6.5 Sulfur Content of Crude Oil, Thailand

		Mbbl	ML	Sulfur W %
Domestic	Sirikit	8.728	1,388	0.110
	Bung Ya & Bung Muang	0.232	37	0.130
	Sub Total		1,425	
			Domestic Known/Total=1,425ML/3,368ML=0.42	
Import	Brunei Champion		443	0.120
	Seria Light		3,164	0.063
	Minas		48	0.081
	Anoa		32	0.040
	Belida		251	0.020
	Widuri		118	0.070
	Lalang		48	0.050
	Badak		5	0.032
	Tapis Blend		1,972	0.030
	Durang		450	0.120
	Labuan		1,115	0.070
	Bach-Ho		126	0.030
	Griffin		104	0.030
	Cossack		416	0.040
	Elang		66	0.030
	Nan Hai Light		553	0.059
	Iranian Light		1,486	1.350
	Basran Light		1,378	1.950
	Kuwai Crude		1,805	2.520
	Oman		5,268	0.940
	Khafuji		837	2.850
	Arabian Extra Light		1,500	1.150
	Arabian Light		913	1.770
	Abu Safah		80	2.850
	Arabian Medium		78	2.490
	Dubai		1,474	2.000
	Murban		3,994	0.780
	Upper Zakum		3,141	2.000
	Umm Shaif		84	1.510
	Qatar Marine		1,165	1.420
	Qatar Land		198	1.270
	Masila		4,338	0.670
	Forcados		162	0.180
	Cabinda		77	0.170
	Sub Total		36,889	
			Import Known/Total=36,889MLML/39,242ML=0.94	
			(Domestic+Import) Known/Total=38,324ML/42,610ML=0.90	

Average Sulfur = 1.01%

Data Source: Oil and Thailand 2000, DEDP
HPI Consultants. Inc.
Plat's Oil Guide to Specifications

6.6 Cost Estimation

6.6.1 Estimate Conditions

1) Estimated cost are economic costs

Costs are clearly separated from expenses. The evaluation framework is thus a least (economic) cost method and not an (financial) expenditure minimization. Financial components (or expenditure) are thus excluded from raw cost data. This means that taxes, fees, custom duties, subsidies and similar transfer items are excluded in order to arrive at economic costs.

2) Fixed Costs at constant prices at January 2002 price level

The cost rare estimates of the real cost in Thailand and are presented in constant prices on the cost level of in the beginning of year 2002. No future domestic or international inflation is thus assumed. There has not been any basis for the assumption of different price developments inside and outside Thailand in the future. Nor has there been a basis for projection of real cost increases or cost decrease for any specific items. In practice therefore, all future costs are based upon the prices in the beginning of year 2002.

3) Currency

In the study all costs are presented in local currency, Baht. Where costs are related to the use of international resources, the exchange rate used has been 1 USD= 43 Baht

4) Annual Cost and Total Costs

Two types of cost below are calculated in this study.

(1) Annual cost

For ranking of the proposed countermeasures, annual cost per ton (of reduction pollutant) is calculated as sum of annual capital cost, operation and maintenance cost. In these annual costs are included indirect costs for each countermeasure. In this way all capital costs are transformed to annualized costs with use of a discount rate of 4 per cent per year considering the current interest rate. Annual costs per vehicle and factory are calculated for most of the countermeasures.

(2) Total cost

The total costs of the proposed best mix of countermeasures, for instance, strategies are presented for the period between year 2000 and 2011, and include investments and annual operation and maintenance cost during the same period. No investments are included for the year 2012 or later. The total cost for the strategies of countermeasures are assumed

for projected investments that included in the total costs. Reinvestments are also assumed for projected investments are included.

The total economic costs are thus the sum of the following items related to the involved countermeasures:

- Investments;
- The sum of annual operation and maintenance costs;
- The sum of annual interest; and
- The sum of annual depreciation due to the assumed life of the investments.

The following indirect costs or positive costs (which could be called benefits) that are not included in the cost estimates because of insufficient information and data.

- reduced demand on health care as a result of reduce air pollutant related sickness such as asthma, cancer patients and other persons affected by poor air quality; and
- reduced corrosion of building, vehicles, industrial and private equipment due to improved air quality.

5) Cost Estimation Method – With-Without Analysis

With case (Countermeasure) - Without case (Business as Usual)
= Additional Cost for implementation of countermeasures

6) Cost for Business as Usual Scenario

In this study cost for the Business as Usual (hereafter "BAU") case up to year 2011 are not included. This means that the costs for the Metro or the cost for the currently planned development of the bus and street systems are not included in the calculations in this report. This can also be expressed as follows: these costs could be said to be included in all calculation sum, and then deducted at the end as being equal for the alternatives which are compared.

7) Residual Value after 2011

For some countermeasures, investments made during the period 2000-2011 will give residual value after the end of the period. In order to calculate economic cost for the ranking of countermeasures according to baht/ton, such residuals are of not important, as the economic costs are basically as annualized cost including annual capital costs. Therefore, there is no problem of residual value in this case.

6.6.2 Cost Estimation for the Countermeasures

For three countermeasures, i.e. reduction of sulfur content in fuel oil, flue gas desulfurization, and fuel shift to natural gas, the details of approximate estimation are summarized in Table 6.6.2.1. Based on the estimate conditions mentioned above, modification by production amount, plant size, and exchange rate are applied and estimated.

Table 6.2.2.1 (1) Cost Estimation

Reduction of Sulfur Content in Fuel Oil	
Referred Data	- Capital Investment: 880 Billion yen (at 1990 price, Japan's Experience in the Battle against Air Pollution) for 2.3Mbbl/D (Processed from Handbook of Energy & Economic Statistics in Japan, 2002) - Operating Cost: 11Billion yen for 7,000Million Litre (Showa Shell Sekiyu, 2001 Environment Report)
Modification by Plant Size	- Proportionate to fuel oil consumption
Yearly Cost	- Repayment of loan: 15-year equal repayment of a principal and interest - Depreciation cost: 15-year equal depreciation, 10% remnant - Maintenance cost: 3% of investment - Operating cost: According to modification by plant size
Fuel Oil Consumption in BMR	- 3,106Million Litre (2011 BAU case, Estimation by the JICA Study Team)
Flue Gas Desulfurization	
Referred Data:	- Capital Investment: 18,000 yen/kW for a fuel oil firing power station, 22,000 yen/kW (Yoichi Nishijima, Reengineering the Global Environment) - Operating Cost: 0.36 yen/kWH (Yoichi Nishijima, Reengineering the Global Environment)
Modification by Plant Size	- Capital Investment: Modified by the 0.7^{th} power (Empirical rule) - Labor cost: Modified by 0.64^{th} power (Matsui, Tuchida, Matsuoka, Morita, Integration of Computable General Equilibrium Model and End-use Model for Sewage Sludge Management) - Utility cost: Modified by 0.86^{th} power (Matsui, Tuchida, Matsuoka, Morita, Integration of Computable General Equilibrium Model and End-use Model for Sewage Sludge Management)
Yearly Cost	- Repayment of loan: 15-year equal repayment of a principal and interest - Depreciation cost: 15-year equal depreciation, 10% remnant - Maintenance cost: 3% of investment - Operating cost: According to modification by plant size

Table 6.2.2.2 (2) Cost Estimation

Fuel Shift to Natural Gas	
Referred Data	- Capital Investment: 7 MBht/km for branch pipeline (PTT) 1.5 MBht/boiler (PTT)
Yearly Cost	- Repayment of loan for investment by factory: 15-year equal repayment of a principal and interest (Because investment of branch pipeline is recovered by price, repayment for pipeline is not counted.) – Depreciation cost: 15-year equal depreciation, salvage value 10% – Maintenance cost: 3% of investment – Operating cost: Increment cost is not expected.
Energy Saving Merit	- 3% of fuel consumption (PTT)

7. Countermeasures for NO_2 in BMR

7.1.1 Method and Conditions of Cost Estimates for Countermeasures

7.1.1.1 Estimate Conditions

1) Estimated Cost

Costs are clearly separated from expenses. The evaluation framework is thus a least (economic) cost method and not an (financial) expenditure minimization. Financial components (or expenditure) are thus excluded from raw cost data using the conversion factor of 0.85. This means that taxes, fees, custom duties, subsidies and similar transfer items are excluded in order to arrive at economic costs.

2) Fixed costs at constant prices at January 2002 price level

The cost rare estimates of the real cost in Thailand and are presented in constant prices on the cost level of in the beginning of year 2002. No future domestic or international inflation is thus assumed. There has not been any basis for the assumption of different price developments inside and outside Thailand in the future. Nor has there been a basis for projection of real cost increases or cost decrease for any of the specific items. In practice therefore, all future costs are based upon the prices in the beginning of year 2002.

3) Currency

In the study all costs are presented in local currency, Baht. Where costs are related to the use of international resources, the exchange rate used has been 1 USD= 43 Baht

4) Total Cost and Annualised Cost

Two types of cost below are calculated in this study.

(1) Total cost

The total costs of the proposed best mix of countermeasures, for instance, strategies are presented for the period between 2000 and 2011, and include investments and annual operation and maintenance cost during the same period. No investments are included for the year 2012 or later. The total cost for the strategies of countermeasures are assumed for projected investments that included in the total costs. Reinvestments are assumed for projected investments are included. The total economic costs are the sum of the following items related to the involved countermeasures:

- Investments;
- The sum of annual operation and maintenance costs;
- The sum of annual interest; and
- The sum of annual depreciation due to the assumed life of the investments

The following indirect costs or positive costs (which could be called benefits) that is not included in the cost estimates because of insufficient information and data.

- reduced demand on health care as a result of reduce air pollutant related sickness such as asthma, cancer patients and other persons affected by poor air quality; and
- reduced corrosion of building, vehicles, industrial and private equipment due to improved air quality.

(2) Annualised cost

For ranking of proposed countermeasures, annualised cost per ton (of reduction pollutant) is calculated as sum of annual capital cost, maintenance and operation cost. In these annual costs are included indirect costs for each countermeasure. In this way all capital costs are transformed to annualised costs with use of a discount rate of 4 per cent per year considering the current interest rate in Thailand although 12 per cent is commonly used. The annualized costs per vehicle and factory are calculated for most of the countermeasures.

5) Cost Estimation Method - With-without Analysis

Estimate cost is necessary cost for implementation of proposed countermeasures but does not include the cost derived from planned countermeasures, for instance Business as Usual (BAU) case. This means that the cost for currently planned development of the bus and street systems are excluded in the calculation by the method below.

With case (Proposed Countermeasure) - Without case (Business as Usual)
= Additional Cost for implementation of countermeasures

6) Residual Value after 2011

For some countermeasures, investments made during the period from 2000 to 2011 will give residual value after the end of the period. In order to calculate economic costs for ranking of countermeasures according to baht/ton, such residuals are of not important, as the economic costs are basically as annual cost including annual capital costs.

7.1.1.2 Details of Cost estimation

Leasing Cost: NG2, NG3, VR1, VR2

NG bus [2500 Bt/day/vehicle x (7.7/5.5)] – Diesel bus [2500 Bt/day/vehicle]
x 365days x total number of bus replaced

Cost for NG engine conversion: NG1

Total cost per bus for NG engine conversion [0.8 Bt] X converted bus number per year

Cost savings for fuel: NG1, NG2, NG3

Fuel cost of Diesel per km (13.59/2.1) - Fuel cost of CNG per km (5.9/1.58)
x 260 service km/day /vehicle x 365days x Replaced bus number per year

Benefit from selling old bus: NG3, VR1, VR2

Trade-in price of old aged vehicle [Price of new vehicle X 10 %] X replaced vehicle number

Reimbursement Cost for Truck Replacement: VR2

Calculated based upon equally monthly payment with interest assuming the loan condition of 7 % interest rate and 4 years loan period (information from HINO and Truck association)

O&M (Operation and Maintenance): All cases

Since the differences of O & M costs between with and without case are negligible as the reasons indicated below, any costs are not accounted.

Countermeasures	Reasons
NG1: BMTA's old aged buses (1987-2001) will be converted to NG bus by Kit	Maintenance cost for new diesel bus is almost same as NG bus.
NG2: BMTA's bus replacement to be new CNG buses	Leasing fee on both new NG and new diesel buses include maintenance cost.
NG3: BMTA's old aged buses (1987-2001) will be replaced to NG bus	Old aged buses that mainly are used by private bus operators are not maintained appropriately. The cost is very little. While, for NG buses maintenance cost are included in leasing fee
VR1: BMTA's old aged buses (1987-2001) will be replaced to new ones	ditto
VR2: Old aged coach and truck in BMA will be replaced to new ones	Maintenance costs for new diesel bus and truck are same as old ones

7.1.1.3 Basic Data for Cost Estimate

Table 7.1.1.1 Price of Vehicle

Item	Purchase M Bt/vehicle	Leasing M Bt/vehicle	Source
New CNG full size bus	7.5	-	Hino, Benz and Volvo
New Diesel full size bus	5.5	9.1	Hino, Benz and Volvo
Taxi	1.0	-	
Car	0.7	-	
Ban	0.6	-	
CNG conversion including CNG kit	0.8	-	Other study
Old Diesel full size bus	0.6		Hino, Benz and Volvo 10 years old
Old Truck	0.3		Hino, Benz and Volvo 10 years old

Table 7.1.1.2 Price of Fuel

	Bt/liter	Source
CNG	5.90	PTT
Diesel fuel	13.59	PTT

Table 7.1.1.3 Operation of BMTA and Private Bus Companies

Items	Unit		Source
Service	km/year	324,197,986	BMTA 2001 Annual Report
	km/day	888,762	ditto
	km/bus/day	259	ditto
Fuel Consumption	liter/year	153,073,668	ditto
	day/day	419,380	ditto
	lire/bus/day	123	ditto
	km/day	2.10	ditto
Natural Gas	liter/year	2,265,901	ditto
	liter/day	6,208	ditto
	liter/bus/day	178	ditto
	km/liter	1.58	ditto

7.1.2 Cost Estimate for Countermeasures

7.1.2.1 EURO 4

1) Assumption

- More stringent standard EURO 4 will comply for new vehicles
- The standard will start from year 2010.
- Targeted vehicles include LDV (LDGV, TAXI, LDDV and LDDT) and HDV (Bus and Truck)
- The numbers of the vehicles are forecasted based upon the long-term GDP projection.
- Cost for the compliance: vehicle price (refer to Table 7.1.1.1) will be increased by 20% (information from automobile industry).
- Loan conditions for truck: 7% annual interest rate, 4 years repayment period (average loan condition was employed, because financial companies provide various loans)
- Annualised cost: based upon investment cost and benefit, annualised economic cost is calculated.
- O&M (Operation and Maintenance) cost: Since the differences of O & M costs between with and without case are negligible, any costs are not accounted.

2) Vehicle Number and Economic cost

Table 7.1.2.1 LDGV in BMR

year	No.of LDGV	Base Case			12% Disc. Rate			4% Disc. Rate		
		Cost	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004										
2005										
2006										
2007										
2008										
2009										
2010	289,800	29,600	0	29,600	26,400	0	26,400	28,500	0	28,500
2011	321,200	32,800	0	32,800	29,286	0	29,300	31,500	0	31,500
Total	611,000	62,400	0	62,400	55,686	0	55,700	60,000	0	60,000
Annualised				31,200			27,900			30,000

Table 7.1.2.2 TAXI in BMR

year	No.of TAXI	Base Case			12% Disc. Rate			4% Disc. Rate		
		Cost	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004										
2005										
2006										
2007										
2008										
2009										
2010	8,100	1,400	0	1,400	1,300	0	1,300	1,300	0	1,300
2011	9,000	1,500	0	1,500	1,339	0	1,300	1,400	0	1,400
Total	17,100	2,900	0	2,900	2,639	0	2,600	2,700	0	2,700
Annualised				1,500			1,300			1,400

Table 7.1.2.3 LDDV in BMR

year	No.of LDDV	Base Case			12% Disc. Rate			4% Disc. Rate		
		Cost	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004										
2005										
2006										
2007										
2008										
2009										
2010	69,400	7,100	0	7,100	6,300	0	6,300	6,800	0	6,800
2011	99,400	10,100	0	10,100	9,018	0	9,000	9,700	0	9,700
Total	168,800	17,200	0	17,200	15,318	0	15,300	16,500	0	16,500
Annualised				8,600			7,500			8,300

Table 7.1.2.4 LDDT in BMR

year	No.of LDDT	Base Case			12% Disc. Rate			4% Disc. Rate		
		Cost	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004										
2005										
2006										
2007										
2008										
2009										
2010	504,500	60,000	0	60,000	53,600	0	53,600	57,700	0	57,700
2011	564,700	67,200	0	67,200	60,000	0	60,000	64,600	0	64,600
Total	1,069,200	127,200	0	127,200	113,600	0	113,600	122,300	0	122,300
Annualised				63,600			56,800			61,200

Table 7.1.2.5 LDV in BMR

year	Total No. of LDV	Base Case			12% Disc. Rate			4% Disc. Rate		
		Cost	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004										
2005										
2006										
2007										
2008										
2009										
2010	871,800	98,100	0	98,100	87,600	0	87,600	94,300	0	94,300
2011	994,300	111,600	0	111,600	99,600	0	99,600	107,300	0	107,300
Total	1,866,100	209,700	0	209,700	187,200	0	187,200	201,600	0	201,600
Annualised				104,900			93,600			100,800

Table 7.1.2.6 Bus in BMR

year	No. of Buses	Base Case			12% Disc. Rate			4% Disc. Rate		
		Cost	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004										
2005										
2006										
2007										
2008										
2009										
2010										
2011	28,300	26,500	0	26,500	23,700	0	23,700	25,500	0	25,500
Total	28,300	26,500	0	26,500	23,700	0	23,700	25,500	0	25,500
Annualised				26,500			23,700			25,500

Table 7.1.2.7 Truck in BMR

year	No. of Trucks	Base Case			12% Disc. Rate			4% Disc. Rate		
		Cost	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004										
2005										
2006										
2007										
2008										
2009										
2010										
2011	229,100	214,200	0	214,200	191,300	0	191,300	206,000	0	206,000
Total	229,100	214,200	0	214,200	191,300	0	191,300	206,000	0	206,000
Annualised				214,200			191,300			206,000

Table 7.1.2.8 HDDV (Bus +Truck) in BMR

year	Total for HDV	Base Case			12% Disc. Rate			4% Disc. Rate		
		Cost	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004										
2005										
2006										
2007										
2008										
2009										
2010										
2011	257,400	240,700	0	240,700	214,900	0	214,900	231,400	0	231,400
Total	257,400	240,700	0	240,700	215,000	0	214,900	231,500	0	231,400
Annualised				240,700			214,900			231,400

7.1.3 Introduction of NG buses

7.1.3.1 Cost Estimates

1) Assumption

- NG1: Old aged buses (1987-2000) mainly used by private bus operators will be converted the engine to NG engine by purchase
- NG2: The BMTA's bus will be replaced into new NG buses by lease
- NG3: Old aged buses (1987-2000) mainly used by private bus operators will be replaced to NG buses by lease
- Implementation of countermeasures start from 2004.
- All buses over 10 year-old will be changed into NG buses during 2004-2001
- Vehicle price: refer to the Basic data (Section 7.1.1.3)
- Leasing price for diesel bus: 2500 Bt/day (from Hino, Benz and Volvo)
- Leasing price for new NG bus: 2800 Bt/day (estimated based upon leasing price of the diesel bus)
- Annualised cost: based upon investment cost and benefit, annualised economic costs are calculated.
- O&M (Operation and Maintenance) cost: Since the differences of O & M costs between with and without case are negligible, any costs are not accounted.
- Numbers of the vehicles are estimated based upon the vehicle age distribution: refer to Table 7.1.3.1
-

Table 7.1.3.1 No. of Buses to be replaced to NG Buses

Type of countermeasures \ year	2004	2005	2006	2007	2008	2009	2010	2011	Total
NG1	300	600	900	700	900	1,000	700	1,000	6,100
NG2	500	600	800	1,000	1,200	1,700	2,300	3,300	11,400
NG3	300	600	900	700	900	1,000	700	1,000	6,100

Source: JICA Study Team analyzed

2) Vehicle Number and Economic Cost

Table 7.1.3.2 NG1: BMTA's old aged buses (1987-2000) will be converted to NG engine

year	No. of Bus	Base Case			12% Disc. Rate			4% Disc. Rate		
		Cost*	Benefit**	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004	300	240	100	140	200	100	100	200	100	100
2005	600	480	200	280	400	200	200	500	200	300
2006	900	720	400	320	600	400	200	700	400	300
2007	700	560	600	-40	500	500	0	500	600	-100
2008	900	720	800	-80	600	700	-100	700	800	-100
2009	1,000	800	1,000	-200	700	900	-200	800	1,000	-200
2010	700	560	1,100	-540	500	1,000	-500	500	1,100	-600
2011	1,000	800	1,300	-500	700	1,200	-500	800	1,300	-500
Total	6,100	4,880	5,500	-620	4,200	5,000	-800	4,700	5,500	-800
Annualised				-100			-100			-100

Note:
***Cost for NG engine conversion**
Total cost per bus for NG engine conversion [0.8 Bt] X converted bus number per year
****Cost savings for fuel**
Fuel cost of Diesel per km (13.59/2.1) - Fuel cost of CNG per km (5.9/1.58)
x 260 service km/day /vehicle x 365days x Replaced bus number per year

Table 7.1.3.3 NG2 : BMTA's bus replacement to be new NG buses

year	No. of Bus	Base Case			12%Disc. Rate			4% Disc. Rate		
		Cost*	Benefit**	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004	500	100	100	0	100	100	0	100	100	0
2005	600	300	200	100	300	200	100	300	200	100
2006	800	500	400	100	400	400	0	500	400	100
2007	1,000	800	600	200	700	500	200	800	600	200
2008	1,200	1,200	900	300	1,100	800	300	1,200	900	300
2009	1,700	1,600	1,300	300	1,400	1,200	200	1,500	1,300	200
2010	2,300	2,300	1,800	500	2,100	1,600	500	2,200	1,700	500
2011	3,300	3,200	2,500	700	2,900	2,200	700	3,100	2,400	700
Total	11,400	10,000	7,800	2,200	9,000	7,000	2,000	9,700	7,600	2,100
Annualised				300			300			300

Note
***Leasing Cost**
NG bus [2500 Bt/day/vehicle x (7.7/5.5)] – Diesel bus [2500 Bt/day/vehicle]
x 365days x total number of bus replaced
****Cost savings for fuel**
Fuel cost of Diesel per km (13.59/2.1) - Fuel cost of CNG per km (5.9/1.58)
x 260 service km/day /vehicle x 365days x Replaced bus number per year

Table 7.1.3.4 NG3: BMTA's old aged buses (1987-2000) will be replaced to NG buses

Unit: million bahts

year	No. of Bus	Base Case			12%Disc. Rate			4% Disc. Rate		
		Cost*	Benefit**	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004	300	100	100	0	100	100	0	100	100	0
2005	600	600	200	400	500	200	300	600	200	400
2006	900	1,300	400	900	1,200	400	800	1,300	400	900
2007	700	2,200	600	1,600	2,000	500	1,500	2,100	600	1,500
2008	900	3,000	800	2,200	2,700	700	2,000	2,900	800	2,100
2009	1,000	4,100	1,000	3,100	3,700	900	2,800	3,900	1,000	2,900
2010	700	5,000	1,100	3,900	4,500	1,000	3,500	4,800	1,100	3,700
2011	1,000	5,900	1,300	4,600	5,300	1,200	4,100	5,700	1,300	4,400
Total	6,100	22,200	5,500	16,700	20,000	5,000	15,000	21,400	5,500	15,900
Annualised				2,100			1,700			1,800

Note:

***Leasing Cost- Benefit from selling old bus**

Leasing Cost

NG bus [2500 Bt/day/vehicle x (7.7/5.5)] – Diesel bus [2500 Bt/day/vehicle]
x 365days x total number of bus replaced

Benefit from selling old bus

Trade-in price of old aged vehicle [Price of new vehicle X 10 %] X replaced vehicle number

****Cost savings for fuel**

[Fuel cost of Diesel per km (13.59/2.1) - Fuel cost of CNG per km (5.9/1.58)]
x 260 service km/day /vehicle x 365days x Replaced bus number per year

7.1.4 Over Aged Vehicle Retirement Program

7.1.4.1 Cost estimates

1) Assumption

- VR1: The BMTA's old aged buses (1987-2000) will be replaced to new ones
- VR2: Old aged coach and truck in the BMA will be replaced to new ones
- Old buses and trucks over 10 years will be retired and replaced into new vehicle
- Loan conditions for Truck: 7% annual interest rate, 4 years repayment period (average loan conditions)
- Leasing cost for Buses: 2,500Bt/day is applied for both regular buses and coaches
- Annualised cost: based upon investment cost and benefit, annualised economic cost is calculated.
- O&M (Operation and Maintenance) cost: Since the differences of O & M costs between with and without case are negligible as the reasons indicated below, any costs are not accounted.

2) Vehicle Number and Economic Cost

Table 7.1.4.1 VR1: Old aged buses will be replaced to new ones

year	No. of Buses	Base case			12% Disc. Rate			4% Disc. Rate		
		Cost*	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004	300	100		100	100	0	100	100	0	100
2005	600	300		300	300	0	300	300	0	300
2006	900	900		900	800	0	800	900	0	900
2007	700	1,800		1,800	1,600	0	1,600	1,700	0	1,700
2008	900	2,400		2,400	2,100	0	2,100	2,300	0	2,300
2009	1,000	3,200		3,200	2,900	0	2,900	3,100	0	3,100
2010	700	4,200		4,200	3,800	0	3,800	4,000	0	4,000
2011	1,000	4,800		4,800	4,300	0	4,300	4,600	0	4,600
Total	6,100	17,700		17,700	15,900	0	15,900	17,000	0	17,000
Annualised				2,200			1,800			1,900

Note:
***Leasing Cost- Benefit from selling old bus**
Leasing Cost
NG bus [2500 Bt/day/vehicle x (7.7/5.5)] – Diesel bus [2500 Bt/day/vehicle]
x 365 x total number of bus replaced
Benefit from selling old bus
Trade-in price of old aged vehicle [Price of new vehicle X 10 %] X replaced vehicle number

Table 7.1.4.2 VR2 (1): Old aged Coaches will be replaced to new ones

year	No. of Coaches	Base case			12% Disc. Rate			4% Disc. Rate		
		Cost*	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004	1,600	300		300	300	0	300	300	0	300
2005	3,000	1,900		1,900	1,700	0	1,700	1,800	0	1,800
2006	2,000	4,500		4,500	4,000	0	4,000	4,300	0	4,300
2007	1,200	6,200		6,200	5,500	0	5,500	6,000	0	6,000
2008	1,300	7,300		7,300	6,500	0	6,500	7,000	0	7,000
2009	1,200	8,500		8,500	7,600	0	7,600	8,200	0	8,200
2010	1,800	9,600		9,600	8,600	0	8,600	9,200	0	9,200
2011	2,200	11,300		11,300	10,100	0	10,100	10,900	0	10,900
Total	14,300	49,600		49,600	44,300	0	44,300	47,700	0	47,700
Annualised				6,200			4,900			5,300

Note:

***Leasing Cost- Benefit from selling old bus**

Leasing Cost

NG bus [2500 Bt/day/vehicle x (7.7/5.5)] – Diesel bus [2500 Bt/day/vehicle] x 365 x total number of bus replaced

Benefit from selling old Coaches

Trade-in price of old aged vehicle [Price of new vehicle X 10 %] X replaced vehicle number

Table 7.1.4.3 VR2 (2): Old aged Trucks will be replaced to new ones)

year	No. of Trucks	Base case			12% Disc. Rate			4% Disc. Rate		
		Cost*	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004	10,500	18,100		18,100	16,200	0	16,200	17,400	0	17,400
2005	6,900	37,260		37,260	33,300	0	33,300	35,800	0	35,800
2006	1,600	44,840		44,840	40,000	0	40,000	43,100	0	43,100
2007	20,000	80,400		80,400	71,800	0	71,800	77,300	0	77,300
2008	25,000	112,000		112,000	100,000	0	100,000	107,700	0	107,700
2009	18,300	144,220		144,220	128,800	0	128,800	138,700	0	138,700
2010	21,200	189,680		189,680	169,400	0	169,400	182,400	0	182,400
2011	34,700	215,780		215,780	192,700	0	192,700	207,500	0	207,500
Total	138,200	842,280		842,280	752,200	0	752,200	809,900	0	809,900
Annualised				105,300			83,600			90,000

Note:

***Reimbursement Cost for Truck Replacement**

Calculated based upon equally monthly payment with interest assuming the loan condition of 7 % interest rate and 4 years loan period (information from HINO and Truck association)

Table 7.1.4.4 VR2 (1)+(2): Old aged coach and truck in BMA will be replaced to new ones

year	No. of Trucks + Coaches	Base case			12% Disc. Rate			4% Disc. Rate		
		Cost	Benefit	Total	Cost	Benefit	Total	Cost	Benefit	Total
2004	12,100	18,400		18,400	16,400	0	16,400	17,700	0	17,700
2005	9,900	39,160		39,160	35,000	0	35,000	37,700	0	37,700
2006	3,600	49,340		49,340	44,100	0	44,100	47,400	0	47,400
2007	21,200	86,600		86,600	77,300	0	77,300	83,300	0	83,300
2008	26,300	119,300		119,300	106,500	0	106,500	114,700	0	114,700
2009	19,500	152,720		152,720	136,400	0	136,400	146,800	0	146,800
2010	23,000	199,280		199,280	177,900	0	177,900	191,600	0	191,600
2011	36,900	227,080		227,080	202,800	0	202,800	218,300	0	218,300
Total	152,500	891,880		891,880	796,400	0	796,400	857,500	0	857,500
Annualised				111,500			88,500			95,300

7.2 Financial Arrangement

7.2.1 Bus operation by BMTA and Private bus companies

Table 7.2.1.1 Types and Numbers of Buses in BMR and Private Bus Companies

Ownership	Type of bus	No. of buses
BMTA	Total	3,726
	Regular bus (non-air conditioned)	1,738
	Air conditioned bus	1,988
Private Bus Companies*	Total	9,642
	Regular bus (non-air conditioned)	2,038
	Air conditioned bus	625
	Small bus	
	minibus	1,175
	bus in soi	2,279
	van	3,525

* Private bus companies are operating under the management of BMTA
Source: BMTA 2001 Annual Report

Table 7.2.1.2 Comparison of Main Expenditures for Bus Operations between Diesel and NG Buses by Leasing

	Leasing fee Bt/day	Fuel cost Bt/day	Total
Diesel Bus	2,500	1,683	4,183
NG Bus	3,409	971	4,380
difference	909	-712	197

Source: JICA Study Team analyzed

Table 7.2.1.3 Profit (Loss) Statement of BMTA
As of 30 September 2000 and 2001

Unit: Baht

Items \ Year	2001	2000
Operating Revenues		
Revenues from bus operation		
Revenues from regular buses ticket sales	1,975,741,836.50	2,133,403,242.00
Revenues from air-conditioned buses ticket sales	4,288,120,866.50	4,109,694,365.25
Revenues from monthly ticket sales	513,272.00	687,427.00
Revenues from joint venture buses	55,818,645.41	48,248,183.40
Revenues from mini buses	1,037,857.50	49,531,386.00
Revenues from Micro buses	49,938,000.00	49,938,000.00
Revenues from selling ticket to joint buses and minibuses	0.00	2,837,860.00
Revenues from rental buses	3,098,560.00	2,844,133.56
Total operating revenues	6,379,615,098.82	6,400,158,158.71
Operating Expenses		
Bus operating expenses	6,004,300,752.55	5,738,830,107.34
Maintenance expenses	1,884,853,982.71	1,689,447,296.76
Administration expenses	474,990,581.66	447,681,788.10
Zone office general administration expenses	464,224,346.43	433,820,236.54
Head office general administration expenses	291,210,308.24	342,396,872.95
Overdue debt interest expenses	355,754,637.03	280,469,629.27
Bank Loan interest	335,052,054.17	403,570,663.52
Loan bond interest	161,628,976.45	312,245,980.72
Total operating expenses	9,972,015,639.24	9,648,462,575.20
Profit [Loss] from operation	-3,592,400,540.42	-3,248,304,416.49
Other income received	268,817,421.06	331,691,226.28
Government subsidies	433,451,865.11	323,089,831.50
Profit [loss] before deducting expenses	-2,890,131,254.25	-2,593,523,358.71
Interest borne by government	433,451,865.11	323,089,831.50
Net profit [loss]	-3,323,583,119.36	-2,916,613,190.21

Source: BMTA 2001 Annual Report

Table 7.2.1.4 Balance Sheet of BMTA
As of 30 September 2000 and 2001

Unit: Baht

Items \ Year	2001	2000
Assets		
Current assets		
Cash and deposits at banks	978,488,632.68	727,811,000.93
Inventories	23,735,491.25	31,240,945.60
Accrued receivables	491,177,905.19	501,454,163.04
Prepaid expenses	60,940,517.65	55,139,251.22
Total current assets	1,554,342,546.77	1,315,645,360.79
Receivable and Loans		
Advances receivable	3,687,412.39	4,671,397.54
Damages receivable	59,530,922.21	91,735,788.13
Damages in process	31,210,874.56	33,834,859.00
Advances receivable for accident cased	21,346,636.87	20,519,522.41
Other receivable	143,489,544.97	139,102,779.84
Total receivables and loans	259,265,391.00	289,864,346.92
Investments in securities	0.00	0.00
Land - building and equipment net	2,486,110,411.32	3,122,017,712.20
Properties awaiting disposal	2,760,084.03	53,435,915.03
Leasehold for buses	0.00	0.00
Donated Car	0.00	0.00
Other assets	118,400,659.60	60,852,797.67
Total assets	4,420,879,092.72	4,841,816,132.61

Source: BMTA 2001 Annual Report

Table 7.2.1.5 Private Bus Companies: Balance Sheets

As of 31 December 1999

Unit: million bahts

Company (Legend below) / Items	1	2	3	4	5	6
ASSETS						
Current Assets						
Cash on hand and at banks	3	12	5	0	0	14
Inventories	0	1	1	3	0	31
Other current assets	1	3	6	2	0	13
Total current assets	4	16	12	5	0	58
Advances receivable	5	1	3	1	0	17
Property, plant & equipment, net	36	31	407	44	135	340
Other assets	1	0	7	3	1	2
Total Assets	46	48	429	53	136	417
LIABILITIES AND EQUITY						
Liabilities						
Bank overdrafts	0	0	7	21	0	73
Accrued expense	2	4	8	5	45	187
Other current liabilities	0	0	88	0	0	360
Staff security deposit	3	7	4	0	0	0
Accounts payable	0	3	186	0	343	0
Promissory notes	5	0	101	0	0	0
Bank loans	0	0	20	9	0	211
Total Liabilities	10	14	414	35	388	831
Paid-up equity						
Equity						
Paid-up equity	50	68	24	5	5	500
Accumulated profit (loss)	-14	-34	-7	13	-257	-915
Total equity	36	34	17	18	-252	-415
Total Liabilities and Equity	46	48	431	53	136	416

Source: BMTA 2001 Annual Report

Note:

1 Bangkok Joint Service Bus Company, Ltd.
2 Bangkok Transport Company, Ltd.
3 Dhonburi Union Service Company, Ltd.
4 Thep Niramit Transport Company, Ltd.
5 SK Tour and Service Company, Ltd.
6 Bangkok Micro Bus Company, Ltd.

Table 7.2.1.6 Private Bus Companies: 1999 Profit/Loss Statements

As of 31 September 1999

Unit: million baths

Company (Legend below) / Items	1	2	3	4	5	6
Revenue						
Fares	110	212	428	75	258	486
Other revenue	0	1	0	0	0	17
Total revenue	110	213	428	75	258	503
Expense						
Bus operating expense	102	199	375	63	100	463
General & administrative expense	5	10	31	9	227	88
Interest on loan	1	0	13	3	0	29
Total operating expense	108	209	419	75	327	580
Net profit (loss)	2	4	9	0	-69	-77
Net profit margin	2%	2%	2%	0%	-27%	-16%
Bus expense as % of fares	93%	94%	88%	84%	39%	95%
Return on equity	6%	12%	53%	0%	27%	19%

Source: BMTA 2001 Annual Report

Note:

1 Bangkok joint Service Bus Company, Ltd.
2 Bangkok Transport Company, Ltd.
3 Dhonburi Union Service Company, Ltd.
4 Thep Niramit Transport Company, Ltd.
5 SK Tour and Service Company, Ltd.
6 Bangkok Micro Bus Company, Ltd.

7.2.2 Soft Loan

7.2.2.1 Fund supporting to Private Sector In case of buying CNG bus by of Environmental Fund of Office of Natural Resource and Environmental Policy and Planning

1. The person who request for support must have money investment in total fixed assets not over 400 million baht
   (The value of fixed assets mean the value of land, building, constructed facility, machinery and others that are shown in the financial account including value of land, building, constructed facility and machinery or the proposed project.)

2. Type of support : loan only

3. Supporting limit : give loan especially in case of air pollution investment
   This case is change the engine to CNG only not include buying a new vehicle

4. The amount of loan : not over 20% of the capital of the total fixed assets and not over the investment of air pollution system and give loan without interest 5% of total loan amount of the project

5. A grace period not more than 2 years

6. Repayment period include grace period not more than 7 years

7. Interest

7.1 Public organization
- MLR-2 per year if guaranteed by a bank
- MLR-1.5 per year if guaranteed by other properties.

7.2 Private entity
- MLR-3 per year if guaranteed by a bank
- MLR-2.5 per year if guaranteed by other properties

Note: MRL: Minimum Loan Rate

7.2.2.2 JBIC's Two-Step Loan:

Table 7.2.2.1 Environmental Protection Promotion Program

Executing Agency	Industrial Finance Corporation of Thailand (IFCT)
Local Contact Address	Mrs. Duangta Luengviriyasang, Manager Fund Disbursement Section Debt Management Division, Finance Department Tel:662-253-7111(ext.2411) Fax:662-253-9678
Maximum Amount	Less than 1.7 billion baht (5 billion yen)
Purpose	To prevent industrial pollution in Thailand through provision of IFCT's low-interests sub-loans to private enterprises whose projects are mainly focusing on environmental protection
Deadline for application	2003.1.27 (the date is going to be postponed up to 2005.1.27)
Conditions of projects and sub loaning	
Target enterprise (end-user)	・all enterprise or industry (no restriction on fixed assets)
Type of Industry and projects	・all sector of industry ・project for environmental conservation and pollution control (only for the projects which meet the emission standards for environmental conservation)
Loan amounts (currency)	less than 300 million bahts for one industry or enterprise target funding : capital investment cost for pollution prevention Currency: baht, exceptionally Yen or US$
Interest	Interest for Funding Cost＋IFCT Cost（max: 2.3%）. Both Variable and Fixed rate applicable.
Repayment period	less than 15 years（including grace period of less than 3 years）

7.2.3 Clean Development Mechanism (CDM)

7.2.3.1 CO_2 Reduction Amount Estimate for CDM

Table 7.2.3.1 Reduction Amount of CO_2 by Introduction of NG buses

	2004	2005	2006	2007	2008	2009	2010	2011
BMTA (No. of Vehicle)	500	1,106	1,858	2,813	4,057	5,724	8,030	11,333
Private Bus Operators (No. of Vehicle)	267	902	1,810	2,481	3,358	4,346	5,058	6,051
Total No of vehicle	767	2,008	3,668	5,294	7,415	10,070	13,088	17,384
Reduction Amount of CO_2 (C-T)	997	2,610	4,768	6,882	9,640	13,091	17,014	22,599

Source: JICA Study Team analyzed

Table 7.2.3.2 Energy Cost Saving (NG2 case)

year	No. of NG bus	Accum. No. of NG bus	Energy Cost Saving
2004	500	500	130
2005	606	1,106	287
2006	752	1,858	483
2007	955	2,813	731
2008	1,244	4,057	1,054
2009	1,667	5,724	1,487
2010	2,306	8,030	2,086
2011	3,303	11,333	2,944
Total	11,333		9,201

Source: JICA Study Team analyzed

Table 7.2.3.3 Energy Cost Saving (NG3 case)

year	No. of NG bus	Accum. No. of NG bus	Energy Cost Saving
2004	267	267	69
2005	635	902	234
2006	908	1,810	470
2007	671	2,481	644
2008	877	3,358	872
2009	988	4,346	1,129
2010	712	5,058	1,314
2011	993	6,051	1,572
Total	6,051		6,305

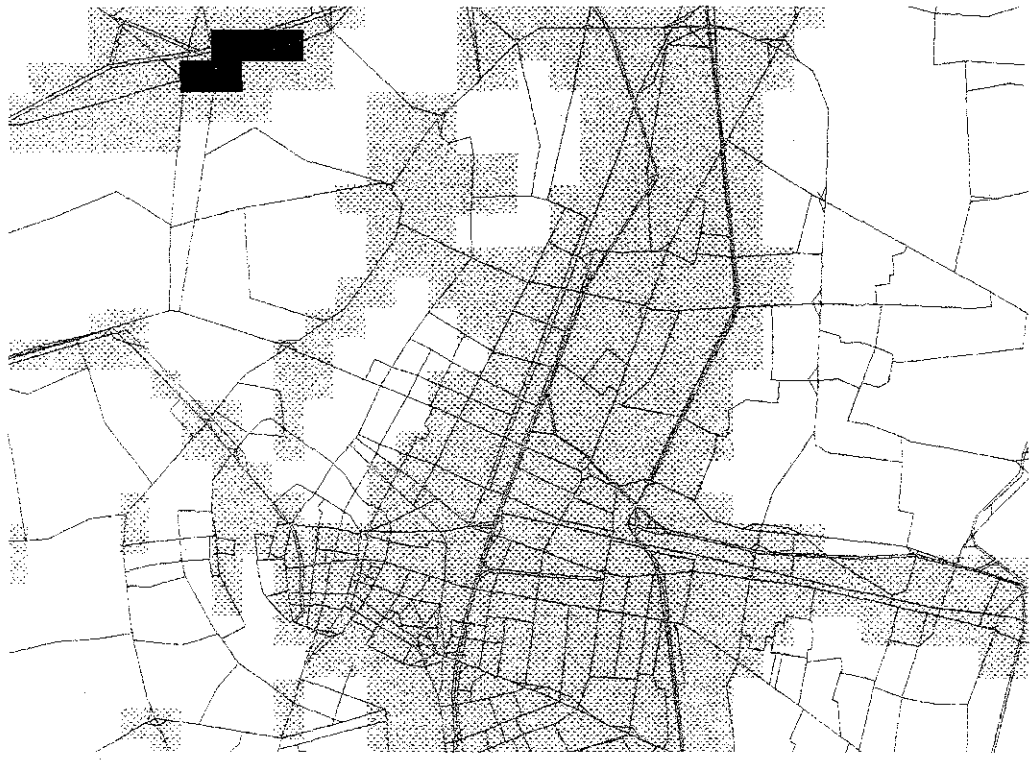
Source: JICA Study Team analyzed

7.3 NO_2 Concentration at year 2011

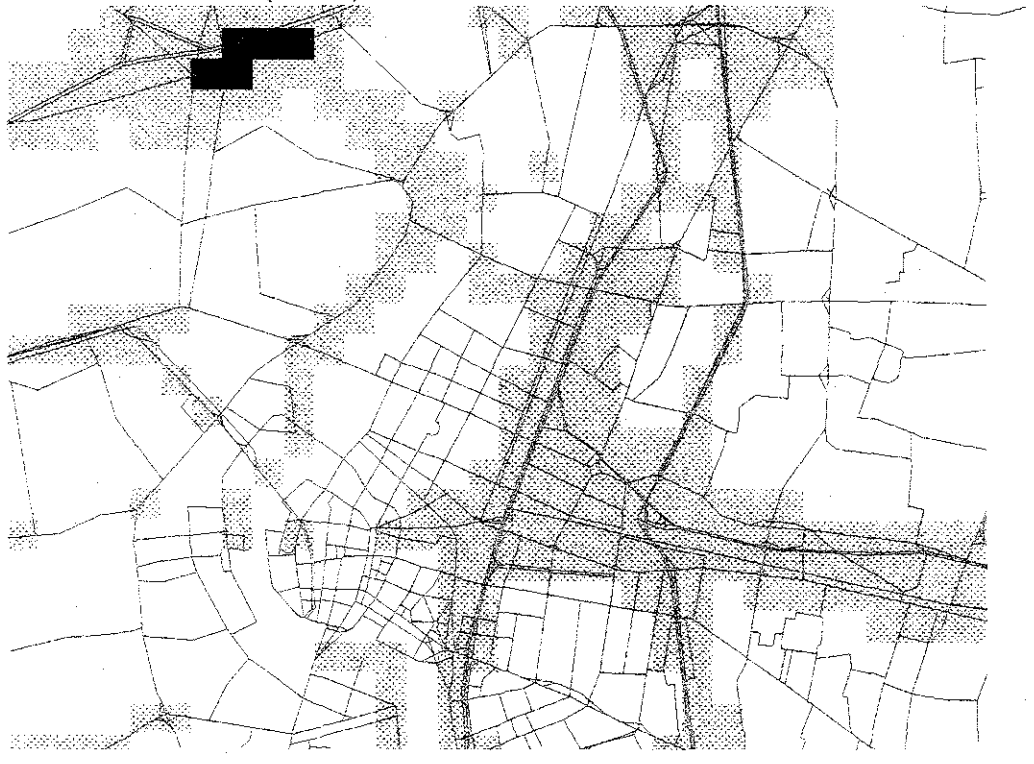
Figure 7.3.1.1 shows the Airviro Simulation Results of NO_2 concentration in BMR (center of BMA) in 2011 of the following cases,

- BAU Case
- Traffic Control (Case 1)

2011 BAU Case



2011 Traffic Control (Case 1)



■ : Grid over Thai NO_2 ambient air quality standard

■ : Grid over WHO NO_2 ambient air quality guideline

Figure 7.3.1.1 Simulation Result of ambient NO_2 concentration for Supplemental Control Case

7.4 Additional NG2 Case (NG2')

7.4.1 Basic Assumption

As BMTA's plan to limit life duration of their buses for human health and safety including less exhaust emission from their old buses, "The New Buses Procurement Project" is formulated for providing the new buses with the lower emission than the notification of the National Environmental Board. Through the project, their old buses, which have been operated over 10 years, would be replaced with new buses for better service.

The objectives of the project are,

- To upgrade the public bus service by improving the quality of BMTA's buses according to a growing demand for air-conditioned bus,
- To increase BMTA's income, and
- To follow the Government Policy against air and noise pollution.

Implementation plan

Implementation Year	No. of Bus to be purchased
2002-2003	Amount 115 buses
2005-2006	Amount 44 buses
2006	Amount 38 buses

7.4.2 Reduction Amount

year	No. of NG-Bus to be purchased	instead of ..	Diesel-Bus EF g/mile	NG-Bus EF g/mile	Mile travelled by a bus at 2011	NOx Reduced (t)	NOx(t) per one NGV
2002	115	Thai-EURO 2	29.83	3.88	57,294	171	1.49
2005	44	Real-EURO 2	10.56	3.88	57,294	17	0.38
2006	38	Real-EURO 3	7.40	3.88	57,294	8	0.20
NOx Emission Reduction by NG2'						195	-
NOx Emission Reduction by Real-EURO only						183,392	-
NOx Emission Reduction by Real-EURO & NG2'						183,197	-

7.4.3 Cost Estimate

mil Bahts

		Cost			Benefit		4% Disc. Rate		
year	No. of bus	Accumu. No. of bus	Leasing	O&M	Saving from fuel switch	Benefit from selling old vehicle	Cost	Benefit	Total
2002	115	115	32	0	25	0	32	25	7
2003		115	32	0	25	0	32	25	7
2004		115	32	0	25	0	32	25	7
2005	44	159	45	0	35	0	45	35	10
2006	38	197	56	0	43	0	56	43	13
2007		197	56	0	43	0	56	43	13
2008		197	56	0	43	0	56	43	13
2009		197	56	0	43	0	56	43	13
2010		197	56	0	43	0	56	43	13
2011		197	56	0	43	0	56	43	13
Total	197		477	0	368	0	477	368	109
Annualised									11

8. Web Development

8.1 Objective

The objective of the Website development is to publicize the study on the Acid Deposition Control Strategy. To develop the website, hardware and software were purchased for this project by JICA.

Points of development are as follows.

1. To set the webserver, it is necessary to consider security system that protects from the outside attack.
2. To develop the website, it is necessary to provide interesting contents.

8.2 Outline of Web Development

First, the security policy on setting firewall was discussed and decided between PCD and the JICA Study Team. The security system depends on the policy of PCD. Second, the hardware and the software were selected and set in the PCD.

The first web content was provided by the JICA Study Team. After the start of website, web contents will be provided by both PCD staff and the JICA Study Team

8.2.1 Network

The image of network is illustrated in Fig. 7.2.1.1. The firewall and the webserver were setup in the PCD, 7th floor. Scanner, backup equipment and UPS were arranged in the proximity of the webserver.

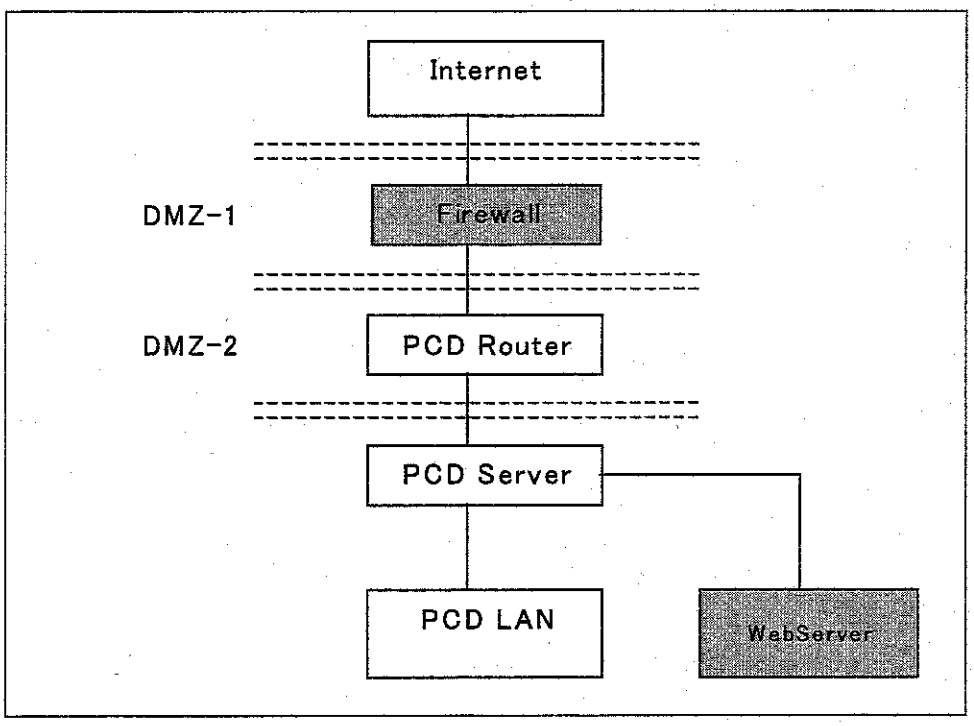


Figure 8.2.1.1 Network Image

8.2.2 Security Policy

PCD Network has two De-Militarized Zones (DMZ). DMZ consists of DMZ-1 and DMZ-2. The JICA Study Team composed and provided the framework of the security policy.

8.2.3 Firewall

The firewall is set at the DMZ-1. The firewall settings that depend on basic Internet security, are as follows.

- Open the port of
  http (80), https (443), dns (53), ftp (21/20),
  smtp (25), pop3 (110), and telnet (23).

- Acquire the Access log from outside PCD

8.2.4 Hardware

The list of hardware is as follows.

Table 8.2.4.1 List of the hardware

Classification	Type	Amount
Web Server	HP Netserver tc4100 (PIII-1.4GB, 512MB memory, 17inch display)	1
	36GB harddisk	2
	Windows2000+5clients Microsoft IIS	1
Scanner	Canon D2400UF	1
Backup equipment	HP Sure Store DAT24i-24GB	1
	DAT tape 24GB	5
Firewall	Zywall 100	1
UPS for Webserver	Smart UPS SUA1000i	1
UPS for Firewall	APC Smart 620	1

8.2.5 Software

The list of software is as follows.

Table 8.2.5.1 List of the software

Classification	Product	Amount
Virus guard	Norton Antivirus 2002 Enterprise Edition	1
Web tool	Macromedia Dreamweaver 4.0	1
	Adobe Acrobat 5.0	1
	Quantified Urchin	1
Security	Firewall tool (software attached to Zywall 100)	1

8.2.6 Web Content

First, the web content provided and arranged by the JICA Study Team. The premises of the Web content design are as following.

- Basic html and images,
- Some Frame pages,
- Available to download PDF files, and
- Visible in 800*600 dot and 1024*768 dot screen.

The list of web content is as follows.

Table 8.2.6.1 List of the web content

Content	Language	Maximum pages	Time of update	Remarks
Objectives of the Study	English	4	17th,July, 2002	Design
Background of the Study	English	10	17th,July, 2002	Design
Report of the Study (ongoing)	English English	100 200	October, 2002 February, 2003	Only link
Report of the Study (ongoing)	English, English	100 200	October, 2002 February, 2003	PDF Foramt
Information of Seminar	English English	3 3	1st,October, 2002 1st,December, 2002	Design
Update information, Seminar report, Link information.	English	50	from July, 2002 to February, 2003	Design
The part of above contents that designated the First Party	Thai	150	Date designed by the First Party	The same design as above contents

Now Top page and Introduction of the Study are already publicized. Other contents will be created gradually. The image of top page is shown in Fig.7.2.6.1.

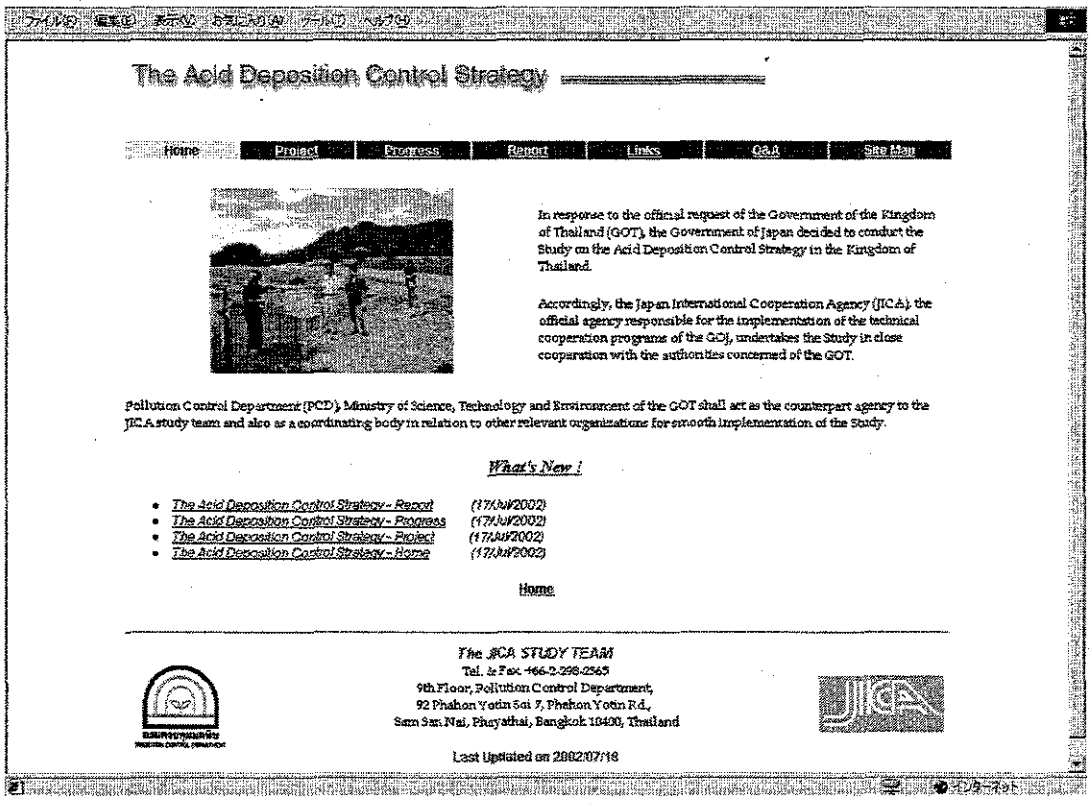


Figure 8.2.6.1 Image of Top page

The domain name is http://acidrain.pcd.go.th/ .

8.3 Management of Website

The management of website during the Study period is as follows.

Table 7.3.1 Management of Website

	PCD Air Pollution Staff	PCD Network Staff	JICA Study Team
Security	Antivirus	Maintain	Maintain during the project
Hardware	Maintain		Maintain during the project
Software	Maintain		Maintain during the project
Web contents	Create and Maintain	Link	Create and Maintain during the project

8.4 Schedule

The schedule of preparing web content is as follows.

Table 7.4.1 Schedule of Preparing Web Content

Date	Output
1, Jul, 2002	Preparation of the web contents
10,Jul, 2002	Provision of the webserver and the firewall
	Setting of the webserver and the firewall
	Creation of the web contents
17,Jul, 2002	Publicity of the website
	Report of the access analysis Log
1,Sep, 2002	Information of the 2nd Seminar
Oct, 2002	Web contents update (by content of Inception Report)
Dec, 2002	Information of the International Seminar
Feb, 2003	Web contents update (by content of Draft Final Report)

9. Critical Load Approach

9.1 What is Critical Load?

The vulnerability of ecosystem to acidification varies from place to place. Therefore, it is effective that the emission control of acidifying substances should be strict with sources which have a possibility to damage to vulnerable area for ecosystem and not be strict with other sources relatively. This control method requires quantifying the relation between acid deposition amount and its impact on ecosystem. The critical load concept can provide answer for this request. The critical load is defined as "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified elements of the environments do not occur according to the present knowledge".

Speaking of the details of beginning to use the critical load, the critical load map based on the steady-state mass balance model was developed in Europe. And it was practically used as the negotiation tool in meeting for Oslo Protocol (Second Sulphur Protocol) in 1994. It was the first time that the critical load was used for emission control of acidifying substances.

The estimated reduction amount of emission based on this critical load required some countries to reduce 100% of emission amounts. It was supposed to be impossible to complete 100% emission reduction. Therefore, the meeting introduced the target load as the goal of environmental improvement by considering the economic condition and feasibility of emission reduction of each country in addition to critical load.

The reduction amount was defined to reduce 60% of gap between the sulfur deposition amount of year 1990 and critical load. After that, the critical load concept was accepted in Europe. In Multi-effect, Multi-pollutant Protocol in 1999, the target load was defined to reduce 90 - 95% of gap between the sulfur deposition amount of year 1990 and critical load.

In USA the research-level estimation of critical load was executed. However, USA did not tend to use the critical load practically and was negative to use it. In addition, scientists in Europe posed many doubts about the methods of estimating critical load, especially, validity of estimation.

In Asia the RAINS-ASIA project, in which the similar method used in Europe was applied to Asian field, started in cooperation with the western scientists. However, there are so many disputes not only about problem of critical load itself but also about validity of applying European method of critical load to Asian ecosystem.

9.2 Problem of Critical Load Approach

The estimation of critical load is based on the extreme simplification of circulation and neutralization process of acidifying substances in soil and the evaluation of environmental impact using single index. This point causes many doubts and criticisms about reliability of critical load estimation.

The main points of doubts and criticisms are mentioned below.

1) Critical loads are very different depending on indices of acidification limit used for estimation.

In the steady-state mass balance model the index of acidification limit is defined using leaching amount of Aluminum which is known to be harmful to plants.

Critical load is the maximum of acidifying substance which can be put to soil under the condition that the index of acidification balances with limit.

3 methods to estimate the index of acidification limit are proposed, which are methods using 1) limit based on the relation between BC/AL ratio, the ratio of Aluminum solution to base solution, and damage to growth of plant, 2) limit based on the relation between Aluminum solution in soil and damage to growth of plant, 3) limit that Aluminum oxide is not short. The critical loads estimated based on these 3 indices are very different depending on the methods used for estimation. The value based on BC/AL ratio used most widely is relatively lower than values based on the other 2 indices, which are twice as much as that calculated by BC/AL ratio. The difference due to these indices could influence the evaluation of impact on ecosystem.

2) It is doubtful whether the limits of BC/AL ratio defined in experiments can be applied to natural field.

The limits of BC/AL ratio are defined based on many researches which studied about the effects of soil acidification on growth of plants. All limits of BC/AL ratio were defined to be 1.0 in Europe. In Asia limits of BC/AL ratio were defined to be 0.1 - 20.0 by kinds of tree using the results of the experiments in China.

The many factors in natural field such as temperature, moisture contents of soil, nutriment amount are different from those of the experiments. It is doubtful whether the evaluation of effects on ecosystem with only experimental value is reliable ignoring differences of conditions between experiments and natural field.

3) Methods to estimate the weathering rate for acid buffer capacity are doubtful.

The 5 methods to estimate the weathering rate are proposed, which are methods using 1) long-term weathering rate, 2) current rate, 3) Strontium isotope, 4) models like MAGIC model or PROFILE model, 5) solution experiment. The weathering rates are very different depending on the methods used for estimation.

9.3 How to Handle Critical Load in this Study

As mentioned in previous section, the critical load approach has many problems caused by simplification of process. So, it is criticized in various ways from viewpoints of natural science.

Therefore, in this study the critical load should not be used as index for deciding reduction amount of acidifying substance in Thailand due to many problems.

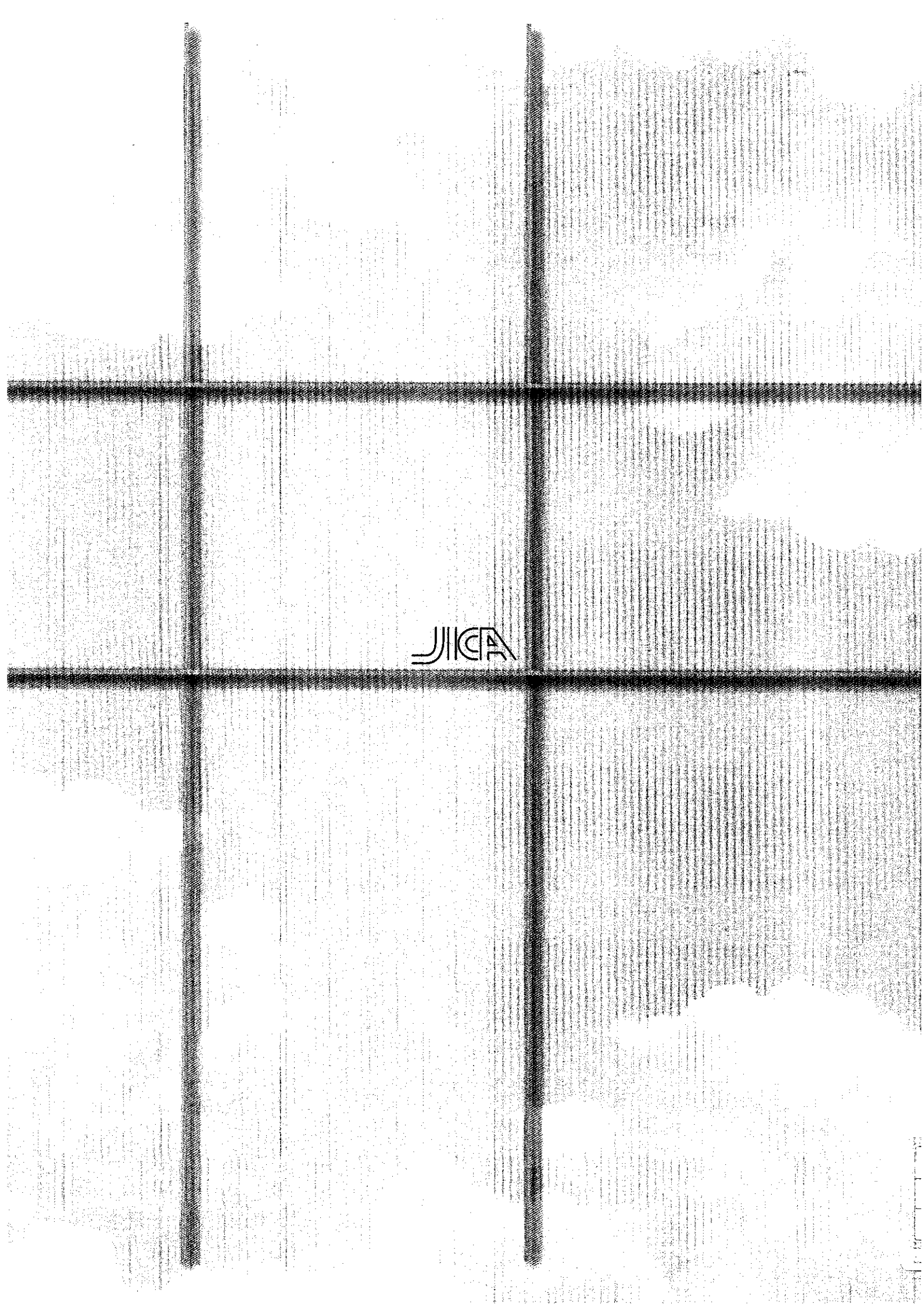
The critical load would be used for reference instead of index for acid deposition control strategy in Thailand.

9.4 How to Handle Critical Load in Future

The critical load is considered to be meaningful in Europe as tool of international negotiation.

The international scheme like meeting of Convention on Long-Range Transboundary Air Pollution has not been established yet in Asia.

The critical load evaluation of acid deposition in Thailand should be studied to be executed considering how to handle the critical load in Asia and the improvement of scientific reliability.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