8.6 Conclusion

8.6.1 Shift to Natural Gas

The shift to natural gas is a countermeasure of the first priority for the mitigation of SO_2 concentration in BMR. It can be introduced by economic mechanisms, and need not prepare new or more stringent regulations. It is consistent with the national policy to enhance natural gas in the manufacturing sector.

Natural gas is almost domestic energy for Thailand. And in many cases, the shift to natural gas brings energy saving effects. Moreover it is an environmentally friendly measure in many aspects, such as lower dust and SOx emissions and lower chance of black smoke.

Currently in BMR, a trunk pipeline is laid in eastern area. Another trunk line in western area will be laid by the end of the year 2005. After the completion of the western part, Bangkok Gas Ring will be finished and available. Bangkok Gas Ring will enable many areas in BMR to shift to natural gas, mainly in industrial estate.

The price of natural gas has enough competitiveness with other fuel. In the case of shift to natural gas, it is necessary to lay branch pipes and gas pipes in factory premises, and to install meters and gas burners. Even considering these costs, because of energy saving merits, natural gas has competitiveness with other conventional fuels.

8.6.2 Exceeding Grids

However, simulation analysis showed the necessity of investigation in detail. According to the inventory prepared by generalized economic growth frame and Airviro Grid module simulation, three grids exceeded the concentration of Thai standard in the 2011 BAU case (Chapter 6). Three grids locate in Bangkok, Nonthaburi and Samut Sakhon. In the 2011 Control case, one grid in Samut Sakhon showed the exceeding concentration of Thai standard. It is not appropriate to identify the share of ground level concentration of respective emission source by the current simulation. However it is possible to consider sources around exceeding grids.

Concerning sources around exceeding grids of Bangkok and Nonthaburi, they might be attributed to aggregation of small sized ones. Concerning Samut Sakhon, they might be regarded as group of large sized sources. However, as mentioned already, it is necessary to investigate by appropriate simulation model and detailed inventory including future operation plan by respective factory.

8.6.3 Step by Step Implementation

Currently, Thai SO_2 standard is satisfied in BMR. According to the simulation result, some limited grids would not satisfy the standard in the year 2011. For mitigation of this possible deterioration of the environment, the shift to natural gas is recommended. The shift to natural gas can be introduced by economic mechanisms without new or more stringent regulations, i.e. the introduction will not burden private companies with extra economic costs.

In order to mitigate possible deterioration beforehand, it is appropriate and realistic to enhance step by step introduction. Generally high concentration grids appear in high emission source areas by Airviro simulation. Therefore, the first priority is the introduction of the shift in and around high concentration grids. After the introduction of shift in and around high concentration grids, other grids become targets of the introduction of the shift to natural gas.

At actual stage of the implementation, it is important to take into consideration that the mitigation measure for some factories depend on specific conditions, not general conditions. In such cases, various measures can be regarded as possible. In specific cases, the fuel shift from fuel oil, i.e. heavy oil, to lighter oil and the utilization of lower sulfur coal and lignite might be possible measures. In order to satisfy environmental and economic requirements, the best way can be selected.

Concerning attainment of WHO guideline, the shift to natural gas would be able to reduce number of grids exceeding the guideline significantly. However still 35 grids showed exceeding value by Airviro simulation in 2011 Control case. The attainment of WHO guideline is a future long-term issue. According to NEQA, B.E. 2535, ambient air quality standard shall be modified and improved in the light of scientific and technological progresses and changes in economic and social conditions of the country. WHO guideline will be an important reference for modification.

For the sake of reference, the critical load approach is described. If the idea of the critical load was adopted and a 25% risk ratio value by BC/AL ratio was applied, ATMOS2 simulation results showed following (Supporting Report, Chapter 5 and 9). By 2011 Control case, almost all grids in BMR exceeded critical load values, and maximum exceeding ratio was more than 3. If the target of countermeasure was supposed to keep critical load, it was necessary to introduce countermeasure with larger reduction amount. The situation was similar in Eastern and Central regions where deposition amount by ATMOS2 showed larger value than critical load values (Supporting Report, Chapter 5).

8.7 Consideration of Action Plan

8.7.1 Financial Arrangement

According to the Energy Policy Plan Office (EPPO) and the Petroleum Authority of Thailand (PTT), the fuel shift to natural gas is one of important energy policies. PTT's natural gas pipeline network is being expanded vigorously with the support of the government. However, even when the pipeline is laid down, the connection of industries to the pipelines depends upon their willingness. In fact, even the area where the pipeline is laid down, limited industries that could obtain benefit from the fuel conversion have connected to the network. The price scheme that PTT provides gives incentives for the big industries that can produce a profit from the conversion due to the price difference, but does not work for the small and medium-size industries as incentives. For such industries that especially encounter financial problems due to the economic crisis and cannot afford the connection, some reasonable financial supports are indispensable.

The network pipeline after the main pipeline is costly. The cost is charged in the price of the natural gas as demand charge.

8.7.1.1 Existing Financial Supports for Fuel Conversion to Natural Gas

1) Soft Loan by Environmental Fund or others

As listed in the Table 8.7.1.1, the Environmental Fund of the Office of Natural Resource and Environmental Policy and Planning (ONREPP, the former OEPP), and the Bangkok Bank are now providing soft loans with low interest and long-term repayment period for the small and medium-size industries who plan to change their facilities and equipment to reduce the pollution emitted from the industries (refer to Figure 8.7.1.1).

Table 8.7.1.1 Types of Soft Loans

Related Agencies	Contents	Problems
Environmental fund	Soft loan (low interest and long-term repayment period) for small and medium-size industries to prevent pollution	Grant is allowed to provide for governmental agency, local administration, state enterprise, public organization, private entities and NGOs.
Bangkok Bank: SME Loan	INVEST Loan to expand your factory, buy new machinery or update old Energy Efficiency Loan to save on the costs of electricity	

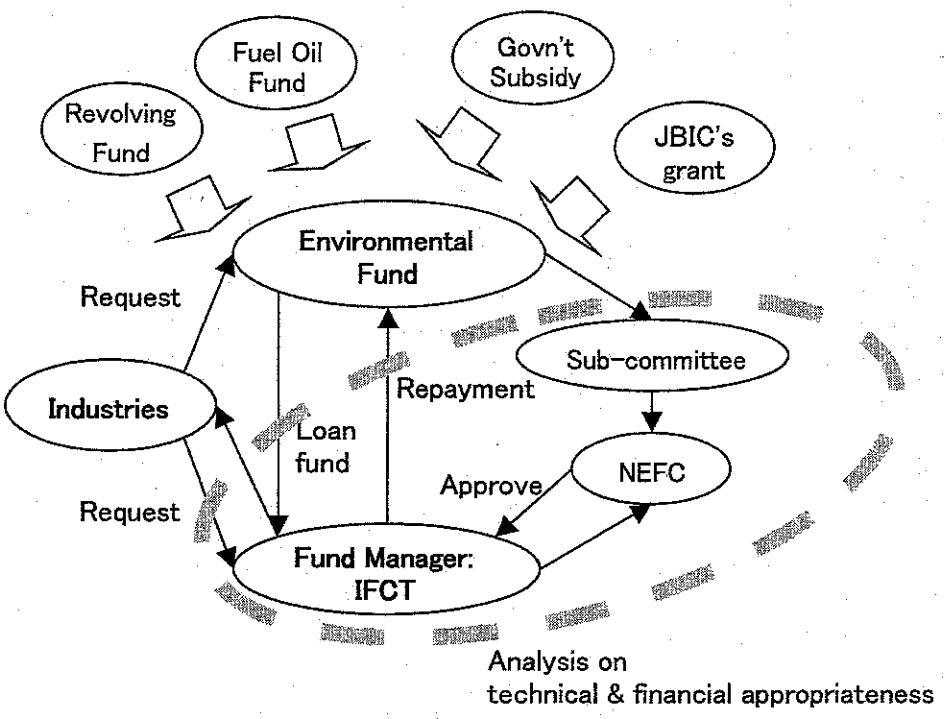


Figure 8.7.1.1 Process of the Environmental Fund

2) JBIC's Two-Step Loan

The Japan Bank for International Cooperation (JBIC) currently provides two types of two-step loans services for the Funds of the Industrial Finance Corporation of Thailand (IFCT) in order to enhance the improvement of facilities and operation of small and medium-size industries and enterprises (refer to Figure 8.7.1.2, and Chapter 7 of the Supporting Report). Both loans could be applicable for the fuel conversion to natural gas.

According to the cost estimation as mentioned above, the necessary investment cost for fuel conversion is about 2,000MBt for SOx reduction of 10,000 ton/year which is half of the total loan amount.

In this scheme the contract between JBIC and IFCT has been established, and so eligible industries under the conditions and criteria could have loans from the IFCT directly. The detailed information on the loan scheme is described in Chapter 6 of the Supporting Report.

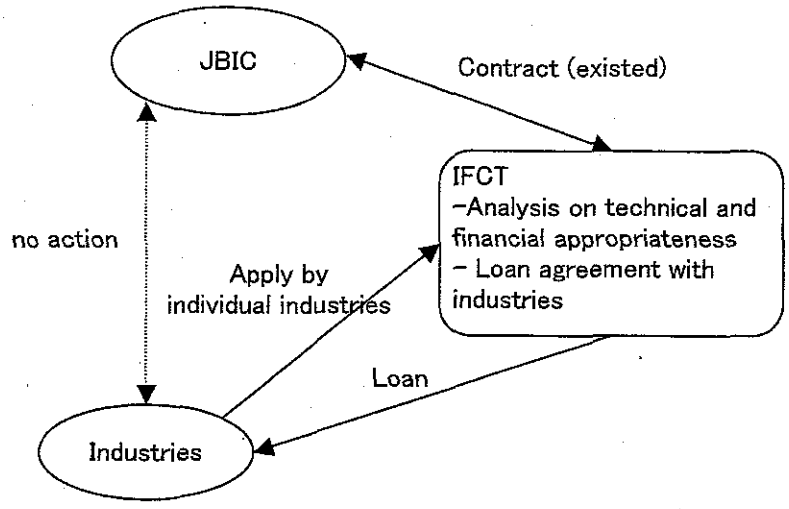


Figure 8.7.1.2 Procedure of JBIC's two step loan

8.7.1.2 Overseas Investment by CDM as a Financial Source

This is the case that assumes to invite overseas investments (donations) from the foreign governments or enterprises in the developed countries. The CDM (Clean Development Mechanism) is one possible way although the Thai government ratified the Kyoto Protocol but does not have complete domestic procedures as mentioned above.

As Figure 8.7.1.3 shows, a project proponent is needed in order to accept investment from foreign governments or enterprises and therefore in this case the Environmental Fund is assumed to be the proponent that allocates the investment for industries as Figure 8.7.1.3 & 8.7.1.4 show, because individual factories cannot be a proponent.

The total reduction amount of CO_2 is estimated at 211,000 C-T/year which is equivalent to about 90 M Bt calculated based upon the CO_2 selling price of 10 US$/C-T. 155 M Bt of annual energy cost also can be reduced by the fuel conversion. In case of assuming 15 year's time for the necessary machines or facilities for the conversion in order to consider the total effect of countermeasures, the reduction amount, energy cost saving and economic value of CO_2 are estimated below.

Case	Energy Cost Savings	Reduction Amount of CO_2	Economic Value of CO_2
1 year	155 Million Bt	211,000 C-T	90 Million Bt
15 years	2,325 Million Bt	3,165,000 C-T	1,350 Million Bt

The above estimation is rough because of insufficient information and data on the industries in BMR, therefore in advance of the CDM application, a kind of feasibility study

should be conducted as show in Figure 8.7.1.3.

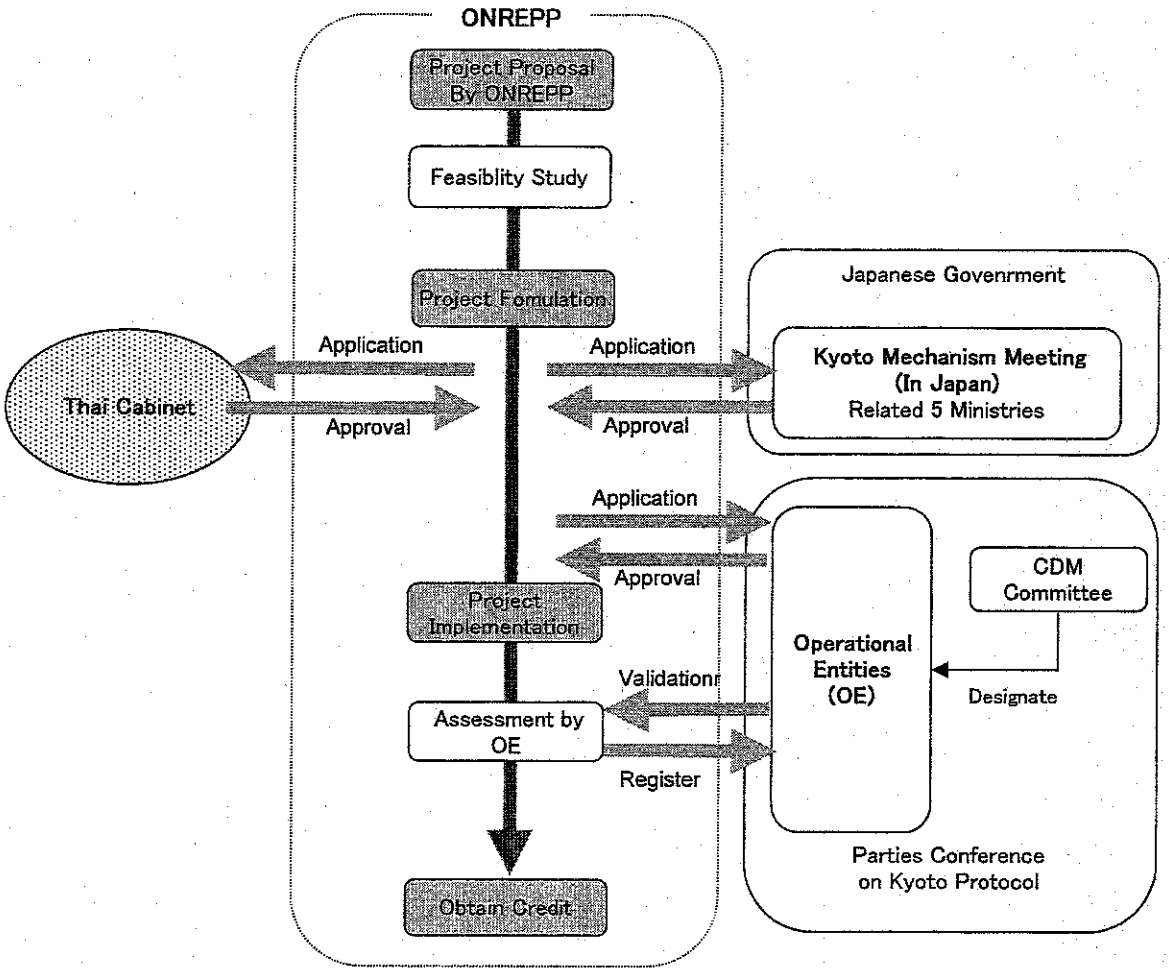


Figure 8.7.1.3 Procedure of Clean Development Mechanism

8.7.1.3 Financial Arrangement for Industries

As aforementioned, there are several soft loans which domestic banks and the JBIC provide with low interest and long-term repayment periods for small and medium-size industries. This kind of financial support could give them somehow incentives. Assuming the soft loan conditions (refer to Chapter 6 the Supporting Report), the annual loan repayments would be estimated at about 140 M Bt year which is less than the energy cost saving of 155 M Bt/year by the fuel switch. From this calculation, it would be understood that the soft loans would give incentive to the industries generally although this depends upon the relationship between energy cost saving and loan repayment.

On the other hand, financially weak industries that cannot apply for the soft loans due to the economic crisis need to be given financial support. Such industries need some special

treatments by governmental subsidies or overseas donations. In case the project is accepted as a CDM project, the overseas investment could be used as financial supports for such industries. Table 8.7.1.2 shows an implementation schedule including overseas investment by the CDM.

Table 8.7.1.2 Implementation Schedule

year	2003	2004	2005	2006	2007	2008	2009	2010	2011
Environmental Fund									
JBIC's Two-Step Loan									
Exploration of Possibility for Clean Development Mechanism (CDM)									
Preparation for a CDM project by Thai Gov.									
Feasibility Study									

means that equipment and facilities will be individually installed by industry available funds.

8.7.2 Institution and Capacity

For acid deposition and ambient air pollution control, on account of the complexity of the phenomena, the series of tasks need to be consolidated. They are a combination of administrative processes and scientific approaches.

The scientific approaches are the studying processes, the realization of current situations, analyzing necessary countermeasures, simulation analyses of effect of options, the selection of policies and reviews of results. In order to enhance acid deposition control, scientific capacity should be enhanced.

8.7.2.1 Institutional Issue for Shift to Natural Gas

The shift to natural gas is consistent with national policy to enhance the introduction of natural gas in the manufacturing sector, and it can be introduced by economic mechanisms. It is not necessary to prepare new or more stringent regulations. However, it is necessary to enhance the shift by the environmental administration.

Natural gas is distributed solely by Petroleum Authority of Thailand (PTT). PTT has the intention to promote gas distribution in BMR. Therefore PCD should discuss with PTT the plan of the shift, i.e. what area should be prioritized for introduction and how apply supporting mechanism by the Government. The base data for the selection of areas is the simulation result of the Study. After the arrangement of plan, PCD should raise public awareness for shift to natural gas.

8.7.2.2 Reinforcement of Institution

1) Characteristics of Environmental Administration

Thailand had experienced the mitigation of various environmental problems in the past. Basically the Thai people resolved the difficulties of implementing control measures by themselves. The administrative process is established in Thailand.

There are some characteristics in the environmental administration of Thailand. One of them is the primacy of the Enhancement and Conservation of National Environmental Quality Act, B.E. 2535 (NEQA 1992). Fields of environmental administration are wide. Atmosphere, ground water, soil and noise in living places are examples of fields. NEQA 1992 alone covers almost all fields. There are not laws that cover respective environmental fields, such as air, water and noise, independently.

Another characteristic is that direct environmental administration to industry is carried out conceptually by Department of Industrial Works, Ministry of Industry, Central Government.

2) Scientific Advisory Function

The policy for acid deposition control may be elaborated through three stages of committees in Thailand. They are National Environment Board, Pollution Control Board and Sub-Committee on the Acid Deposition Monitoring Network in Thailand. Representatives from relevant agencies and designated specialists formulate these committees. Authority and responsibility is assigned sophisticatedly to a respective agency in the field of environment. The selected agencies are 14 for National Environment Board, 14 for Pollution Control Board and 12 for Sub-Committee.

Needless to say, acid deposition is the result of various natural processes. Therefore, in order to build effective policy, the starting point is the realization of natural processes. And after this, valid policies will be formulated. The capacity of scientific approach enables to formulate adequate policy. The scientific approach is an assigned core function of PCD. However, because of limited resources, PCD cannot fulfil all necessary functions literally. One such function is scientific advisory function for the policy setting committees.

The function will be performed by a well-formulated body. The body that mobilizes core scientists of the field can perform the scientific advisory function. As some parts of the functions that are performed by current committees can be substituted by the well-formulated body, it may be possible to re-organize committees. PCD undertakes the secretary function of the body, which include studying the topics of committees beforehand.

3) Designation of Analysis and Simulation Group

A major subject for expansion of the capacity is the designation of an analysis and simulation group in an adequate sized administration unit. Concerning acid deposition, the evaluation of ambient air quality, critical load and simulation analysis are typical subjects of the group. The role of the group is not collecting monitoring data but analyzing the causes and results of environmental issues. Besides, it is necessary to analyze the effect of policy options by simulation. Thus PCD with the analyzing and simulation group has the capability of taking the initiative in the environmental administration.

The function of analysis and simulation cannot be completed by government agencies only. The involvement of the private sector after adequate and clear job assignment is necessary.

4) Designation of Inventory Group

In order to analyze causes of the environmental issues, inventory data are indispensable. Currently inventory databases of environmental field in Thailand are not sufficient. Data sets of other agencies are not sufficient for the administration of PCD. Inventory databases are essential for analyses. Periodical and continuous compilation of inventory data should be assigned to the group.

The function of preparation of inventory cannot be completed by government agencies only. Involvement of the private sector after adequate and clear job assignment is necessary.

5) Decentralization

In 1997, the Constitution of Thailand was amended, and the concept of decentralization was introduced wider than before. In 1999, the law for decentralization was formulated. The enhancement of local administrative power and the extent of commissioning authority of central government to local bodies are current topics.

At present, the majority of environmental management in Thailand is implemented by the central government. The central government and its provincial officer administrate local environmental issues with the cooperation of Local Administrative Organization (including Provincial, Municipality's, and Tambon's Administrative Organization).

PCD, however does not have provincial officers, and is tackling decentralization issues. One of them is improvement of air quality monitoring by decentralization and cooperation with Local Administrative Organizations. Decentralization is a chance for the enhancement of the administrative capacity.

In Japan, concerning environmental administration, practically all enforcement power is mandated to local governments. People elect their governor and assembly members for local government. The local governments have their own resources (staff, facilities and

budget) for execution of environmental administration. In order to tackle severe SO_2 pollution in Japan, local governments played a pioneering and substantial role (Japan's Experience in the Battle against Air Pollution).

8.7.2.3 Reinforcement of Capacity

1) Administrative Capacity

In Thailand, the environmental monitoring capacity is outstanding. Concerning ambient air quality, approximately 50 stations are operated by AQNMB in the year 2000, for acid deposition 5 stations are operated. Emission gases from vehicles are analyzed by chassis-dynamo-meter. Discharged amounts of some factory's pollutants are transmitted to the office. They are maintained consistently. However, the utilization of collected data may not be sufficient. It is necessary to review monitoring data by all standards, to compare emission data to Mobile 5, and to compile emission inventory information. In order to carry out reviewing, comparing and compiling by own effort, the expansion of the current capacity of environmental administration is indispensable. That type of capacity is indispensable for performing scientific function.

Currently Continuous Emission Monitoring (CEM) has been developing. Full utilization of CEM depends on realization of production process and abatement plant. Besides it requires detailed checks of data. It cannot be undertaken well without equal knowledge of engineers of factories on monitoring systems, abatement methods, analyzing machines and manufacturing processes. It is necessary to expand capacity of administration.

2) Accountability

The publication of the monitoring and analyzing result is the implementation of accountability. Accountability is twined with authority and responsibility of administration. In this context, it is necessary to publish periodically the monitoring result after institutional check. The publication of the annual report with review and evaluation of the monitoring result is indispensable also. The broad publication of environmental information is one of realization of accountability.

The implementation of accountability is an essential component of capacity building. The study and investigation for review and evaluation provide indispensable opportunities for human resource development. The results of the study and investigation is materials for the annual report. In this sense, more wider publication and reporting are indispensable opportunities for capacity building.

Besides publication and reporting gives chances for public relations, public involvement, and can raise public awareness for acid deposition.

3) Capacity Building of the Private Sector

The expansion of capacity of government agencies as well as the capacity building of the private sector is important. The function of preparing inventory and analysis and simulation cannot be completed by the government agencies alone. It is necessary to nurture the capacity of the private sector and to involve them. Adequate guidance and clear job assignment is necessary for involvement.

In Thailand, the private sector has considerable difficulties to access information. It is important to collect information and compile them into inventory by the cooperation between PCD and capable private sectors.

4) Formulation of the Society for "Atmospheric Environment Conservation in Thailand"

The capacity for acid deposition control reflects public concern. The enhancement of public concern for acid deposition control is another important issue. It is regarded as effective to formulate a sort of society that gives chances for scientific meetings and discussion on environmental issues. For this end, it is a possible way to formulate "the society for atmospheric environment conservation." Table 8.7.2.1 shows the brief frame of the society.

Table 8.7.2.1 Brief Frame of "the Society for Atmospheric Environment Conservation"

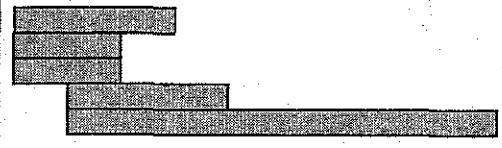
Target Fields	(1) Monitoring and Investigation Concentration of Pollutants (including VOC, O3 and others) Deterioration of land, forest, river, sea shore, sea (2) Simulation Model Atmosphere Acid deposition (Long range transportation of Acid Deposition causing materials) (3) Analysis and Research Monitoring Result, Simulation Result (4) Mitigating Technology Desulfurization, Denitrification, Fuel Switching, Fuel Improvement, Energy Saving (5) Control Policy
Participants	(1) Administration staff (2) Scientists and academic researchers (3) NPO, NGO (4) Consultants in relating fields
Activities	In order to enhance environmental concern, following items are expected. (1) Wide scope, Science-based Discussion (2) Chance for presenting results of scientific analysis in the course of management, results of research and experiences by mitigation measures For the meeting of the society, regular meeting (twice a year), special meeting for topics (Such as Johannesburg Summit, Conference on Climate Change, Emission Trading), and occasional sectional meeting for interested issues by members are expected.

8.7.3 Action Plan

In order to enhance the shift to natural gas, because of natural gas is distributed solely by Petroleum Authority of Thailand (PTT), PCD should discuss with PTT the plan of the shift, i.e. what area should be prioritized and how apply supporting mechanism by the Government. After the arrangement of plan, PCD should raise public awareness for shift to natural gas.

Table 8.7.3.1 shows tentative schedule of the shift to natural gas and reinforcement of institution and capacity for acid deposition and SO_2 mitigation.

Table 8.7.3.1 Action Plan for the Shift to Natural Gas

	2003 2004 2005 2006 2007 2008 2009 2010 2011
Countermeasure: Shift to Natural Gas Western Part of Bangkok NG Ring (Main Pipeline by PTT) Installation Planning (PCD and PTT) Supprting Planning (PCD, PTT, and IFCT) Public Relation for Shift to NG Instalation of Necessary Facilities by Individual Industries (Application of Environmental Fund, JBIC's Two Step Loan)	
Reinforcement of Institution and Capacity of PCD Designation of Analyzing & Simulation Group Designation of Inventory Group Nurturing Private Sector	

Charpter 9

Countermeasures for NO2 in BMR

9. Countermeasures for NO_2 in BMR

9.1 Methodology

To begin with the Countermeasures Selection, the 1st draft countermeasures list was compiled from the analysis of the 2011 (BAU Case) simulation result. Through the analysis, the target of countermeasures was identified and the effective countermeasures were complied as 1st draft. The list of draft countermeasures was screened through two steps. At the first step, they were evaluated from social, financial acceptability and technical possibility, at the preliminary level. And then, at the next, the selected countermeasures at the first step were evaluated by a cost-effectiveness analysis. And then, the effect of the combination of selected countermeasures was simulated.

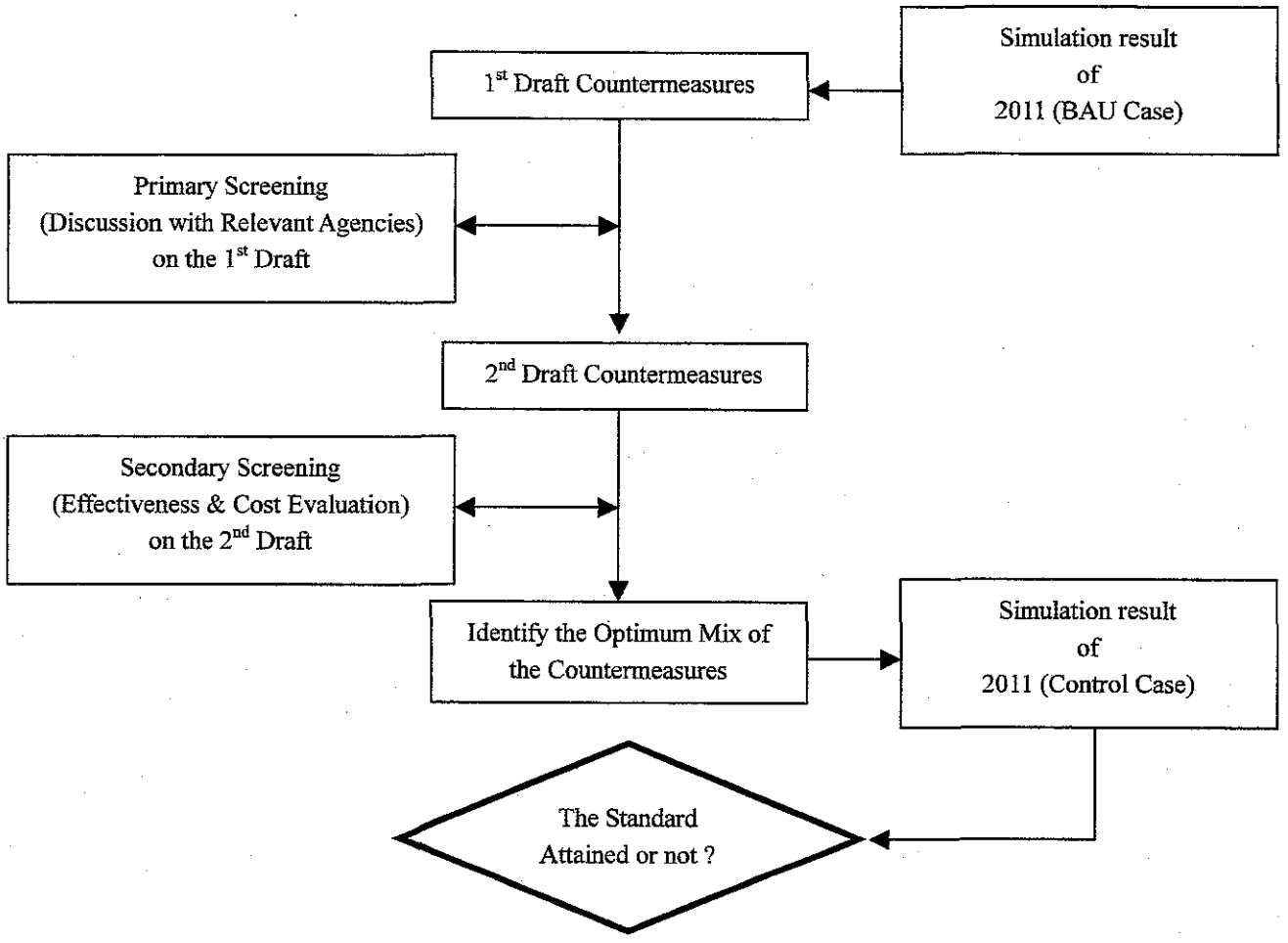


Figure 9.1.1.1 Basic Flowchart for Building the Scenario of NO_2 Countermeasures

9.2 NO_2 Concentration at 2011 (BAU Case)

As explained in Chapter 6, ambient NO_2 concentration at 2011 (BAU Case) was simulated based on the emission inventory of mobile sources and stationary sources at the same year and case as discussed in Chapter 3 and 4. Mobile sources had much more impact on NO_2 concentration than stationary sources, so that the condition of the mobile sources emission inventory should be reviewed carefully for ambient NO_2 concentration simulation. Table 9.2.1.1 shows the future emission control and road/MRT projects, which are considered in the BAU Case, since they are considered to be completed up to 2011 by URMAP.

Table 9.2.1.1 Emission Control and Transport Projects considered in the BAU Case

Emission Control		
	More Stringent Emission Standard Enforcement (EURO 3, Level 5) - LDGV, LDDV, LDDT (EURO 3: 2004-) - HDDV (EURO 3: 2006-) - MC (Level 5: 2004-)	
Transport Projects reviewed in URMAP		
	Conceptual Mass Rapid Transit Implementation Master Plan (CMIP)	
	Mass Transit Feeder Systems Study	
	Bangkok Railroad Improvement Project (BRIP)	
	DOH Highway Projects - Bang Bua Thong-Bang Khun Thian, - Outer-ring Road (Bang Yai - Bang Pong), etc.	
	Other Agencies' (ETA, PWD, BMA, etc) Projects	
MRT Projects considered to be completed in BAU Case (2011)		
	Red Line Commuter (Access to Second Bangkok International Airport)	
	R01	Phaya Thai-Makkasan-SBIA
	R02	Bang Sue-Phaya Thai
	R03	Hua Lamphong-Bang Sue
	R04	Bang Sue-Rangsit
	R08	Bang Sue-Don Muang
	Green Line	
	G01	Mo Chit-On Nut (existing)
	G02	Rama 1- Saphan Taksin (existing)
	G03	On Nut-Samrong
	G04&G06	Saphan Taksin- Taksin Road-BSTC
	G07A	Mo Chit-Ratchayothin
	Blue Line	
	B01	Eastern Circumferential (Bang Sue-Asok-Hua Lamphong)
	B02&B03	Hua Lamphong-Tha Phra-Bang Wa

Figure 9.2.1.1 shows the Airviro Simulation Result of NO_2 concentration in BMR at 2011 (BAU Case), based on the abovementioned simulation conditions.

■ : Grid over Thai NO_2 ambient air quality standard

▣ : Grid over WHO NO_2 ambient air quality guideline

Figure 9.2.1.1 NO_2 Airviro Simulation Result of 2011 (BAU Case)

The areas, where ambient NO_2 concentration would exceed Thai ambient air quality standard, mainly appeared in the following areas,

- Roadside of the Western Outer Ring Road (Bang Bua Thong-Bang Khun Thian)
- Roadside of the Rama III Road (Dao Kanong-Outer Ring Road)
- Roadsides of the Rathawithi Road and the Pinklao Elevated Way (Buddhamonthol Sai2-Nakhon Chaisri Sai 338)
- Roadside of the Wat Nakhorn Inn Bridge Road
- Major Intersections (Bangkok Noi, Lad Krabang, Samut Prakan, etc.)

The areas, where the ambient NO_2 concentration would exceed the WHO ambient air quality guideline, occur in the following areas.

- Major parts of the areas closed by the Middle-ring Road

- Roadsides of major trunk road (Western/Sourthern Outer Ring Road, Phayathai-Outer Ring Road, etc.)

Table 9.2.1.2 shows the Summery of NOx/ NO_2 Simulation Result

Table 9.2.1.2 Summery of NOx/ NO_2 Simulation Result

Case Description	NOx Emission Volume (kt@2011)	No. of Grid over the standard (BMR: 26,320 Grids)	
		Over WHO	Over Thai
BAU Case	277	2,127 (8%)	60 (0.2%)

9.3 Countermeasures Selection

9.3.1 Target Type of Emission Source

As shown in Figure of "Estimated NOx Emission of Mobile Sources in BMR" in "NOx and SOx Emission of Mobile Sources in BMR", the emission share of road traffic in total mobile source would be approx. 86% in 2011 (BAU Case). It shows that road traffic should be targeted for NOx emission reduction among mobile sources.

Furthermore, as shown in Figure 9.3.1.1, HDDV/T, which consists of H-Trucks and Buses, would share approx. 80% of total NOx emission from mobile source in 2011 (BAU Case). That concludes the countermeasures for mobile sources should be considered as NOx emission control of HDDV/T.

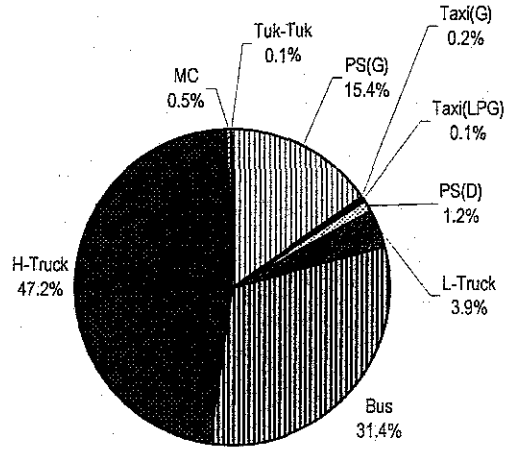


Figure 9.3.1.1 NOx Emission estimated by Vehicle Type in 2011 (BAU Case)

9.3.2 Rationale for the Selection of First draft countermeasures

The first draft countermeasures were selected and were screened in the next steps, namely primary screening process or secondary screening process, if they were considered effective for the reduction of NOx emission from HDDV/T.

Although PCD was studying the Methanol-blended fuel or Enhancement of I/M program as a future countermeasure against vehicle oriented air pollution, they were not selected because the normal I/M program target only black smoke for HDDV/T, except IM240, which is considered as too advanced I/M program in Thailand even in the future up to the year 2011, and for Methanol-blended fuel countermeasure, the detailed reason is described below.

Box: Fuel Quality Improvement Program (Ethanol Blended Gasoline)

As one of the oxygenates in the fuels, Ethanol has lured considerable attention through the success of the Brazilian program initiated in 1975 as a response to the global oil crisis of the 1970s. When ethanol is blended with ordinary gasoline in proportions up to 22 percent, the resulting mixture known as gasohol, may be burned in ordinary spark-ignition (SI) engines, while a special engine is required to burn mixtures in richer than 22 percent ethanol.

Such fuels reduce emissions by incorporating oxygen into the fuel itself, improving combustion. The largest impact of these oxygenated fuels is seen on CO emissions and it may be effective for CO non-attainment area. However its effects on NOx emission, as shown below, were considered too undetectable to take into account in the Study.

The Effects of Gasohol Observed or Described in Existing Data or Reports

Effects Observed or *Described*	Source
10 motorcycles were tested (7: 2 stroke, 3: 4 stroke). Test data shows slight increase in gasohol of 2 stroke and inconsistent change in 4 stroke.	PCD Emission test data of Motorcycles
The effects of oxygenate content in gasoline on NOx emissions is both very slight and inconsistent (small increases for some vehicles, small decreases for others), and ... , the net effect on NOx emission factors of RFG (Reformulated Gasoline) is negligible.(p. 1-24)	US EPA, 1994, User's guide to MOBILE5a (Mobile sources emission factor model)
It was noted that NOx emission depends on the engine operating condition rather than the ethanol content.	Hsieh, W. D. et al. Engine performance and pollutant emission of an SI (Spark Ignition) engine using ethanol-gasoline blended fuels. Atmospheric Environment 36 (2002) 403-410

Even though some transport projects, like the MRT project or traffic control, may bring certain effects on NO_2 reduction, the Study team did not consider them as the countermeasure, for the following reasons,

MRT Projects

- The MRT Projects, which are assessed to be completed up to 2011 in the URMAP study, had already considered in the BAU Case of the Study.
- The other MRT projects, which are not considered in the period up to 2011, are assessed to be completed after 2011 in URMAP.
- Feasibility assessment study on future MRT projects is out of the scope of this JICA study. The JICA study should rely on the other respectable transportation studies for the assessment and utilize the existing results of these studies.

Traffic Control

- According to OCMLT, environment-oriented traffic control was considered unrealistic.
- According to OCMLT, there was No study for Vehicle Type Traffic Control (H-Truck Entrance Ban in City Center). Therefore the effect of traffic control cannot be estimated in the Airviro Simulation.

However the effect of traffic control was preliminarily estimated in the study as a supplement on even rough assumption described later.

9.3.3 Primary Screening

The primary screening aimed to evaluate the 1st draft countermeasures, which were listed up through the consideration of the simulation result of 2011 (BAU Case) and the analysis of the target type of emission source, both of which were mentioned above.

Table 9.3.3.3 shows the summary of the below-mentioned countermeasures and Table 9.3.3.4 shows the summary of the screening results of them.

9.3.3.1 EURO 4 Enforcement (EURO 4)

1) Rationale

Enforcement of EURO 3 for Light-Duty Vehicles/Trucks, which PCD proposed, has been gazetted. PCD is considering the enforcement of more stringent emission standards, namely EURO 4 for LDGV, LDDV, LDDT and HDDV, after due consideration of ambient air quality.

Table 9.3.3.1 shows the past and future emission standards for new vehicles. The emission standards in bold letters were selected in the Control Scenario.

2) Screening Results

Thai Oil refineries agreed that they would begin to provide high speed diesel oil under 350 ppm Sulphur, EURO 3 requirement level, before 2004 while they would provide gasoline fuel under 150 ppm Sulphur from 2008. For the low sulphur program up to 50 ppm, EURO 4 requirement level, it was considered possible to attain from 2010 for both gasoline and high speed diesel oil.

Thai vehicle manufacturers, according to them, Thai Automobile Industry Association (TAIA), would have to import vehicles in completed product for EURO 4, while they had the capability to attain EURO 3 with certain modification on their production line, whenever they need. Though it would increase the vehicle unit price from 15% to 20%, it would be possible with certain financial support.

The enforcement years for EURO 4 were considered different between HDDV/T and the others. The interval of emission standard upgrade from EURO 3 to EURO 4 should be 5 years at shortest in PCD's experience. Therefore EURO 4 for HDDV/T would begin from 2011, one year behind the enforcement on the other vehicle types, 2010.

Table 9.3.3.1 Past and Future Emission Standards for New Vehicles

Type	Lv.	EURO	EU Directive	Thai Industrial Standards	Enforced Date
Light-Duty Gasoline Vehicle	1	---	83/351/EEC	TISI.1085-2535(1992)	(not enforced)
	2	---	88/76/EEC	TISI.1120-2535(1992)	30 Mar. 1995
	3	I	91/441/EEC	TISI.1280-2538(1995)	24 Mar. 1996
	4	I	93/59/EEC	TISI.1365-2539(1996)	1 Jan. 1997
	5	II	94/12/EC	TISI.1440-2540(1997)	1 Jan. 1999
	6	II	96/69/EC	TISI.1870-2542(1999)	25 Aug. 2001
	7	III	98/69/EC(A)	---	2004 (gazetted)
	8	**IV**	**98/69/EC(B)**	—	**2010(planned)**
Light-Duty Diesel Vehicle/ Truck	1	---	88/76/EEC	TISI.1140-2536(1993)	29 Jan. 1995
	2	I	91/441/EEC	TISI.1285-2538(1995)	23 Feb. 1996
	3	I	93/59/EEC	TISI.1370-2539(1996)	1 Jan. 1997
	4	II	94/12/EC	TISI.1435-2540(1997)	30 Sep. 2001
	5	II	96/69/EC	TISI.1875-2542(1999)	25 Aug. 2001
	6	III	98/69/EC(A)	---	2004 (gazetted)
	7	**IV**	**98/69/EC(B)**	---	**2010(planned)**
Heavy-Duty Diesel Vehicle/ Truck	1	---	(ECE R49-01)	TISI.1180(1)-2538(1995)	(not enforced)
	2	I	91/542/EEC(A)	TISI.1290-2538(1995)	12 May 1998
	3	II	91/542/EEC(B)	TISI.1295-2541(1998)	23 May 2000
	4	III	1999/96/EC(A)	---	2006 (planned)
	5	**IV**	**1999/96/EC(B)**	---	**2011(planned)**

Source: Air Quality and Noise Management Division, PCD (Jun. 2000) and others
Note: Emission standards in bold are future emission standards to be proposed.

9.3.3.2 Low Emission Vehicle (LEV)

1) Rationale

The possibility of substituting cleaner-burning alternative fuels for gasoline and diesel has drawn increasing attention over the past decade. Alternative fuels have the potential to conserve oil products and preserve energy sources, as well as reduce or eliminate pollutant emissions. However when the air quality with using alternative fuels is evaluated, the same or even greater emission reductions could be achieved using a conventional fuel with an advanced emission control technology. It would depend on the relative costs of the conventional and alternative fuels and which approach is more cost-effective.

At this stage, LEV included HDDV/T with Hybrid, Fuel Cell or NG engine. On the other hand, neither Electric nor LPG were included because the Electric system was considered inappropriate for heavy-duty vehicles and LPG promotion was considered against a part of the national energy policy of LPG consumption suppression proceeded by the Taxi fuel shift from LPG to NG. Then this countermeasure means not only LEV purchase, but also Aged-vehicle replacement with LEV.

2) Screening Result

Regarding Hybrid or Alternative energy vehicles like Fuel cell as Low emission vehicles, normally they require a special environment to run as compared to conventional fuel vehicles, namely special garages equipped with specific parts to be replaced regularly, fully-trained technicians and their own refueling stations especially for Alternative ones, etc. That means they could operate in more limited areas than conventional ones. Furthermore, their unit prices are too expensive for operators to recover their initial investments by the savings from fuel efficiency. Therefore they were not considered feasible in the study.

On the other hand, NGV has enjoyed a better environment since natural gas vehicles have been promoted by PTT and PTT has constructed and operated 5 refueling stations and constructs 3 more (according to PTT on Nov. 2002). Though natural gas vehicles are also expensive, they are not as expensive as Hybrid or the other alternative energy ones.

The environment, however, has been improved only in BMR because refueling stations, so called Mother types, can be located along the natural gas pipeline. The limitation on the travel range by one-time refueling, ranges from 180km to 250 km currently, according to the specifications of NG buses of Japan although the limit would be raised in the future.

And NGV requires high level of technique for maintenance, which could be available only at well-equipped and well-staffed garage in metropolitan area, BMR. Those facts narrow down a target to vehicles operated only in BMR.

Furthermore NGV is potentially at a disadvantage in the engine power to diesel engine for heavy-duty use. NGV would demand higher-powered and larger-scaled engine than diesel one if it needs to accomplish the equal duty. It is usually difficult to install larger engine than the originally equipped, since engine compartment is likely to be special-designed for the original. If it is not replaced with the larger but with the similar-sized, the converted truck could accomplish only lighter duty. This fact would be the inevitable issue for converting diesel-fueled truck to NG one, which is likely to be loaded up to the maximum level.

This concluded that NGV could be appropriate for Urban Buses, which have been operated by BMTA.

For the safety issues with such a gaseous fuel, recent natural gas vehicle uses thick-walled reinforced aluminum cylinders, steel cylinders or 100% composite materials to store compressed natural gas as a vehicle fuel, according to International Association for Natural Gas Vehicle. And natural gas vehicles submitted to test crashes up to 52 miles per hour, which have been totally destroyed, but show little or no damage to the compressed gas cylinders. The standards of cylinder structure examined by these severe tests ensure that compressed natural gas cylinders could be durable and safe with periodic inspection and maintenance, which sometimes requires advanced techniques with higher cost than diesel vehicles.

9.3.3.3 Overage Vehicle Retirement (OVR)

1) Rationale

Although the more stringent emission standard limits the emission from new vehicles, the effect would be limited and the ambient NO_2 level could not be improved drastically, since the worn-out vehicles from overwork and overage engines, especially overage HDDV/Ts emit considerable amounts in total. Also in the study, the retirement program of the vehicles would be appropriate.

2) Screening Results

Regarding OVR for Urban Buses, BMTA itself agreed since it has retired over 10 years old buses as a rule and sold them to under-licensed private operators. It concluded complete financial support to them should be essential for OVR.

For Coaches or H-Trucks, as with the Urban Buses operated privately, the operators should need substantial financial support to replace with the new.

9.3.3.4 HDDV/T Substantial Compliance with the Emission Standard (Real-EURO)

1) Rationale

As discussed in the "Mobile Source Inventory", the emission factors were determined from the Chassis Dynamometer Test Data and the test data of the Light Duty Vehicles were screened with the emission standard applied. However the test data of HDDV/T (PRE and EURO 2 level) were only selected by PCD and the HDDV/T emission factors were estimated on them. The HDDV/T emission standards have adopted the emission test by

engine dynamometer instead of chassis dynamometer and therefore, the test data (g/km) cannot be compared and screened simply by the standards (g/kWh). However they were considered to be 2 to 3 times as high as the default emission level of COPERT3 or MOBILE5a.

Table 9.3.3.2 shows the comparison of them and the actual emissions of EURO 2 HDDV/T in Thailand were considered higher than they are supposed to be if they meet the EURO 2 standards.

Table 9.3.3.2 Emission Factors Comparison between default of the other sources and Thai

Standard			COPERT g/mile		MOBILE5a	EF(Thai_BAU)	compared with	
level	Imp. Year	g/kWh	Truck	Bus	HDDV:g/mile	g/mile	COPERT	MOBILE5a
Pre EURO	-	-	5.7-31.2	21.0-24.0	9.87-25.97	**51.43**	165-902%	198-521%
EURO2	1995	7	2.8-12.5	8.4-12.0	8.13	**29.83**	239-1065%	367%

Note: HDDV in COPERT includes weight classes, <7.5t, 7.5-16t, 16-32t and >32t.
MOBLIE5a's EF for EURO 2 are assumed as the default ones at these impiemantation year, 1995.

For the cause of this matter, the study team considered that the current compliance system of the HDDV/T emission standard would not work well enough and it should be stricter. The following description in Box 1-4 might support this matter.

BOX 1: EURO 2 Bus in Thailand

New diesel-fueled buses are required to meet the EURO 2 standards. To meet the EURO 2 and EURO 1 standards, virtually all diesel engines require direct fuel injection and computerised engine maintenance systems. But many buses operating as EURO 2 buses **do not employ such computer control technologies**, and are unlikely to be operating to meet the EURO 2 standards.[1]

BOX 2: HDDV Defeat Strategies in US

This problem (the matter mentioned in Rationale) was also very widespread in the U.S. until it ("defeat devices" developed by engine manufacturer) was detected by the EPA. Essentially, a "defeat device" is an element of the **control software for the engine electronic control unit** that allows the ECU to recognize when it is being subjected to an emission test, when it is not being tested for emissions. When it is being subjected to the emission test, it uses one set of pre-programmed control values for such variables as fuel injection timing. This set of control values is optimised for the lowest possible emissions. When the engine detects that it is NOT being subjected to an engine test, it uses another set of control values that are optimised for power and fuel economy. These control values generally include much more advanced fuel injection timing, which results in **NOx emissions two or three times higher** than the values achieved on the emission test.

U.S. legislation has always prohibited the use of "defeat devices". Thus, when these devices were discovered to be in widespread use, the EPA and Department of Justice arrived at an out-of-court

[1] Thailand Environment Monitor 2002, World Bank

settlement (see BOX 4), under which the manufacturers paid hundreds of millions of dollars in penalties, and agreed to accelerate the introduction of lower-emitting engines as a partial compensation for their cheating. Had they not agreed to this settlement, the manufacturers could have been liable for fines of up to US$ 25,000 for each engine they had sold that contained the defeat devices.[2]

BOX 3: Defeat Device Investigations in US

Manufacturers are required to test vehicles and engines under a prescribed Federal Test Procedure testing (FTP) to demonstrate that vehicles' emissions do not exceed a set standard. Manufacturers must also ensure that vehicle emission control systems operate in-use as they do on the test. If, without properly informing EPA, an emission control system operates differently when in-use, the emission control system is considered "defeated" and a "**defeat device**" is present. **Such defeat devices can cause vehicles to exceed the emissions standard by 300% or more.**[3]

BOX 4: Heavy Duty Diesel Engine Settlement in US

On October 22, 1998, the Department of Justice and the Environmental Protection Agency announced a settlement with seven major manufacturers of diesel engines who will spend more than one billion dollars to resolve claims that they installed **illegal computer software on heavy-duty diesel engines that turned off the engine emission control system during highway driving.** The settlement included an $83.4 million total penalty, the largest civil penalty ever for violation of environmental law. This settlement will prevent 75 million tons of harmful **nitrogen oxide (NOx)** emissions nationwide by the year 2025.[4]

This countermeasure would contribute not only to reduce excessive emission from such a doubtful HDDV/T supposed to comply the latest standard, but also to improve the effect of the more stringent emission standard enforcement.

There was no plan to improve the compliance and this unfavourable situation would continue as it was. This fact indicated that this matter would not be cleared up in BAU Case, therefore the study team considered the stricter compliance should be one of the countermeasures to be proposed.

2) Screening Result

The emission standard should be complied as a principle. TISI should have responsibility to enforce the compliance. It should be the focus task for all of the relevant agencies.

[2] This information is quoted from the e-mail on 18 December 2002 from Christopher S. Weaver, P.E. President of Engine, Fuel, and Emissions Engineering, Inc.

[3] http://www.epa.gov/compliance/civil/programs/caa/caaenfpriority.html#Defeat

[4] http://www.epa.gov/compliance/civil/programs/caa/diesel/index.html

9.3.3.5 Traffic Controls for Heavy Trucks (supplement)

1) Rationale

OCMLT has planned traffic controls for H-Truck for the past 10 years. Recently it has followed,

- 1st step since 15 Jun. 2000: No H-Truck Parking for all day on the Ratanakosin island and adjacent area,
- 2nd step since 1 Sep. 2000: No H-Truck Parking for all day in the area close to the Middle-ring road,
- 3rd step (planned from early Jan. 2003): No H-Truck Entrance between 6:00-9:00 on weekdays into the area close to the Middle-ring road, and
- 4th step (under consideration): No H-Truck Entrance for 24 hours on weekdays into the area close to Middle-ring road.

OCMLT would decide to implement the 4th step if it is necessary for mitigating traffic congestion furthermore after analyzing the results of the 3rd step.

2) Methodology

There was no traffic simulation result available for the study, so the Study assumed the traffic volume with the traffic control, as follows,

- There were Two types of traffic volume variation assumed,

  Case 1: No vehicle type shift from HDDT to the other vehicle types would occur

  Case 2: A vehicle type shift from 1 HDDT to 6 LDDTs would occur, since a HDDT was presumed to be loaded to 9 tons of the average 10 ton capacity and a LDDT was presumed with 1.5 tons loads,
- The traffic control would allow the negligible volume of HDDT, which was treated as zero in the calculation, in the controlled area,
- The traffic control would change the traffic situation only in the controlled area, but not change outside this. They were assumed the same as the BAU Case.

Table 9.3.3.3 Outline of Tentative Countermeasures

	Countermeasure	Description
BAU Case	■ EURO 3 Enforcement (**EURO 3**) - Light-duty Vehicle/Truck (2004 -) - Heavy-duty Vehicle/Truck (2006 -)	- EURO 3 is a more stringent emission standard than EURO 2. - Unlike EURO 2, the EURO 3 vehicles require lower sulphur content in gasoline and diesel oil to attain the emission standards.
Tentative Countermeasures for Control Case	■ EURO 4 Enforcement (**EURO 4**) - Light-duty Vehicle/Truck (2010 -) - Heavy-duty Vehicle/Truck (2011 -)	- EURO 4 is a more stringent emission standard than EURO 3. - Like EURO 3, the EURO 4 vehicles require lower sulphur contents in gasoline and diesel oil (lower than EURO 3 level) to attain the emission standards.
	■ Low-Emission-Vehicle Promotion (**LEV**) - NGV - Hybrid or others	- Target vehicle type is HDDV/T, namely Urban Bus (BMTA), Coach (Long-haul Bus) and H-Truck (Heavy Truck) - LEV generally emits NOx much lower than conventional Diesel vehicles. - For LEV promotion, Aftermarket engine conversion of old (In-use) HDDV/T and New LEV purchases were considered.

	■ Overage Vehicle Retirement (**OVR**)
	- Accelerating retirement of overage vehicle
	- Introduction of inducements to New vehicles
		- Target vehicle type is HDDV/T, namely Urban Bus (BMTA), Coach (Long-haul Bus) and H-Truck (Heavy Truck)
		- By this countermeasure, Over 10 year old HDDV/Ts could not be registered in BMR, for the following reasons,
		  - The air pollution problem occurs primary in BMR and the major HDDV/T traffic in BMR is considered as HDDV/T registered in BMR.
		  - If it also covers up-country, it would cause fatal impact there.
		- Tampering (mainly engine replacement) would be prohibited as a rule since,
		  - The vehicle age control assumes that the engine age should be the same as the fleet age. If the engine can be replaced without certification, the vehicles emit higher than they are supposed by their age deterioration
		  - Tampering normally would be accompanied with the removal or disabling of emission control devices and cause high emission.
		However it is allowed only when the engine switched vehicles match exactly any certified configuration of the same or newer model year as the chassis. (Tampered vehicle should be treated as new vehicle when it is tampered)

	■ HDDV/T Substantial Compliance with emission standard (**Real-EURO**)	- PCD test data show that the actual NOx emissions of EURO 2 HDDV/T in Thailand are much higher than they are supposed to be if they meet the EURO 2 standards. This countermeasure would require HDDV/T to comply with the EURO stricter standard through random sampling/testing by unannounced inspection, and to emit as the same level as European HDDV/T.
Supplement	■ *Traffic Control* *- No HDDT (24hrs) in Middle-ring Road Area (113 km²)*	- *This is the 4th stage of OCMLT traffic control plan for the mitigation of traffic congestion. It is not treated as a countermeasure.* - *There is no traffic simulation of this control. The Study team estimate presumable traffic volume on a rough assumption, namely no HDDT in the control area without any vehicle type shift (Case 1), with shift from 1 HDDT to 6 LDDTs (Case 2) with the same traffic situation as BAU case*

Note: Traffic control was not considered as a countermeasure since it was not environment-oriented. However, they were treated as supplement to estimate their impact preliminary.

Table 9.3.3.4 Primary Screening Results of 1st Draft Countermeasures (Financial Acceptability & Technical Possibility)

Program			F/S Interview	Social/Financial Acceptability	Technical Possibility	Screening Results
EURO 4 (LDV/T: 2010-) (HDV/T: 2011-)	Low Sulphur Program (50ppm)		Oil Refineries	O	O	*Acceptable and Possible*
	Emission Standard		Automakers (TAIA)	Financial support	O	*Acceptable and Possible*
LEV (HDDV/T: 2004-) Promotion of Low Emission Vehicle	NGV	- Urban Bus (UB)	Bus Operator (BMTA)	Financial support	O	*Acceptable and Possible*
		- H-Truck (Tr) - Coach (Ch)	Transportation Association	Financial support	X	Limitation on - Travel range by one-time refuelling (180-250km) - Refuelling Station (only at NG pipeline planned in BMR and the adjacent area) - Proper Garage equipped with trained staff and special parts for NGV.
			PTT (Natural Gas Supplier)	O	O	*Acceptable and Possible*
			NEPO	O	O	*Acceptable and Possible*
	Hybrid or others		Bus Operator (BMTA) Transportation Association	X	O	Expensive (the Hybrid one is almost double of the Diesel of the same type) Lack of the infrastructure if required (Fuel Stations, Proper Garages, etc.)
OVR (HDDV/T: 2004 -) Overage Vehicle Retirement	Overage vehicle Retirement Program replaced by New HDDV/T (UB, Ch, Tr)		Bus Operator (BMTA)	Financial support	O	*Acceptable and Possible*
			Transportation Association	Financial support	O	*Acceptable and Possible*
Real-EURO (HDDV/T: 2004 -)	Substantial Compliance with HDDV/T emission standard		TISI PCD	O	O	*Acceptable and Possible*
Traffic Control (Supplement) (4th Stage)	*No H-Truck (24hrs) in Middle-Ring Road Area (113km2)*		OCMLT	*Depend on the result of 3rd stage*	O	---

9.3.4 Secondary Screening

The secondary screening aimed to evaluate the 2nd draft countermeasures, which were selected through the primary screening process, from cost-effectiveness and institutional aspects.

For the cost-effectiveness evaluation, the effectiveness was considered as the NOx reduction amount in 2011 and the cost was estimated as annual economic cost of each countermeasure. And the cost-effectiveness is evaluated as "the annual cost for 1 ton of NOx reduction" with these two factors. The Cost-Effectiveness Evaluation results of the 2nd Draft Countermeasures are shown in Table 9.3.4.9.

For the institutional evaluation, firstly, the agencies concerned in the selected countermeasures were identified as shown in Table 9.3.4.8 and secondly, they were evaluated for each countermeasure as described below.

Finally, the 2nd draft countermeasures were evaluated from both aspects, as shown in Figure 9.3.4.1 and then recommendable countermeasures were selected.

9.3.4.1 EURO 4 Enforcement (EURO 4: all vehicle type)

1) Reduction Amount Calculation

The NOx reduction amount due to the EURO 4 enforcement was calculated by traffic volume of the 2011 (BAU Case), which was described before, and the emission factor, which was reduced by the enforcement. The emission factors for the EURO 4 vehicles were calculated by the reduction rate from the EURO 1 level, which is shown in the Table of "Reduction rates of NOx Emission Factor in EURO 2 onward from EURO 1". The emission factors and deterioration rates of the EURO 4- and EURO 4 are shown in Table 9.3.4.1.

Table 9.3.4.1. Emission Factors and Deterioration Rates

unit:g/mile (except HDDV: g/BHP-hr)

Vehicle category	Std.	Imp.Year	Base	det.1	det.2	Standard	
LDGV/Taxi (Gasoline)	Pre	-	3.44	0.00	0.00	---	
	ECE R83-B	1995	0.50	0.08	0.22	HC+NOx	5.96
	EURO1	1996	0.21	0.08	0.19	HC+NOx	1.56
	EURO2	1999	0.13	0.08	0.20	HC+NOx	0.80
	EURO3	2004	0.08	0.08	0.20	NOx	0.24
	EURO4	2010	0.04	0.08	0.20	NOx	0.13
LDDV	Pre	-	1.84	0.04	-	---	
	ECE R83-C	1995	1.84	0.04	-	HC+NOx	5.96
	EURO1	1996	1.62	0.04	-	HC+NOx	2.74
	EURO2	2001	1.32	0.03	-	HC+NOx	1.93
	EURO3	2004	1.18	0.03	-	NOx	1.26
	EURO4	2010	0.59	0.03	-	NOx	0.63
LDDT	Pre	-	2.49	0.08	-	---	
	ECE R83-C	1995	2.49	0.08	-	HC+NOx	13.90
	EURO1	1997	1.36	0.03	-	HC+NOx	2.74
	EURO2	2001	1.18	0.03	-	HC+NOx	1.93
	EURO3	2004	0.92	0.03	-	NOx	1.26
	EURO4	2010	0.46	0.03	-	NOx	0.63
HDDV/T	Pre	-	20.38	0.06	-	---	
	EURO1	1998	16.74	0.06	-	NOx	8.0 g/kWh
	EURO2	2000	14.65	0.00	-	NOx	7.0 g/kWh
	EURO3	2006	10.46	0.00	-	NOx	5.0 g/kWh
	EURO4	2011	7.33	0.00	-	NOx	3.5 g/kWh

Note 1: EURO 2- Standards of LDGV, LDDV, and LDDT, which limit HC+NOx, and their NOx E.F. are not directly comparable.
2: In case that Emission Standards are different among Vehicle specs, the largest emission levels are shown.
3: E.F. of HDDV/T based on Test Data of Chassis Dynamometer and Standards of Engine Bench Test are not comparable.

2) Cost Estimates

(1) Basic Assumption

- More stringent standard EURO 4 will comply for new vehicles
- The compliance will start from the year 2010.

- Targeted vehicles include LDVs (LDGVs, TAXIs, LDDVs, and LDDTs) and HDVs (Buses and Trucks)
- The numbers of the vehicles are forecasted based upon the long-term GDP projection.(refer to Chapter 2 of the Supporting Report)
- Cost for the compliance: the vehicle price (refer to 7.1.1.3 of the Support Report) will be increased by 20% (information from the automobile industry).
- Loan conditions for trucks: 7% annual interest rate, 4 year repayment period (average loan condition was employed, because financial companies provide various loans)
- Annualised cost: based upon the investment cost and benefit, annualised economic cost is calculated.

(2) Annualised Cost

Table 9.3.4.2 shows the replaced vehicle numbers and the necessary annualised cost by vehicle type and the total. The details are described in Chapter 7 of the Supporting Report.

Table 9.3.4.2 Investment and Annualised cost for LDV and HDDV

Vehicle category	No. of Vehicles to be replaced	Investment Cost (Billion Bt)	Annualised Cost (Billion Bt)
LDGVs	611,000	73	30
Taxis	17,000	4	1
LDDVs	169,000	20	8
LDDTs	1069,000	150	61
LDVs	**1,866,000**	**247**	**100**
Buses	28,000	5	26
Trucks	229,000	252	206
HDDVs	**257,000**	**257**	**232**
LDVs+HDDVs	**2,133,000**	**504**	**332**

3) Institutional Evaluation

The basic institutional structure for the enforcement of the new stringent emission standard was considered to be already in place and it was considered to have worked properly. It is not considered necessary to reform the current institutional structure for the standard enforcement.

9.3.4.2 Low Emission Vehicles (LEVs: NG Urban Buses)

1) Reduction Amount Calculation

The NOx emission factor of NG Urban Buses was quoted from US-EPA, "MOBILE6 Emission Factors for Natural Gas Vehicles (Apr. 2001)". It divides three weight classes, namely Heavy-Heavy, Medium-Heavy and Light-Heavy, and specifies NOx BER emission levels in g/BHP-hr for these three classes. In the study, the Urban Bus is classified into Heavy-Heavy and therefore, its emission factor was determined by 1.908 g/BHP-hr, the lifetime average NOx BER emission level of the Heavy-Heavy class, and its default conversion factor, 2.036, in MOBILE5a. The emission factors and deterioration rates of conventional HDDV/Ts and NG Buses are shown in Table 9.3.4.3.

Table 9.3.4.3 Emission Factors/Deterioration Rates of Conventional HDDV/Ts and NG Buses

unit: g/BHP-hr

Vehicle category	Std.	Imp.Year	Base	det.1	det.2
HDDV/T	Pre	-	20.38	0.06	-
	EURO1	1998	16.74	0.06	-
	EURO2	2000	14.65	0.00	-
	EURO3	2006	10.46	0.00	-
	EURO4	2011	7.33	0.00	-
NG Bus	-	2004	1.91	0.00	-

2) Cost Estimates

(1) Basic Assumption

- NG1: Old aged buses (1987-2000) mainly used by private bus operators will be replaced the engine with the NG engine by purchase
- NG2: The BMTA's buses will be replaced with new NG buses by lease
- NG3: Old aged buses (1987-2000) mainly used by private bus operators will be replaced by NG buses by lease
- The Implementation of countermeasures start from 2004.
- All the buses over 10 year-old will be changed into NG buses during 2004-2001
- Vehicle price: refer to the Basic data in Chapter 7 of the Supporting Report.
- Leasing price for diesel buses: 2500 Bt/day (from Hino, Benz and Volvo)
- Leasing price for new NG buses: 2800 Bt/day estimated based upon the leasing price of the diesel buses
- The numbers of vehicles are estimated based upon the forecast of the private consumption expenditure for vehicle purchases using the long-term GDP projections (refer to Chapter 2 of the Supporting Report).

- Annualised cost: based upon the investment cost and benefit, the annualised economic cost is calculated.

(2) Investment and Annualised Cost

Table 9.3.4.4 shows the vehicle replacement number and annualized cost by countermeasures. The details are described in Chapter 6 of the Supporting Report.

As mentioned in Chapter 4 "4.3.2 Mobile Source Inventory of the Year 2011(BAU Case) in the BMR", the future number of Urban Bus (BMTA) was estimated by future GDP growth. The other NG2 case, with the reduced number of purchased Bus, is described as NG2' in Appendix for supplemental information.

Table 9.3.4.4 Investment and Annualised Cost

Type of Countermeasures	No. of Buses to be replaced	Investment Cost (Billion Bt)	Annualised Cost (Billion Bt)
NG1	6,100	5	*
NG2	11,400	12	0.3
NG3	6,100	30	1.8

Note: * means the cost is negligible or minus (saving)

3) Institutional Evaluation

The BMTA has purchased 82 NG buses in 1993 by the ENCON Fund. Some of them are operated in the route No. 503, which connects Rangsit and the Southern Bus terminal through the Si Ayutthaya road. The PTT is in charge of planning and building the infrastructure for NG buses, namely the NG pipeline and refuelling stations. The BMTA needs close connections with the PTT for the NG bus operation since the PTT's NG service plan is the essential factor, while they were considered to work well enough to implement this countermeasure in the future. Therefore it was not necessary to reform the current institutional structure for the implementation itself.

9.3.4.3 Overage Vehicle Retirement (OVR: HDDV/T)

1) Reduction Amount Calculation

The HDDV/T's age distribution, which is one factor to calculate its emission factors, was modified from the following assumption,

- The enforcement year was 2004, which was considered earliest,
- The number of replaced HDDVs/Ts of age class from 11 to 25 (assumed as maximum age) years old was normalized from 2004 to 2011, and
- The target old HDDVs/Ts were assumed to be replaced with the latest ones.

Table 9.3.4.5 shows the Age Distributions of the BAU Case and OVR Case at 2011.

Table 9.3.4.5 Age Distributions of the BAU Case and OVR Case at 2011

2011	Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
(BAU)	Share	18%	13%	9%	7%	5%	4%	3%	3%	2%	2%	2%	1%	1%	1%	4%	5%	5%	4%	3%	2%	1%	1%	1%	1%	1%
2011	Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
(OVR)	Share	21%	16%	12%	10%	9%	7%	7%	6%	6%	5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

2) Cost Estimates

(1) Basic Assumption

- VR1: The BMTA's old aged buses (1987-2000) will be replaced with new ones by lease
- VR2: Old aged coaches and trucks in the BMA will be replaced with new ones by loan
- Old buses and trucks over 10 years will be retired and replaced with new vehicles
- Loan conditions for Truck: 7% annual interest rate, 4 year 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.

(2) Investment and Annualised Cost

The vehicle replacement numbers and the necessary investment costs are estimated during 2004-2011 as shown in Table 9.3.4.6. The details are described in the Supporting Report.

Table 9.3.4.6 Investment Cost and Annualised Cost

Vehicle Type	No. of Vehicles to be replaced	Investment Cost (Billion Bahts)	Annualised Cost (Billion Bahts)
VR1 (Bus)	14,300	22	1.9
VR2 (Coach +Truck)	152,500	907	95.3
VR2-1 (Coach)	14,300	61	5.3
VR2-2 (Truck)	138,200	847	90.0

3) Institutional Evaluation

The vehicle age has never been controlled in Thailand. However when the HDDVs/Ts go to LTDs for I/M, their ages are recorded on their test result reports and their age could be controlled by the mean of the existing I/M program by not issuing the certification of the compliance, if the vehicle age is added as another condition to pass the I/M program.

This countermeasure would control the ages of not only the fleets but also the engines. Therefore it basically requires the prohibition of aftermarket engine replacement, which has been allowed, as its precondition and this prohibition and the Anti-tampering program would need to be institutionalised.

Consequently this countermeasure is considered to require a minor institutional arrangement for the vehicle age control through the I/M program and the Anti-tampering program.

9.3.4.4 Substantial Compliance with the Emission Standard (Real-EURO: HDDV/T)

1) Reduction Amount Calculation

The emission factors of Thai HDDV/T would even become close to the European's, if this countermeasure will be enforced. Therefore the Thai emission factors were quoted from the default values in the COPERT 3 and compiled by the vehicle weight shares estimated from the incoming commodity survey at the BMA.

Table 9.3.4.7 shows the Emission Factors of the BAU Case and the Countermeasure Case.

Table 9.3.4.7 Emission Factors of the BAU Case and the Countermeasure Case

Standard			COPERT g/mile		MOBILE5a	EF(Thai_BAU)	Real EURO g/mile	
level	Imp. Year	g/kWh	Truck	Bus	HDDV:g/mile	g/mile	Truck	Bus
EURO2	1995	7	2.8-12.5	8.4-12.0	8.13	**29.83**	**8.88**	**10.56**
EURO3	2000	5	2.0-8.7	5.9-8.4	6.49	**21.30**	**6.22**	**7.40**
EURO4	2006	3.5	0.9-6.1	4.1-5.9	6.49	**14.91**	**4.35**	**5.18**

Note: HDDV in COPERT includes weight classes, <7.5t, 7.5-16t, 16-32t and >32t.
MOBLIE5a's EF for EURO 2 are assumed as the default ones at these implemantation year, 1995.

2) Cost Estimates

This countermeasure would directly require additional inspection of the Thai Industrial Standard Institute (TISI) and the cost might need additional personnel expenses of the TISI. However it was considered negligible since the inspection would be implemented only a few times per year.

3) Institutional Evaluation

The Real-EURO program needs some reform in the Thai Industrial Standard (TIS) for HDDV/T emission. The TISI is the implementing agency of TIS and TIS for HDDV/T emission describes the conformity test procedure for type approval. However as mentioned in the rationale, it is necessary to provide another opportunity for TISI's inspection in order to control the actual emission factor on an international level. That requires some codicil/rider in the TIS, which will enable TISI to initiate legal-supported action.

Also, the Real-EURO program requires an Anti-tampering program to prohibit engine modification as precondition. The abovementioned stricter compliance for new HDDVs/Ts could control only the new ones. Therefore the In-use (aftermarket) HDDVs/Ts should also be controlled continuously by another method implemented by the other agencies and regulations, which means the Anti-tampering program by LTD (regular

I/M program) and the RTP (random on-road inspection). It requires a similar arrangement as discussed in OVR.

9.3.4.5 Traffic Control for Heavy Trucks (supplement)

1) Reduction Amount Calculation

As mentioned in the rationale, two cases, namely just No HDDTs (No vehicle type shift) or one HDDT shift to 6 LDDTs, were considered. In the No HDDTs case, zero was the input in the HDDT traffic volume in the control area and no modification in the other vehicle type or out of the control area. On the other hand, in the shift to the 6 LDDT case, 6 times of the HDDT traffic volume were added to the LDDT traffic volume at the same roads in the control area.

2) Cost Estimates

Currently policemen are already located at the major intersections, which cover the necessary checking points for this countermeasure, for the other purpose, namely traffic control. It is considered that they can handle this additional task. Therefore, no additional cost was estimated.

9.3.4.6 Screening Results

On the institutional aspect, all countermeasures of the 2nd draft were considered possible though some of them, the Real-EURO and OVR, needed minor reforms, since it was considered that the environmental administration concerning the emission control of road traffic had been well-developed in Thailand.

On the cost-effective aspect, however, the EURO 4 enforcement was considered unfeasible compared to the other countermeasures for LEV, OVR and Real-EURO, as shown in Table 9.3.4.9 cost evaluation results of the 2nd draft countermeasures.

The overall screening results were expressed graphically in Figure 9.3.4.1, the schematic diagram for the secondary screening process and are described as follows,

- Real-EURO should be placed first priority because it was considered to be the most effective in spite of minor institutional reform.
- EURO 4 should be rejected from the definitive viewpoint of only NOx reduction, because it would need the largest financial support if it is to avoid that end-users (new vehicle buyers) will carry the burden of the unit price increase, even though small effectiveness.
- OVR and LEV were considered competitive with each other to be placed as second priority, therefore the possible combinations of their options were analyzed and the optimum mix was selected in the next section.

Table 9.3.4.8 Agencies Concerned in the 2nd Draft Countermeasures

Program		PCD (DENR)	MOTC		Office of Prime Minister		DCR(MOC)	TISI(MOI)	Private Sector
			LTD	BMTA	EPPO	RTP			
EURO 4	Low Sulphur G/D	A	---	---	A Mandate the low sulphur specs gasoline and diesel oil	---	A Implement the low sulphur program gasoline and diesel oil	---	Oil Refinery Companies
	Emission Standard	A	---	---	---	---	---	A Issue the new emission standard on the Industrial Product Standard Act	TAIA
LEV	Urban Bus	B	---	A Purchase/Replace with NG buses	---	---	---	B Issue the NGV standard on the Industrial Product Standard Act	PTT
OVR	Urban Bus	B	A Utilize the I/M program to detect the vehicles over the certain age on amended Land Transport Act. Prohibit engine replacement through I/M program	B Retire their buses over the regulated age.	---	B Inspect the vehicles without I/M program certification on road on Land Traffic Act.	---	---	Bus Operators except BMTA
	Coach/ H-Truck			---	---		---	---	Transportation Association
Real EURO	Urban Bus Coach/ H-Truck	A	A Prohibit engine modification and replacement through I/M program	B Encourage operators to follow	---	A On-road checks of engine modification and replacement	---	A Monitor HDDV/T manufacturers' compliance with the emission standard	TAIA

Note: "A" means to play key role. "B" means to play active role. "---" means indirect concern.

Table 9.3.4.9 Cost-Effectiveness Evaluation Results of 2nd Draft Countermeasures

Program		Annualised Cost (Billion Bahts)		Effectiveness Reduction (kt@2011)	C/E Th. Bt/t	Result	Remark
EURO 4 LDV: 2009- HDV: 2011-	Low Sulphur (50ppm)	*	Estimates in NEPO report	6 (2%)	**55,300**	**X**	---
	Emission Standard	332	15%-20% of unit production cost				
LEV 2004 -	Transition to NG - Urban Bus	*- 2	For Old Urban Buses (BMTA), - Aftermarket NG Conversion - Replaced with New NG Buses For New Urban Buses, - New NG Buses Purchase instead of the Diesel	8-14 (3-5%)	*- 200	Δ	Urban Buses operated by BMTA were considered as the most applicable vehicle types for NG since it overcome NG vehicle's limitation as shown in the table of the screening result. Aftermarket NG engine conversion is considered to become popular up to 2011. NG vehicles need less fuel cost than diesel ones. NG buses could be also offered on a lease as well as diesel buses (EURO 2).
OVR 2004 -	Latest Urban Bus	2	Urban Bus (BMTA) (the Leasing price) – (the Trade-in price of the Old)	5 (2%)	400	Δ	Coach (Long-haul Buses) and H-Trucks would be the proper target. Replacement with old engine is proposed to be prohibited. It will be proposed that BMTA should lease buses to private operators rather than sell.
	Latest Coach /H-Truck	95	Coach/H-Truck (Annual payment of 4 yr loan for the New) – (Trade-in price of the Old)	29 (10%)	3,300		
Real-EURO 2004 -	- all HDDV/T	*	Unannounced and Random sampling and tests, to be proposed, are possible with the existing facility and personnel.	94 (34%)	*	O	The HDDV/T of Thai EURO 2 shows quite higher value of Chassis dynamometer test data than they are supposed.
Traffic Control (Supplement)	*Case 1*	*	*Currently policemen are already allocated at major intersections for traffic control and they can control*	*7***	*The Airviro Simulation Result of ambient NO_2 concentration in Traffic control (Case 1) is shown in Appendix.*		
	Case 2	*		*5***			

Note: * means the cost is negligible or minus (saving)
** The Traffic Control would reduce 29% (No H-Truck Case) or 22% (Shift to LDDT Case) of the NOx emitted from inside the Middle-ring Road in the BAU Case.

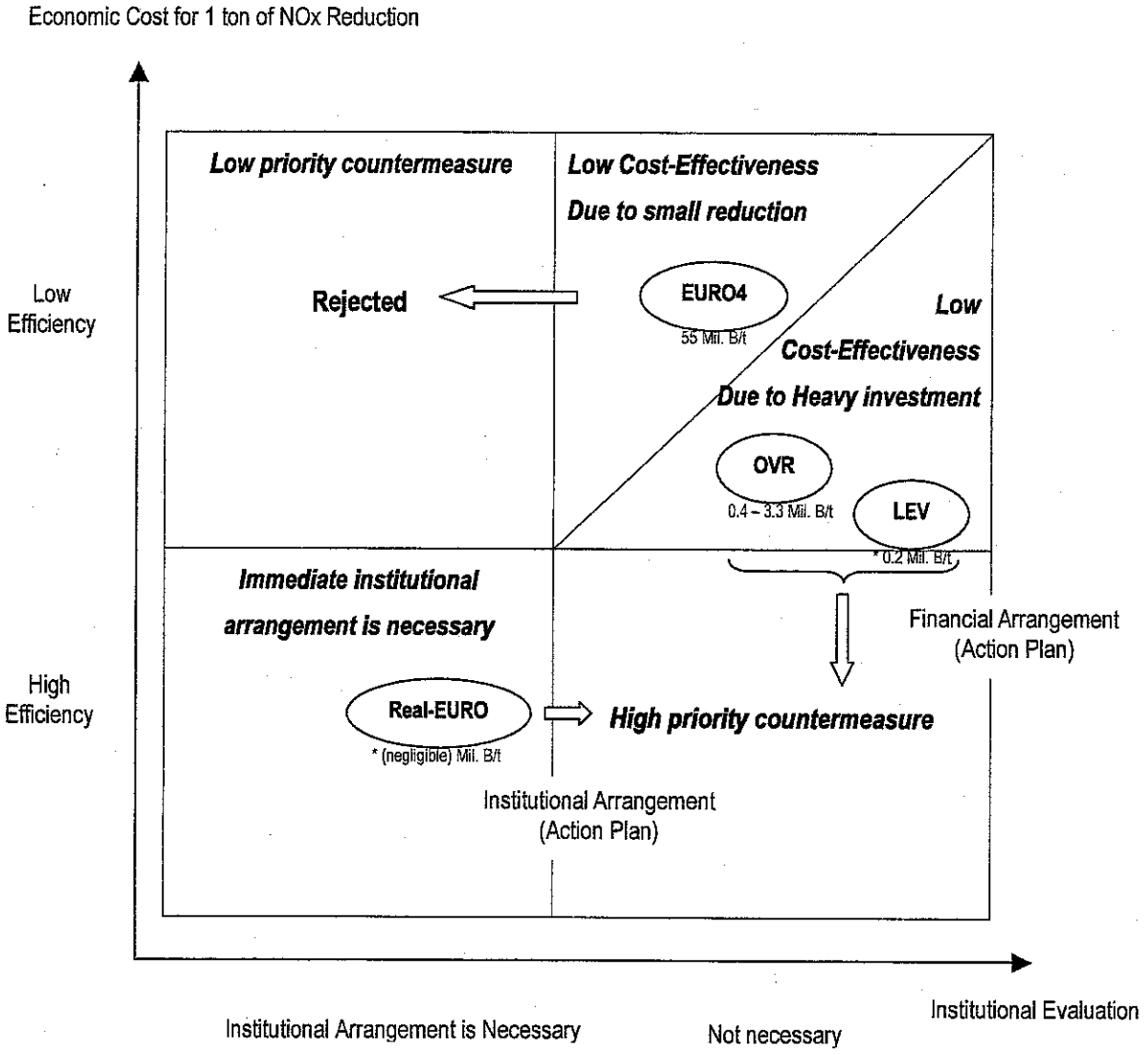


Figure 9.3.4.1 Schematic Diagram for the Secondary Screening Result

9.3.5 Optimum Mix of Countermeasures

9.3.5.1 Method

There were many types of combinations of LEV and OVR possible. And both of them were considered similar in the viewpoint that both would aim at the vehicle replacement with low emission vehicles, which mean NGVs in LEV or the latest standard vehicles in OVR.

In this section, the possible combinations were identified even though some of them seemed unrealistic, and the cost (annualized cost) and the effectiveness (annual NOx reduction amount) were estimated for all. And then the one optimum mix was identified by the cost-effectiveness analysis and the effect of both the optimum mix and Real-EURO was simulated.

Table 9.3.5.1 shows the possible combinations of LEV and OVR, and Figure 9.3.5.1 shows a schematic description of LEV/OVR by target vehicle type.

Table 9.3.5.1 LEV/OVR Countermeasure Mix Matrix

Case		**UB**: Urban Bus (BMTA)		**Ch./Tr.**: Coach + H-Truck	
		New UB	Old UB	New Ch./Tr.	Old Ch./Tr.
BAU Case		(Purchase planned)	(Nothing done)	(Purchase planned)	(Nothing done)
Control Case	1. Aftermarket NG Conversion	---*1	---*1	---*2	---*2
	2. Purchase New Diesel Bus/Truck (Latest Standard)	(Same as BAU)	**VR1** Replaced with Latest Diesel Bus	(Same as BAU)	**VR2** Replaced with Latest Diesel
	3. Purchase New NG Bus/Truck	**NG2**	**NG3**	---*2	---*2

*1: Aftermarket NG conversion is not considered possible always for the reason described in the box below.
*2: NG Trucks are considered to have difficulty for promotion due to the limitation on travel range by one-time refueling and refueling stations.

The aftermarket NG conversion is also one of the measures to promote the usage of NGV. The study team, however, did not consider it as a countermeasure for the reason mentioned in the following BOX.

BOX: Aftermarket NG conversion of HDDV/T

There are three main options, bi-fuel, dual-fuel (diesel and natural gas) and dedicated natural gas.

Bi-fuel systems use only one fuel at a time while dual-fuel run on a combination of natural gas and diesel (they inject both fuels into the combustion chamber at the same time). **The emission after treatment device, namely catalytic converter, is not suitable for bi-fuel and dual-fuel system, while the dedicated system can reduce NOx emissions with it** because they are tuned to optimize the operation on only one fuel. Therefore, in this study only the dedicated one is considered for the NOx emission reduction countermeasures.

For aftermarket conversion to dedicated natural gas vehicles, there will be a need for significant engine testing to obtain reasonable performance and emissions levels for a new engine type. It means to redesign and convert the engine to dedicated gas operation with spark ignition, reduce the engine compression ratio and install a gas carburetor and spark plugs. In Thailand, there has been experience of failure to convert existing diesel engine vehicles to natural gas ones due to the unexpected engine power loss (20-25%) and inappropriate tune-up (according to PTT).

The conversion of an existing diesel engine to natural gas is not always possible and requires significant testing to obtain optimum performance. It cannot be undertaken without adequate engineering and equipment support. And some type of engine configuration may not be suitable for NG conversion.

Therefore **the study team did not consider the aftermarket NG conversion of HDDVs/Ts was quite feasible technically** and it was NOT treated as one option of the countermeasures.

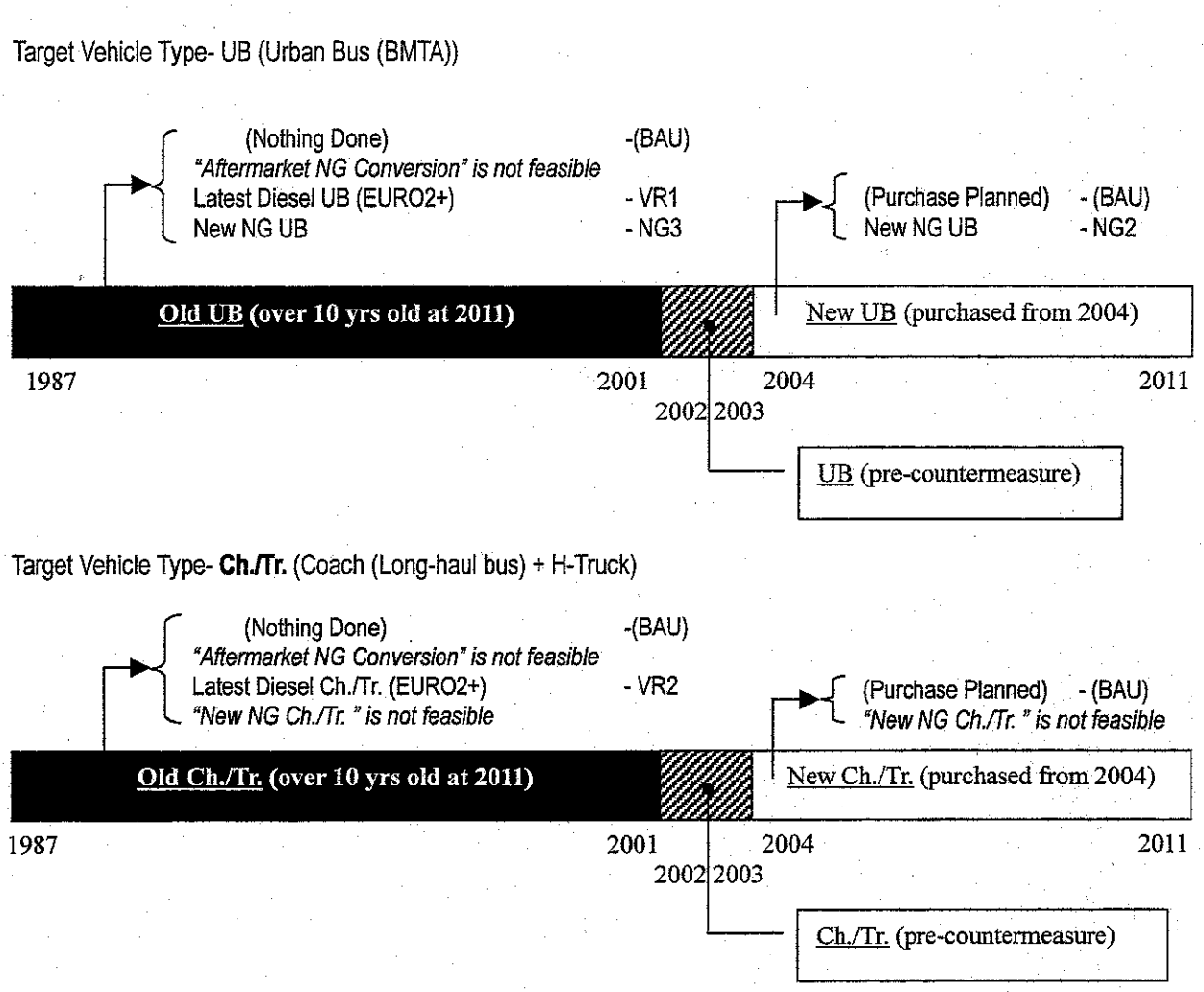


Figure 9.3.5.1 Schematic Description of LEV/OVR Countermeasure by Target Vehicle Type

9.3.5.2 Optimum Mix Selection

Table 9.3.5.2 shows the results of the cost-effectiveness analysis of the LEV/OVR combination. The result is selected the recommended countermeasures from among the two top combinations as follows,

First-Recommended Case;

- All HDDV/Ts except Urban Buses, namely Coaches and H-Trucks, should comply stricter with the latest emission standard when they come onto the market,
- New NG Urban Buses should be purchased instead of conventional diesel ones,
- Over aged Urban Buses (over 10 years) should be replaced with New **NG** ones.

Second-Recommended Case;

- All HDDV/Ts except Urban Buses, namely Coaches and H-Trucks, should comply stricter with the Thai latest emission standards when they come onto the market,
- New NG Urban Buses should be purchased instead of conventional diesel ones, and

- Over aged Urban Buses (over 10 years) should be replaced with New **Diesel** ones.

Besides the abovementioned two combinations, Real-EURO itself could reduce certain amount of NOx, as shown in Table 9.3.5.2, and Real-EURO without LEV/OVR was proposed as the Third recommended case.

Table 9.3.5.2 Evaluation of NOx Reduction and the Cost on LEV/OVR Countermeasure Mix

Case ID	Urban Bus		Coach/Truck		NOx Reduction Volume from BAU (ton)	Annualized Cost (Bil. Bahts)	Cost for 1 t NOx Reduction (Th. Bahts)	Case Description
	New	Old	New	Old				
BAU					—	—	—	BAU Case
VR1		VR1			4,577	1.9	415	UB Transition from Old to New Diesel
NG3		NG3			(8,220)	(1.8)	(219)	UB Transition from Old to New NG
VR2				VR2	(28,975)	(95.3)	(3,289)	Ch/Tr Transition from Old to New Diesel
VR1+VR2		VR1		VR2	32,551	97.2	2,986	UB, Ch/Tr Transition from Old to New Diesel
NG3+VR2		NG3		VR2	(37,014)	(97.1)	(2,623)	UB Transition from Old to New NG and Ch/Tr Transition from Old to New Diesel
NG2	NG2				14,338	0.3	21	New NG UB purchase only
NG2+VR1	NG2	VR1			18,915	2.2	116	New NG UB purchase and UB Transition to Old to New Diesel
NG2+NG3	**NG2**	**NG3**			**22,558**	**2.1**	**93**	**New NG UB purchase and UB Transition to Old Diesel to New NG**
NG2+VR2	NG2			VR2	(43,449)	(95.6)	(2,200)	New NG UB purchase and Ch/Tr Transition from Old to New Diesel
NG1+NG2+VR2	NG2	OUB1		VR2	52,346	96	1,826	New NG UB purchase, Old UB NG conversion and Ch/Tr Transition from Old to New Diesel
NG2+VR1+VR2	NG2	VR1		VR2	47,890	97.5	2,036	New NG UB purchase, UB Transition from Old to New Diesel and Ch/Tr Transition from Old to New Diesel
NG2+NG3+VR2	NG2	NG3		VR2	52,346	97.4	1,861	New NG UB purchase, UB Transition from Old to New NG and Ch/Tr Transition from Old to New Diesel

Note: The following combinations were considered difficlut for the following reasons,

NG3	UB Transition from Old to New NG could not happen without NG2 (New NG UB purchase as New UB)
VR2	Ch/Tr Transition from Old to New Diesel could not happen to prior to UB.
NG3+VR2	UB Transition from Old to New NG could not happen without NG2 (New NG UB purchase as New UB)
NG2+VR2	Ch/Tr Transition from Old to New Diesel could not happen to prior to UB.

First-Recommended Case

Real EURO(all) + NG2(UB) + NG3(UB)	**105,898**	**2.1**	**20**	**New NG UB purchase and UB Transition to Old Diesel to New NG, and the stricter compliance with EURO standard by Ch/Tr.**

Second-Recommended Case

Real EURO(all) + NG2(UB) + VR1(UB)	**104,599**	**2.2**	**21**	**New NG UB purchase and UB Transition to Old to New Diesel, and the stricter compliance with EURO standard by Ch/Tr.**

Third-Recommended Case

Real EURO (all)	**93,557**	**	**	**The stricter compliance with EURO standard by all HDDV**

Table 9.3.5.3 shows the summary of the simulation result of ambient NO2 concentration in BAU and Control Cases, and Figure 9.3.5.2 shows the concentration maps for them. At 2011 in the First-recommended Case, the number of the grids over the Thai NO2 standard would be reduced from 60 to 5 and over the WHO guidelines from 2,127 to 1,075. In the Second-recommended Case, the number of the grids over the Thai NO2 standard would be reduced from 60 to 5 and over the WHO guidelines from 2,127 to 1,086. In the Third-recommended Case, the number of the grids over the Thai NO2 standard would be reduced from 60 to 7 and over the WHO guidelines from 2,127 to 1,237.

Table 9.3.5.3 Simulation Results of the Recommended Control Cases

Control Case and Countermeasure Description	Reduction Volume (kt@2011)	Reduced No. of Over-standard Grid	Airviro Simulation (BMR: 26,320 Grids)		
			No. of Grid	Over WHO	Over Thai
First-Recommended Case - Substantial Compliance with HDDV/T emission standard - Purchase New NG Urban Buses (BMTA) - Replace Over 10 years old Urban Buses with New **NG** Buses (BMTA)	-106 kt (277 kt :BAU)	-1,052 (WHO) -55 (Thai)	BAU Case	2,127 (8%)	60 (0.2%)
			Control Case	1,075 (4%)	5 (0.0%)
Second- Recommended Case - Substantial Compliance with HDDV/T emission standard - Purchase New NG Urban Buses (BMTA) - Replace Over 10 years old Urban Buses with New **Diesel** Buses (BMTA)	-105 kt (277 kt :BAU)	-1,041 (WHO) -55 (Thai)	BAU Case	2,127 (8%)	60 (0.2%)
			Control Case	1,086 (4%)	5 (0.0%)
Third-Recommended Case - Substantial Compliance with HDDV/T emission standard	-94 kt (277 kt :BAU)	-890 (WHO) -53 (Thai)	BAU Case	2,127 (8%)	60 (0.2%)
			Control Case	1,237 (5%)	7 (0.0%)

2011 BAU Case

2011 First-Recommended Case (Real-EURO + NG2 + NG3)

Figure 9.3.5.2(1) Airviro simulation result of the ambient NO_2 concentration in the BAU/Control Case

2011 Second-Recommended Case (Real-EURO + NG2 + VR1)

2011 Third-Recommended Case (Real-EURO)

Figure 9.3.5.2(2) Airviro simulation result of the ambient NO_2 concentration in the Control Cases

9.4 Conclusion

The countermeasures are recommended as follows,

Substantial compliance with the latest emission standards (Real-EURO)

- All HDDV/Ts should comply more strictly with the latest emission standard when they come onto the market (Real-EURO)

Low Emission Vehicle Promotion (LEV)

- New NG Urban Buses should be purchased instead of conventional diesel ones (NG2),
- Over aged Urban Bus (over 10 years) should be replaced with New NG ones (NG3)

Overage Vehicle Retirement (OVR)

- Over aged Urban Bus (over 10 years) should be replaced with New Diesel ones (VR1)

Substantial Compliance with the Latest emission standard (Real-EURO) is considered essential for NOx emission reduction in BMR, since it could reduce nearly a third of the total NOx emission from vehicle there even by itself. Therefore it is concluded that Real-EURO should be assigned as the highest priority countermeasure among them. It was highly recommended that government of Thailand should consider Real-EURO as emergency countermeasures and should implement Real-EURO as soon as possible.

The other countermeasures, namely Low Emission Vehicle Promotion (LEV) and Overage Vehicle Retirement (OVR), should be launched with Real-EURO at the further steps for additional NOx reduction although their additional effects were estimated relatively small. Because the traditional countermeasures for NOx reduction, namely enforcement or compliance of stricter emission standard for new vehicles, would have their definite limits in the near future like that Japan is confronting. Therefore LEV and OVR should be provided for future full implementation immediately.

Nevertheless some areas were predicted not to attain the Thai ambient NO_2 standard with the countermeasures according to the Simulation Result of the First-recommended Control Case. The over-standard areas are located at the following two intersections,

- Wat Nakorn Bridge Road (planned to be completed at 2006 in URMAP) and Rathawithi Road/Pinklao Elevated Road, and
- Outer Ring Road and Rama 2 Road,

and the part of roadside of Rama 2 Road stretching beyond Outer Ring Road.

The simulation result showed heavy traffic there would cause those areas to be unattainable and it was considered to be inevitable since the trunk roads there were appointed and designed to accommodate heavy traffic.

Therefore, the study team recommended PCD to conduct a further study of future NO_2 concentration for those areas. If a further study will ascertain that the NO_2 concentration will exceed the standard and it will bring sever health damages, only passive countermeasures, like land-use control, would be considered for those areas.

9.5 Action Plan

As shown in the Schematic Diagram for the Secondary Screening Result, the Real-EURO would require institutional arrangements and LEV/OVR would require financial arrangements to overcome their problems for full-implementation. In this section, the action plans for these recommended countermeasures are described.

9.5.1 Substantial Compliance with the Emission Standard (Real-EURO: HDDV/T)

9.5.1.1 Institutional Arrangement

1) PCD

In advance to the institutional arrangements for the relevant agencies, PCD should implement Feasibility Study for the Real-EURO to confirm the validity of the Real-EURO enforcement by close and diligent investigation concerning the emission factor of Thai HDDV/Ts. The major tasks were presumed as follows,

- Collect much more Chassis Dynamometer test data of in-use/new HDDV/T by vehicle specifications, such as type, weight, engine displacement, loading capacity (if necessary), and the state of the test vehicles, such as odometer value, age and the other conditions affected by maintenance (for the in-use only).
- Collect the Engine Dynamometer test data of the sample vehicles, which has been tested by the Chassis Dynamometer. For the engine test, unnecessary engine modification for the test should be avoided since it may affect the emission level.
- Check the attainment of the HDDV/Ts engine emission standard by the engine dynamometer test of the new engines removed from the chassis of the new HDDV/Ts, which have been just assembled by manufacturers and are about to be sold, even though they already have been certified by type approval. The test samples should be collected at random in an unannounced way.
- Estimate the Thai conversion factor between the emission on the Engine Dynamometer and the Chassis Dynamometer for each vehicle/engine category.

And PCD should make a continuous effort to conduct the research not only for the Real-EURO implementation but also for updating the emission factor to attain adequate accuracy.

2) TISI

TISI should call the technical committee to discuss the amendment of TIS to enable TISI to implement the following additional conformity inspection for the stricter compliance,

- Conduct unannounced (surprise) inspections of Thai HDDV/T manufacturers' assembly lines for the quality control of certified production process and the check of the emission standard attainment as the result,
- Order HDDV/T manufacturers to remove the engines from chassis assembled (although they have been type-approved), which are selected randomly by the skilled inspectors from TISI who are assigned to witness the whole process to avoid any adjustment on the selected engine,
- Check the selected engines emission on engine dynamometer with the applicable standard, before they come onto the market, in addition to the current procedure.

BOX: Defeat "Defeat Device"

In October, 1999, the EPA proposed a revision to the 2004 heavy-duty emission standards, originally adopted in 1997, including **"Introduction of supplemental standards and testing procedures for heavy-duty diesel engines" namely NTE and steady state test.**

The supplemental testing requirements include **not-to-exceed (NTE) limits** and testing over the European **ESC steady-state test.** Heavy-duty engines will be required to meet the same emission standards on both the existing **FTP transient cycle and on the ESC test.** In addition, **an NTE limit of 1.25 times the FTP standard will have to be met at any engine operating conditions**, steady or transient, within an "NTE zone" in the engine torque-speed map, as defined by the regulation.

Both the NTE limits and the steady-state test are designed to **prevent the possibility of the engine control software (Defeat Device)** to advance injection timing during periods of highway cruising, in order to improve fuel economy at the expense of increased NOx emission.[5]

[5] http://www.dieselnet.com/news/0008epa.html." US EPA SIGNS FINAL 2004 HD ENGINE EMISSION RULE"

3) MOTC

MOTC should amend the Land Transport Act from the viewpoint of anti-tampering program for HDDV/T, which can detect any damage, disablement or removal of emission control components. If a vehicle is detected through the program, the owner would be required to restore the vehicle's emission control system and have the vehicle re-inspected. This would not only avoid owner's intentional tampering, but also includes malfunction, derived from insufficient maintenance, of which the vehicle owner is aware.

Typical types of tampering, which can affect emission, were presumably considered as follows,

- Incorrect fuel injection timing (diesel injection pumps)
- Improper air-fuel ratio control settings (diesel injection pumps: it can be identified by tamper-evident seal)
- Engine replacement (it can be identified by the check of serial number of engine and license plate number of chassis)

On the other hand, this amendment of the Act should allow the engine replacement only when the engine-replaced vehicles match exactly any certified configuration of the same or newer model year as the chassis.

4) LTD

LTD should follow the Land Transport Act, which would have been amended by MOTC, and inspect tampering like engine replacement in addition to the existing checkpoints.

First of all, LTD should develop appropriate training program for technical service staff in charge of HDDV/T I/M program and then promote all concerned staff to be trained. It was considered not to take long time to familiarise themselves and quality control would be easy, since the number of concerned staff is relatively limited and I/M program for HDDV/T is centralized in Bangkok.

The checkpoints added by this amendment were considered as follows,

- Top dead center of compress process at the reference cylinder and diesel injection pumps (Incorrect fuel injection timing)
- Tamper-evident seal at diesel injection pumps (Improper air-fuel ratio control settings)
- Serial number of engine and License plate number of chassis (Engine replacement)

5) RTP

RTP should conduct random roadside emission test to complement the periodic I/M program, which was considered not to detect tampering efficiently since it is predictable and gives "carney" vehicle owners an opportunity to evade the program. Tentative tasks of RTP were considered as follows,

- Increase the number of the existing smoke inspection team,
- Provide temporary inspection station at roadside location to avoid traffic congestion by inspecting on road, and
- Change the inspection points randomly.

The inspection team is preferred to divide into two parties,

Observing party is

- allocated on-road
- to observe approaching HDDV/T visibly and direct excessive-smoke emitters to the temporary station.

Measuring party is

- allocated temporary inspection station at the other roadside location
- to conduct free-acceleration smoke test with a smoke opacity meter
- to sent them back to road if they pass within the allowable range
- to issue a traffic citation, which can be cleared only after it is repaired, if they fail

Table 9.5.1.1 Action Plan

year	2003	2004	2005	2006	2007	2008	2009	2010	2011
PCD (FS Study)									
PCD (Periodical Update Research)									
TISI (TIS Reform)									
TISI (Additional Inspection)									
MOTC (Land Transport Act Amendment)									
LTD (Prohibition against Engine Replacement by I/M Program)									
RTP (Random roadside emission test)									