

Scenarios reducing greenhouse gas emission from motor vehicles in State University of Malang

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Abstract. State University of Malang (UM) is one of the universities in Malang city. It has the second largest number of student after Brawijaya University (UB) with the growing number of students each year, resulting in increase the amount of motorized vehicle usage on campus. The State University of Malang condition shows the number of motorcycles in the provided parking area exceeded the capacity, causing the emergence of the improperly parking area. The condition causes the increase of mileage for vehicles that do not get a parking space. They must find and move to another parking area were still empty. The movement to another parking area resulted in the increase of exhaust emissions from motorized vehicles into the air. The main purpose of the research was to create alternative scenario of greenhouse gas emissions reduction in the State University of Malang. Alternative emission reduction based on strategies of Avoid-Shift-Improve (A-S-I), and the importance level of alternative determined with Multi Criteria Analysis (MCA). The result showed that selected alternative in emission reduction with the highest score of 40 per cent was centralized parking management.

1. Introduction

The convention resulted in the consent of The Kyoto Protocol by reducing the amount of greenhouse gas emissions generated from various sources so as not to exceed the limits set. In The Kyoto Protocol, there are sections Annex A and Annex B. The Annex 'A' section mention types of Greenhouse Gases (CO₂, CH₄, N₂O, HFCs, PFCs, and SF₆) along with the source of the producer. While in Annex 'B' there is a list of member countries of The Kyoto Protocol which amounts to 39 countries [1]. Indonesia was not a member of The Kyoto Protocol, so it has no obligation to reduce its emissions.

The Government of Indonesia participates in efforts to reduce the effects of Greenhouse Gases. In an effort to fulfil the greenhouse gas emission reduction commitment at the G-20 meeting in Pittsburg, the Government of Indonesia has prepared steps to be taken in [2] on the National Action Plan for Greenhouse Gas Emission Reduction (RAN-GRK). Greenhouse gas emissions reductions in Indonesia for 2020 are targeted at 26% and 41% if there is international assistance. One of the sectors included in the greenhouse gas reduction section is the energy sector. Transportation sector is part of the energy sector in the calculation of greenhouse gas emissions, because in the use of transportation means energy is always needed as a driving force [3, 13]. CO₂ emission reductions are targeted at 0.008 Giga tons (26%) and 0.011 Giga tons (41%) for energy and transportation. Some policies related to the transport sector include reducing the need for travel (avoid), shifting the model of private vehicle use into the model of low carbon transport such as non-motorized transport and public transport (shifts), and increasing energy efficiency and reducing carbon expenditure on motor vehicles (improve).

RAN-GRK is a guideline for the making process of greenhouse gas reduction plans. East Java Province has issued East Java Governor Regulation No. 67 of 2012 on Regional Action Plan for Greenhouse Gas Emission Reduction East Java Province. Malang city has a number of college institutions that became the goal of many prospective students continue their studies. Some of the existing universities are Brawijaya University, State University of Malang, State Islamic University of



Malang, National Institute of Technology, University of Islam Malang, State Polytechnic of Malang, and several other universities [4]. Due to the high number of students whose can be accommodated by the existing universities in Malang resulting in an increase number of motorists (student). The increase in the number of motor vehicles is always followed by the rising level of fuel oil consumption as the driving force of motor vehicles that will eventually cause an increase in the amount of exhaust gas in the air. This also happened to the State University of Malang which has 24,989 undergraduate students in 2015, State University of Malang is in second place after Brawijaya University with the number of undergraduate students 50.015 students [5].

Some problems arise such as increasing the number of students at the State University of Malang each year. The number of students in the State University of Malang increased by 8,287 people from 2013 to 2014 [6]. The increasing number of students resulted in an increase in the number of motor vehicles within the campus. The use of motor vehicles, the amount of emissions discharged into the atmosphere also increased. Impacts that occur due to emissions of motor vehicle exhaust are the emergence of air pollution and the number of motorcycles parked in the parking area provided by the State University of Malang exceeds the existing parking capacity (Field Survey, 2017). Due to this reason, the path that originally for pedestrians closed and replaced into a parking area. Moreover, when the number of vehicles is excessive, it is anticipated by the impromptu parking area at the location that was originally not destined for parking vehicles (Parking Section in the State University of Malang). These conditions cause the increase of vehicles mileage that does not get parking spaces. They had to find and move to another empty parking area. Moving to another parking area leads to an increase in the exhaust from the vehicle to the air. This study was conducted to determine how much greenhouse gas emissions mainly generated from motor vehicles in the campus area and provide an alternative reference for the reduction of greenhouse gas emissions in the State University of Malang.

2. Methods

The research location is at the State University of Malang with the boundary of Ambarawa Road in the West, Veteran Road in the North, Senior High School Laboratory of State University of Malang (UM) and Jakarta Road in the East, and Terusan Surabaya Road in the South. State University of Malang has 4 main gates as access to and exit of the Veterans Gate (entrance and exit), Semarang gate (entrance and exit), Gate of the Surabaya Canal (entrance point), and Ambarawa Gate (special entrance and exit of motorcycle / MC). The map of The State University of Malang is shown in figure 1.

2.1. Origin destination matrix

Origin destination matrix is a two-dimensional matrix that contains information about the amount of movement between locations (zones) within a certain area. The line represents the origin zone and the column represents the destination zone, so its matrix cell represents the amount of current from the origin zone to the destination zone [7]. Examples of matrix form of origin of destination can be seen in table 1.

Table 1. Origin Destination Matrix.

Zone	Zone				O_i	A_i
	1	2	3	n		
1	T_{11}	T_{12}	T_{13}	...	O_1	A_1
2	T_{21}	T_{22}	T_{23}	...	O_2	A_2
3	T_{31}	T_{32}	T_{33}	...	O_3	A_3
n	T_{nn}	O_n	A_n
D_d	D_1	D_2	D_3	D_n	Σ	
B_d	B_1	B_2	B_3	B_n		

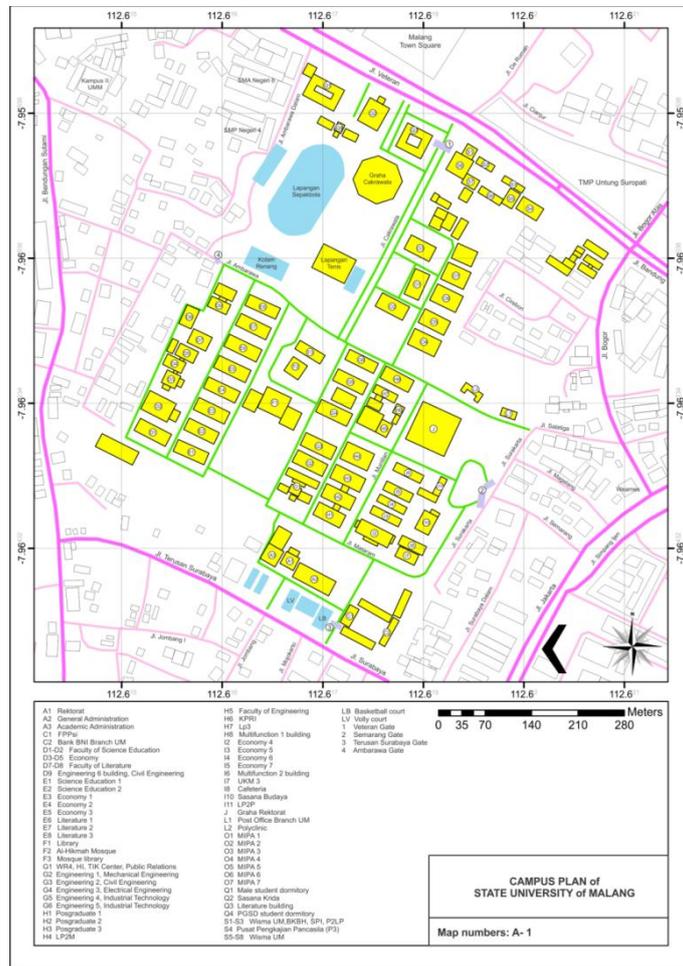


Figure 1. Research location.

It is necessary to set up some data such as data on the number of vehicles, the data capacity of parking, and the data mileage to create an origin destination.

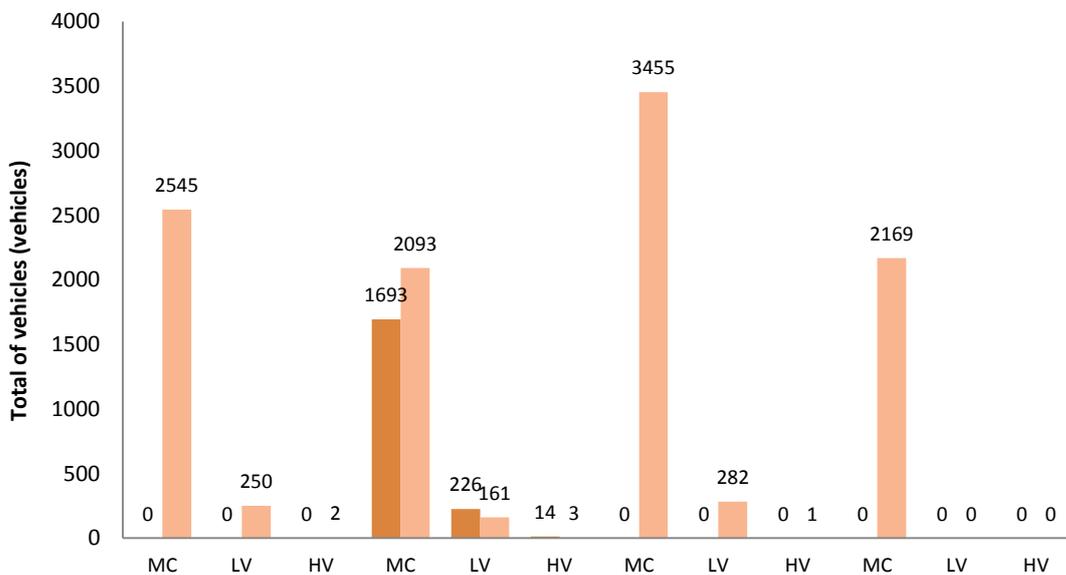


Figure 2. Total vehicles recapitulation

The number of vehicles data obtained through the primary survey is the recording of the number of vehicles entering the State University of Malang through the main gates. Recording is done on Wednesdays and Saturdays with three shifts: morning shift (06.15 am - 07.45 am), afternoon shift (11.45 am - 13.15 pm), and evening shift (15.00 pm -16.30 pm). The selection of days and hours obtained from the results of the initial survey. The results of the survey of vehicle numbers are shown in figure 2.

Parking capacity is shown in table 2. The parking area is divided into 3 types: student parking area (P code), parking area of lecturer / employee (Q code), and other parking area (R code).

Table 2. Parking capacity (Vehicles).

Code	Location	Capacity		
		MC	LV	HV
P1	Gombang Road	537	-	-
P2	MIPA I	426	-	-
P3	MIPA II	725	-	-
P4	MIPA III	-	33	-
P5	MIPA IV	-	40	-
P6	Center (near monument)	1066	-	-
P7	Block D (near pool)	1052	-	-
P8	Block D (north of the mosque)	336	-	-
P9	Block D (car)	-	96	-
P10	Ambarawa Gate	1087	-	-
P11	Back of The Economy	940	-	-
P12	Economy (car)	-	33	-
P13	C Block (economy)	440	-	-
P14	D2 (car)	-	9	-
P15	VIP (motorcycle)	645	-	-
P16	VIP (car)	-	75	-
P17	G3 – G4 car	-	37	-
P18	G2 Mechanical Engineering	282	-	-
P19	A Block (car)	-	79	-
P20	A Block (motorcycle)	619	-	-
P21	H Block (canteen)	627	-	-
P22	H Block (fence)	268	10	-
P23	P Block (Psychology)	370	-	-
Q1	Civil Engineering side	-	7	-
Q2	South of the Mosque I	36	4	-
Q3	Across the economy	90	6	-
Q4	H6 (KPRI)	-	15	-
Q5	I5	21	32	-
Q6	Parking leader	-	14	-
R4	SLB	89	6	-
Total		9656	482	-

Distance data is the length of the road from each gate to each parking area at the State University of Malang. The value obtained initially has a unit of meter (m), so it needs to be converted to units of kilometer (Km). There are only two suitable places for parking that are R2 (outside parking of Graha Cakrawala) and E7-E8 (Building of Literature Faculty) for heavy vehicles. The full results are shown in table 3.

Table 3. The gate distance to the parking area (km).

MC				
Parking	Veteran Gate	Semarang Gate	Terusan Surabaya Gate	Ambarawa Gate
P1	0,042	1,013	0,904	0,531
P2	0,159	0,956	0,845	0,475
P3	0,188	0,987	0,878	0,508
P6	0,342	0,689	0,578	0,246
P7	0,396	0,75	0,541	0,169
P8	0,412	0,768	0,659	0,179
P10	0,56	0,963	0,853	0,026
P11	0,774	0,749	0,637	0,345
P13	0,709	0,683	0,573	0,281
P15	0,83	0,576	0,464	0,401
P18	0,603	0,482	0,37	0,572
P20	0,75	0,262	0,152	0,652
P21	0,901	0,101	0,24	0,8
P22	0,87	0,072	0,268	0,772
P23	0,903	0,337	0,009	0,803
Q2	0,508	0,865	0,754	0,274
Q3	0,655	0,584	0,473	0,349
Q5	0,634	0,244	0,272	0,53
R4	0,854	0,287	0,062	0,754
LV				
Parking	Veteran Gate	Semarang Gate	Terusan Surabaya Gate	
P4	0,21	1,01	0,899	
P5	0,183	0,854	0,742	
P9	0,413	0,768	0,658	
P12	0,655	0,73	0,617	
P14	0,752	0,641	0,53	
P16	0,723	0,52	0,398	
P17	0,947	0,553	0,438	
P19	0,742	0,28	0,169	
P22	0,87	0,072	0,268	
Q1	0,529	0,86	0,748	
Q2	0,508	0,865	0,754	
Q3	0,655	0,584	0,473	
Q4	0,509	0,273	0,405	
Q5	0,634	0,244	0,272	
Q6	0,793	0,329	0,218	
R4	0,854	0,287	0,062	
HV				
Parking	Veteran Gate	Semarang Gate	Terusan Surabaya Gate	
R2	0,226	0,827	0,722	
E7-E8	0,565	0,85	0,738	

2.2. CO₂, CH₄, and N₂O Emission

Greenhouse gases are the atmospheric gases and cause the greenhouse effect that is where the infrared radiation of the reflected sun cannot escape from the atmosphere causing the earth's surface temperature to rise [2]. This study selected CO₂, CH₄, and N₂O gases because it is a type of gas from fossil fuel combustion from motor vehicles that is directly the cause of greenhouse gas [8]. Fuel consumption is the amount of fuel used by motor vehicle to travel a certain distance. Fuel

consumption values for motors (MC), light vehicles (LV), and heavy vehicles (HV) are obtained through sales brochures, manufacturing sites, and other sites that test fuel consumption. The fuel consumption value of motor vehicles is shown in table 4.

Table 4. Fuel Consumption of Vehicles Recapitulation.

Average of Fuel Consumption		
Type		Fuel consumption lt/km
Motorcycle	M	0,0251
	C	
Light Vehicles	LV	0,0866
Hight Vehicles	H	0,1667
	V	

In this study, the types of fuel used are Pertamina (Gasoline) and Solar (Diesel Fuel). The CO₂, CH₄ and N₂O emission factors for both types of fuel are shown in table 5.

Table 5. Emission Factor of CO₂, CH₄, and N₂O.

Fuel	CO ₂ (ton/GJ)	CH ₄ (g/GJ)	N ₂ O (g/GJ)
Pertamax	0,069	5,00	0,60
Solar	0,074	5,00	0,60

The result of the origin destination matrix shows the number of distribution vehicles to each parking area. Based on [8], the number of vehicles acquired and then entered (Equation 1) to calculate the fuel used by all motor vehicles entering the State University of Malang.

$$Fuel = \sum_{i,j} (V_{i,j} \cdot Di_{i,j} \cdot Ci_{i,j}) \quad (1)$$

Notes:

Fuel = Total fuel (Lt)

V_{i,j} = Total vehicles (vehicles)

Di_{i,j} = Vehicles mileage (Km)

Ci_{i,j} = Fuel consumption (Lt/Km)

i = Type

j = Fuel type

Since the emission factor has a Kg/GJ unit, the amount of fuel having a unit Liter (Lt) is converted to Giga Joule (GJ) units using a conversion factor of 1 Liter of fuel to Joule (table 6). The amount of fuel obtained, put into Equation 2 to calculate the amount of CO₂, CH₄, and N₂O emissions.

Table 6. Conversion Factor of Fuel.

Fuel Type	Conversion 1 Lt of Fuel (GJ)
Gasoline	0,0322
Diesel Fuel	0,0359

$$Emission = \sum_a (Fuel_a \cdot EF_a) \quad (2)$$

Notes:

Emission = Total emission (Kg)

Fuel = Fuel used (GJ)

EF = Emission factor (Kg/GJ)

a = Fuel type

2.3. Multi Criteria Analysis

Data and information from various sources, alternative choices, and assessments are required to make decisions. The difficulty is the existence of various criteria in choosing or determining alternatives, opposing goals, and improper decision makers. The Multi Criteria Analysis method emerges as an aid to decision makers in establishing alternatives that have multiple criteria [9,10].

In this study the decision makers (expert) are the people who participate in the determination of regulations and understand about the condition of transportation at the State University of Malang. Some of the resource persons encountered by researchers are:

- Head of Household Subdivision
- Head of Law and Administration Subdivision
- Head of Sub Administration.
- Head of Planning Sub-division
- Head of Planning and Information System
- Members of the security guard
- Posko Satpam Admin Staff
- Head of Center for Research and Dedication for Environment and Natural Disaster Management (P3LHMBA) of The State University of Malang (UM).

Table 7. Important Level.

Important Level	Definition
1	Just as important
3	Quite important
5	Important
7	Very important
9	The most important
2,4,6,8	The level of importance between the values above
The opposite value above	The value of importance is seen from the opposite direction

The experts filling out questionnaire about comparison of interest rates between alternatives and their importance, as shown in table 7. The next comparison results will be incorporated into a pair wise comparison matrix to obtain priority values.

3. Result and Discussion

3.1. Origin destination matrix

Table 8 shows the distribution of the result matrix of destination matrix on Wednesday. The total value for each gate is equal to the number of motors (MC) entering the State University of Malang in figure 2. The calculation results of motor distribution (MC) and then made into a Map of Motor Destination (MC). Specified five segments for the number of vehicles that indicated by line thickness. The thicker the line means the number of vehicles going to the parking lot more and more. Next the line is drawn from the entrance gate as the origin of the movement and ends at the destination parking area.

3.2 Emission of CO_2 , CH_4 , and N_2O

Equation 1 generates the total fuel amount of vehicles entering the State University of Malang on Wednesday; Motor (MC) uses the most fuel of 50.9 Litre, followed by light vehicles (LV) of 20.2 Litre, and heavy vehicles (HV) of 0.6 Litre. While on Saturday the motor (MC) is still the largest fuel user with 28.6 Litre followed by light vehicle (LV) with 11.2 Litre. Heavy vehicles (HV) on Saturday experienced an increase in fuel consumption of 1.9 Litre, due to the number of heavy vehicles entering the State University of Malang more than Wednesday. The amount of fuel used is shown in figure 3.

Table 8. Motor Distribution (MC) on Wednesday.

Parkir	Wednesday			
	Veteran Gate	Semarang Gate	Terusan Surabaya Gate	Ambarawa Gate
P1	537	0	0	0
P2	426	0	0	0
P3	725	0	0	0
P6	857	0	0	109
P7	0	0	0	549
P8	0	0	0	175
P10	0	0	0	567
P11	0	0	0	490
P13	0	0	0	229
P15	0	15	1087	2
P18	0	6	478	0
P20	0	17	1047	0
P21	0	1406	0	0
P22	0	601	0	0
P23	0	0	634	0
Q2	0	0	0	19
Q3	0	1	57	29
Q5	0	47	0	0
R4	0	0	152	0
Total	2545	2093	3455	2169

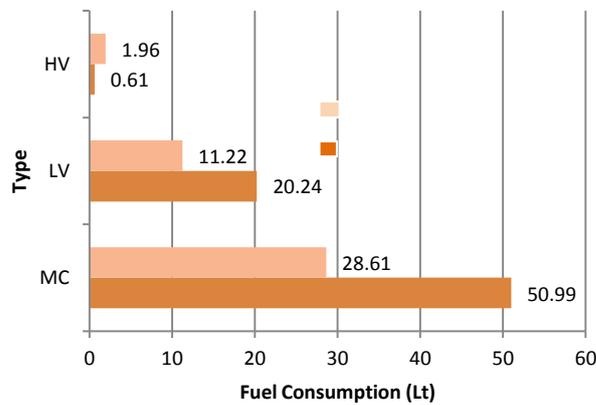


Figure 3. Total fuel consumption.

To get the average emission value per hour, the value divided by 4.5 hours (table 9). The average emission value is then multiplied by the number of working hours at the State University of Malang. Based on [14] on working days and hours at the State University of Malang, working hours are from 07.00 am to 16.00 pm (9 hours).

Table 9. Total Emission per hour.

Type	Total Emission (Kg)					
	CO ₂		CH ₄		N ₂ O	
	Wednesday	Saturday	Wednesday	Saturday	Wednesday	Saturday
MC	25,18	14,13	0,00182	0,00102	0,00022	0,00012
LV	9,99	5,54	0,00072	0,00040	0,00009	0,00005
HV	0,36	1,16	0,00002	0,00008	0,00000	0,00001
Total	35,53	20,83	0,00257	0,00150	0,00031	0,00018

3.3 Alternative to reduce CO₂, CH₄, N₂O emission

Based on the results of the questionnaire survey on the level of importance, then searched the average score so as to get one value as input in a matrix of pairwise comparisons. The research used the average equation of geometry in Equation 5 to obtain the input value. Table 10 shows stakeholder's opinion for alternative selection.

$$a_{ij} = (z_1, z_2, \dots, z_n)^{1/n} \quad (3)$$

Notes:

- a_{ij} = The average value of the opinion of expert
 z_n = Expert opinion
 n = Total expert

Table 10. Pairwise comparison matrix.

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Alt. 1	1	0,867	0,454	3,784
Alt. 2	1,153	1	0,837	4,587
Alt. 3	2,201	1,195	1	5,002
Alt. 4	0,264	0,218	0,200	1
Σ	4,619	3,281	2,491	14,373

After pair wise comparison matrices are made, and then the value is summed per column for subsequent normalization. The results of normalization then added per line, to get the Priority (Priority Vector) value of each Alternative (table 11).

Table 11. Alternative Priority Value.

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Priority Vector
Alt. 1	0,217	0,264	0,182	0,263	0,232
Alt. 2	0,250	0,305	0,336	0,319	0,302
Alt. 3	0,477	0,364	0,401	0,348	0,398
Alt. 4	0,057	0,066	0,080	0,070	0,068
Σ	1,000	1,000	1,000	1,000	1,000

Consistency Index gets value $0.01 < 0.1$. While the ratio of consistency with random index value for 4x4 matrix of 0.9, gets the value of Consistency Ratio $0.011 < 0.1$. From the result of consistency check, it can be concluded if the opinion of the informants related to alternative selection is consistent. Furthermore, the priority level of Alternatives can be ranked from the highest percentage to the lowest as follows:

- Alt. 3 Centralized parking management 40 percent
- Alt. 2 Increase in non-motorized infrastructure investment 30 percent
- Alt. 1 Reduction of travel distance 23 percent
- Alt. 4 Hourly parking fee 7 percent

4. Conclusion

The total emissions for Wednesday are 319.79003 Kg of CO₂, 0.02316 Kg CH₄, and 0.00278 Kg of N₂O. While total emission of CO₂ for Saturdays are 187.42971 Kg, 0.01353 Kg CH₄, and 0.00162 Kg of N₂O. Alternative sequences of CO₂, CH₄ and N₂O emissions reductions from motor vehicles at the State University of Malang are centralized parking management, additional non-motorized infrastructure investment, reduced travel distance and hourly parking fees.

5. Acknowledgements

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