                      |
| 6  | Kemayoran Urban Village       | 61          | 7,995.5                                       |
| 7  | Pengeranan Urban Village      | 661         | 14,510.4                                      |
| 8  | Pejagan Urban Village         | 211         | 8,446.1                                       |
| 9  | Kraton Urban Village          | 86          | 1,208.3                                       |
| 10 | Demangan Urban Village        | 225         | 1,431.4                                       |
| 11 | Bancaran Urban Village        | 118         | 1,147.2                                       |

Table 4 demonstrates that the tree absorption against the biggest emission happened in Mlajah and Pengeranan Urban Villages. Meanwhile, the biggest emission residue in both Urban Villages can be seen in Table 5. The data indicated that the highest absorption value did not correlate with total trees as can be seen in Martajasah Village due to limited shade trees having high absorption capacity for emission. On the contrary, trees with low absorption capacity of emission occupied great numbers. In the other words, there were many shade trees in Martajasah Village but they had low capacity to absorb emission. The ability of a plant to absorb carbon is determined by three factors i.e. leaf size, total leaves, and tree canopy. In addition, emission residue in Martajasah Village was the fewest.
because the activities of vehicles in this area were extremely low. As a result, all emissions of vehicles could be absorbed perfectly by GOS.

Table 5. The Calculation of Emission Residue (kg/week)

| No | Location                      | Total Emission (kg/week) | Total Tree Absorption per Week (kg) | Emission Residue (kg/week) |
|----|-------------------------------|--------------------------|------------------------------------|----------------------------|
| 1  | Langkap Village               | 17,104.0                 | 4,299.1                            | 12,805.0                   |
| 2  | Burneh Village                | 41,924.6                 | 624.0                              | 41,300.6                   |
| 3  | Tunjung Urban Village         | 39,767.1                 | 679.1                              | 39,088.0                   |
| 4  | Martajasah Village            | 350.4                    | 948.1                              | -597.7                     |
| 5  | Mlajah Urban Village          | 79,816.9                 | 10,228.8                           | 69,588.2                   |
| 6  | Kemayoran Urban Village       | 73,229.8                 | 7,995.5                            | 65,234.3                   |
| 7  | Pengeranan Urban Village      | 17,710.0                 | 1,208.3                            | 16,501.7                   |
| 8  | Pejagan Urban Village         | 48,167.5                 | 1,431.4                            | 46,736.1                   |
| 9  | Kraton Urban Village          | 29,603.9                 | 14,510.4                           | 15,093.5                   |
| 10 | Demangan Urban Village        | 33,232.2                 | 8,446.1                            | 24,786.1                   |
| 11 | Bancaran Urban Village        | 20,204.8                 | 1,147.8                            | 19,057.6                   |

Based on the data of all tables, the researchers developed software by inputting the data of research location, data collection time, total vehicles, total vehicle emission, and total emission absorption of trees. Data input aimed at calculating GOS adequacy so that engineering could minimize the value of emission residue. Figure 1 shows the display of software that was successfully developed.

4. Conclusions
1. Out of eleven locations of measurement, one location obtained the lowest emission residue and all emissions could be absorbed by GOS namely Martajasah Village. Besides, two GOSs gained the biggest shade trees i.e. Keraton and Demangan Urban Villages.
2. The results of GOS adequacy calculated manually were suitable with the ones calculated through the developed software. Accordingly, the usability of software contributed significantly as it could ease the process for calculating the coverage adequacy of urban GOS, thereby saving time.

5. References

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