Effectiveness of engine tune up and maintenance of Bangkok's public buses operating by private operators to reduce emission and save energy

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Abstract

The private buses joint with Bangkok Mass Transit Authority (BMTA) are in use of very old and overload engine including out of good maintenance. This causes of high fuel consumption and high emission of air pollutants. The objectives of this project are (a) to study the benefits in terms of emissions rates, fuel consumption and related costs from engine tune-up or overhaul and preventive maintenance programs in the privately-run buses and (b) to compare the results from two different groups-private buses with existing tune up or overhaul and maintenance by themselves and private buses with tune up or overhaul by car manufacturer included preventive maintenance program.

The summary of this study show overhaul engine by manufacturer included preventive maintenance program is the most benefit that can reduce emission of private buses at least 40%, 20%, 55%,15% and 27% for CO, HC, PM, Black smoke and Opacity respectively. Moreover, daily fuel consumption rate is reduced at least 9%. In addition, economic analysis shows that this option will give a maximum value of NPV, B/C ratio and IRR to private bus operators compared with other options. Whereas, engine tune up included preventive maintenance program will have a maximum benefit considering as a cost-effectiveness of emission reduction, fuel consumption reduction and a maximum NPV per one cost unit.

Key words : Overhaul, Preventive maintenance, Tune up, Fuel consumption

1.Introduction

The private buses in Bangkok Metropolitan Administration (BMA) and vicinity areas are highly operating everyday and facing with very hard traffic condition leading to overload engines. If the engines have no very good engine tune up and out of good maintenance approximately, therefore, the engines could emit high emission and lead to high fuel consumption. The study of Emission Source in BMA and vicinity areas in 1997 have concluded mobile sources are the most importance emission source in BMA and vicinity areas that presented NO_x (80%) , CO (75%) , TSP (54%) and HC (100%) (PCD,2001).

The existing situation of fuel crises in the world leads to high operating cost of private operators. Therefore, they need to concern and focus on how to save that kind of operating cost as much as possible. Saving fuel consumption should be considered firstly to reduce the operating cost and engine tune up and maintenance is the importance measure that need to be implemented continually. Thailand government by the Pollution Control Department (PCD) has been conducted and implemented the Effectiveness of engine tune up and maintenance of Bangkok's public buses operating by private operators for emission reduction and energy saving project with the objectives to encourage the private operators to concern and understand how benefit and importance of engine tune up and maintenance program routinely leading to saving fuel consumption.

2.Related work and similar studies

The Petroleum Authority of Thailand (PTT) has been promoted an engine tune up and maintenance project with a target group as passenger cars which are using diesel and gasoline engines. The results of the project show engine tune up and maintenance can reduce fuel consumption as 7% per each car including it can reduce emission as 18.5 % to 54.8 %.In addition, the engines would have high efficiency performance and have a long life after tuning up and maintenance engine.(PTT,2001) Moreover, a research study of turning up and maintenance engine in Indonesia found that a very good tune up and maintenance engine can reduce fuel consumption as 9 % and also can reduce emission as 22%.(Paul Butarbutar,2000)

3.Objectives

The objectives of this project are (a) to study the benefits in terms of emissions rates, fuel consumption and related costs from engine tune-up or overhaul and preventive maintenance programs in the privately-run buses and (b) to compare the results from two different groups-private buses with existing tune up or overhaul by themselves and private buses with tune up or overhaul by car manufacturer.

4.Methods and materials

4.1 Research Design

The results of the research project will be used to evaluate and solve the air pollution problems especially automotive air pollution. The relation between reduction of emission and fuel consumption and engine tune up and maintenance would be benefit to implement to private operator and any organization in order to better air quality in Bangkok and any mega cities in Thailand.

4.2 Selection of vehicles

20 private's buses which are using pre-EURO I standard engines were selected as vehicle samples.The vehicles were devided into 2 groups as shown in Fugure 1.

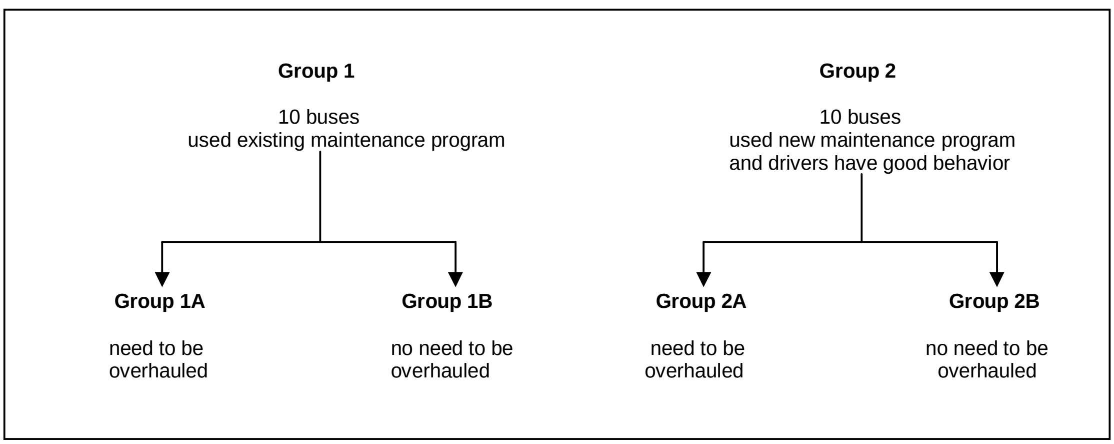


Figure 1 Groups of Vehicle samples

4.3 Variable Parameters

(1) Fuel consumption
(2) Emission rate such as black smoke, Particulate matter(PM),hydrocarbon (HC),carbon monoxide (CO) and nitrogen dioxide (NOx)
(3) Any operation cost

4.4 Emission and fuel consumption testing

Emission and fuel consumption testing were done on chassis dynamometer system at PCD's Emission Laborlatory using 3 differences driving cycles that are US Heavy Duty Transient Computer Control Cycle (USHDTCC cycle), Central Business District Cycle (CBD Cycle) and

New York Bus Cycle (NYBC).Those kind of driving cycle are very good represents of driving pattern in any mega cities or urban areas appropriately because they are composting with start and stop activities including low speed average. The example of driving cycle is shown in Figure 2.

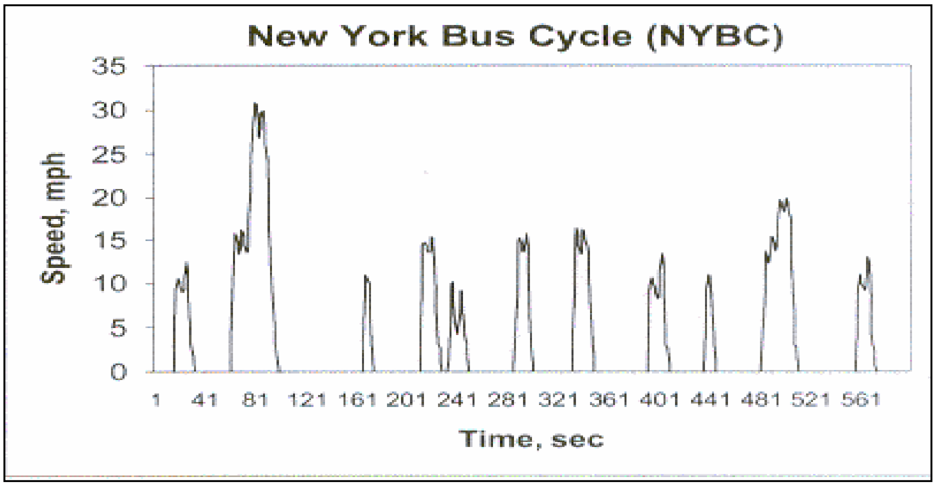


Figure 2 New York Bus Cycle (NYBC) Driving Cycle

4.5 Methods and Testing Plan

(1) The buses were sampling to conduct and study a very good engine tune up and maintenance standard method in order to reduce emission and fuel consumption.

(2) Basic information related with buses,emission testing and operation cost were collected by using questionair before stating the research project as following:

2.1) Fuel consumption data
2.2) Vehicle travelling per day per vehicle
2.3) Black smoke data measuring by PCD
2.4) Operation cost of each vehicle such as maintenance cost,spare parts cost,fuel cost,income and expend of each vehicle per month or year
2.5) Emission testing results on chassis dynamometer

(3) Starting tune up and maintenance program following study plan as shown in Table 1 and Table 2.

Table 1 Group 1 Buses that follow existing Maintenance Program

Duration Time	Study Plan	
	Group 1A	**Group 1B**
	1. Emission and Fuel consumption Testing on Chassis Dynamometer	
4 **Months**	**2.Buses are operating commonly and following existing maintenance program** 2.1 Black smoke (Filter system) / every week 2.2 Collecting data such as fuel consumption, fuel cost and operation and maintenance cost	
	3. Emission and Fuel consumption Testing on Chassis Dynamometer	
	4. Engine overhaul, tune up and maintenance following existing maintenance program of private operators	**4. Engine maintenance following existing maintenance program of private operators**
	5. Emission and Fuel consumption Testing on Chassis Dynamometer	
4 **Months**	**6.Engine maintenance following existing maintenance program of private operators** 6.1 Black smoke (Filter system) every week 6.2 Collecting data such as fuel consumption, fuel cost and operation and maintenance cost	
	7.Emission and Fuel consumption Testing on Chassis Dynamometer	
3 **Months**	**8.Engine maintenance following existing maintenance program of private operators** 8.1 Black smoke (Filter system) every week 8.2 Collecting data such as fuel consumption, fuel cost and operation and maintenance cost	
	9.Emission and Fuel consumption Testing on Chassis Dynamometer	

Table 2 Group 2 Buses that follow the Preventive Maintenance Program

Duration Time	Study Plan	
	Group 2 **A**	**Group** 2 **B**
	1.Emission and Fuel consumption Testing on Chassis Dynamometer	
4 **Months**	**2.Buses are operating commonly and following existing maintenance program** 2.1 Black smoke (Filter system) / every week 2.2 Collecting data such as fuel consumption, fuel cost and operation and maintenance cost	
	3.Emission and Fuel consumption Testing on Chassis Dynamometer	
	4.Engine overhaul, tune up by manufacturer and preventive maintenance program	**4.Engine tune up by manufacturer and preventive maintenance program**
	5. Emission and Fuel consumption Testing on Chassis Dynamometer	
4 **Months**	**6.Buses are operating commonly and following preventive maintenance program** 6.1 Black smoke (Filter system) / every week 6.2 Collecting data such as fuel consumption, fuel cost and operation and maintenance cost	
	7. Emission and Fuel consumption Testing on Chassis Dynamometer	
3 **Months**	**8.Buses are operating commonly and following preventive maintenance program** 8.1 Black smoke (Filter system) / every week 8.2 Collecting data such as fuel consumption, fuel cost and operation and maintenance cost	
	9.Emission and Fuel consumption Testing on Chassis Dynamometer	

5.Results and discussions

5.1 Emission testing, Fuel consumption and Engine power testing

5.1.1 Emission testing and Fuel consumption

Emission testing and fuel consumption were done on chassis dynamometer system at PCD's Emission Laboratory in Pathumthanee province where is 50 kilometers from BMA.The emission results are presented in gram per kilometers and changing of concentration in percent (%) of each pollutant of tested vehicle was compared to evaluate the research study.For fuel consumption that be presented in kilometer per litre,changing in percent (%) of each tested vehicle between before and after following the tune up and maintenance program was evaluated.The average of the results of each sample group are the represent of each sample group as shown in Table 3 ,Figure 2 and Figure 3.

Table 3 Average Changing of Emission and fuel consumption of each sample group

Group	Duration Time	Average Changing rate (%)				
		CO	HC	NOx	PM	Fuel consumption
1A	Compared with before O/H					
	after O/H	-46.83	-31.69	-5.77	-24.81	-6.69
	after O/H 4 months	-36.46	14.66	20.64	-41.64	-4.03
	after O/H 7 months	-16.47	32.49	44.95	2.09	8.06
1 B	Compared with before starting research project					
	after project 4 months	12.97	0.03	5.57	53.67	-11.55
	after project 11 months	-9.72	66.13	-30	9.36	-16.67
2 A	Compared with before O/H					
	after O/H	-54.99	-36.01	8.24	-63.79	-26.22
	after O/H 4 months	-57.74	-43.17	-57.93	-54.52	-31.23
	after O/H 7 months	-39.73	-19.99	29.47	-66.93	-20.00
2 B	Compared with before tune up					
	after tune up	-12.98	5.93	-9.54	-24.53	-6.77
	after tune up 4 months	-16.63	17.88	11.63	-52.87	-9.13
	after tune up 7 months	-25.00	35.37	34.80	-42.45	-3.62

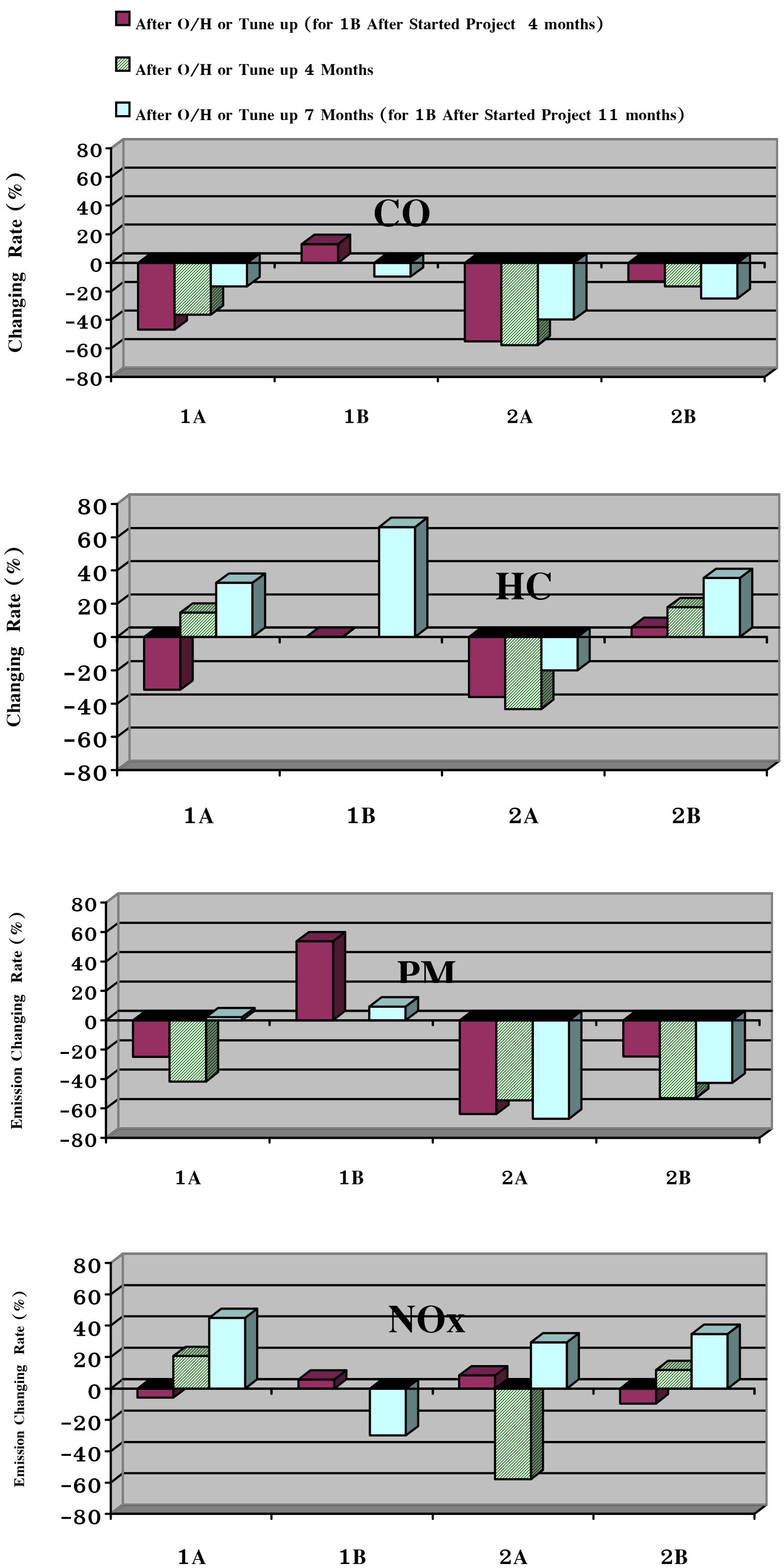


Figure 2 Average Changing rate of emission of each duration time compared with before O/H or tune up

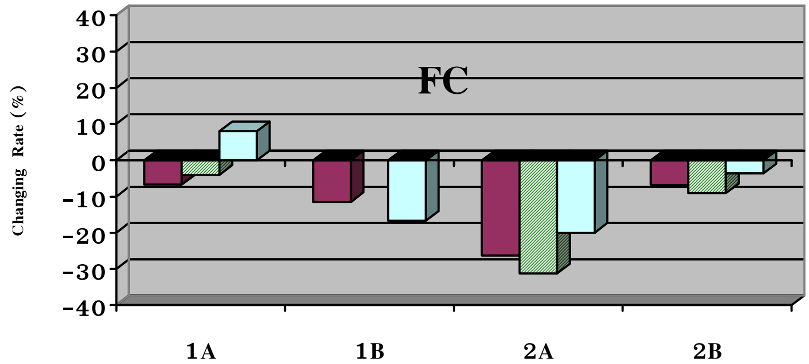


Figure 3 Average Changing rate of fuel consumption of each duration time compared with before O/H or tune up (For Group 1B compared with before starting the project)

5.1.2 Engine power testing

3 buses of eacg group were tested an engine power on chassis dynamometer after that the results of each vehicle group were evaluated in average percent changing (%) as shown in Table 4 and Figure 4.

Table 4 Changing rate (%) of engine power of each vehicle group

Group	Duration Time	Average Changing rate of engine power (%)
1A	**Compared with**	**before O/H**
	after O/H	1.53
	after O/H 4 months	2.5
	after O/H 7 months	3.07
1B	**Compared with before**	**stating research project**
	after project 4 months	-9.4
	after project 11 months	-33.3
2 A	**Compared with**	**before O/H**
	after O/H	-13.2
	after O/H 4 months	-3.36
	after O/H 7 months	1.71
2 B	**Compared with**	**before tune up**
	after tune up	7.92
	after tune up 4 months	14.24
	after tune up 7 months	11.44

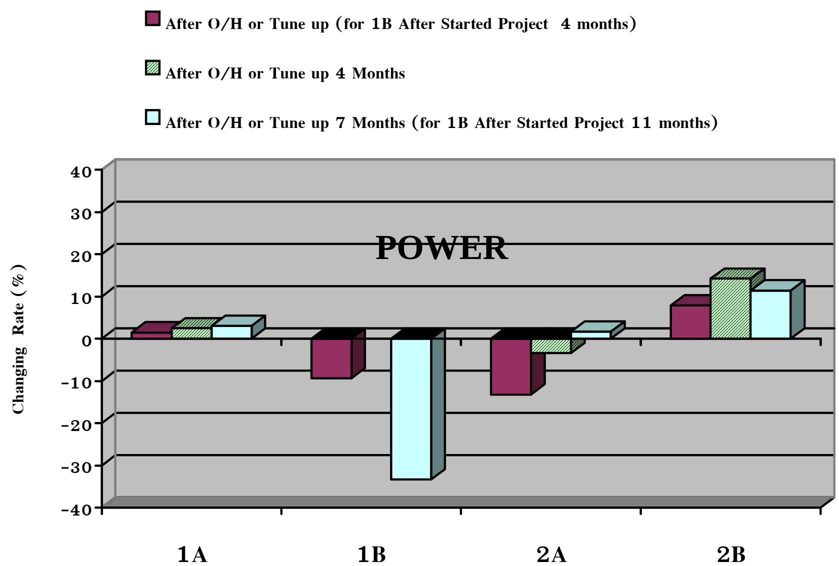


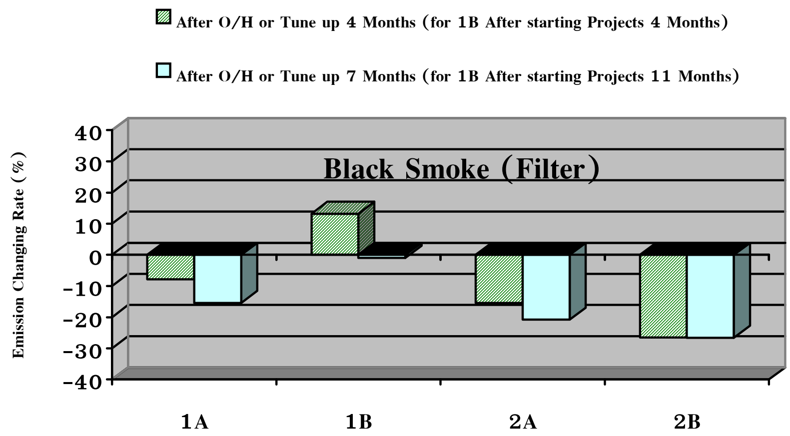
Figure 4 **Average Changing rate of engine power of each duration time compared with before O/H or tune up (For Group 1B compared with before starting the project)**

5.1.3 Black Smoke Testing

Black smoke testing was measuring every week during study period. Changing of black smoke of each vehicle group of each duration time was evaluated as shown in Table 5 and Figure 5.

Table 3 Average changing rate of Black smoke of each vehicle group

Group	Duration Time	Average changing rate (%)	
		Black smoke (Filter)	Black smoke (Opacity)
1A	**Compared with after project 4 months/before O/H**		
	after O/H 4 months	-7.9	-16.25
	after O/H 7 months	-15.45	-26.92
1 B	**Compared with before project**		
	after project 4 months	13.21	92.2
	after project 11 months	-0.94	72.19
2 A	**Compared with after project 4 months/before O/H**		
	after O/H 4 months	-15.43	-27.01
	after O/H 7 months	-20.83	-30.07
2 B	**Compared with after project 4 months/before tune up**		
	after tune up 4 months	-26.43	-31.78
	After tune up 7 months	-26.57	-13.66



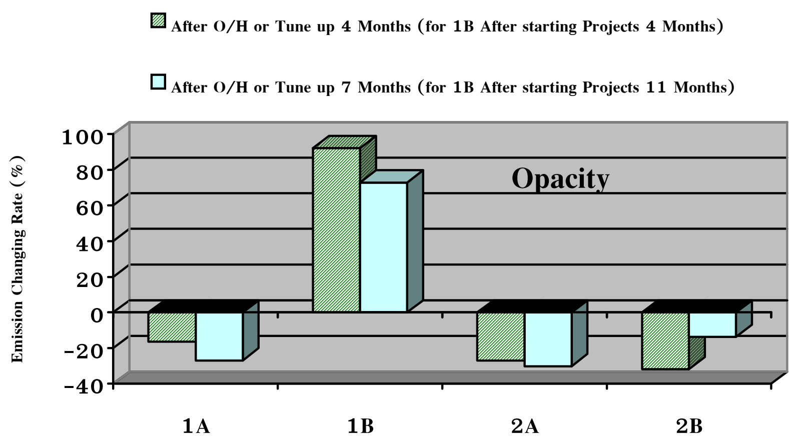


Figure 5 Average changing rate of Black smoke of each vehicle group per week

5.1.4 Fuel consumption per day

Fuel consumption per day of each vehicle group was recorded and the average fuel consumption per day of each vehicle group is shown in Table 6 and Figure 6.

Table 6 Fuel consumption per day

Group	Duration Time	Average changing Rate (%)
1A	**Compared with after project 4 months/before O/H**	
	after O/H 4 months	7.57
	after O/H 7 months	9.06
1B	**Compared with before project**	
	after project 4 months	4.2
	after project 11 months	0.59
2A	**Compared with after project 4 months/before O/H**	
	after O/H 4 months	-11
	after O/H 7 months	-8.76
2B	**Compared with after project 4 months/before tune up**	
	after tune up 4 months	-3.3
	After tune up 7 months	-5.31

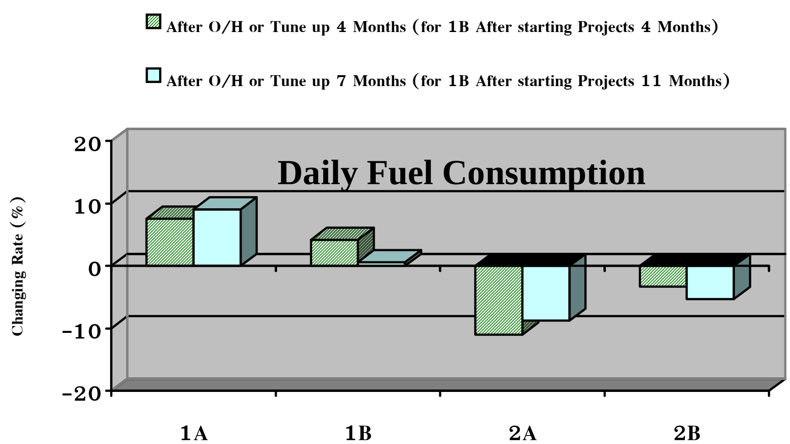


Figure 6 Fuel consumption per day of each vehicle group

6.Conclusions and Recommendations

6.1 Conclusions

The results of this research study show that overhaul engine and/ or tune up engine including maintenance engine with appropriate duration time lead to emission and fuel consumption reduction.It is also not affect to low engine power in a short and long term period. However,the maintenance of private’s buses may have difference standards and programs leading to difference of efficiency of emission and fuel consumption reduction including power engine.For this study,since there are 4 difference standard methods to overhaul and tune up engine,therefore,the efficiency of emission and fuel consumption reduction are differences as shown in Table 7 to Table 9.

Table 7 Results of Engine overhaul/tune up by difference methods

Parameters	Average changing rate (%)					
	1 A (Overhaul and maintenance by private operators)		2 A (Overhaul by manufacturer and Preventive Maintenance)		2 B (Tune up by manufacturer and Preventive Maintenance)	
	↑	↓	↑	↓	↑	↓
CO		47.0		55.0		13.0
HC		31.7		36.0	5.9	
NOx		5.8	8.2			9.5
PM		24.8		63.8		24.5
FC		6.7		26.2		6.8
Engine Power	1.5			13.2	7.9	

Table 8 Results of Engine overhaul/tune up after 4 months

Parameters	Average changing rate (%)							
	1 A		1B (existing maintenance program)		2 A		2 B	
	↑	↓	↑	↓	↑	↓	↑	↓
CO		36.5	13.0			58.0		16.6
HC	14.7		0.3			43.2	17.9	
NOx	20.6		5.6			58	11.6	
PM		41.6	53.7			54.6		52.9
FC		4.0		11.6		31.2		9.1
Engine Power	2.5			9.4		3.63	14.2	
FC/day	7.6		4.2			11		3.3
Black smoke (Filter)		8	13.2			15.4		26.4
Black smoke (Opacity)		16.3	92.2			27.0		31.8

Table 9 Results of Engine overhaul/tune up after 7 months

Parameters	Average changing rate (%)							
	1 A		1B		2 A		2 B	
	↑	↓	↑	↓	↑	↓	↑	↓
CO		16.5		9.7		39.7		25.0
HC	32.5		66.1			20.0	35.4	
NOx	45.0			30.0	29.5		34.8	
PM	2.1		9.4			67.0		42.5
FC	8.1			16.7		20.0		3.6
Engine Power	3.1			33.3	1.7		11.4	
FC/day	9.1		0.6			8.8		5.3
Black smoke (Filter)		15.5		0.9		20.8		26.6
Black smoke (Opacity)		26.9	72.9			30.0		13.7

(1) Engine overhaul and tune up following standard methods of manufacturers included preventive maintenance program (Group 2A),would benefit to reduce emission and save energy in both short and long time period.

(2) Engine overhaul and tune up following methods of private operators (Group 1A) would benefit in a short duration time to reduce emission and save energy respectively.However, if the engines have good maintenance oftenly ,the efficiency to reduce emission and save energy would be increased in a long time period.

(3) Engine tune up following manufacturer's maintenance program and engine maintenance by preventive maintenance program (Group 2 B) will benefit in a short time period to reduce emission and save energy that is lower than Group 2A.However,it will be benefited to reduce emission and save energy increasingly in a long time period that is lower than Group 1A.

(4) Engine overhaul and tune up following methods of private operators (Group 1B) after operating for a long time can cause of poor performance of engine, uncomplete combustion , low engine power and high emission.

6.2 Recommendations

(1) If private operators still using existing maintenance program to reduce emission and save energy, they should have preventive maintenace in order to reduce emission and save energy in a long time period.
(2) After overhauling or turning up engine for 7 months,the engine should be inspected and evaluated once.If the engine be found unusual, it need to be turned up oftenly following the methods of manufacturer and preventive maintenance program.
(3) In a short time period, if private operators have no budget to overhaul,they have to tune up engine following the preventive maintenance program in order to reduce emission and save energy.

(4) Government should establish and implemet mitigation measures in a long time period to reduce emission problem and save energy of BMTA's buses by using the preventive maintenance program in order to better air quality in Thailand and save energy.
(5) Engine tune up and maintenance following standard methods will benefit to reduce emission and save energy in short and long time period and it is also have low cost.Therefore,preventive maintenance program is proper measure in a short time period to reduce and save energy of BMTA's buses.

Economics Analysis

1.Benefit cost Analysis

1.1 Emission based unit (EBU)

To evaluate impcts and effects of diesel engine emission to evrionment such as NOx, CO,CO_2,HC and PM_{10}

1.2 Dose response function (DRF)

To evaluate impacts and effects of PM10 to environment focusing on medical expense and lost of working day of the people in study areas including premature mortality. by illness cost and lost opportunity caused of air pollution.

2.Net Present Value (NPV)

To calculate a benefit of the project between total benefit of the project and total budget of the project as following equations:

$$PV_B = PV_T (1 + I)^{-t} \qquad (1)$$

$$PV_c = PV_T (1 + I)^{-t} \qquad (2)$$

Where : PV_B= Total existing benefit
PV_c = Existing value of TC
PV_T = Total budget /total benefit at T year
I = reduction rate

3.Internal Rate of Return (IRR)

To calculate the benefit of this study by the following equation:

$$IRR= B_t / (1 + r)^t = 0$$

IRR will be calculated by trial and error method to find appropriate r valuae that make $B_t / (1 + r)^t = 0$

4.Cost effectiveness Analysis

To calculate a coefficient of marginal comparison of emission reduction rate,fuel consumption reduction rate and a benefit of existing budget of each mitigation measures.

5.Results

Table 1 Total Economic value of the project evaluated from emission reduction rate (Baht/year)

Group	Main polluting substance	Total Economic Value
$1A^1$	PM_{10} / NO_X / CO / CO_2 / HC	89,796,987.00
$1A^2$	PM_{10} / NO_X / CO / CO_2 / HC	81,170,945.00
$2A^1$	PM_{10} / NO_X / CO / CO_2 / HC	1.78E+08
$2A^2$	PM_{10} / NO_X / CO / CO_2 / HC	1.76E+08
$2B^4$	PM_{10} / NO_X / CO / CO_2 / HC	1.08E+08
$2B^5$	PM_{10} / NO_X / CO / CO_2 / HC	87,771,835.00
$1B^3$	PM_{10} / NO_X / CO / CO_2 / HC	73,668,748.00

Source : Calculated by the results on chassis dynamometer testing of each vehicle groups

Remarks : [1] Before overhaul, tune up / After overhaul, tune up 4 months
[2] Before overhaul, tune up / After overhaul, tune up 7 months
[3] After maintenance followed existing program 4 months / After maintenance followed existing program 11 months
[4] Before preventive maintenance, tune up / After preventive maintenance, tune up 4 months
[5] Before preventive maintenance, tune up / After preventive maintenance, tune up 7 months
: PM10, NO_X calculated by Emission Based Unit
: CO and HC calculated by Emission charge and taxs
: CO_2 calculated by Carbon sequestration value

Table 2 Fuel consumption before and after engine overhaul and tune up (Unit: litre/year)

Group	Based. of Fuel consumption (L/Year)	Changing of Fuel consumption (L/Year)	Difference of Fuel consumption (L/Year)	Percent of Difference (%)	Cost of difference value (Baht/Year)*
1A[1]	62,053,527	55,068,172	-6,985,355	-11.26	1.02E+08
1A[2]	62,053,527	52,797,015	-9,256,512	-14.92	1.35E+08
2A[1]	64,451,437	49,783,852	-1.5E+07	-22.76	2.19E+08
2A[2]	64,451,437	49,708,536	-1.5E+07	-22.87	2.19E+08
2B[4]	63,248,013	56,045,046	-7,202,966	-11.39	1.05E+08
2B[5]	63,248,013	53,835,078	-9,412,935	-14.88	1.37E+08
1B[3]	55,728,193	51,880,015	-3,848,178	-6.91	5,6144,917

Source : Calculated by the results on chassis dynamometer testing of each vehicle groups
Remark: Calculated by using total fuel that was sold in BKK since January to April 2004

Table 3 Cost of emission effects evaluated by DRF equation (Unit : Baht/year)

Group	Premature mortality[6]	respiratory hospital admission :RHA[7]	emergency room visit : ERV[8]	restricted activity days : RAD[9]	lower respiratory illness in children : LRI[10]
1A[1]					
High	4,704,900.00	10,934.41	1,170.50	1,630,343.00	3,023.19
Medium	3,474,387.00	8,798.75	856.34	10,38160.00	2,819.79
Low	2,311,088.00	5,577.45	542.18	729,429.80	2,557.44
1A[2]					
High	6,234,609.00	13,943.36	1,497.15	2,160,407.00	3,251.29
Medium	4,604,019.00	11,113.32	1,080.84	1,375,687.00	2,981.77
Low	3,062,495.00	6,844.68	664.54	966,579.40	2,634.12
2A[1]					
High	9,879,171.00	21,112.23	2,275.40	3,423,296.00	3,794.75
Medium	7,295,388.00	16,627.83	1,615.73	2,179,852.00	3,367.67
Low	4,852,735.00	9,863.87	956.07	1,531,593.00	2,816.79
2A[2]					
High	9,929,899.00	21,212.01	2,286.23	3,440,874	3,802.32
Medium	7,332,848.00	16,704.59	1,623.18	2,191,045	3,373.04
Low	4,877,654.00	9,905.90	960.13	1,539,457	2,819.33
2B[4]					
High	4,851,469.00	11,222.72	1,201.80	1,681,131	3,045.05
Medium	3,582,624.00	9,020.52	877.85	1,070,500	2,835.31
Low	2,383,084.00	5,698.87	553.90	752,152.4	2,564.79
2B[5]					
High	6,339,966.00	14,150.60	1,519.65	2,196,915.00	3,267.00
Medium	4,681,821.00	11,272.73	1,096.31	1,398,934.00	2,992.92
Low	3,114,247.00	6,931.96	672.97	982,912.7.00	2,639.40
1B[3]					
High	2,591,893.00	6,778.12	719.29	898,158.20	2,708.11
Medium	1,914,013.00	5,601.60	546.23	571,928.90	2,596.06
Low	12,73161.00	3,827.01	373.16	401,852.10	2,451.53

Remarks :

[3] After maintenance followed existing program 4 months / After maintenance followed existing program 11 months
[4] Before preventive maintenance, tune up / After preventive maintenance, tune up 4 months
[5] Before preventive maintenance, tune up / After preventive maintenance, tune up 7 months
[6] decrease number of population who are premature mortality affected from emssion in BKK and vicinity areas calculated by income cost
[7] decrease number of illness people affected from emission in bKK and vicinity areas
[8] decrease number of average of curing day (day) affected from emission
[9] income lost from working day off
[10] decrease number of illness children who affected from emission in bKK and vicinity areas based on 1,000 vehicles

Table 4 Summary of Coefficient of marginal comparison Ranking

Group	Coefficient of fuel consumption reduction Ranking	Coefficient of fuel consumption Ranking	Coefficient of benefit value Ranking
1A	-5990.4190 (2)	-17.7350 (3)	0.7730 (3)
1B	-7622.2660 (4)	-22.9310 (4)	1.0720 (4)
2A	-3166.5360 (1)	-9.4847 (1)	0.3893 (1)
2B	-7519.4827 (3)	-13.5323 (2)	0.6870 (2)

Remark : Calculated a coefficient of fuel consumption reduction of each vehicle group

Table 5 Summary of Economics Index Analysis

Group	NPV	B/C : Ratio	IRR	Equivalent Annual Cost
1A[1]	2.72E+08	1.79	15	1.12E+08
1A[2]	1.13E+08	1.18	2	2.07E+08
1B[3]	-2.2E+07	.93	62	1.0467E+08
2A[1]	9.80E+08	3.92	23	1.0464E+08
2A[2]	5.90E+08	1.91	23	1.99E+08
2B[4]	2.27E+08	1.66	17	1.13E+08
2B[5]	1.94E+08	1.44	12	1.44E+08

Remark : Duration time of project (n =5)
Calculated at 12 % rate
Based on 1,000 vehicles

6.Conclusions and discussions

6.1 Decission Making Index using NPV

(1) In case of accept / reject the project, if the NPV more than 0, the project will be acceptted, however, if the NPV less than 0, the project will be ejected. Based on those economics indexs, therefore, the study programs of vehicle group 1A, 2A and 2B are possibel to be acceptted.To make decission which programs will be chosen using NPV ranking,vehicle group 2A (following maintenance program appropriately by time and overhaul/tune up engine), 2B (following maintenance program appropriately by time but no overhaul/tune up engine) and 1A (following maintenance program appropriately by time and overhaul/tune up engine) will be chosen ordinary.
(2) In case of mutully exclusive projects, only one project will be acceptted and other projects will be ejected and the project that has the most NPV benefit will be

chosen.Therefore,vehicle group 2A (following maintenance program appropriately by time and overhaul/tune up engine) that can make the most NPV will be chosen and it make potential pareto improvement compared with other programs.

6.2 Decission Making Index using NPV

Typically,the projectes would be acceptted if the B-C ratio of those projectes more than 1.It means those projects will be benefit more than project budget or expense.The projects that have B-C ratio less than 1 will not be acceptted.For choosing project by using B-C ratio,vehicle group 2A (following maintenance program appropriately by time and overhaul/tune up engine) will be acceptted because this program has the most B-C ration that is more than 1.

6.3 Decission Making Index using IRR

Typically,the projects which have IRR higher than reduction rate /opportunity budget lost as 12 % will be acceptted.However,using IRR can cause of many problems such as multiple roots and negative capital problem.Based on IRR, vehicle group 2A (following maintenance program appropriately by time and overhaul/tune up engine) will be acceptted.

6.4 Appropriate Time to Maintenance

The results of study show NPV, B-C ratio, IRR and coefficient of marginal comparison of emission reduction and fuel consumption are related with duration time of engine operating conversely.It shows,appropriate time to tune up and overhaul engine including preventive maintenance will be the most benefit as subject to minimum cost and economics benefit.Beside that,it can reduce emission that affected to the people's health, environment and social cost.It is also the most efficiency program to save energy.

7.Recommendations

1.An engine tune up and preventive maintenance and management system of BMTA's buses should be promoted and developed especially standard maintenance program should be implemented including engine tune up and overhaul by time appropriately.

2.Economics tools should be applied such as emission charge and tax and emission trading to support private operators in order to emission reduction.

3.Conducting any research related to engine tune up/overhaul focusing on private operators.

4.An environment management system should be promoted and applied appropriately to private operators in order to control and reduce environmental problem.In addition,environmental performance indicators should be implemented using proper economics indexs.

5.Inspection and maintenance program should be implemented annually.Emission standards such as black smoke and noise level should be stricked especially buses of provate operators.

6.Promote ansd support to private operators to use alternative fuels such as biodiesel and dieselhol in order to emission reduction and save energy.

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