TECHNICAL PAPER

A Simplified Approach to Estimating Area Pollution from Mobile Sources

Haryo Satriyo Tomo[1], Shanty Meta F. Syahril[2]
[1]Lecturer of Department of Environmental Engineering ITB
[2]ADB Technical Consultant RETA 5937
E-mail: haryo@tl.itb.ac.id , shanty-s@indo.net.id

Abstract

There are many models have been developed to estimate pollution from mobile sources. However, the sufficient data related to support an actual mobile emission, emission factor and traffic condition is hardly available. The paper describes a method to simplify the estimation of mobile source emission in the area. The simplification method is used to estimate emission factor using the data of idle vehicle emission test and to combine the data of vehicle fleet, traffic condition and road network to estimate daily vehicle density. To compute the mobile source emission, the area was divided into grids based on the sub-district administrative boundaries. The result indicates that the model is the appropriate available approach to estimate the mobile emission to emulate the data of idle vehicle emission test as emission factor. Further emission estimation using dynamic mode and the modified local driving condition are vitally important to improve the results of emission estimation as well as actual condition.

Introduction

Vehicles emission test (VET) is important in developing mobile pollution control strategies, ascertaining the effects of mitigation strategies, and a number of other related applications for a variety of users, including national and local agencies, consultants, and industries. For many cases in development countries, like Indonesia, vehicle emission test is only base on idle condition. The result of testing might be useful in Inspection and Maintenance (I/M) Program only. As consideration, the usage of VET based on dynamic mode is to define the actual emission factor from such an area or a country. However, it must also be supported by the data of driving condition.

Mobile emission estimation using the data of VET based on dynamic mode and driving condition gives excellent accuracy on the handling of many traffic scenarios, such as performed by MOBILE5 and SMOKE [1]. Unfortunately, the data are not available at all. The usual current solution is to adopt the data and models from other countries. There are some situations that the data and models are impracticable especially due to the actual vehicle fleet and the driving condition constraints. Consequently, the modeling approach using the available data gains more attention.

Accurate emission estimates are a prerequisite in calculating ambient air quality. In spite of increasingly serious atmospheric pollution, the research on emission estimates of air pollutants used to be limited to a few regulatory pollutants on an annual average basis [2]. Hence, a simplified mobile emission model (SIMEM) becomes a challenging process.

In addition, to attain the SIMEM, the volume of data is required tremendously. An efficient SIMEM should be built in a modular form that allow sub-model to be easily updated once the new information and emission modeling techniques available. The geographic information system/database (GIS/DB) technique will be a useful tool to ensure the ability to retrieve, manipulate, and display this onerous volume of information [3].

Given this limitations and needs, the objective of the study presented in this paper is to develop the SIMEM. Development of the model is meant to input data, process data and represent output (post processor) in a single-user system interface. The prototype of the SIMEM is a beginning to extent the whole system beside infrastructure preparations.

Modeling Frameworks

The SIMEM is built in five sub-models, [a] determining the Grid/Boundary Area; [b] determining the Road Network, including major and minor roads; [c] determining the Traffic Condition, including the inroad vehicles fleet; [d] determining emission factor from idle VET; and [e] calculation of Mobile Emission. The sub-models [a], [b] and [c] are series steps as depicted in Figure 1.

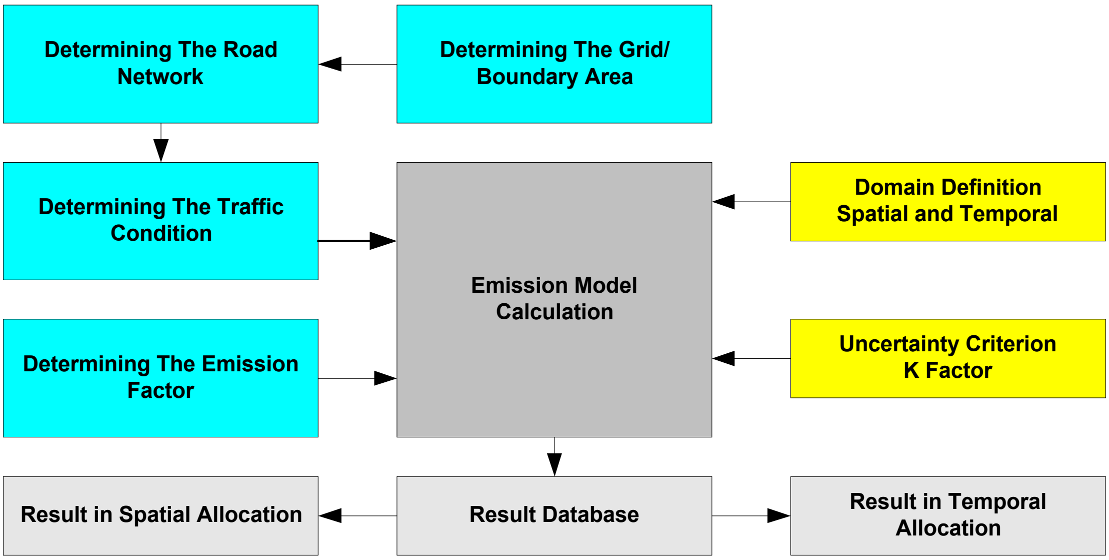

Figure 1. Box-Diagram of SIMEM

The grid areas are adopted from administrative boundary of district. There are some situations that most of the data is based on administrative boundary. Moreover, the collecting data should be comparable to the calculation in spatial condition in term of topographical, population, and especially the landuse. Any number of grids squares may be combined into a single grid based on a uniform topography, a uniform surface type and a uniform source distribution. The uniformity of landuse is used to define OD Matrices that is the tool to measure the traffic condition.

Furthermore, to determine the road network based on administrative boundary, the roads located in grid are divided into major and minor roads. Calculation in this step is about the length, the width, the lane and the service factor from each of major and minor road. The calculation to attain the data could be ignored if the local GIS/DB for road network is available.

The traffic condition is determined in term of traffic volume, vehicle fleet and temporal definition. The data of traffic volume and vehicle fleet based on temporal definition should be combined with spatial definition (grid), OD matrices, and roads classification to adjust the number of source in each grid. Moreover, temporal definition is affected by travelling time unit as the result of relation between traffic volume, road classification and service factor (Table 1).

Table 1. Characterize of Roads and Travelling Time

Condition	Travelling Time (min/mil)	Level of Service	Density (Kendaraan/hari)
Highway	0.8 - 1.0	0 - 0.2	2000/lane
Major Roads	1.5 - 2.0	0.4 - 0.6	1800/lane
Minor Roads	2.0 - 3.0	1.0 - 1.5	1800/total width

Source : Tamin, 2000

The decisive step of SIMEM is the model of emission factor that is based on idle VET. There are two approaches to represent the data of idle VET, using concentration unit and mass per time unit. Both are the results of different testing equipment. The unit that is used in SIMEM is mass/time unit as comparable with idle VET unit of US-EPA. Moreover, It should be preprocessing if the unit in concentration. Basic equation to convert unit concentration to mass/time as follows:

$$mass/time = concentration \quad x \quad Qpump \qquad (eq.\ 1)$$

where: Qpump is the volumetric rate of the test instrument pump.

The assumption of conversion is the concentration is in quasi-steady state. Because of the difficulties to attain actual mileage travel, idle VET is divided into two levels of classification, the vehicle composition and vehicle age.

For using idle VET, there is an implication to the paradigm of mobile source. Mobile source should be transform as like as non-mobile source. Consequently, the definition of vehicle density as an 'uncompressible state' must be properly implemented in the model. It is the interesting matter of the SIMEM.

The SIMEM is a model using several assumptions. For each assumption in the model must be adjusted with actual condition. The differences should be handled in the equation to estimate the mobile emission. Furthermore, the uncertainty factor is needed to add in the circumstance.

Basic equation to calculate vehicle density as follows:

$$D_{(i,j,k,l)} = Veh_{(j,k,l)} * [Lr_{(l)} / Vel_{(k,l)}] \quad \textit{(eq. 2)}$$

$$E_{(i,j,k,l)} = D_{(i,j,k,l)} * EF_{(i,j)} * kv \quad \textit{(eq. 3)}$$

$$k_v = f(Li, Wr, LOS) \quad \textit{(eq. 4)}$$

where: E = emission, Veh = vehicle, Lr = length of road, Vel = mean vehicle's velocity, EF = emission factor, k_v = traffic constant, Li = number of line, Wr = width of line, LOS = level of service, i = type of pollutant, j = type of vehicle, k = type of peak hour, l = grid.

The usage data in the SIMEM is stored in database input and output related to numerous entity and access during the calculation process. The summary of system in the SIMEM is shown in Figure 2.

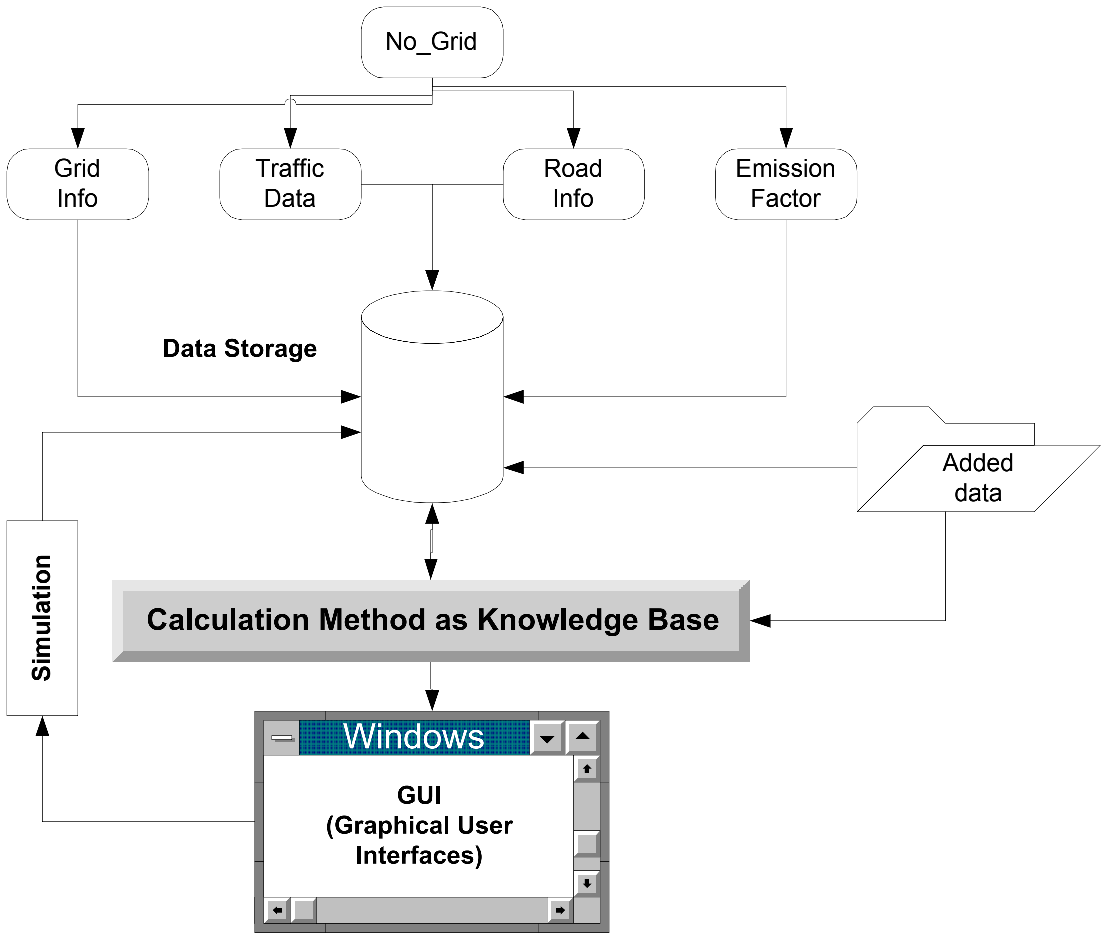

Figure 2. System Diagram of SIMEM

Result and Discussion

The SIMEM is applied to calculate mobile emission in Jakarta. Considering the previous paper, Jakarta is divided into 23 grid as depicted in Figure 3. Idle VET is derived from DLLAJ (2000) and vehicle fleet scenario until December 1994. The result of SIMEM is compared with calculation using emission factor derived from Walsh (2002). The result of comparison is depicted in Figure 4 and 5.

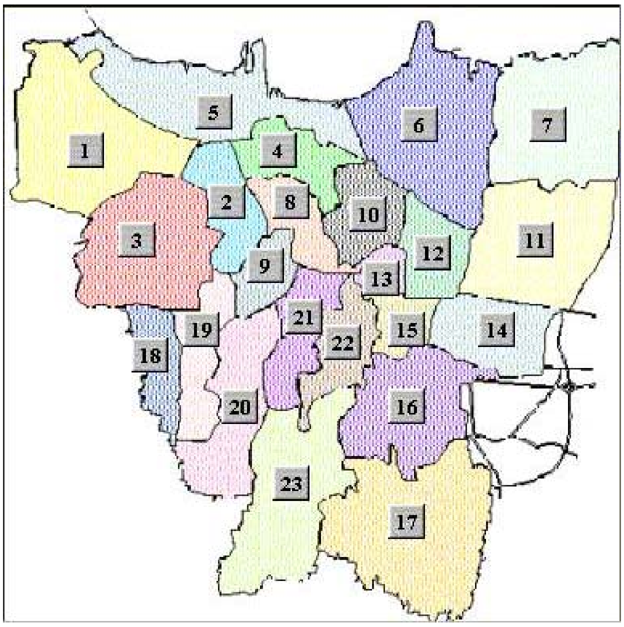

Figure 3. Jakarta in Grid

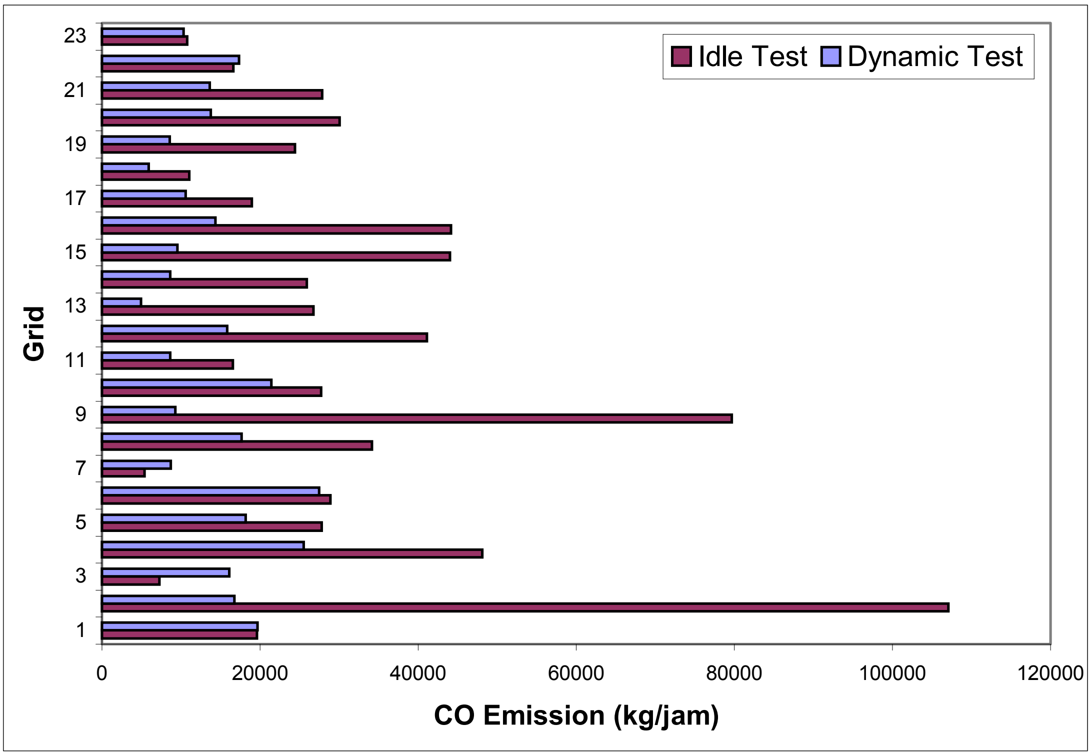

Figure 4. Estimation of CO Emission

The result shows that SIMEM has differences for about 35.2% for CO and 32.8% for HC compare to the calculation using dynamic test. As an alternative approach, mobile emission estimation using SIMEM is reliable even though the calculations do not include the uncertainty factor. However, the level of confidence of the model is still beyond of this research due data deficiency.

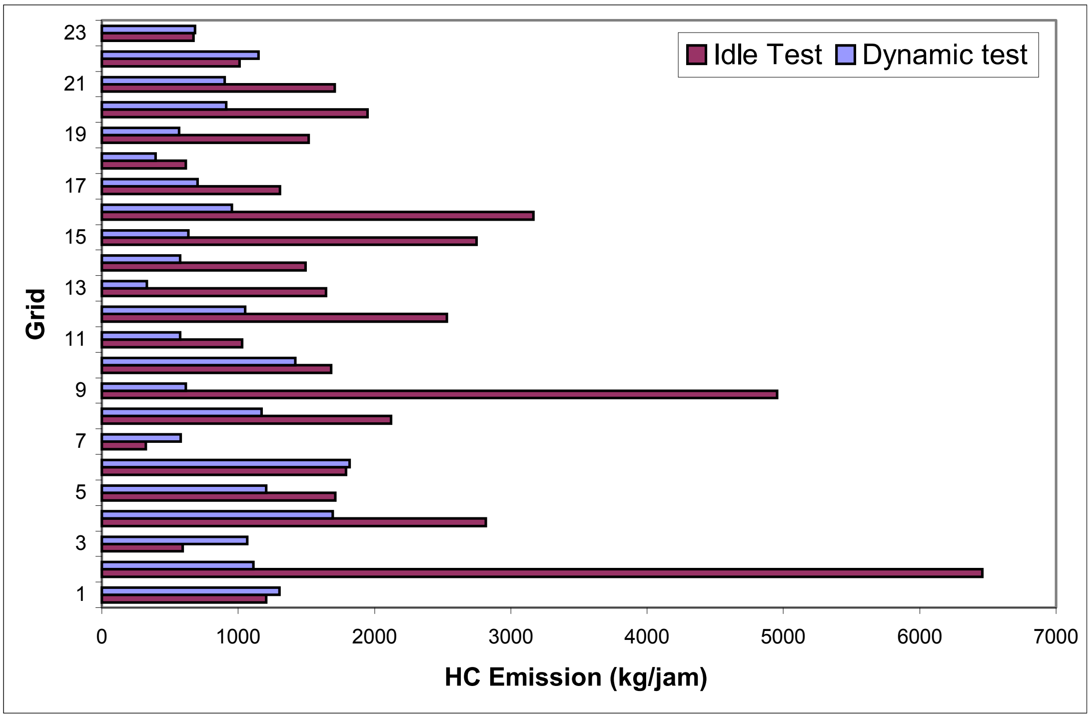

Figure 5. Estimation of HC Emission

Conclusion

The finding suggests that the simplified mobile emission estimation method presented in this paper show a positive indication to be appropriate available approach to emulate the data of idle vehicle emission test as emission factor. However, further emission estimation using dynamic mode and the modified local driving condition are vitally important to improve the results of emission estimation as well as actual condition. The data that varies in term of spatial and temporal are now required to determine level of confidence of the model. In addition, the model should be included in couple system with GIS/DB.

Reference

1. Tomo,H., *Development on Couple System As Decision Support System For Urban Air Quality Related to Transportation*, Master Seminar ITB, 2001, Bandung

2. Purwanto E., ***Benefit Cost Analysist of Transport Air Pollution in Jakarta***, Master Thesis TU Graz, 2001, Austria

3. Olsthoorn, T.N., et.al., ***Integrated Modeling in Netherlands***, Riso International Conference, Elsevier, 1990, Amsterdam

4. Walsh, M.P.: *Motor Vehicle Emissions Inventory Model*, 2002

5. Tamin, O., ***Perencanaan Pemodelan Transportasi***, 2000, Penerbit ITB, Bandung