CHAPTER 4
RESULTS AND DISCUSSION

4.1 Preamble

The aim of this chapter is to document the results of the research conducted and imply the validity of the results based on theoretical and methodological approached. This chapter has been divided into four sections starting with Developing air pollution prevention techniques by using the guide for pollution prevention of U.S. EPA, Clarifying all activities of transport sector in the Bangkok urban area by the process maps to find how air emissions are created and finding the root cause of problems and possible prevention strategies, Evaluating 4 high-potential alternative solutions in the first step by integrated transport and vehicle emissions model and selecting the best solution in order to minimize the air emissions or to enable the air emission pollutants to meet ambient air standards. Overall outputs of the prevention strategies of air pollution prevention are discussed under these sections.

4.1 Applied process characterization with hierarchical process mapping

On the basis of pollution prevention concept, the whole system of travel is taken into consideration by process mapping in an origin and destination. This chart gives an idea for understanding of inputs and outputs for each trip purpose in transport sector as shown in Figures 4.1 - 4.3.

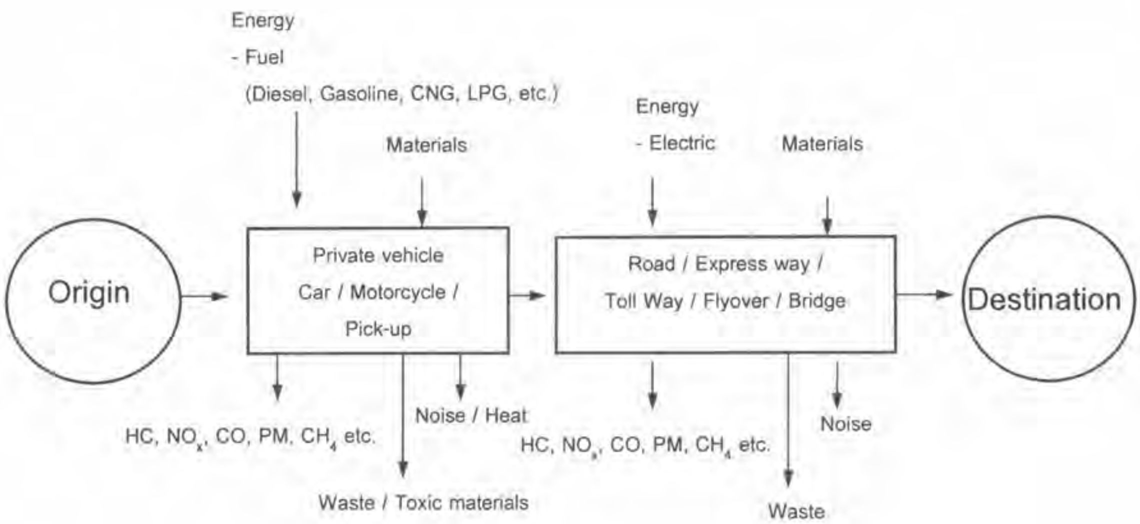


Figure 4.1 Process map of travel by private vehicle

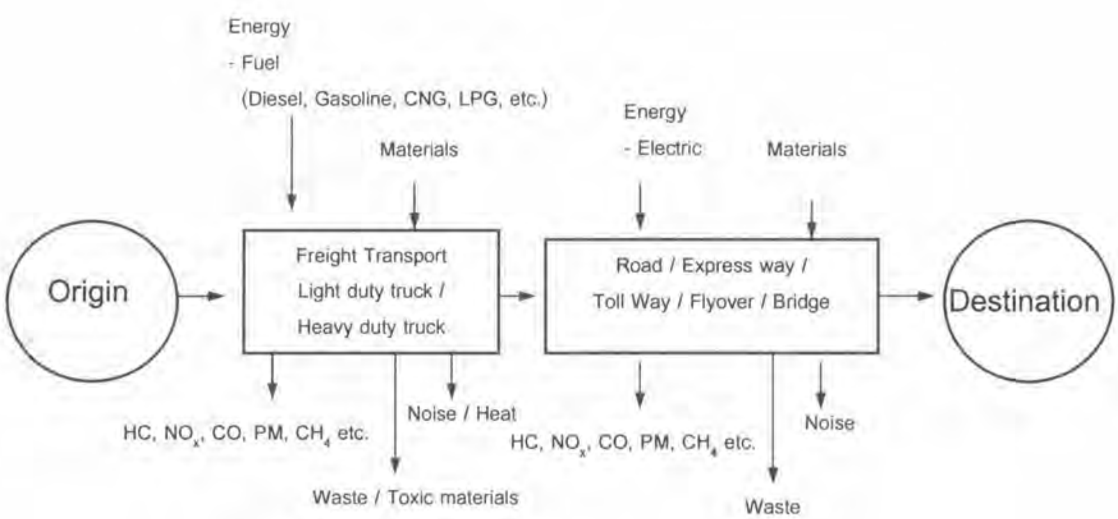


Figure 4.2 Process map of freight transport

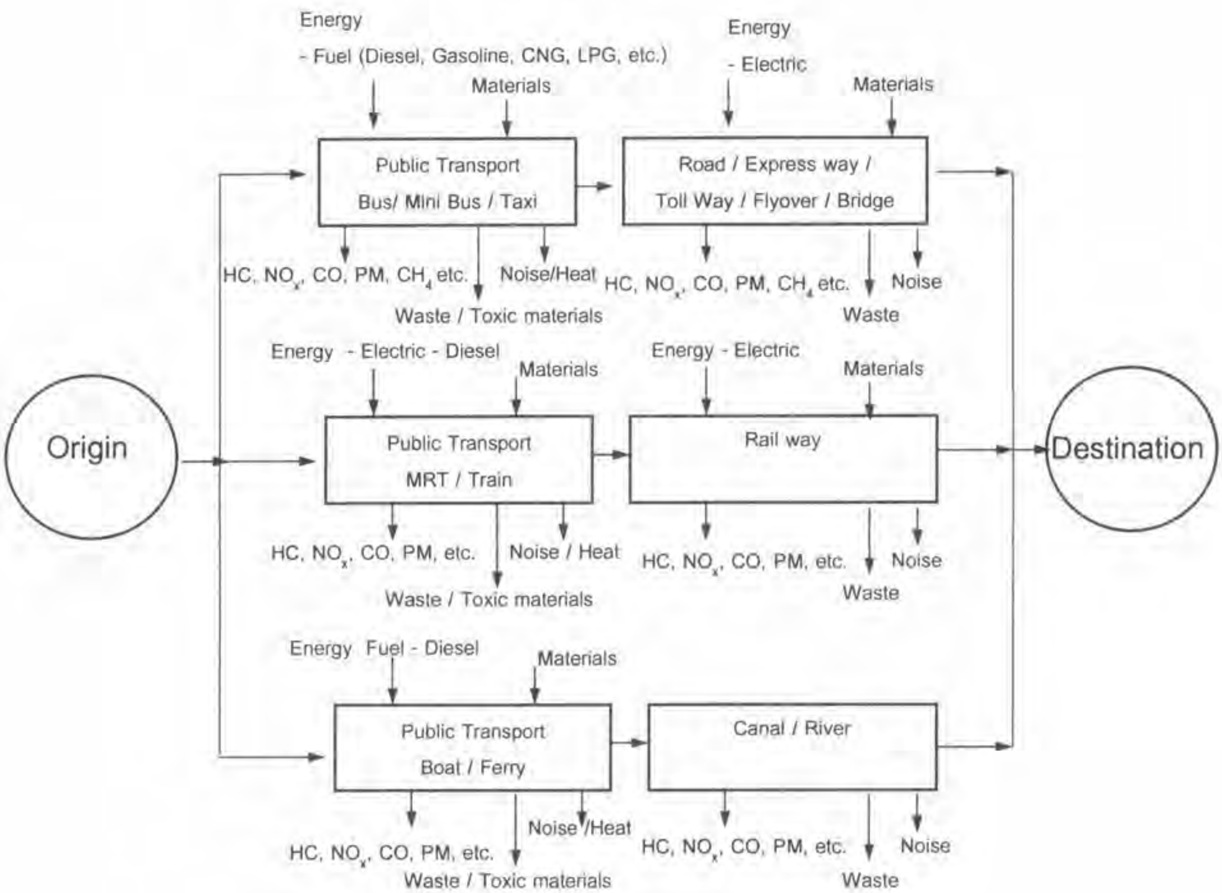


Figure 4.3 Process map of public transport

These figures show road or pathway conveys many benefits. It allows all activities of people need to travel or transfer goods from origin to destination. Road or pathway like most other production processes and sectors generate primary products and variety of the unintended by-products such as air emissions, noise, and waste or effects which are unpleasant and undesirable. These are side effects from the road or pathway, generally well-known as the environmental effects or environmental impacts. This study had evaluated the potential environmental impacts of any trip proposed from road or pathway in transportation sector, and focused to 3 main pollutants (CO, NO_2 and PM) of air emissions.

4.2 Root – cause analysis

In this study step, the major effect of the study was derived and the sub-causes of the effect were identified. Interviewing with the focus group, target people and experts who are involved with air quality and transport were carried out, of which the following outputs.

1) Initially, an interview was conducted for 40 participants from the Ministry of Natural Resources and Environment, Ministry of Transport, Police Department, various Universities and other related organization. An open questionnaire was used and the responses were classified. The questions were based on 4 categories viz. Man, Machine, Method and Material, of the P2 technique. The results from the 40 participants were then used for framing the questionnaire for the experts.

Results obtained all the perceived causes for air pollutions of transportation sector from the 40 participants. The responses are classified in the 4 mentioned as shown in Table 4.1, which are described as follows.

Table 4.1 Results obtained all the perceived causes for air pollutions of transportation sector from 40 participants

Main Causes	Causes of air pollution from transportation sector
Man (People)	Low public Awareness and bad attitude.
	Inconsistency & carelessness.
	Poor regulation and maintain inventory for vehicle driving.
	Not sufficiently trained for people.
	Limited of funding from transport sector for people emotion.

Table 4.1 (Cont) Results obtained all the perceived causes for air pollutions of transportation sector from 40 participants

Main Causes	Causes of air pollution from transportation sector
Method	Less strengthen quality monitoring for air emissions from vehicle.
	Lack of advanced technology to measure effectiveness for vehicle inspection.
	Lack of integrated transport & land use planning.
	Poor public transport.
	Weak implementation and commitment to enforce emission standard.
	Weak vehicle inspection and maintenance program.
Machine	Poor vehicle maintenance.
	Old vehicle engine of model.
	Poor and low quality to control pollution from vehicle engine.
	Large vehicle engine made more fuel consume.
Materials	Weak fuel demand management.
	Lack of fuel pricing mechanism.
	Less alternative fuel for vehicle.
	Poor quality of fuel such as poor standard setting and composition.
	Poor pollutant contents reduction of fuel.

Man: Due fundamentally to the lack of driving motive in terms of government subsidy and fixed fare basis, these discouraged drivers to pay attention on maintaining their vehicle conditions and failed to provide proper/ sufficient training to public transport drivers leading to poor attitude and careless driving behavior. Most of public buses that shared and owned by private individuals are quite old. They are major producers of air emission on streets. Similarly, due to the lack of convenience and reliability of public bus services, these discouraged passengers to use private transport instead. These factors generated the increase level of air emission on road as well.

Method: The less strengthened air quality monitoring especially in air emissions are resulted from the lack of advanced technology for effective measurement and also poor follow-up program. Moreover, the unqualified emissions standard and fuel specification have encouraged the weak implementation, monitoring and inspection technology including lack of integrated transport & land use planning, those make high air emissions.

Machine: The main air emissions occurred from motor vehicle engine may be caused by poor maintenance, old engine or model resulted in more fuel consumption. This is partially because of the favor use of the large engine with low quality of pollution controls from engine.

Material: Low or poor quality of fuel will make high levels of air emissions such as, composition of high pollutant contents, poor fuels standard setting, invariable of the fuels or the alternative of fuel. Moreover, lack of fuel pricing mechanism will make less choice to consume the fuel encouraging CO_2 emissions too.

Based on the results obtained from the initial survey of 40 participants, the perceived results were then made into a questionnaire for 20 environmental and transportation experts. The experts were also asked to grade the questions based on their expertise in the areas of man, methods, machines, and materials.

The answers from the questionnaires were computed by AHP and Fuzzy software programs to obtain the output. The results have been depicted in Tables 4.2 and 4.3. Based on the responses it was found that "Poor Public Transport" was ranked as the highest cause (0.512) for increased vehicular emissions. Details of the output from AHP and Fuzzy estimation are presented in Appendix D.

Table 4.2 Results obtained all the perceived causes for air pollution of transportation sector from 20 experts.

Rank	Causes of air pollution from transportation sector	Scores
1	Poor public transport.	**0.512**
2	Lack of integrated transport & land use planning.	0.478
3	Weak vehicle inspection and maintenance program.	0.432
4	Poor vehicle maintenance.	0.424
5	Weak implementation and commitment to enforce emission standard.	0.411
6	People have low public Awareness and bad attitude.	0.402
7	Poor and low quality to control pollution from engine.	0.401
8	Less alternative fuel for vehicle.	0.397
9	Poor quality of fuel such as poor standard setting and composition.	0.395
10	Large engine made more fuel consume.	0.391

Table 4.2 (Cont) Results obtained all the perceived causes for air pollution of transportation sector from 20 experts.

Rank	Causes of air pollution from transportation sector	Scores
11	Weak fuel demand management.	0.388
12	Poor regulation and maintain inventory for vehicle driving.	0.385
13	Poor pollutant contents reduction of fuel.	0.384
14	Old engine of vehicle model.	0.380
15	Less strengthen quality monitoring for air emissions from vehicle.	0.342
16	Lack of advanced technology to measure effectiveness for vehicle inspection.	0.339
17	People Inconsistency & carelessness.	0.321
18	Lack of fuel pricing mechanism.	0.315
19	Limited of funding from transport sector for people emotion.	0.312
20	Not sufficiently trained people.	0.310

Table 4.3 Results of priority problem or main root cause of air emissions from **transportation sector.**

Main Problem	Criteria	Factors	Evaluation Grades				
			Poor	Indifferent	Moderate	Importance	Extreme importance
Poor Public Transport : 0.512	Man : 0.041	Knowledge : 0.292					0.90
		Attitude & Emotion : 0.178			0.70		
	Method : 0.270	Implementation : 0.306				0.80	
		Regulations & Standard : 0.289					0.90
	Material : 0.074	Alternatives : 0.162		0.60			
		Composition : 0.246		0.60			
	Machine : 0.143	Model & Specification : 0.303			0.70		
		Age of engine : 0.427					0.90

It can be noted from the interview conducted for 20 experts that "Poor Public Transport" is identified as the influential cause for air emissions from transportation sector in Bangkok by using a cause-and-effect diagram as shown in Figure 4.4.

In order to find an alternative solution, the experts were questioned on possible alternative for addressing the issue of air pollution. The results are discussed in the section below.

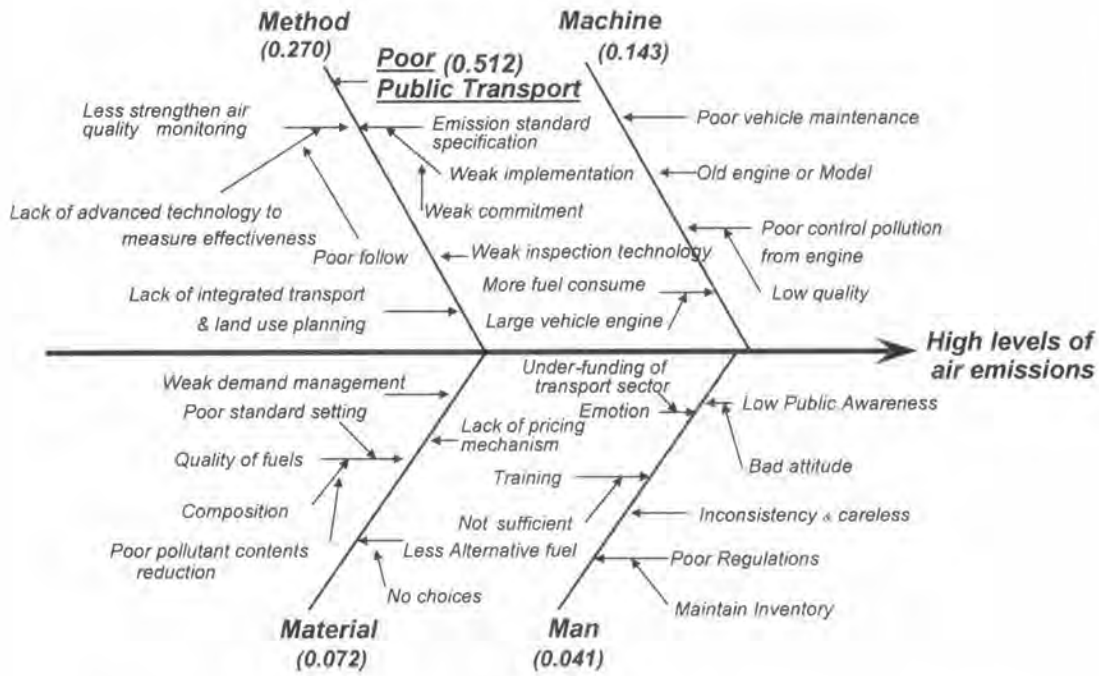


Figure 4.4 Cause-and-effect diagram of priority problem (poor public transport) of air emissions from transportation sector.

4.3 Generation and selection of alternative solutions

As discussed above, "Poor Public Transport" was identified as the influential cause for high levels of emissions. In order to identify alternative solutions, the same group of 20 experts had been questioned for viable alternatives solution to address the issue of high level of air emissions from transportation sector. The experts had also graded and weighed their answers on categories viz. Implementation Impacts, Environmental Impacts, Economic Impacts and People and Public Impacts.

The results of their responses are shown in Table 4.4. It was found that majority of the respondents perceive that promoting or implementing NGV bus and rerouting the existing services would yield maximum benefits (ranked at 0.551). It was followed by increasing the mass rapid transit network (ranked at 0.452), while promoting a NGV powered bus rapid transit network and improving the fare structure of public transport were ranked at 0.374 and 0.309 respectively. This perception of the experts would be counter tested by using an integrated model, discussed in the forthcoming sections, as shown in Table 4.5. Details of AHP and Fuzzy evaluation are presented in Appendix D.

Table 4.4 Results obtained all alternative solutions for poor public transportation from the 20 experts.

Rank	Alternative solutions	Scores
1	Implementing NGV buses and rerouting.	0.551
2	Increasing the mass rapid transit network.	0.452
3	Increasing NGV buses rapid transit network.	0.347
4	Improve fare structure of public transport	0.309
5	Transit frequency increase.	0.304
6	Increase feeder system.	0.297
7	Promoting use public transport.	0.295
8	With–flow bus lane.	0.288
9	Contra-flow bus lane.	0.276

Table 4.4 (Cont) Results obtained all alternative solutions for poor public transportation from the 20 experts.

Rank	Alternative solutions	Scores
10	Develop more interchange for public transport.	0.275
11	Strong enforce bus lane.	0.263
12	Adjust tax policy for public transport.	0.262
13	Improve public transport parking.	0.261
14	Staff bus service.	0.253
15	School bus service for student.	0.245

Table 4.5 Results of 4 alternative solutions for poor public transport.

Alternative Solutions	Criteria	Factors	Evaluation Grades				
			Poor	Indifferent	Moderate	Importance	Extreme importance
Implementing NGV bus and rerouting : 0.551	Environment Impacts : 0.387	Emission reduction : 0.436					0.90
		Air quality : 0.337				0.80	
	Implement Impacts : 0.280	Best practices : 0.325				0.80	
		Barriers to implementation : 0.177				0.80	
	Economic Impacts : 0.235	Investment cost : 0.280			0.70		
		Break even : 0.230			0.70		
	People & Public Impacts : 0.297	Fairness : 0.405					0.90
		Acceptability : 0.310			0.70		

Table 4.5 (Cont) Results of 4 alternative solutions for poor public transport.

Alternative Solutions	Criteria	Factors	Evaluation Grades				
			Poor	Indifferent	Moderate	Importance	Extreme importance
Increasing Mass rapid transit network : 0.452	Environment Impacts : 0.302	Emission reduction : 0.327					0.90
		Air quality : 0.261				0.80	
	Implement Impacts : 0.157	Best practices : 0.204				0.80	
		Barriers to implementation : 0.313			0.70		
	Economic Impacts : 0.056	Investment cost : 0.104		0.60			
		Break even : 0.145	0.50				
	People & Public Impacts : 0.324	Fairness : 0.312			0.70		
		Acceptability : 0.335			0.70		
Increasing NGV Bus rapid transit network : 0.374	Environment Impacts : 0.149	Emission reduction : 0.271					0.90
		Air quality : 0.178				0.80	
	Implement Impacts : 0.221	Best practices : 0.306			0.70		
		Barriers to implementation : 0.289		0.60			
	Economic Impacts : 0.112	Investment cost : 0.162		0.60			
		Break even : 0.246		0.60			
	People & Public Impacts : 0.226	Fairness : 0.303			0.70		
		Acceptability : 0.427			0.70		

Table 4.5 (Cont) Results of 4 alternative solutions for poor public transport.

Alternative Solutions	Criteria	Factors	Evaluation Grades				
			Poor	Indifferent	Moderate	Importance	Extreme importance
Improve Fare Structure of public transport : 0.309	Environment Impacts : 0.056	Emission reduction : 0.436				0.80	
		Air quality : 0.337			0.70		
	Implement Impacts : 0.289	Best practices : 0.325			0.70		
		Barriers to implementation : 0.177	0.50				
	Economic Impacts : 0.208	Investment cost : 0.280	0.50				
		Break even : 0.230		0.60			
	People & Public Impacts : 0.346	Fairness : 0.405			0.70		
		Acceptability : 0.310				0.80	

4.4 Selecting of alternative solutions

1) Transport Model: Modifying eBUM to Bangkok Urban Area Model (BUAM)

For the purpose of the study, an already existing model eBUM or extended Bangkok Urban Model was utilized. The reason for utilizing this model was the ready availability of data and also the model has been in use by the local government for forecasting their traffic and transport projects. Nevertheless, the model focuses on Greater Bangkok area which is larger than the proposed study site, so there is a need for modifying the model to focus on the Bangkok urban area.

The aspects of eBUM that were modified to form BUAM such as zoning and network, population, number of households, average household size, average household income and employment as shown in Figures 4.5 - 4.8.

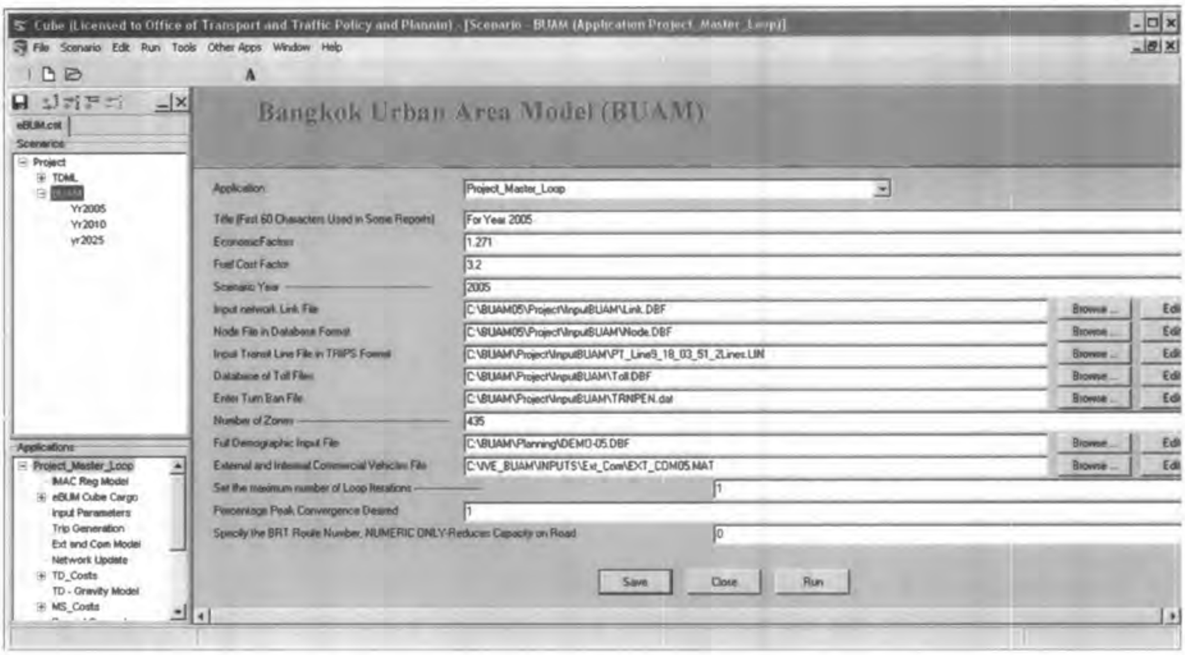


Figure 4.5 Application project master loop of BUAM

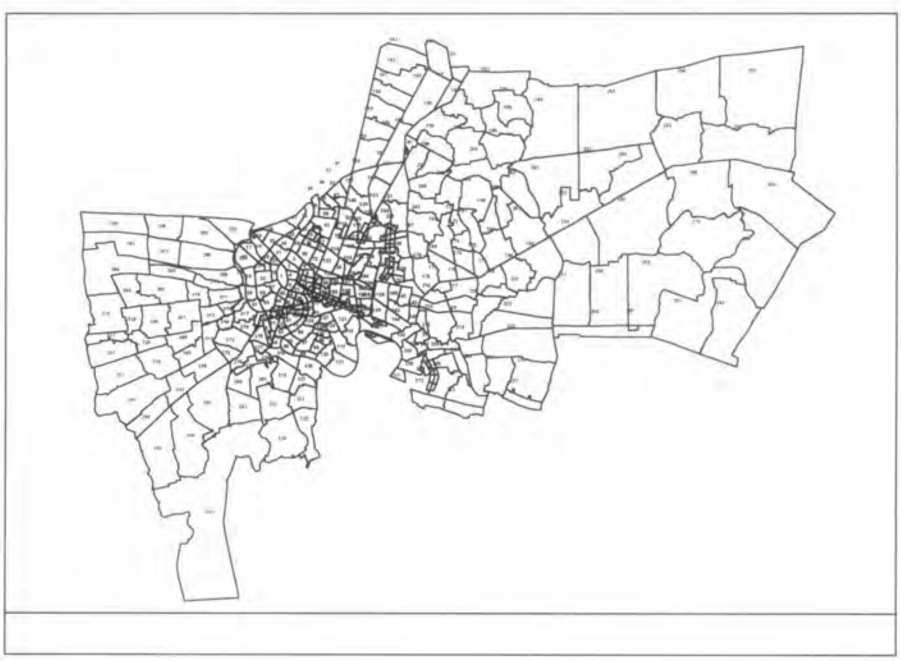
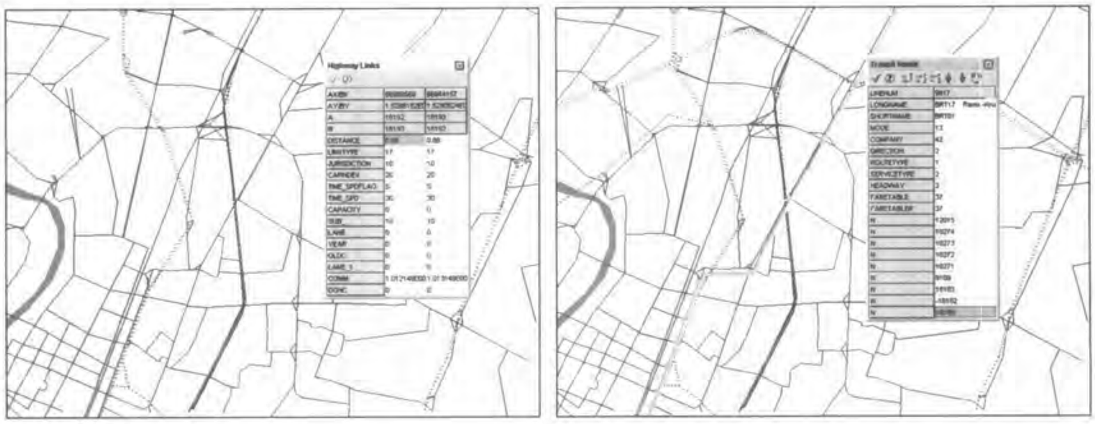


Figure 4.6 Traffic zones of BUAM



Highway network Transit network

Figure 4.7 Highway and transit network of BUAM

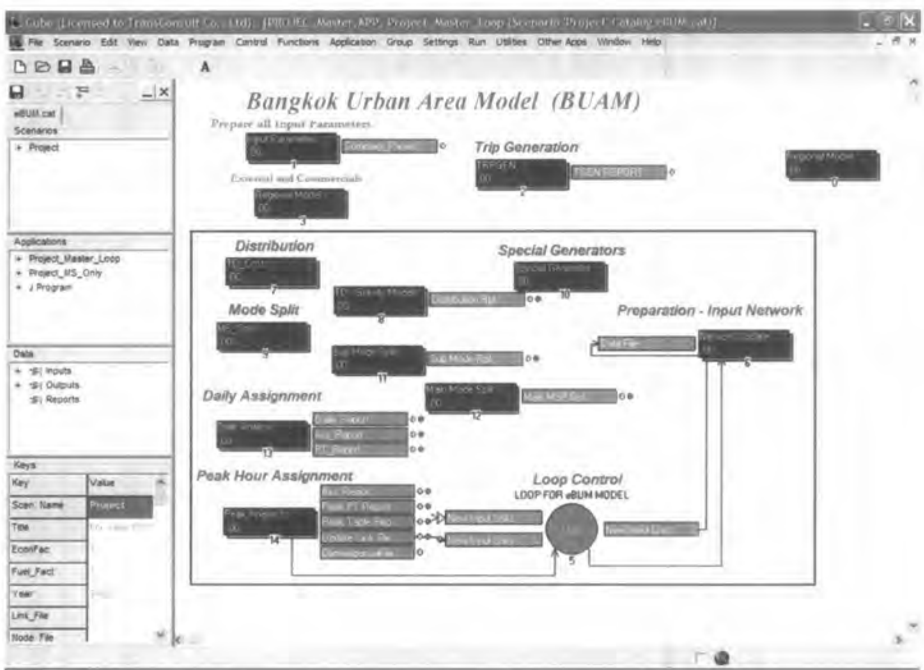


Figure 4.8 Main page of Bangkok Urban Model (BUAM)

2) International Vehicle Emissions Model (IVE).

The transport model discussed above does not have the component for forecasting the emissions. Hence, there is a strong need for either a new model or integrating the above mentioned transport model with an existing emission model. As there is data available for the above mentioned transport model, integrating an emission model with BUAM will be sensible, instead of having a new model considering the time and economic constraints the main page of IVE-BUAM as shown in Figure 4.9.

Figure 4.9 Main page of IVE model (IVE-BUAM).

3) Integrated transport model and vehicle emission model

Integrated transport model (BUAM) and vehicle emission model (IVE-BUAM) is simulated for analyzing and evaluating the 4 high-potential alternative solutions was modified the input from transport model (BUAM) by writing more new scrip files as shown in Figure 4.10 for imported the input data to the vehicle emission model (IVE-BUAM) such as road data and fleet data.

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"; Script for program MATRIX in file ""C:\BUAM05\DY\CRMATS\DATA_CTL\DYMAT00A.S"""
;;<<GENERATED SCRIPT>><<MATRIX>>;;
;  Development of Daily Private Vehicle and Private Person Trip table >>>
;Input  PA Matrix File for 0 Vehicle Household: {SCENARIO_DIR}\WEON_0V.MAT
;Input  PA Matrix File for 1 Motorcycle Household: {SCENARIO_DIR}\WEON_MC.MAT
;Input  PA Matrix File for 1 Car Household: {SCENARIO_DIR}\WEON_1C.MAT
;Input  PA Matrix File for Multi Vehicle Household: {SCENARIO_DIR}\WEON_MV.MAT
;Input  Special Generator Trips: {SCENARIO_DIR}\SG_PCU.MAT
;Input  External and Commercial Vehicle Trips: {SCENARIO_DIR}\EXT_COM.MAT

;Output PA Person Trips by Private Mode: C:\BUAM05\DY\CRMATS\MATS\DY_PVT_PER.PA
;Output PA Vehicle(pcu) Trips by Private Mode: C:\BUAM05\DY\CRMATS\MATS\DY_PVT_VEH.PA
;Output Summary File for Reporting Purposes: C:\BUAM05\DY\CRMATS\MATS\SUM_PVT.MAT


;;<<End Parameters>>;;
; Do not change filenames or add or remove FILEI/FILEO statements using an editor. Use Cube/Application Manager.
"RUN PGM=MATRIX PRNFILE=""C:\BUAM05\DY\CRMATS\RUN\DYMAT00A.PRN"" MSG='Development of Daily Private Mode Tables Person and Vehicle'"
"FILEI MATI[1] = ""{SCENARIO_DIR}\WEON_0V.MAT"""
"FILEI MATI[2] = ""{SCENARIO_DIR}\WEON_MC.MAT"""
"FILEI MATI[3] = ""{SCENARIO_DIR}\WEON_1C.MAT"""
"FILEI MATI[4] = ""{SCENARIO_DIR}\WEON_MV.MAT"""
"FILEI MATI[5] = ""{SCENARIO_DIR}\SG_PCU.MAT"""
"FILEI MATI[6] = ""{SCENARIO_DIR}\EXT_COM.MAT"""
;
;
;   Developed by PRADITPHET P. during the IVE-BUAM STUDY
;
;
"FILEO MATO[1] = ""C:\BUAM05\DY\CRMATS\MATS\DY_PVT_PER.PA"","
"MO=1-4,NAME[1]='Car_Person',NAME[2]='Taxi_Person',NAME[3]='Motorycle_Person',NAME[4]='Bus_Person'"
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"MO=5-9,NAME[1]='Car',NAME[2]='Taxi',NAME[3]='Motorycle',NAME[4]='SpecialBus',NAME[5]='Truck'"
"FILEO MATO[3] = ""C:\BUAM05\DY\CRMATS\MATS\SUM_PVT.MAT"","
"MO=10-35,"
"NAME[1]='HBW_Car',                  ; Name for Output Matrix 10"
"NAME[2]='HBW_Taxi',                 ; Name for Output Matrix 11"
"NAME[3]='HBW_Motorcycle',           ; Name for Output Matrix 12"
"NAME[4]='HBW_Bus',                  ; Name for Output Matrix 13"
"NAME[5]='HBE_Car',                  ; Name for Output Matrix 14"
"NAME[6]='HBE_Taxi',                 ; Name for Output Matrix 15"
"NAME[7]='HBE_Motorcycle',           ; Name for Output Matrix 16"
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"NAME[9]='HBO_Car',                  ; Name for Output Matrix 18"
"NAME[10]='HBO_Taxi',                ; Name for Output Matrix 19"
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"NAME[13]='NHB_Car',                 ; Name for Output Matrix 22"
"NAME[14]='NHB_Taxi',                ; Name for Output Matrix 23"
"NAME[15]='NHB_Motorcycle',          ; Name for Output Matrix 24"
"NAME[16]='NHB_SpecialBus',          ; Name for Output Matrix 25"
"NAME[17]='Special_Generator(pcu)',  ; Name for Output Matrix 26"
"NAME[18]='External_Car(pcu)',       ; Name for Output Matrix 27"
"NAME[19]='External_Taxi(pcu)',      ; Name for Output Matrix 28"
"NAME[20]='External_MC(pcu)',        ; Name for Output Matrix 29"
"NAME[21]='External_Truck(pcu)',     ; Name for Output Matrix 30"
"NAME[22]='Commercial_Veh(pcu)',     ; Name for Output Matrix 31"
"NAME[23]='Special_Generator(person)', ; Name for Output Matrix 32"
"NAME[24]='External_Car(person)',    ; Name for Output Matrix 33"
"NAME[25]='External_Taxi(person)',   ; Name for Output Matrix 34"
NAME[26]='External_MC(person)'       ; Name for Output Matrix 35
;
;
; SPECIAL BUS IS DEFINED AS A SCHOOL AND EMPLOYEE BUSES
;
; External Vehicles and Goods Matrices are in PCU format
```

Figure 4.10 Scrip files for imported the input data from BUAM to IVE-BUAM

4) Base case

The Year 2005 was taken as the base case due to availability of comprehensive data required for the study. The integrated model would forecast for years 2010 and 2025. It is expected that by the year 2025 there will be a complete mass transit network in Bangkok, as the master plan shown in Tables 4.6 -4.9. The results obtained from simulating the model are shown below.

Table 4.6 Results of Integrated transport model and vehicle emission model (Base case: Daily)

Base Year	PCU-Km	Speed Km/hr	NO_2 g/km	CO g/km	PM_{10} g/km
2005	6,544,860	17.23	15,707,664	3,861,467	458,140
2010	7,688,940	16.4	19,222,350	4,920,922	692,005
2025	9,959,460	13.45	27,886,488	7,668,784	1,195,135

Table 4.7 Results of Integrated transport model and vehicle emission model (Base case: A.M. Peak)

Base Year	PCU-Km	Speed Km/hr	NO_2 g/km	CO g/km	PM_{10} g/km
2005	458,140	15.4	1,099,536	250,995	34,361
2010	522,848	14.3	1,326,342	344,465	47,748
2025	717,081	12.6	2,091,487	529,146	95,611

Table 4.8 Results of highway network (Base case: Daily).

Year	PCU-km	Car PCU-Km	Taxi PCU-Km	Bus PCU-Km	Truck PCU-Km	Motorcycle PCU-Km
2005	6,544,860	2,775,021 (42.4%)	734,988 (11.23%)	2,350,914 (35.92%)	264,412 (4.04%)	419,526 (6.41%)
2010	7,688,940	3,221,666 (41.9%)	781,196 (10.16%)	2,810,308 (36.55%)	305,251 (3.97%)	570,519 (7.42%)
2025	9,959,460	4,134,172 (39.24%)	921,250 (9.26%)	3,695,956 (37.11%)	386,427 (3.88%)	821,655 (10.51%)

Table 4.9 Results of public transport network (Base case: Daily).

Rail system (Mass Rapid Transit / Train /BRT)	Year 2005 Passengers boarding/day	Year 2010 Passengers boarding/day	Year 2025 Passengers boarding/day
Mass Rapid transit (MRT)			
- Red Line	-	449,215	1,443,254
- Green Line	472,561	895,421	1,336,125
- Blue Line	201,283	538,458	1,076,214
- Orange Line	-	-	521,478
- Yellow Line	-	-	291,145
- Purple Line	-	118,754	1,229,254
- Pink Line	-	-	231,092
- Brown Line	-	-	31,556
Train - Train	53,458	60,142	79,214
Bus rapid transit (BRT) - BRT	-	55,147	455,293
Total	727,302	2,117,137	6,696,650

From the table above, its may notice that, there have slightly changes in PCU-km and speed of vehicles in highway network even though the network of mass rapid transit are complete in public transport network. That's because of the increase of population and more need of travel demands. Due to these causes, the number of vehicles on road will be increase. However, the mass rapid transit system could meet some demand of travel and help to release some of traffic congestion, especially in urban city area.

5) Validation of the model

In order to ascertain that the model is functioning properly, the model needs to be validated by providing the observed data and calculating the difference between the estimated data from BUAM and IVE-BUAM and the observed data from Office of Transport Policy and Planning (OTP) and Pollution Control Department (PCD). The average percentage difference for the model needs to be below 30% for the model results to be accepted as shown in Tables 4.10 and 4.11.

Table 4.10 Validation of transport model: BUAM (Base case: A.M. Peak).

Road	Observed (OTP)		Estimate (Model)		Percent Diff.	
	PCU	Speed Km/h	PCU	Speed Km/h	PCU %	Speed %
Dindang (Vipavadee)	64,834	15.2	68,096	17.5	5.03	15.13
Rama VI	48,166	19.5	45,653	24.2	-5.22	24.10

Radchadaphisek	54,423	17.3	56,998	15.6	4.73	-9.83
Phaholyothin (Lardprao)	44,870	18.5	52,458	22.4	16.91	21.08

Table 4.10 (Cont) Validation of transport model: BUAM (Base case: A.M. Peak).

Road	Observed (OTP)		Estimate (Model)		Percent Diff.	
	PCU	Speed Km/h	PCU	Speed Km/h	PCU %	Speed %
Intharapitak	16,366	14.4	20,450	17.5	24.95	21.53
Rama III	28,585	19.1	31,254	22.1	9.34	15.71
Ramkumheng	64,817	13.6	70,948	17.4	9.46	27.94
Ladprao (ChockChai 4)	44,219	15.7	39,457	16.8	-10.77	7.01

Table 4.11 Validation of vehicle emission model: IVE-BUAM (Base case: A.M. Peak).

Road	Observed (PCD)			Estimate (Model)			Percent Diff.		
	NO_2 ppb	CO ppm	PM_{10} ug	NO_2 ppb	CO ppm	PM 10 ug	NO_2 %	CO %	PM_{10} %
Dindang (Vipavadee)	42.4	1.6	3.1	39.9	1.9	2.7	-5.9	18.8	-12.9
Rama VI	21.6	0.3	1.9	26.6	0.4	2.1	23.1	33.3	10.5
Radchadaphisek	28.8	1	1.7	25.4	1.2	1.6	-11.8	20.0	-5.9
Phaholyothin (Lardprao)	30.2	0.9	2.09	24.2	0.7	1.75	-19.9	-22.2	-16.3
Intharapitak	24.4	1	1.3	22.9	1.2	1.5	-6.1	20.0	15.4
Rama III	25.8	0.8	1.9	20.9	0.7	1.6	-19.0	-12.5	-15.8
Ramkumheng	18.7	0.6	1.4	16.6	0.7	1.9	-11.2	16.7	35.7
Ladprao (ChockChai 4)	21.1	0.7	1.6	25.4	0.8	1.9	20.4	14.3	18.8

Note: The emissions shown in this table was represented only one point of each area.

Table 4.12 Analysis of 4 high-potential alternative solutions

Year	Daily					A.M. Peak				
2005	B11	C11	C12	C13	C14	B211	C211	C212	C213	C214
2010	B21	C21	C22	C23	C24	B221	C221	C222	C223	C224
2025	B31	C31	C32	C33	C34	B331	C331	C332	C333	C334

Note:

B11, B21, B31, B211, B221, B331 : Base case

C11, C21, C31, C211, C221, C331 : Implementing NGV bus and rerouting

C12, C22, C32, C212, C222, C332 : Increasing Mass rapid transit network

C13, C23, C33, C213, C223, C333 : Increasing NGV Bus rapid transit (BRT) network

C14, C24, C34, C214, C224, C334 : Improve Fare Structure of public transport

6) Evaluation of 4 high-potential alternative solutions

Integrated transport model (BUAM) and vehicle emission model (IVE-BUAM) is simulated for analyzing and evaluating the 4 high-potential alternative solutions obtained as a result of surveys mentioned in sections 4.2 and 4.3.

Base case:

Base cases are the same existing situation without any changes to the transport system in years 2005, 2010 and 2005 as same as above outputs.

Solution 1: Implementing NGV bus and rerouting.

It is expected that the existing buses will be replaced by NGV buses and their existing networks will be rerouted/optimized for efficiency. The main expected changes will be reduction of the exiting buses from 7900 to 6200 and replaced by NGV buses, while keeping the coverage area constant and the number of routes would be reduced to 181 from 214 as shown in Table 4.13.

Table 4.13 Comparison between existing and new bus network

Criteria	Existing Bus network	New Bus network
Number of bus routes	214	181
Number of expressway buses	29	17
Average route directness	0.54	0.75
Average trip length (km)	27.7	18.5
Fleet size (buses)	8,900	6,200
Kilometer of network (km)	7,486	6,690

Although route planning will be outlined on the basis of geographical zones, this is only relevant for planning purposes and for grouping routes under operational frameworks. The design of routes is not limited by operational constraints, which would compromise the functionality of the total network.

To assist in the route planning, 7 major zones have been defined relative to groups of existing major corridors as follows:

- Eastern Zone (Bus Zone 1),
- South-Eastern Zone (Bus Zone 2),
- Northern Zone (Bus Zone 3),
- Western Zone (Bus Zone 4),
- South-Western Zone (Bus Zone 5),
- Far Eastern Zone (Bus Zone 6), and

- Central Zone (Bus Zone 7)

Solution 2: Increasing Mass rapid transit network.

It is expected that the existing mass rapid transit network will be extended to 7 lines and will cover most of the Bangkok area. The service length will increase from existing 43.7 km. to 291.2 km.

The main concept of increasing mass rapid transit (MRT) network in Bangkok must include area Coverage, Accessibility, and Efficiency in order to be the new alternative transportation mode for people. These can be classified, by route patterns, into 3 main categories as shown in table 4.14, including;

(i) Circumferential Route: 1 route,

- Blue line (Ratchada - Jarunsanitwong)

(ii) North-South Radius Route: 3 routes, including,

- Red line N-S (Rangsit - Mahachai)
- Green line N-S (Sapan mai - Bangwa)
- Purple line (Bangyai - Rajburana)

(iii) East-West Radius Route: 3 routes, including.

Red line E-W (Talingchan - Suvarnabhumi)

Green line E-W (Prannok - Samutprakan)

Orange line (Bangbumru - Bangkapi)

Table 4.14 Summaries of mass rapid transit network.

Line		Section	Project Owner	Distance (km)
Green 1.1	Light Green	Sukhumvit Line	BMA	9.4
Green 1.2	Light Green	On Nut-Sam Rong	BMA	8.9
Green 1.3	Light Green	Sam Rong-Samut Prakan	BMA	7.9
Green 1.4	Light Green	Rama1-Pran Nok	BMA	6.8
Green 2.1	Dark Green	Silom Line	BMA	14.3
Green 2.2	Dark Green	Mor Chit-Sapan Mai	BMA	12
Green 2.3	Dark Green	Taksin Bridge-Taksin Road	BMA	2.2
Green 2.4	Dark Green	Taksin road-Phetkasem	BMA	4.5
Blue 3.1	Blue	Bang Sue-Hua Lumpong	MRTA	20
Blue 3.2	Blue	Hug Lumpong-Tha Pra	MRTA	6.5
Blue 3.3	Blue	Bang Sue-Tha Pra	MRTA	13.1
Blue 3.4	Blue	Tha Pra-Bang Kae	MRTA	7.7
Purple 4.1	Purple	Bang Sue-Pra Nang Klao	MRTA	11.6
Purple 4.2	Purple	Pra Nang Klao-Bang Yai	MRTA	8.1
Purple 4.3	Purple	Bang Sue-Sam Sen	MRTA	4.9
Purple 4.4	Purple	Sam Sen-Raj Burana	MRTA	14.8
Orange 5.1	Orange	Bang Kapi-Sam Sen	MRTA	20
Orange 5.2	Orange	Sam Sen-Bang Bum Ru	MRTA	4
Red 6.1	Red N-S	Bang Sue-Rang Sit	SRT	22.7
Red 6.2	Red N-S	Hua Lampong-Bang Sue	SRT	7.5
Red 6.3	Red N-S	Hua Lampong-BSTC	SRT	6.5
Red 6.4	Red N-S	BSTC-Maha Chai	SRT	28.3

Table 4.14 (Cont) Summaries of mass rapid transit network.

Line		Section	Project Owner	Distance (km)
Red 7.1	Red E-W	Phaya Thai-SBIA	SRT	28.5
Red 7.2	Red E-W	Bang Sue-Phaya Thai	SRT	6.1
Red 7.3	Red E-W	Bang Sue-Taling Chan	SRT	14.9

Solution 3: Increasing NGV Bus rapid transit network.

Bus Rapid Transit (BRT) system has been proposed as part of the MRT by selection of these corridors was based on travel demand (high occupancy corridors), geometric characteristics of roadways, the formation of total BRT system networks, other intermodal integration, and amenity and system management issues

According to the above criteria, the proposed NGV Bus Rapid Transit network of 9 corridors is shown in table 4.15 respectively.

Table 4.15 Details of NGV Bus Rapid Transit corridors.

Route No.	Origin - destination	Distance (Km)	Connection with MRT (existing and future) and Expressway
1	Taling Chan - Phatthana Kan	26.6	MRT Green line
2	Rang sit - Din Dang	27.0	Commuter train - Red Line 1st Stage Expressway
3	Min Buri - Samut Prakan (via Srinakharin Road)	28.2	MRT Orange line

Table 4.15 (Cont) Details of NGV Bus Rapid Transit corridors.

Route No.	Origin - destination	Distance (Km)	Connection with MRT (existing and future) and Expressway
4	Min Buri – Rama V Road.	30.5	Commuter train – Red Line MRT Blue line and Green Line
5	Rama II – Wong Wien Yai	14.6	Commuter train – Red Line MRT Purple line and Green Line
6	Western Outer Ring Road – Kasetsart Junction	20.1	Commuter train – Red Line MRT Purple line
7	Khlong Prapa – Phitsanu Lok Road.	27.0	2nd Stage Expressway
8	Phra Samut Chedi – Pracha Thipok	24.6	Commuter train – Red Line MRT Purple line and Green Line
9	Pak Kret – Bang kapi	28.9	Commuter train – Red Line MRT Green Line
	Total route length	227.5	

Solution 4: Improve fare structure of public transport.

The existing fare structure which is not consistent among the various modes viz. Mass rapid transit, air-condition bus service and non-air-conditioned bus service. The Mass rapid transit and air-conditioned public bus service currently used a distance based fare structure while the non-air-conditioned service uses a flat fare structure. It is expected that there will be a flat fare structure in all the modes where in the Mass rapid transit will have a fare of 30 baht, air-conditioned bus at 15 baht and non-air-conditioned would be 8 baht.

Setting a new fare scale will need to consider as following;

- That passengers will pay a fare for an entire journey, which may involve one trip or multiple trips on any mode of public transport by paying an 'entry cost' to the system without any penalty for changing buses.

- As the new system has very little comparison with the present system, it is difficult to align new fares with existing structures; therefore, fares should be set at a 'politically sensitive' level that is perceived as 'good value' and is then likely to encourage patronage (these can be finely tuned over time to better suit circumstances).

- That political handling of the introduction of the new fare regime is an important factor, both in ensuring that fares are adequate to ensure reasonable cost recovery, and that public perceptions are managed.

- Setting flat fare for assisting users traveling shorter or longer distances.

- Price incentives used to promote buses in off-peak hours to increase average loadings.

6) Model outputs.

The model outputs, shown in Table 4.16 and Table 4.17 indicate that;

- Passenger Car Unit per kilometer (PCU-km) after evaluated 4 high-potential alternative solutions,

- Average speed (kilometer per hour / km/hr) after evaluated 4 high-potential alternative solutions

- 3 Main air pollutants (NO_2, CO and PM_{10}) that emitted from vehicle after evaluated 4 high-potential alternative solutions.

Table 4.16 Results of Integrated transport model and vehicle emission model (Base case: with 4 high-potential alternative solutions: Daily)

Year	Case	PCU-Km	Speed Km/hr	NO_2 g/km	CO g/km	PM_{10} g/km
2005	B11	6,544,860	18.7	15,707,664	3,861,467	458,140
	C11	6,348,792	20.3	15,016,564	3,658,550	435,685
	C12	6,399,532	19.8	15,136,576	3,687,789	439,167
	C13	6,424,902	19.0	15,196,582	3,702,409	440,908
	C14	6,501,011	19.1	15,376,601	3,746,267	446,131
2010	B21	7,688,940	16.4	19,222,350	4,920,922	692,005
	C21	7,696,629	17.7	18,574,802	4,784,980	671,128
	C22	7,758,140	17.0	18,723,252	4,823,222	676,492
	C23	7,788,896	16.5	18,797,477	4,842,343	679,174
	C24	7,881,164	16.9	19,020,152	4,899,705	687,219
2025	B31	9,959,460	15.5	27,886,488	7,668,784	1,195,135
	C31	9,664,869	16.8	26,922,538	7,487,738	1,026,435
	C32	9,742,111	16.4	27,137,703	7,547,580	1,034,639
	C33	9,780,732	15.9	27,245,285	7,577,501	1,038,740
	C34	9,896,594	15.7	27,568,033	7,667,264	1,051,045

The above tables discusses in detail the results obtained from the integrated model for the Daily average for the base and forecast years.

In the case where the NGV buses are implemented and the rerouting is done, it can be observed from the table that for these indicators in years 2005, 2010 and 2025 (case C11, C21 and C31) the Passenger Car Unit was lessen than other solutions and the speed of this solution remains highest among the other modes in respective year. At the same time the vehicular emissions NO_2, CO and PM_{10} are also the least among other solutions as increasing mass rapid transit network (case C12, C22 and C32), increasing NGV bus rapid transit (BRT) network (case C13, C23 and C33), and improve fare structure of public transport (case C14, C24 and C34), in the respective years. The forecasted emission levels meet the requirements of the macro ambient air quality standards.

Table 4.17 Results of Integrated transport model and vehicle emission model (Base case: with 4 high-potential alternative solutions: A.M. Peak)

Year	Case	PCU-Km	Speed Km/hr	NO_2 g/km	CO g/km	PM_{10} g/km
2005	B211	458,140	15.4	1,099,536	250,995	34,361
	C211	441,001	16.2	977,566	236,132	33,489
	C212	444,525	16.0	985,378	238,019	33,757
	C213	446,287	15.7	989,285	238,963	33,891
	C214	451,574	15.9	1,001,004	241,793	34,292

Table 4.17 (Cont) Results of Integrated transport model and vehicle emission model (Base case: with 4 high-potential alternative solutions: A.M. Peak)

Year	Case	PCU-km	Speed km/hr	NO_2 g/km	CO g/km	PM_{10} g/km
2010	B221	522,848	14.3	1,326,342	344,465	47,748
	C221	509,765	16.3	1,221,545	335,225	46,296
	C222	513,839	15.5	1,231,308	337,904	46,666
	C223	515,876	15.7	1,236,189	339,244	46,851
	C224	521,987	16.1	1,250,833	343,262	47,406
2025	B231	717,081	13.6	2,091,487	529,146	95,611
	C231	699,289	14.5	1,897,456	515,959	93,674
	C232	704,877	14.3	1,912,620	520,083	94,422
	C233	707,672	14.0	1,920,202	522,145	94,797
	C234	716,055	14.1	1,942,949	528,330	95,920

The above table discusses in detail the results obtained from the integrated model for the A.M. peak average for the base and forecast years.

In the case where the NGV buses are implemented and the rerouting is done it can be observed from the table that for these indicators in years 2005, 2010 and 2025 (case C211, C221 and C331) the Passenger Car Unit was lessen than other solutions and the speed of this solution remains highest among the other modes in respective year. At the same time the vehicular emissions NO_2, CO and PM_{10} are also the least among other solutions as increasing mass rapid transit network (case C212, C222 and C332), increasing NGV bus rapid transit (BRT) network (case C213, C223 and C333), and improve fare structure of public transport (case C214, C224 and C334), in the respective years. The forecasted emission levels meet the requirements of the macro ambient air quality standards.

4.5 Present outputs of P2 alternative solutions

The final results obtained from the above mentioned stages are converted to the Geographical Information Systems (GIS) format for further presentation and decision making process as shown in Figure 4.11.

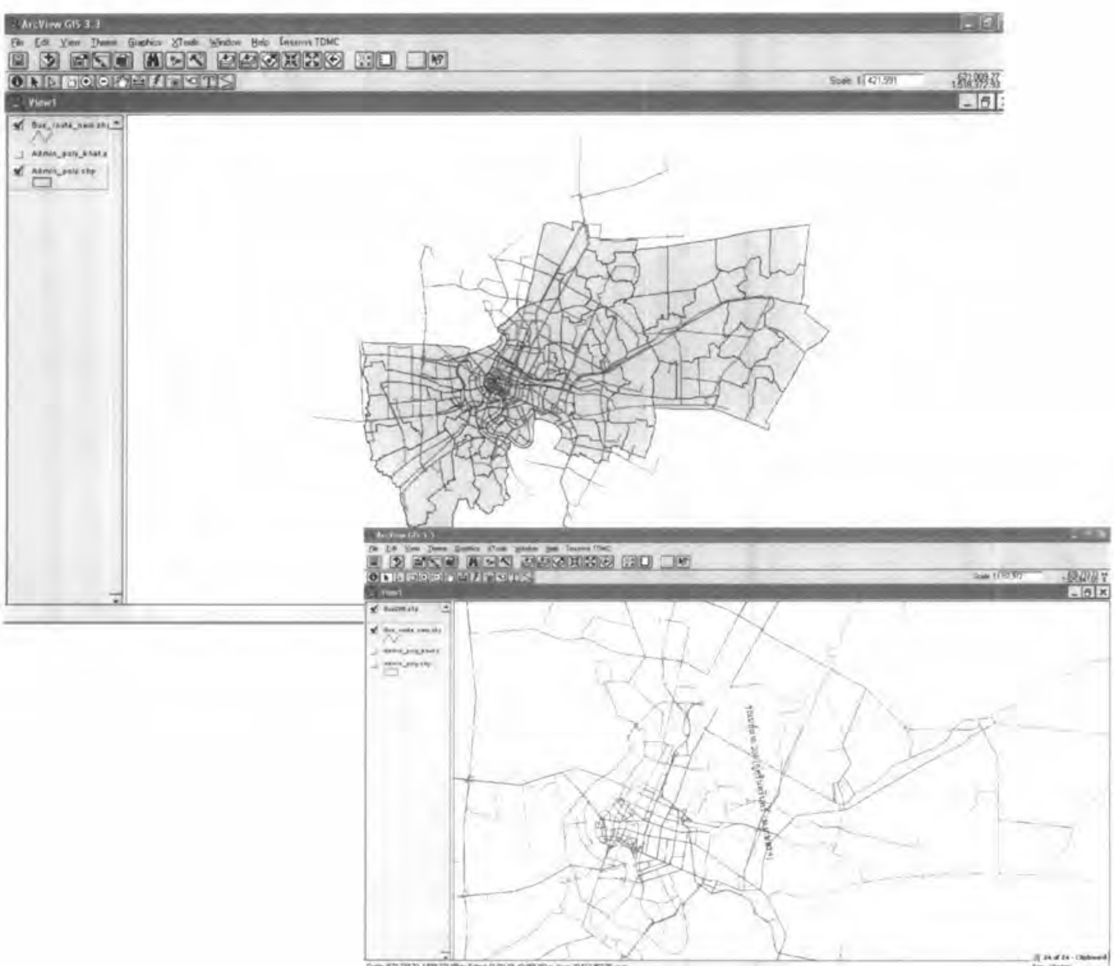

Figure 4.11 Converted results to the GIS format

GIS can perform spatial analysis and produce graphical map displays that can enhance the efficiency of the communication between transport and environment planners with the public. The need for environmental planning in Bangkok is well recognized by the transport and environment planners to take all such measures as it deems necessary for the purpose of preventing, and controlling air pollutions from transportation sector.

The main objective of this part is to provide information to decision support with consideration of air pollution prevention issues. And utilize to formulate several different kinds of decisions such as in transportation issues.