Thus, the NOx emission factor of MCs(2, 4 strokes) and Tuk-tuks are shown in Table 4.2.2.10.

Table 4.2.2.10 NOx Emission Factor of MCs(2, 4 strokes) and Tuk-tuks/Taxis(LPG)

unit:g/km

Engine type	Std. or Cycle	Imp.Year	NOx(31km/h)
2 Stroke	Pre,LEVEL 1	Before 1995	0.02
	LEVEL 2	1995	0.02
	LEVEL 3	1997	0.02
	LEVEL 4	2001	0.02
	LEVEL 5	(2004)	-
4 Stroke	Pre,LEVEL 1	Before 1995	0.26
	LEVEL 2	1995	0.26
	LEVEL 3	1997	0.24
	LEVEL 4	2001	0.23
	LEVEL 5	(2004)	0.15
Tuk-tuk	all	all	0.40
Taxi (LPG)	all	all	0.40

Note: Estimated based on Chassis Dynamo Test of TISI
EF of LEVEL 5 was estimated by reducing from LEVEL 4 (3g/km,HC+Nox) to LEVEL 5 (2g/km,HC+Nox) with 0.67(2/3).
EF of Pre,LEVEL1 were assumed to be equal to LEVEL2.
EF of Tuk-tuk is assumed to be same in all model year and all vehicle speed.
EF of Taxi(LPG) is assumed to be same in all model year.
NOx emissions from 2-strokes are lower than 4-strokes although HC emissions from 2-strokes are higher than 4-strokes.

Additionally the NOx emission factors, which were consolidated from MCs 2/4 strokes by their shares in each year, are shown in Table 4.2.2.11.

Table 4.2.2.11 NOx Emission Factors of MCs

unit:g/km

	2 st. shr	4 st. shr	2 st. EF	4 st. EF	2 + 4 st.
1976-1993	87%	13%	0.02	0.26	0.05
1994	87%	13%	0.02	0.26	0.05
1995	86%	14%	0.02	0.26	0.05
1996	82%	18%	0.02	0.26	0.06
1997	74%	26%	0.02	0.24	0.08
1998	56%	44%	0.02	0.24	0.12
1999	46%	54%	0.02	0.24	0.14
2000	30%	70%	0.02	0.24	0.17

(4) Emission Factors

The emission factors of NOx, for each speed range from 5 to 100 km/h, are shown in Table 4.2.2.12.

Table 4.2.2.12 NOx Emission Factors of All Vehicle Types and Motorcycles

SPEED	NOx Emission of year 2000 (g/km)								
(Km/Hr)	LDGV	TAXI (G)	TAXI (L)	LDDV	LDDT	H-truck	Bus	MC	TUKTUK
5	1.99	1.97	0.60	2.19	2.58	50.78	50.78	0.06	0.40
10	1.89	1.88	0.57	1.98	2.34	46.08	46.08	0.06	0.40
15	1.79	1.79	0.54	1.80	2.12	41.87	41.87	0.06	0.40
20	1.72	1.72	0.52	1.63	1.93	38.16	38.16	0.06	0.40
25	1.66	1.66	0.50	1.49	1.77	34.95	34.95	0.06	0.40
30	1.61	1.62	0.49	1.36	1.63	32.25	32.25	0.06	0.40
35	1.58	1.58	0.48	1.26	1.51	30.04	30.04	0.07	0.40
40	1.56	1.56	0.47	1.17	1.42	28.33	28.33	0.07	0.40
45	1.56	1.55	0.47	1.11	1.36	27.12	27.12	0.07	0.40
50	1.57	1.56	0.47	1.06	1.32	26.42	26.42	0.07	0.40
55	1.60	1.57	0.48	1.03	1.30	26.21	26.21	0.08	0.40
60	1.64	1.60	0.49	1.03	1.31	26.50	26.50	0.08	0.40
65	1.70	1.64	0.50	1.04	1.35	27.29	27.29	0.08	0.40
70	1.77	1.70	0.52	1.08	1.41	28.59	28.59	0.09	0.40
75	1.86	1.76	0.54	1.13	1.49	30.38	30.38	0.09	0.40
80	1.96	1.84	0.57	1.21	1.60	32.67	32.67	0.10	0.40
85	2.08	1.93	0.60	1.30	1.74	35.46	35.46	0.10	0.40
90	2.21	2.04	0.63	1.42	1.90	38.76	38.76	0.11	0.40
95	2.36	2.15	0.67	1.55	2.08	42.55	42.55	0.12	0.40
100	2.53	2.28	0.71	1.71	2.29	46.84	46.84	0.12	0.40

The equation to calculate the emissions for vehicles is provided below.

NOx Emission(kg/year) = NOx emission factor(g/km/vehicle)
* Traffic volume(vehicle/day) * Distance (km) * 365 * 1/1,000

4) Estimated Emission

The estimated NOx and SOx emission of vehicles for the year 2000 in the BMR are shown in Table 4.2.2.13 and Figure 4.2.2.10 , 4.2.2.11.

The NOx and SOx emission of vehicles in the BMR is about 320,000 ton/year, 3,600 ton/year in the year 2000 respectively. The NOx and SOx emissions of Bangkok are biggest in the BMR and account for 49%, 5 7 % in the total emission of the BMR respectively. 85% of NOx emission is emitted from diesel vehicles, about 11% from gasoline vehicles and 0.1% from LPG vehicles. 50% of SOx is emitted from diesel vehicles, about 39% from gasoline vehicles.

Table 4.2.2.13 Estimated NOx and SOx Emission of vehicles in the BMR in the Year 2000

Province	NOx Emission(ton/year)					SOx Emission(ton/year)			
	Vehicles				Traffic	Vehicles			Traffic
	Gasoline	HSD	LPG	total	in Area	Gasoline	HSD	total	in Area
Bangkok	19,216	125,638	198	145,052	11,038	821	870	1,691	363
Nonthaburi	2,511	20,813	26	23,350	377	96	136	232	12
Pathum Thani	5,153	38,030	51	43,234	124	163	224	388	0
Samut Prakan	3,959	28,247	42	32,248	206	140	177	318	1
Nakhon Pathom	3,089	42,720	49	45,859	128	139	315	454	0
Samut Sakhon	1,864	14,862	23	16,749	75	66	99	165	0
Total	35,792	270,310	389	306,492	11,948	1,425	1,822	3,247	377

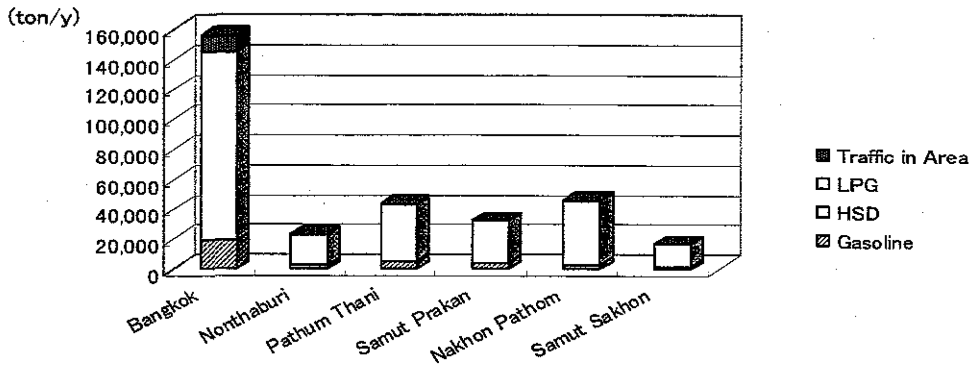


Figure 4.2.2.10 Estimated NOx Emission of vehicles in the BMR in the Year 2000

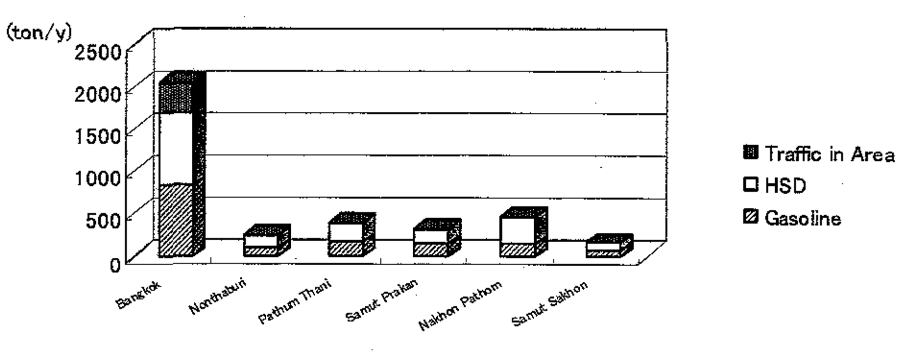


Figure 4.2.2.11 Estimated SOx Emission of vehicles in the BMR in the Year 2000

4.2.2.2 Railways

1) Outline

The flow of NOx and SOx emission estimations of railways of the year 2000 in the BMR is shown in Figure 4.2.2.12.

The NOx emission of railways by line and by province is estimated using the number of operations of trains and the NOx emission factor estimated based on the AP-42 of USEPA. The SOx emission of railways by line and by province is estimated using the number of operations of trains and the SOx emission factor calculated by the actual sulfur contents of fuel and the fuel consumption rate of the trains based on the data of SRT.

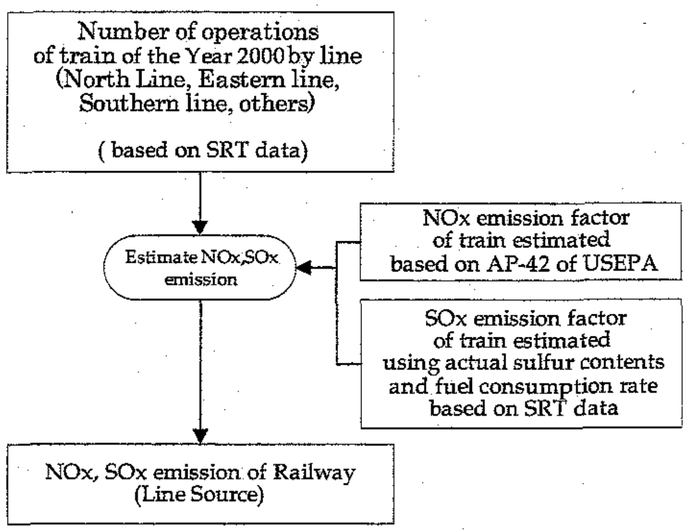


Figure 4.2.2.12 Flow of SOx and NOx emission estimation of railways for the Year 2000 in the BMR

2) Traffic Data

The traffic data of railways is shown in Chapter 4.2.1.2 "Railways 2) Traffic Data".

The location of railwaylines is shown in Figure 4.2.2.2.

3) Emission Factor

The NOx emission factor of railways is shown in Table 4.2.2.14. The SOx emission factor of railways is shown in Table 4.2.1.9.

Table 4.2.2.14 NOx emission factor of railways

Items	Unit	Value		Note
NOx emission factor	Kg/km/operation	0.35	a	JICA Study Team estimated a = c * b /1000
	g/liters	58.1	b	Average of emission factor of Line-Haul cycle and Switch cycle based on AP-42 of USEPA,1997
Fuel Consumption rate	Liter/km/operation	6.0	c	Based on SRT data

The equation to calculate the emissions for railways is provided below.

NOx Emission(kg/year) = NOx emission factor(kg/km/operation) * distance (km) * operation(operation/year)

4) Estimated Emission

The estimated SOx and NOx emissions of railways for the year 2000 in the BMR are shown in Table 4.2.2.15.

The NOx emission of railways in the BMR is about 1,700 ton/year and 17 ton/year for SOx emission.

Table 4.2.2.15 NOx and SOx Emissions of Railways in the BMR in the Year 2000

Line	NOx Emission (ton/year)	SOx Emission (ton/year)
Line in BMR	1,715	17

4.2.2.3 Ships

1) Outline

The flow of NOx and SOx emission estimations of ships for the year 2000 in the BMR is shown in Figure 4.2.2.13.

As for the NOx emission estimation, the NOx emission of vessels in loading, arriving and departing from port is estimated using the number of calls of vessel by port in the BMR and the NOx emission factor based on the NOx manual in Japan. For fishing boats, the NOx emission is estimated using the number of fishing boats and the NOx emission factor of the NOx manual. For small boats, the NOx emission is estimated using the number of trips of express boats, ferry boats and long-tailed boats in the Chao Phraya River and the NOx emission factor of the NOx manual. The NOx emission of boats in other rivers such as the Tha Chin River is negligible because of the small number of trips.

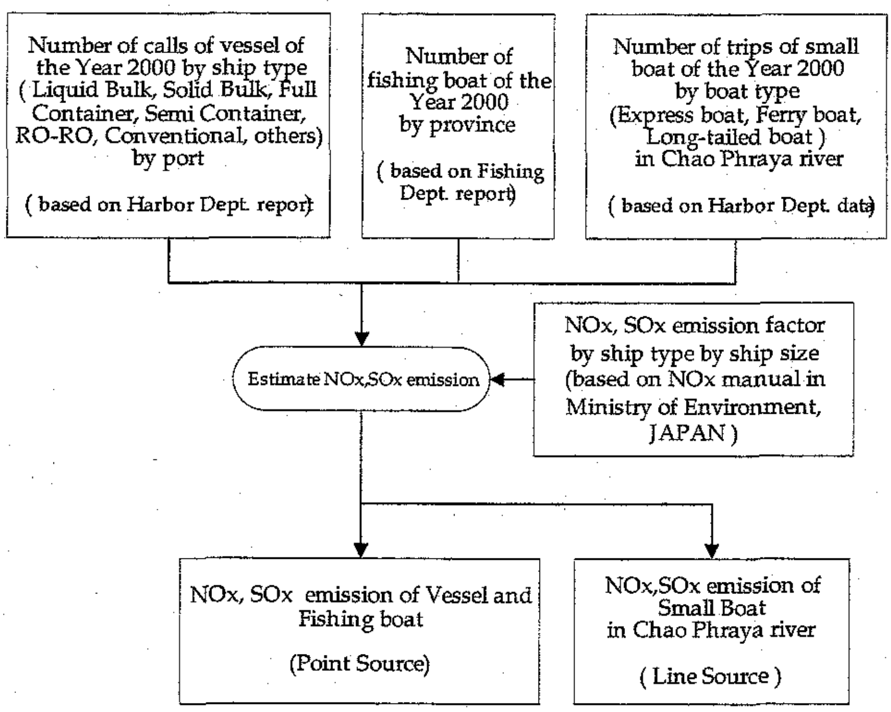


Figure 4.2.2.13 Flow of SOx and NOx emission estimation of ships for the Year 2000 in the BMR

As for the SOx emission estimation, the SOx emission of vessels in loading, arriving and departing from port is estimated using the number of calls of vessel by port in the BMR and the SOx emission factor, which is calculated based on the actual sulfur contents of fuel and the fuel consumption rate of the NOx manual in Japan. For fishing boats, the SOx emission is estimated using the number of fishing boats and the SOx emission factor calculated based on the same method as for ships. For small boats, the SOx emission is estimated using the number of trips of express boats, ferry boats and long-tailed boats in the Chao Phraya River and the SOx emission factor calculated based on the same method as for ships. The SOx emission of boats in other rivers such as the Tha Chin River is negligible because of the small number of trips.

2) Traffic Data

The number of calls of vessels for the year 2000 by port in the BMR is shown in Table 4.2.2.16, which is based on the "Thailand Shipping Statistics 2000". The calls of vessels in private wharves and the Klong Toey wharf of Bangkok port account for 46%, 39% of the total calls of vessels in the BMR respectively. The share of each ship type in the total calls of vessels in the BMR is 38% for Full Cellular Containers and 27% for Conventional.

As for the fishing boats, the number of boats for the year 2000 in the BMR, which is referred to in "The 2000 Intercensal Survey of Marine Fishery", is shown in Table 4.2.2.17. The number of trips of small boats in the Chao Phraya River for the year 2000 is shown in Table 4.2.2.18, which is based on data of the Harbor Department. The number of trips of small boats in the Chao Phraya River is about 6,000 trips/day.

The location of ports and the routes of small boats are shown in Figure 4.2.2.2.

Table 4.2.2.16 Number of Calls of Vessels on Arrival & Departure in the BMR in the Year 2000

Unit: calls of vessel/year

Port		Liquid Bulk	Solid Bulk	Fully Cellular Container	Semi-Container	Ro-Ro	Conventional	Others	Total
Bangkok	Klong Toey Wharf	0	37	2,447	246	92	862	10	3,694
	Klong Toey Pole	0	52	0	1	0	208	0	261
	Bang Hua Suer Pole	0	38	0	8	0	129	3	178
	Sathupradit Buoy	0	277	0	0	0	197	18	492
	Tmn Wharf	0	13	0	0	0	20	25	58
	Private Wharves	957	750	1,110	116	26	1,116	290	4,365
	Others	16	19	13	5	0	21	12	86
Samut Sakhon	Mahachai	3	61	0	0	0	9	97	170
	Thachalom	0	0	0	0	0	1	0	1
	Others	9	12	0	0	0	12	137	170
Total		985	1259	3,570	376	118	2,575	592	9,475

Source: "Thailand Shipping Statistics 2000 Ship Movement Series" (June 2001, Office of the Maritime Promotion Commission, Ministry of Transport and Communications)

Note: The number of calls shows the total sum of calls on arrival and departure.

Vessels in Samut Prakan are included in Bangkok.

Ro-Ro : cargo ships for vehicles.

Table 4.2.2.17 Number of Fishing Boats in the BMR in the Year 2000

Province	Number of Boats
Bangkok	0
Samut Prakan	830
Samut Sakhon	897
Total	1,727

Source: " The 2000 Intercensal Survey of Marine Fishery" (2000, Department of Fisheries Ministry of Agriculture and Cooperatives)

Table 4.2.2.18 Number of trips of Small Boats in the Chao Phraya River in the Year 2000

Unit: trips/day

Type of small boat	Number of trips
Express boat	275
Ferry boat	4,344
Long-tailed boat	1,415
Total	6,034

Source: Harbor Department

3) Emission Factor

The NOx and SOx emission factors of ships are shown in Chapter 4.2.1.3 "Ships 3) Emission Factor ".

4) Estimated Emission

The estimated NOx and SOx emissions of vessels, fishing boats and small boats for the year 2000 in the BMR are shown in Table 4.2.2.19 - 4.2.2.22.

The NOx emissions of vessels, fishing boats and small boats in the BMR are about 3,200 ton/year, 450 ton/year and 180 ton/year respectively. The SOx emission of vessels, fishing boats and small boats in the BMR is about 1,800 ton/year, 9 ton/year and 100 ton/year respectively.

The NOx emissions of private wharves, the Klong Toey wharf of Bangkok port account for 47%, 40% of the total NOx emission of vessels in the BMR respectively. The SOx emissions of private wharves, the Klong Toey wharf of Bangkok port account for 47%, 40% of SOx emission of vessels in the BMR respectively.

The NOx emissions of vessels and fishing boats account for 84%, 12% of NOx emissions of total ships in the BMR respectively. The SOx emissions of vessels and small boats account for 94%, 6% of the total SOx emissions of total ships in the BMR respectively.

Table 4.2.2.19 NOx emissions of Vessels in the BMR in the Year 2000

Unit: ton/year

Port		Liquid Bulk	Solid Bulk	Fully Cellular Container	Semi-Container	Ro-Ro	Conventional	Others	Total
Bangkok	Klong Toey Wharf		8	804	70	60	359	1	1,301
	Klong Toey Pole		11		0		87		98
	Bang Hua Suer Pole		7		2		51	0	60
	Sathupradit Buoy		62				85	2	148
	Tmn Wharf		3				8	2	13
	Private Wharves	488	154	351	32	17	459	23	1,524
	Others	8	4	4	2		9	1	28
Samut Sakhon	Mahachai	1	11				3	6	22
	Thachalom						0		0
	Others	4	2				5	8	19
Total		502	261	1,160	106	76	1,066	43	3,214

Table 4.2.2.20 SOx emissions of Vessels in the BMR in the Year 2000

Unit: ton/year

Port		Liquid Bulk	Solid Bulk	Fully Cellular Container	Semi-Container	Ro-Ro	Conventional	Others	Total
Bangkok	Klong Toey Wharf		5	442	42	33	212	1	735
	Klong Toey Pole		7		0		51		58
	Bang Hua Suer Pole		4		1		30	0	36
	Sathupradit Buoy		37				50	1	88
	Tmn Wharf		2				5	1	8
	Private Wharves	255	92	194	19	9	272	15	856
	Others	4	2	2	1		5	1	16
Samut Sakhon	Mahachai	1	6				2	4	13
	Thachalom						0		0
	Others	2	1				3	5	12
Total		262	156	639	64	43	631	27	1,822

Table 4.2.2.21 Estimated NOx and SOx emissions of Fishing Boats in the BMR in the Year 2000

Province	NOx Emission (ton/year)	SOx Emission (ton/year)
Bangkok	0	0
Samut Prakan	249	5
Samut Sakhon	198	4
Total	447	9

Table 4.2.2.22 Estimated NOx and SOx emissions of Small Boats in the BMR in the Year 2000

Type of small boat	NOx Emission (ton/year)	SOx Emission (ton/year)
Express boat	36	36
Ferry boat	73	71
Long-tailed boat	72	2
Total	181	109

4.2.2.4 Aircrafts

1) Outline

The flow of NOx and SOx emission estimation of aircraft for the year 2000 in the BMR is shown in Figure 4.2.2.14.

The NOx emission of aircraft by airport is estimated using the number of flights for the year 2000 by aircraft type in Don Muang Airport and the NOx emission factor for the LTO cycle based on USEPA. The SOx emission of aircraft by airport is estimated using the number of flights for the year 2000 by aircraft type in Don Muang Airport and the SOx emission factor in LTO cycle based on USEPA.

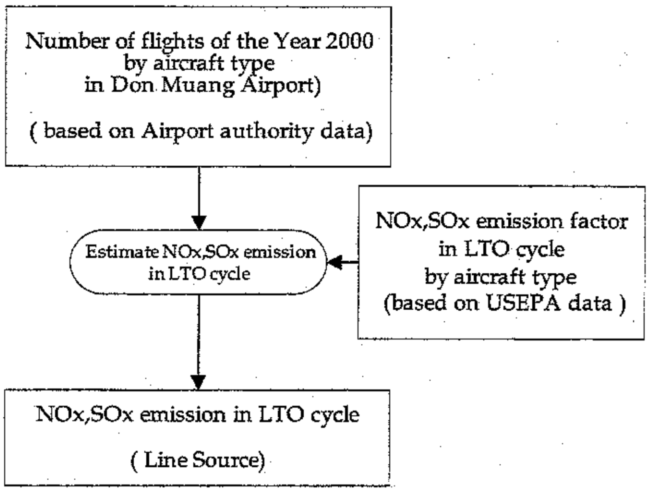


Figure 4.2.2.14 Flow of SOx and NOx emission estimation of aircraft for the Year 2000 in the BMR

2) Traffic Data

The annual aircraft movement in Don Muang Airport in the year 2000 is about 180,000 flights/year, which is shown in Table 4.2.2.23. It is based on data of the Department of Aviation. The location of airports is shown in Figure 4.2.2.2.

Table 4.2.2.23 Annual Aircraft Movement in the Year 2000

Airport	Movement(Flight/year)		
	International	Domestic	Total
Don Muang airport	124,733	55,483	180,216

Source: Department of Aviation, Ministry of Transportation and Communication

3) Emission Factor

The method to estimate the NOx and SOx emission of aircraft is based on the "Evaluation of Air Pollutant Emissions from Subsonic Commercial Jet Aircraft(USEPA)".

The sulfur contents and specific gravity of fuel is shown in Table 4.2.1.26.

The equation to calculate emissions for each aircraft type is detailed below.

Eij = TIMjk X EFijk

Where

Eij = total emissions of pollutant i, in kilograms, produced by aircraft type j, for one LTO cycle

TIMjk = time in mode for k, in minutes, for aircraft type j (shown in Table 4.2.2.25)

EFijk = emission load for pollutant i, for mode k, in kilograms per minutes, for aircraft type j (shown in Table 4.2.2.24 for NOx, Table 4.2.1.27 for SOx)

Table 4.2.2.24 NOx emission factor by aircraft type

Engine Modal Efs (kg/min/Engine)		Number of Engine	TK	CB	AP	ID
Body Type			NOx ef	NOx ef	NOx ef	NOx ef
AIRBUS	A300	2	9.1521	5.5533	0.6694	0.0867
AIRBUS	A310	2	8.8003	5.9689	0.8024	0.1064
AIRBUS	A320	2	3.1026	2.0275	0.2794	0.0485
BEECH	B.99A	2	0.0501	0.0423	0.0272	0.0042
BOEING	B707	4	3.4093	2.2145	0.3986	0.8100
BOEING	B727	2	3.1536	2.0196	0.2949	0.0646
BOEING	B737	2	2.5459	1.6843	0.2796	0.0545
BOEING	B747	4	20.0046	12.7242	1.2347	0.1662
BOEING	B757	2	8.2474	4.9757	0.5227	0.0839
BOEING	B767	2	8.8727	5.8101	0.7860	0.0849
BRITAIRCOR	BAE-111	2	0.5814	0.3745	0.0819	0.0185
BRITAIRCOR	BAE-146	4	1.1628	0.7489	0.1638	0.0370
CONVAIR	CV640	2	0.1099	0.0796	0.0208	0.0101
DE HAVILLAND	DHC-6	2	2.0446	1.4377	0.2002	0.0353
FAIRCHILD	FH-227	2	0.1196	0.0848	0.0088	0.0043
FOKKER	F-27	2	0.1196	0.0848	0.0088	0.0043
FOKKER	F-28	2	1.6354	1.0348	0.1577	0.0253
FOKKER	F-100	2	1.9243	1.2701	0.1573	0.0330
LOCKHEED	L-1011	3	14.6819	8.8800	0.9067	0.1345
MCDONNELL DOUGLAS	DC10	3	14.0363	9.1904	0.9759	0.1304
MCDONNELL DOUGLAS	DC8	4	3.6692	2.4313	0.4546	0.5612
MCDONNELL DOUGLAS	DC9	2	2.6440	1.7000	0.2539	0.0510
MCDONNELL DOUGLAS	MD-11	3	15.2569	8.9283	1.0833	0.1341
NAMC	YS-11	2	0.1099	0.0796	0.0208	0.0101

Note: TK = Take-off; CB = Climb-out, AP = Approach; ID = Idle

Source: "Evaluation of Air Pollutant Emissions from Subsonic Commercial Jet Aircraft"(USEPA)

Table 4.2.2.25 Time-In-Mode

Mode of Operation	Time-In-Mode(min)
Taxi/idle-out	19.0
Take-off	0.7
Climb-out	2.2
Approach	4.0
Taxi/idle-in	7.0

Note: The height of Climb-out and Approach is 1000m.
Source : "Procedure for Emission Preparation Volume IV: Mobile Source"(USEPA,1992)

4) Estimated Emission

The estimated NOx and SOx emission of aircraft for the year 2000 in Don Muang Airport in the BMR is shown in Table 4.2.2.26.

The estimated NOx and SOx emission of aircraft in Don Muang Airport is about 12,100 ton/year and about 440 ton/year respectively. 79 % of NOx emission and 41% of SOx emission of aircraft in Don Muang Airport is emitted during Take-off and Climb-out.

Table 4.2.2.26 Estimated NOx and SOx emission of airport in the BMR in the Year 2000

airport	NOx Emission(ton/year)				SOx Emission(ton/year)			
	Takeoff+ Climb-out	Approach	Taxing	Total	Takeoff+ Climb-out	Approach	Taxing	Total
Don Muang Airport	9,660	1,294	1,173	12,127	182	82	179	443

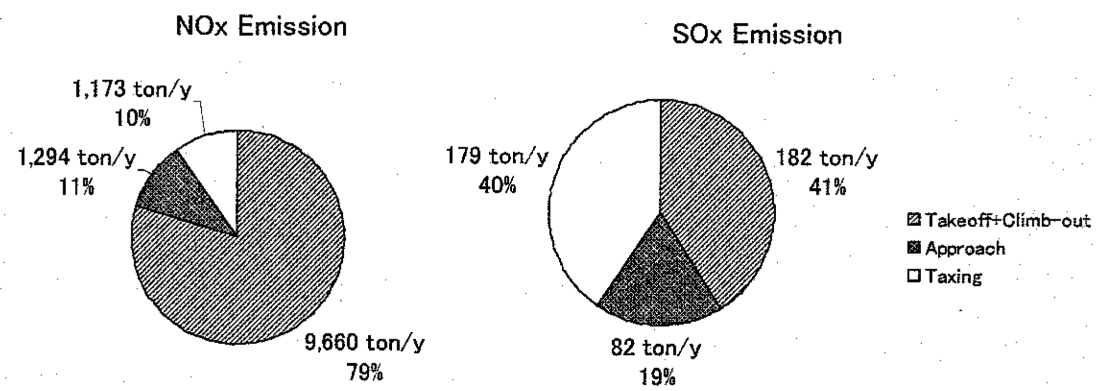


Figure 4.2.2.15 Estimated NOx and SOx emission of airport in the BMR in the Year 2000

4.2.2.5 NOx and SOx Emission of Mobile Sources in the BMR

The Summary of NOx emission of mobile sources of the year 2000 in the BMR is shown in Table 4.2.2.27. The estimated total annual NOx emission of mobile sources is about 336,000 ton/year. The Share of each province in the BMR in the total NOx emission is shown in Figure 4.2.2.16. The NOx emission of Bangkok is about 173,000 ton/year, which accounts for 51% of the total NOx emission of mobile sources in the BMR.

The Share of each mobile source in the total NOx emission is shown in Figure 4.2.2.16. The share is 91% for vehicles on roads, 1% for ships, 3.6% for aircraft, 0.5% for railways and 3.6% for area sources like traffic in local areas.

Table 4.2.2.27 Estimated NOx Emission of Mobile Sources in the BMR in the Year 2000

Unit: ton/year

Province	Vehicles			Railways	Aircraft	Ships				Other	Total
	Gasoline	Diesel	LPG			Vessels	Long Tailed Boats	Express and Ferry boats	Fishing Boats	Area Sources	
Bangkok	19,216	125,638	198	977	12,127	3,173	72	109	0	11,038	172,547
Nonthaburi	2,511	20,813	26	31	0	0			0	377	23,758
Pathum Thani	5,153	38,030	51	349	0	0			0	124	43,708
Samut Prakan	3,959	28,247	42	0	0	0			249	206	32,703
Nakhon Pathom	3,089	42,720	49	275	0	0			0	128	46,262
Samut Sakhon	1,864	14,862	23	82	0	41			198	75	17,146
Total	35,792	270,310	389	1,715	12,127	3,214	72	109	447	11,948	336,123

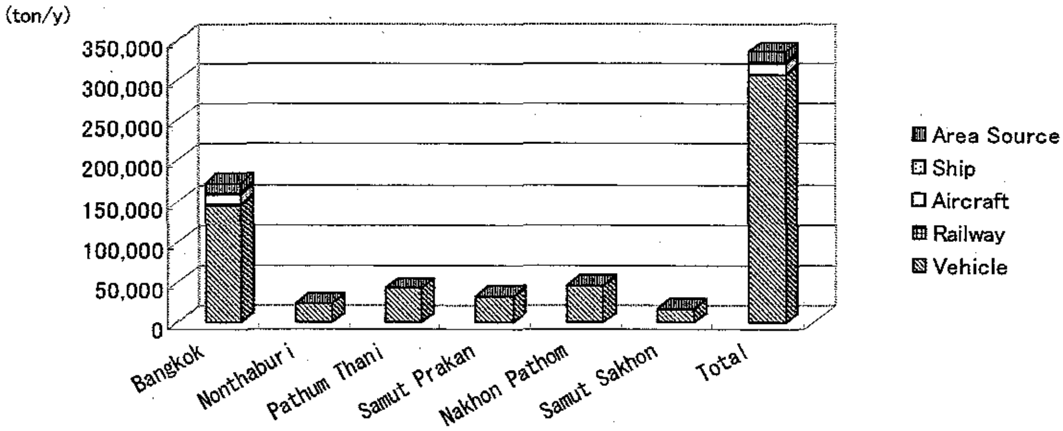


Figure 4.2.2.16 Estimated NOx Emission of Mobile Sources in the BMR in the Year 2000

The summary of SOx emission of mobile sources of the year 2000 in the BMR is shown in Table 4.2.2.28. The estimated total annual SOx emission of mobile sources is about 6,000 ton/year. The share of each province in the BMR in the total SOx emission is shown in Figure 4.2.2.17. The SOx emission of Bangkok is about 4,400 ton/year, which accounts for 73% of the total SOx emission of mobile sources in the BMR.

The share of each mobile source in the total SOx emission is shown in Figure 4.2.2.17. The share is 54% for vehicles on roads, 32% for ships, 7% for aircraft, 0.3% for railways and 6% for area sources like traffic in local areas.

Table 4.2.2.28 Estimated SOx Emission of Mobile Sources in the BMR in the Year 2000

Unit: ton/year

Province	Vehicles			Railways	Aircraft	Ships				Other	Total
	Gasoline	Diesel	LPG			Vessels	Long Tailed Boats	Express and Ferry boats	Fishing Boats	Area Sourcess	
Bangkok	821	870	Neglected	10	443	1,797	2	107	0	363	4,412
Nonthaburi	96	136	Neglected	0	0	0			0	12	245
Pathum Thani	163	224	Neglected	3	0	0			0	0	391
Samut Prakan	140	177	Neglected	0	0	0			5	1	324
Nakhon Pathom	139	315	Neglected	3	0	0			0	0	456
Samut Sakhon	66	99	Neglected	1	0	25			4	0	195
Total	1,425	1,822	Neglected	17	443	1,822	2	107	9	377	6,023

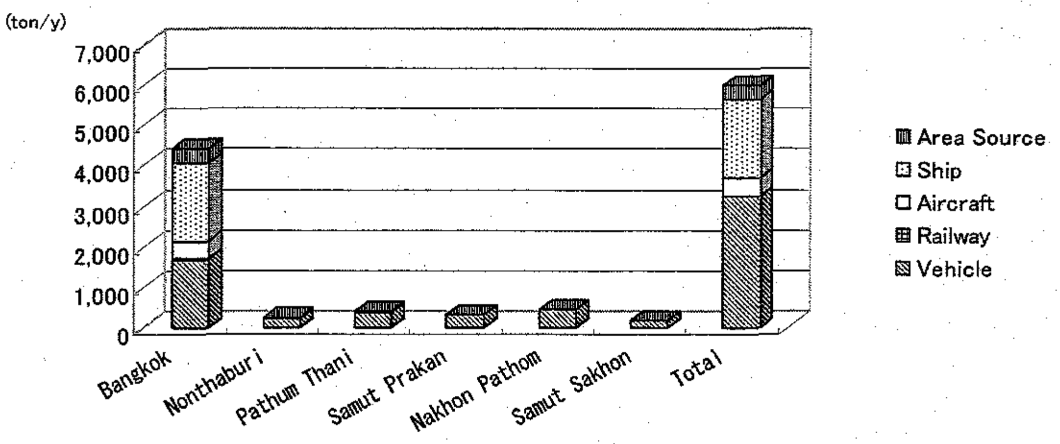


Figure 4.2.2.17 Estimated SOx Emission of Mobile Sources in the BMR in the Year 2000

4.3 Mobile Sources Inventory for the Year 2011(BAU Case)

4.3.1 Mobile Sources Inventory for the Year 2011 in the Whole Thailand

4.3.1.1 Vehicles

1) Outline

The flow of SOx emission estimations of vehicles for the Year 2011(BAU Case: Business as usual Case) in the whole Thailand is shown in Figure 4.3.1.1.

In the BAU Case, the Highway Project (based on the LTP-2 of DOH) in the whole Thailand and the Transport Project and MRT project (based on URMAP of OCMLT) in the BMR are considered. Actual sulfur contents of fuel (gasoline and high speed diesel) which is suitable to EURO3 regulation are adopted.

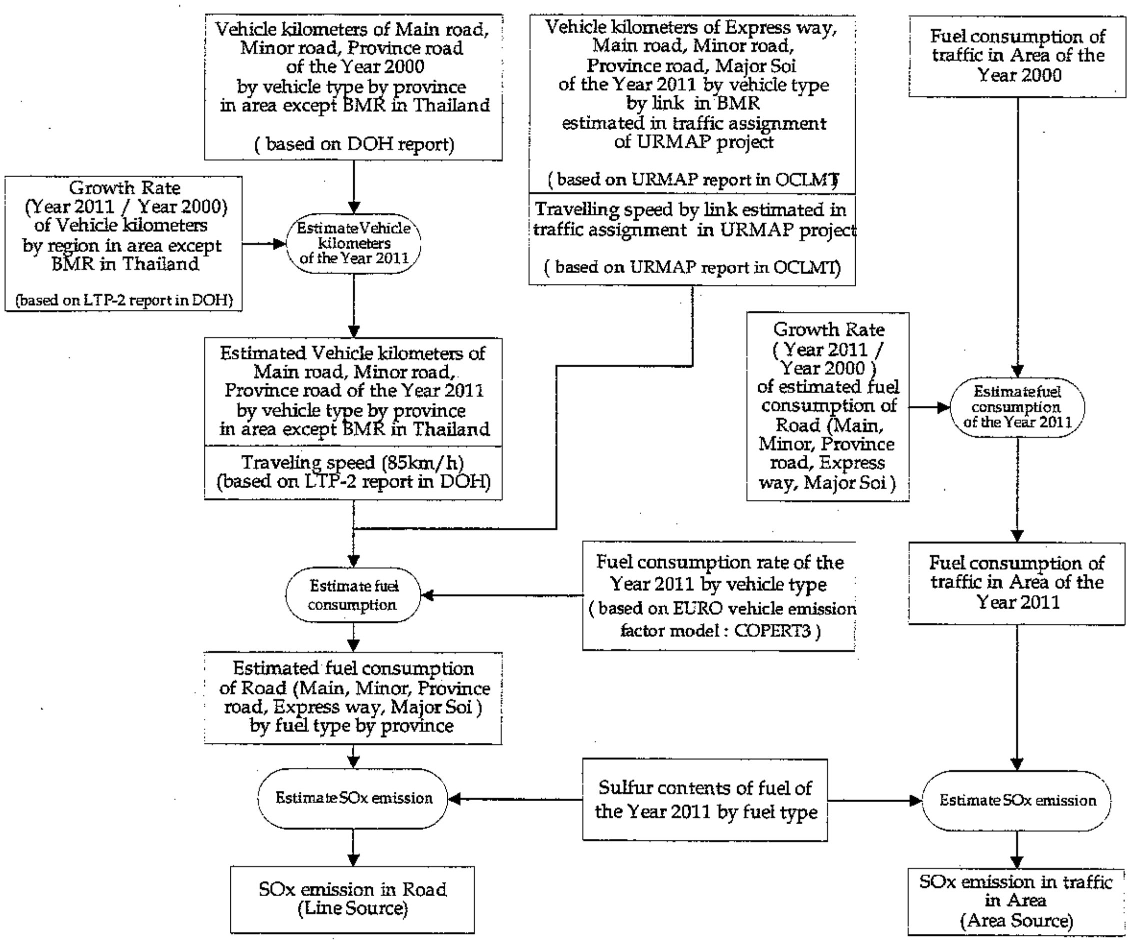


Figure 4.3.1.1 Flow of SOx emission estimation of vehicles of the Year 2011 in whole Thailand

In the same way as for the Year 2000, for the SOx emission estimation of vehicles, two kinds of methods are applied, which are for vehicles on main roads, minor roads, province roads, express ways and major Soi, and for traffic in local areas.

The fuel consumption of road vehicles by province is estimated using the vehicle kilometers for the Year 2011 and the fuel consumption rate for the Year 2011 estimated based on the COPERT3.

The vehicle kilometers for the Year 2011 are estimated using the ones for the Year 2000 and the growth rate of vehicle kilometers by region based on "the Study on the Strengthening of DOH's Management and Updating of the Long-term Strategic Investment Plan (LTP-2, 2001)" report of the DOH in the area except the BMR. In the BMR, the vehicle kilometers for the Year 2011 are estimated based on the traffic assignment data in "Urban Rail Transportation Master Plan (URMAP,2001) " report of OCMLT.

The SOx emission of road vehicles is estimated using the sulfur contents of fuel for the Year 2011 and the estimated fuel consumption.

The fuel consumption of traffic in local areas for the Year 2011 is estimated using the ones for the Year 2000 and the growth rate of fuel consumption of road vehicles by region.

The SOx emission of traffic in local areas is estimated using the sulfur contents of fuel for the Year 2011 and the estimated fuel consumption.

2) Traffic Data

The vehicle kilometers of the Year 2011 by vehicle type in the BMR are shown in Table 4.3.1.1, which are estimated using the Airviro database updated based on the traffic assignment data in the URMAP report of OCMLT. The details of the updated Airviro database are explained in Chapter 6 "Model Simulation". The vehicle kilometers by vehicle type in the areas except the BMR in Thailand are shown in Table 4.3.1.1, which is estimated using the vehicle kilometers of the Year 2000 and the growth rate of vehicle kilometers by region based on the LTP-2 report of DOH and others. The growth rate of vehicle kilometers by region is shown in Table 4.3.1.2.

The annual vehicle kilometers in the whole Thailand is about 280,000 million vehicle-kilometers in the year 2011. The share of the BMR is about 25%, 20% for the northeastern region and 18% for the northern region.

The location of roads is shown in Figure 4.3.1.2.

Table 4.3.1.1 Vehicle Kilometers in Thailand in the Year 2011

Region	Vehicle Kilometers by vehicle type (Million Vehicle-Kilometers/year)					
	Car, taxi	light truck	Bus	heavy truck	Motor-cycle	total
BMR	35,874	10,987	4,896	7,341	10,187	69,285
Central Region	8,687	4,238	1,565	3,511	2,281	20,282
Northern Region	18,207	12,703	2,263	4,267	12,555	49,995
Northeastern Region	22,526	10,545	2,832	4,974	14,429	55,306
Southern Region	14,283	6,853	2,553	3,928	9,782	37,399
Eastern Region	9,449	7,155	1,858	3,837	3,878	26,177
Western Region	7,098	5,572	921	2,750	3,994	20,335
Total	116,124	58,053	16,888	30,608	57,106	278,779

Note: Car, taxi includes passenger car(gasoline and diesel) and taxi(gasoline).
Vehicle kilometer in the BMR is estimated based on the traffic assignment data of URMAP report in OCMLT.

Table 4.3.1.2 Growth Rate of Vehicle Kilometers in the areas except the BMR in Thailand

Region	Growth Rate (Year2011/Year2000)			
	Cars	Buses	Trucks	Motor-cycle
Central Region	2.1	1.7	1.7	1.7
Northern Region	2.3	1.6	1.5	1.7
Northeastern Region	2.5	1.4	1.4	1.9
Southern Region	2.4	1.9	1.5	1.8
Eastern Region	1.8	1.7	1.7	1.7
Western Region	2.2	1.9	1.7	1.9

Note: The detailed data is shown in Chapter 2.
The growth rate of motorcycles is estimated and is based on the trend of the number of registered motorcycles in the LTD data.

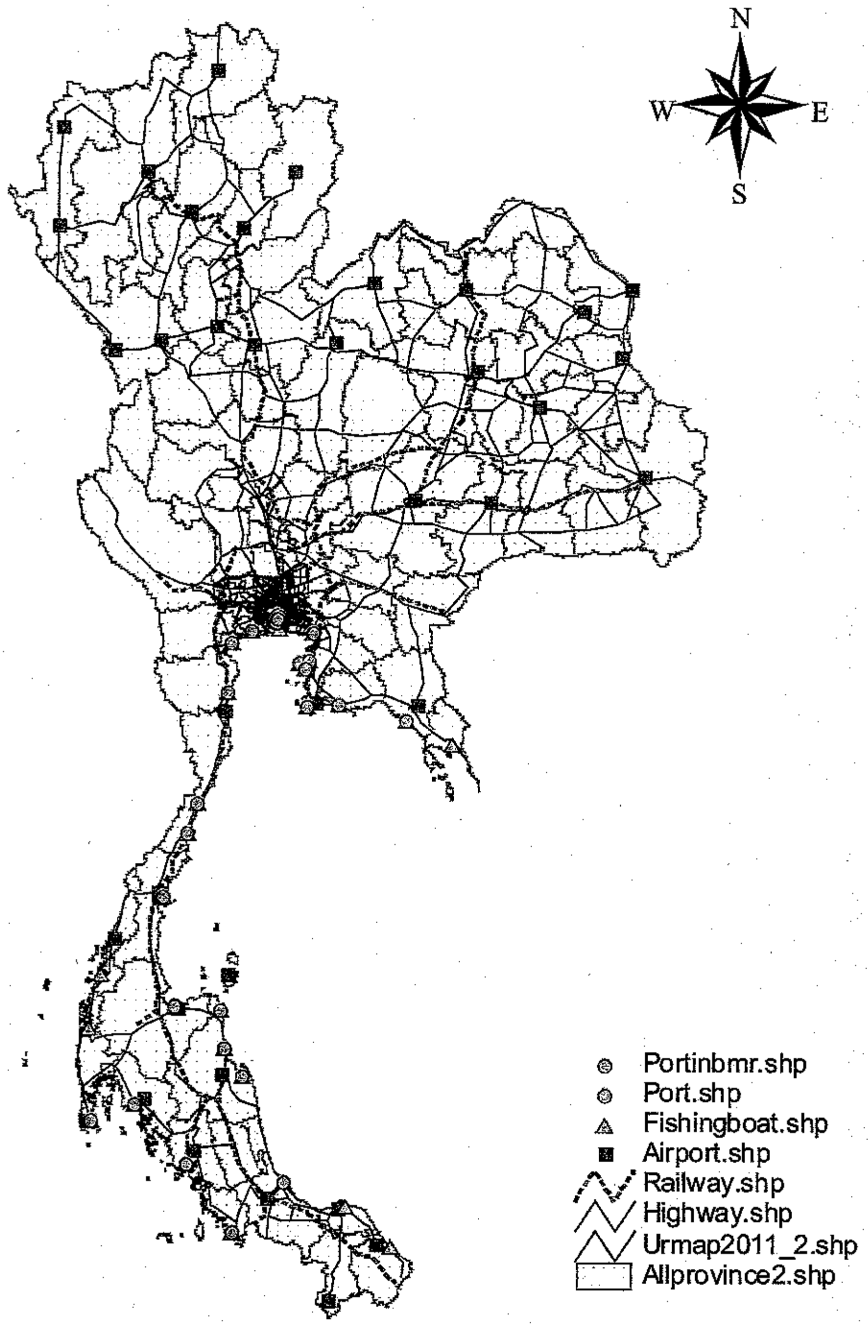


Figure 4.3.1.2 Location of Mobile Sources for the Year 2011 in the Whole Thailand

3) Emission Factor

(1) Method

In order to predict the emission factors in 2011 (BAU: Business As Usual Case), they were calculated basically in the same way as for 2000. However some of the calculation conditions needed to be estimated apart from 2000 since all of them were based on the estimates, therefore the following issues are focused upon here,

- The different methods from 2000, which were applied to 2011 (BAU Case),
- The different calculation conditions from 2000, which have not been discussed in the case of 2000, and
- The other necessary conditions for 2011 (BAU Case), which have not been discussed in the case of 2000.

Figure 4.2.1.3 shows the general workflow of the SOx emission factor calculation. For predicting the future emission factors and fuel consumption rates for 2011 (BAU Case), the age distribution was modified mainly and both effects of aged vehicles in retirement and new ones introduced were produced on the emission factor levels.

Table 4.2.1.2 shows the emission standard enforcement year up to 2011. The more stringent emission standards, EURO 3, for all vehicles and level 5 for motorcycles were considered between 2001 and 2011 since they were officially proposed and the relevant agencies' actions toward their implementation were expected.

Table 4.2.1.3 shows the vehicle type conversion from COPERT 3 to traffic data. It was considered that the shares of gasoline/diesel in Light-Duty Vehicles of 2011(BAU Case) would change significantly from 2000. So that the future shares of them were predicted based on the number of registered Light-Duty Vehicles for 2011(BAU Case), which was estimated by the past trend for each region.

(2) Fleet Data

The future numbers of new registered vehicles in each year were predicted with the regression models shown in Table 4.3.1.3, which were determined on the past trends of the correlations between the number of new registered vehicles and the private consumption expenditure for the purchase of vehicles in the domestic market. Table 4.3.1.4 shows the age distributions predicted for 2011 (BAU Case).

Table 4.3.1.3 Regression model for the future numbers of new registered vehicles

Vehicle Type	Regression Equation	Correlation Coefficient (R2)
LDGV	y = 1.7424x - 788.31	0.89
Taxi	y = 0.0466x + 350.76	0.84
LDDV	y = 2468.2*exp(2E-05x)	0.91
LDDT	y = 3.3504x - 54326	0.94
HDDV	y = 6392.5*exp(2E-05x)	0.86
MC	y = 11.151x + 28797	0.92

Note: y: Number of new-registered vehicle
x: Private Consumption Expenditure for Purchase of Vehicles in the Domestic Market

Mileage distribution for the year 2011, the other portion of the fleet data, was basically the same as the one for the year 2000, except Taxis, which were expected to retire after 12 years. This was determined in section 4.2.1 and shown in Table 4.2.1.4.

Table 4.3.1.4 Age Distributions for the Year 2011 (BAU Case)

2011 BAU Case

age	year	LDGV	Taxi	LDDV	LDDT	HDDV	MC
1	2011	8.5%	13.3%	17.8%	9.5%	18.2%	8.3%
2	2010	7.7%	12.1%	12.4%	8.5%	12.7%	7.5%
3	2009	6.9%	11.0%	9.0%	7.6%	9.2%	6.8%
4	2008	6.2%	10.0%	6.7%	6.7%	6.8%	6.2%
5	2007	5.6%	9.0%	5.1%	6.0%	5.3%	5.6%
6	2006	5.1%	8.2%	4.1%	5.3%	4.1%	5.0%
7	2005	4.6%	7.5%	3.3%	4.7%	3.3%	4.6%
8	2004	4.1%	6.8%	2.7%	4.2%	2.8%	4.1%
9	2003	3.7%	6.2%	2.3%	3.7%	2.3%	3.8%
10	2002	3.4%	5.6%	1.9%	3.2%	2.0%	3.4%
11	2001	3.1%	5.2%	1.7%	2.8%	1.7%	3.1%
12	2000	2.7%	5.1%	1.8%	2.2%	1.4%	2.7%
13	1999	2.0%	0.0%	1.1%	1.8%	1.0%	2.0%
14	1998	1.5%	0.0%	0.9%	1.4%	1.3%	2.1%
15	1997	4.6%	0.0%	3.1%	4.0%	3.9%	3.9%
16	1996	4.8%	0.0%	3.9%	5.7%	5.4%	5.0%
17	1995	4.5%	0.0%	4.2%	5.3%	4.8%	5.3%
18	1994	4.6%	0.0%	4.7%	4.2%	3.7%	4.4%
19	1993	4.2%	0.0%	6.4%	3.5%	3.2%	3.4%
20	1992	3.3%	0.0%	1.8%	3.1%	1.8%	3.3%
21	1991	2.3%	0.0%	1.2%	1.9%	1.2%	2.4%
22	1990	2.5%	0.0%	1.3%	2.1%	1.3%	2.5%
23	1989	1.8%	0.0%	1.0%	1.3%	1.0%	1.9%
24	1988	1.4%	0.0%	0.8%	0.9%	0.8%	1.5%
25	1987	1.0%	0.0%	0.7%	0.3%	0.7%	1.1%
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

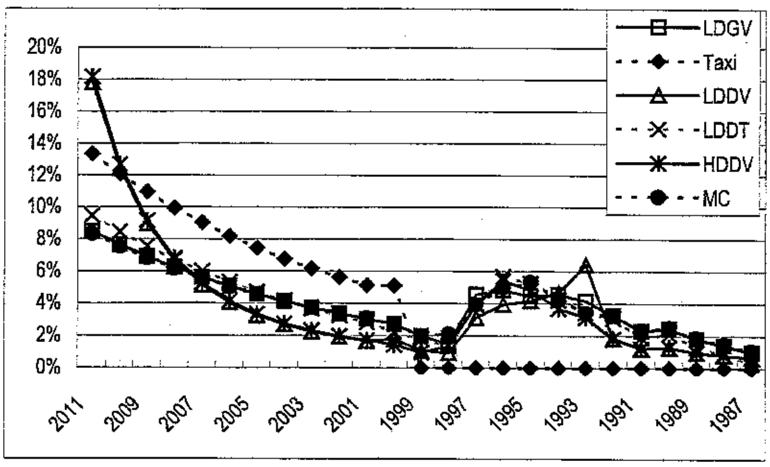


Figure 4.3.1.3 Age Distributions for the Year 2011(BAU)

(3) Emission Factor

Table 4.3.1.5 shows the future sulphur contents and specific gravity of gasoline and diesel (high speed). The more stringent emission standards, EURO3, the plan to be enforced for LDGV, LDDV, LDDT in 2004 and HDDV in 2005. The fuel quality of gasoline and diesel should be improved before EURO3 enforcements to comply with the fuel specs demands for them.

Table 4.3.1.5 Future Sulphur Contents and the Specific Gravity of Fuel

Fuel Type		Actual Contents (wt%)		Specific Gravity	
Gasoline		0.0130	*1	0.758	*2
Diesel	High speed	0.0300		0.870	

Source: Average of actual sulfur contents in Euro market based on the Auto Oil II Program (*1)
Source: DCR, 2000 (*2)

The emission factors of SOx for the year 2011(BAU Case), specified for each speed range from 5 to 100 km/h, are shown in Table 4.3.1.6.

Table 4.3.1.6 Emission Factors of SOx

g/km

Target Year	Speed (km/h)	PS (G) LDGV	Taxi (G) Taxi (G)	PS (D) LDDV	L-Truck LDDT	Bus HDDV	H-Truck HDDT	MC MC
2011	5	0.05	0.04	0.06	0.08	0.34	0.36	0.02
	10	0.04	0.04	0.06	0.08	0.28	0.30	0.02
	15	0.03	0.03	0.05	0.07	0.24	0.26	0.01
	20	0.03	0.03	0.05	0.06	0.20	0.22	0.01
	25	0.03	0.02	0.05	0.06	0.17	0.19	0.01
	30	0.02	0.02	0.04	0.05	0.15	0.17	0.01
	35	0.02	0.02	0.04	0.05	0.14	0.16	0.01
	40	0.02	0.02	0.04	0.05	0.13	0.15	0.01
	45	0.02	0.02	0.04	0.04	0.12	0.15	0.01
	50	0.02	0.02	0.03	0.04	0.12	0.14	0.01
	55	0.02	0.02	0.03	0.04	0.11	0.14	0.01
	60	0.02	0.01	0.03	0.04	0.11	0.13	0.01
	65	0.01	0.01	0.03	0.04	0.11	0.13	0.01
	70	0.01	0.01	0.03	0.04	0.11	0.13	0.01
	75	0.01	0.01	0.03	0.04	0.11	0.13	0.01
	80	0.01	0.01	0.03	0.04	0.11	0.14	0.01
	85	0.01	0.01	0.03	0.04	0.11	0.14	0.01
	90	0.01	0.01	0.03	0.05	0.11	0.15	0.01
	95	0.01	0.01	0.03	0.05	0.12	0.16	0.01
	100	0.02	0.01	0.03	0.06	0.12	0.16	0.01

Figure 4.3.1.4 shows comparisons between the emission factors of 2000 and 2011(BAU Case) by vehicle type. Considerable reductions (approx. 60-70%) were observed in the cases of LDGV and Taxis(G) for the following reasons,

- The fuel consumption rates of LDGVs and Taxis had been improved from the PRE ECE levels to EURO1 and beyond which is considerably more than the ones of the other vehicle types, LDDVs, LDDTs, HDDVs, HDDTs and MCs.
- The over-aged vehicles, which were produced between 1976-1986 (PRE ECE level), would have been totally retired in 2011 as the new vehicles were complying with the more stringent emission standards.
- The sulphur content in gasoline would have been reduced from 0.0382 wt% to 0.0130 wt% (approx. 66% reduction), while the one in diesel from 0.0348 wt% to 0.03 wt% (approx. 14% reduction).

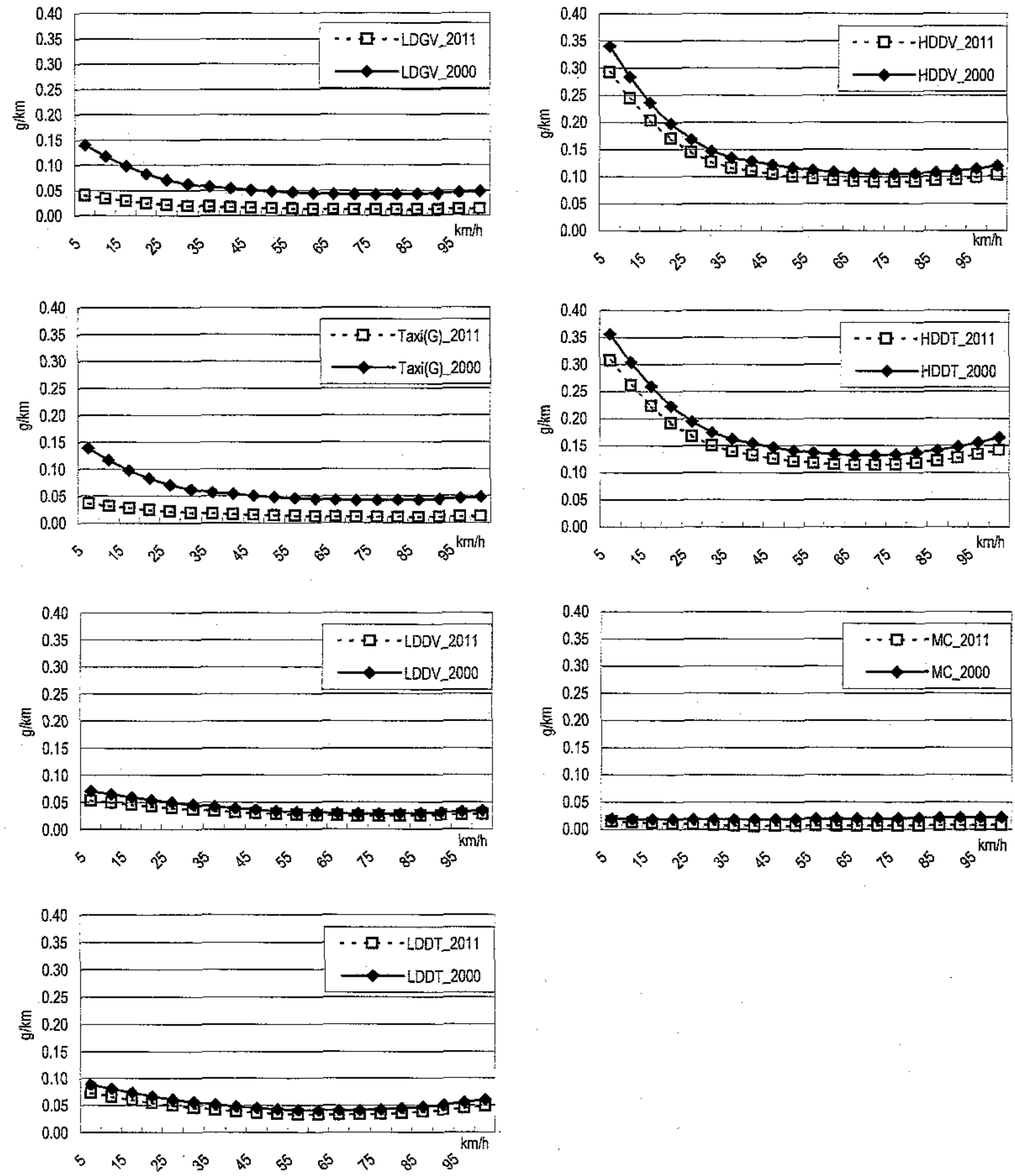


Figure 4.3.1.4 Comparisons of SOx Emission Factors for 2000 and 2011(BAU Case)

4) Estimated Emission

The estimated fuel consumption and SOx emission of vehicles for the Year 2011(BAU Case) in the whole Thailand are shown in Table 4.3.1.7 and Figure 4.3.1.5, 4.3.1.6.

The fuel consumption and SOx emission of vehicles in the whole Thailand are about 23,000 kton/year and 11,000 ton/year in the year 2011 respectively.

The SOx emission of the BMR is biggest and accounts for 30% of vehicular SOx emission of the whole Thailand. About 80% of SOx is emitted from diesel vehicles and 17% from gasoline vehicles. The SOx emission from traffic in local areas accounts for 3%.

Table 4.3.1.7 Fuel Consumption and SOx Emission of Vehicles in the Year 2011

Region	Fuel Consumption (kton/year)				SOx Emission (ton/year)			
	Vehicle			Traffic in Area	Vehicle			Traffic in Area
	Gasoline	HSD	total		Gasoline	HSD	total	
BMR	2,848	3,982	6,829	755	740	2,389	3,129	205
Central	411	1,380	1,791	57	107	828	935	15
Northern Region	1,105	2,177	3,282	0	287	1,306	1,594	0
Northeastern Region	1,197	2,437	3,634	0	311	1,462	1,773	0
Southern Region	879	1,739	2,618	240	228	1,043	1,272	66
Eastern Region	492	1,653	2,145	138	128	992	1,120	39
Western Region	391	1,177	1,568	40	102	706	808	10
Total	7,323	14,545	21,867	1,231	1,904	8,727	10,631	335

Note: HSD:High Speed Diesel

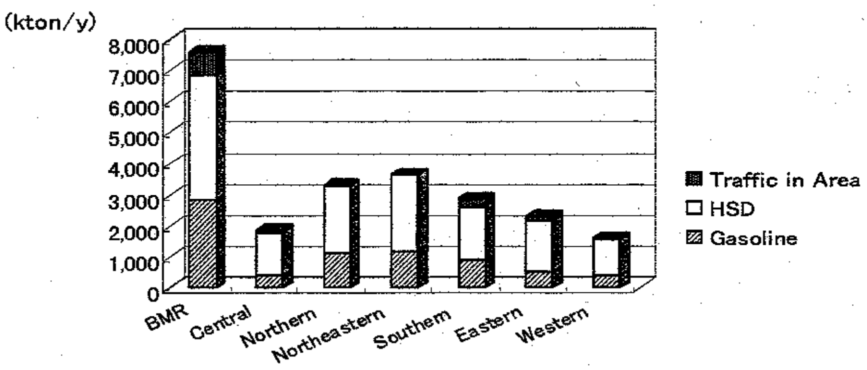


Figure 4.3.1.5 Fuel Consumption of Vehicles in the Whole Thailand in the Year 2011

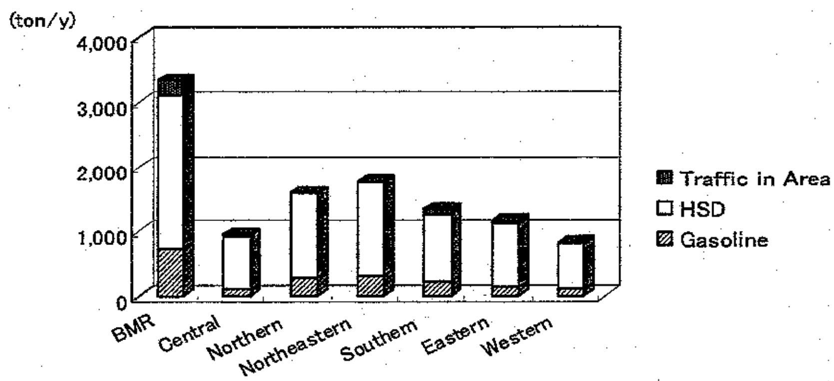


Figure 4.3.1.6 SOx Emission of Vehicles in the Whole Thailand in the Year 2011

4.3.1.2 Railways

1) Outline

The flow of SOx emission estimation of railways for the Year 2011(BAU Case) in the whole Thailand is shown in Figure 4.3.1.7.

In the BAU Case, the Track Doubling Project of SRT is considered. The actual sulfur contents of fuel (high speed diesel) which is suitable to the EURO3 regulation are adopted.

The fuel consumption of railways by line and by province is estimated using the number of operations of trains for the Year 2011 based on "Investment of Capacity Constraints and Determination of the Need for Track Doubling of SRT Network (2002) "report of the State Railway of Thailand (SRT) and the fuel consumption rate of trains. The lines include the North line, the Northeastern line, the Southern line, the Eastern line and others.

The SOx emission of railways is estimated using the sulfur contents of fuel for the Year 2011 and the estimated fuel consumption.

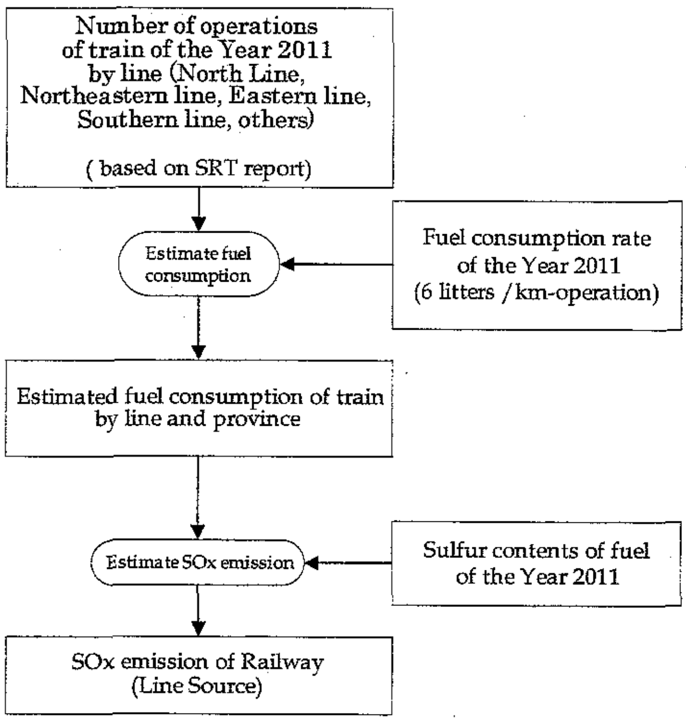


Figure 4.3.1.7 Flow of SOx emission estimation of railways for the Year 2011 in the whole Thailand

2) Traffic Data

The number of operations of trains in 4 major lines (Northern line, Northeastern line, Southern line, Eastern line) and others for the Year 2011 are shown in Table 4.3.1.8, which is based on the "Investment of Capacity Constraints and Determination of the Need for Track Doubling of SRT Network (2002) "report of SRT. The location of railwaylines is shown in Figure 4.3.1.2.

Table 4.3.1.8 Number of Operations of Train in Year 2011

Line	Distance (km)	Operation (one-way/day)
Northern Line	780.25	907
Northeastern Line	1,090.77	310
Eastern Line	515.10	464
Southern Line	1,570.38	505
Mae Klong Line	64.66	42

Source: Investment of Capacity Constraints and Determination of the Need for Track Doubling of SRT Network (SRT, 2002)

3) Emission Factor

The fuel consumption rate of railways and the specific gravity of fuel for the Year 2011 are the same as the ones for the Year 2000, which are shown in Table 4.3.1.9. The sulfur contents of fuel (High Speed Diesel) for the Year 2011 are based on the actual sulfur contents of the Euro market (sulfur contents : 300 ppm for EURO3 regulation) shown in Table 4.3.1.9.

Table 4.3.1.9 Fuel consumption rate and SOx emission factor

Items	Unit	Value		Note
Fuel consumption rate	Liter/km/operation	6.0	a	Based on SRT data
SOx emission factor	Kg/km/operation	0.0025	b	JICA Study Team estimated $b = a * d * c / 100 * 64/32$
Sulfur contents in fuel	Wt%	0.0300	c	Average of actual sulfur contents in Euro market based on Auto Oil II Program
Specific gravity of fuel	Kg/Liter	0.8358	d	DCR, 2000

Note: High speed diesel is used on railways.

4) Estimated Emission

The estimated fuel consumption and SOx emission of railways for the Year 2011(BAU Case) in the whole Thailand are shown in Table 4.3.1.10 and Figure 4.3.1.8. The fuel consumption and SOx emission of railways in the whole Thailand is about 256 kton/year and 153 ton/year respectively.

The fuel consumption of the Southern Line is the biggest and accounts for 31% of fuel consumption of railways in the whole Thailand. The share of Southern Line in SOx Emission is the same as their share in fuel consumption.

Table 4.3.1.10 Fuel Consumption and SOx Emission of Railways in the Year 2011

Line	Fuel Consumption (kton/year)	SOx Emission (tons/year)
Northern Line	80	48
Northeastern Line	63	38
Eastern Line	25	15
Southern Line	85	51
Mae Klong Line	2.4	1
Total	256	153

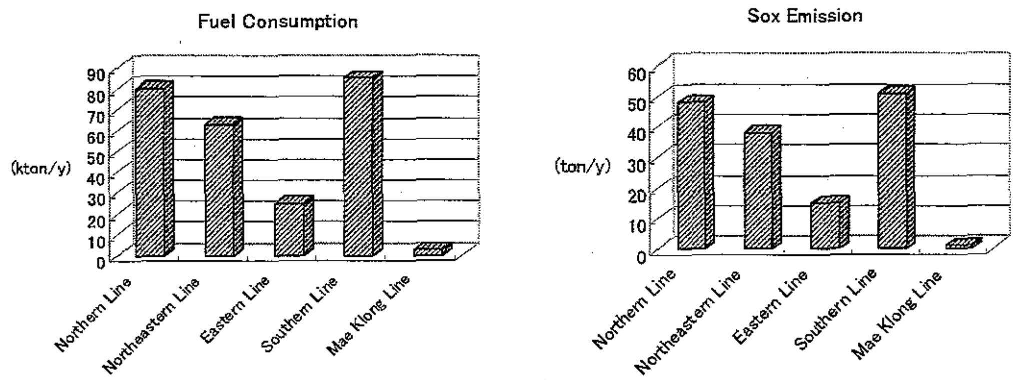


Figure 4.3.1.8 Fuel Consumption and SOx Emission of Railways in the Whole Thailand in the Year 2011

4.3.1.3 Ships

1) Outline

The flow of SOx emission estimation of ships for the Year 2011(BAU Case) in the whole Thailand is shown in Figure 4.3.1.9.

In the BAU Case, demand forecasts of the Port Authority and Harbor Department are considered. The Port Authority's policy is considered, which is that the freight demand of Bangkok Port will not increase due to space limitations in the Chao Praya River, reversely, one of the Laem Chabang Ports will increase due to a new deep sea port.

The actual sulfur contents of high speed diesel which is suitable to the EURO3 regulation are adopted. The actual sulfur contents of fuel oil are the same as for the year 2000.

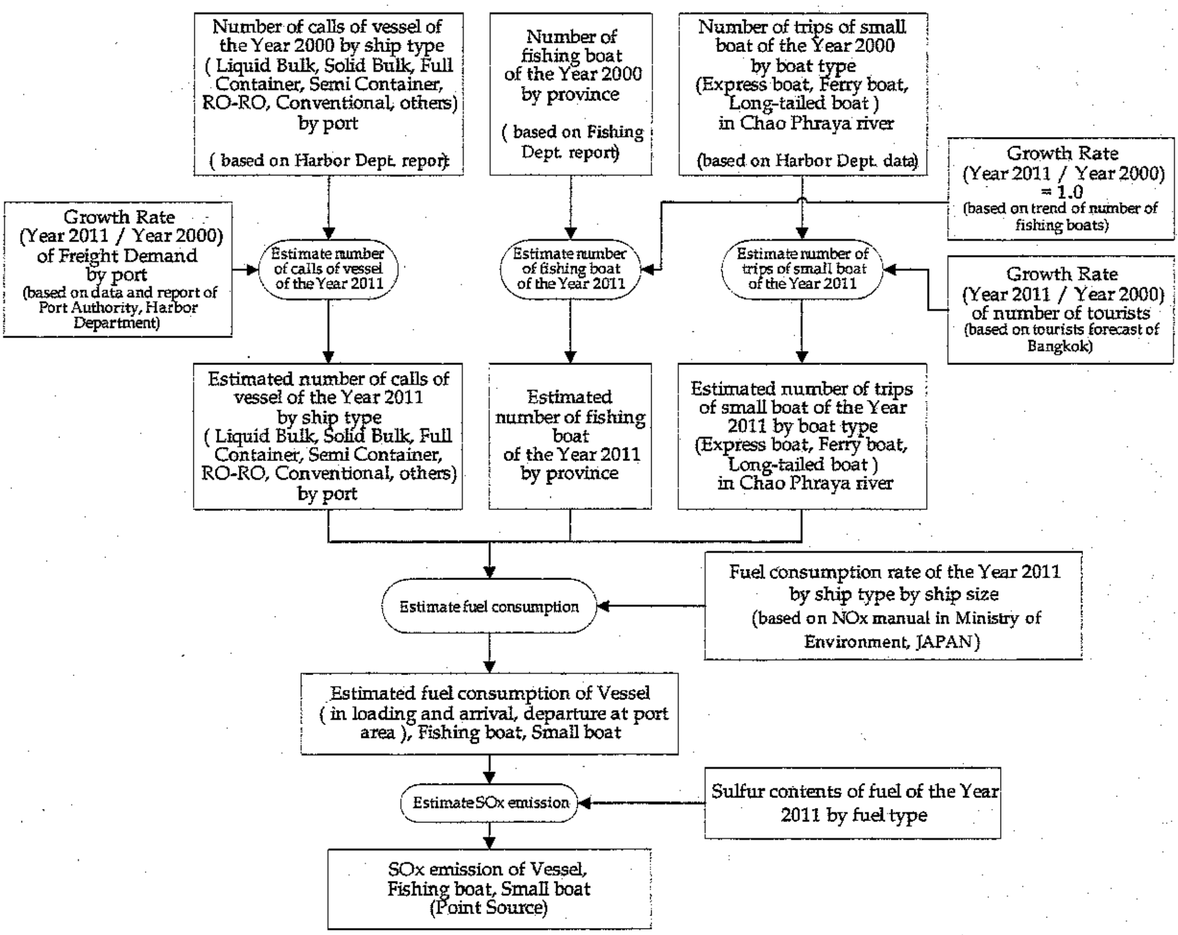


Figure 4.3.1.9 Flow of SOx emission estimation of ships for the Year 2011 in the whole Thailand

In the same way as in the Year 2000, in the SOx emission estimation, three kinds of methods are applied, which are for vessels in port, for fishing boats and for small boats like express boats, ferry boats and long-tailed boats in the Chao Phraya River.

The fuel consumption of vessels in loading, arriving and departing is estimated using the number of calls of vessels for the Year 2011 by port and fuel consumption rates based on the NOx manual in Japan. The number of calls of vessels for the Year 2011 is estimated using the one of the Year 2000 and the growth rate of freight demand based on data of the Port Authority, Harbor Department and "The Master Plan Study for the Coastal Channels and Ports Development (2001)" report of the Harbor Department.

For fishing boats, the fuel consumption is estimated using the number of fishing boats for the Year 2011 and fuel consumption rate of the NOx manual. The number of fishing boats for the Year 2011 is the same as for the Year 2000 because of the trend of number of fishing boats based on the "Thai Fishing Vessels Statistics(1999)" of the Fisheries Department.

For small boats, the fuel consumption is estimated using the number of trips of express boats, ferry boats and long-tailed boats for the Year 2011 in the Chao Phraya River and the fuel consumption rate of the NOx manual . The number of trips of express boats, ferry boats and long-tailed boats for the Year 2011 is estimated using the one of the Year 2000 and the growth rate of the tourist forecast for Bangkok.

The SOx emissions of vessels, fishing boats and small boats are estimated using the sulfur contents of fuel for the Year 2011 and the estimated fuel consumption.

2) Traffic Data

The number of calls of vessels for the Year 2011 by province in the whole Thailand is shown in Table 4.3.1.11, which is estimated using the one for the Year 2000 and the growth rate of freight demand shown in Table 4.3.1.12. The number of ship calls for the whole Thailand is about 41,000 calls/year in year 2011. The calls of vessels in the ports of Bangkok, Chon Buri and Rayong account for 21%, 29%, and 23% of the total calls of vessels in the whole Thailand respectively.

As for fishing boats, the number of boats for the Year 2011 is shown in Table 4.3.1.13. The number of fishing boats in the whole Thailand is about 13,300 boats in the year 2011, which is the same as for the Year 2000.

The number of trips of small boats for the Year 2011 in the Chao Phraya River is shown in Table 4.3.1.14, which is estimated using the one for the Year 2000 and the growth rate of tourists forecast shown in Table 4.3.1.15.

The location of ports is shown in Figure 4.3.1.2.

Table 4.3.1.11 Number of Calls of Vessels on Arrival & Departure by Ship Type in the Year 2011

Unit: calls of vessel/year

Province	Liquid Bulk	Solid Bulk	Fully Cellular Container	Semi-Container	Ro-Ro	Conventional	Others	Total
Bangkok	1,820	2,230	6,732	707	222	4,795	674	17,181
Samut Sakhon	30	175				53	554	812
Chachoengsao	607	2	15	2		301	132	1,058
Chanthaburi							2	2
Chon Buri	2,338	1,769	2,234	443	549	4,423	221	11,978
Chumporn						3		3
Krabi	9	231			21	361	154	775
Nakhon Si Thammarat	144	101		3		196	69	513
Phetchaburi						2		2
Phuket	433	52	36		63	154	348	1,085
Prachuap Khiri Khan		197				715	31	942
Rayong	7,024	737	84	74	10	1,350	72	9,351
Satun						32	121	152
Songkhla	1,082	711	1,055	119	32	322	252	3,572
Surat Thani						2		2
Trang	2	499				89	1,204	1,794
Total	13,488	6,704	10,157	1,348	896	12,798	3,832	49,223

Note: The number of calls shows the total sum of calls on arrival and departure.
Vessels in Samut prakan are included in Bangkok.
Ro-Ro : cargo ship for vehicles.

Table 4.3.1.12 Growth Rate of Freight Demand

Province	Growth Rate(Year2011/Year2000)
Bangkok	0.95
Chachoengsao	1.73
Chanthaburi	2.18
Chon Buri (Laem Chabang)	1.77
Chon Buri (others)	1.70
Chumporn	1.72
Krabi	1.75
Nakhon Si Thammarat	1.72
Phetchaburi	2.48
Phuket	1.57
Prachuap Khiri Khan	2.74
Rayong	1.94
Samut Sakhon	2.37
Samut Songkhram	1.72
Satun	1.75
Songkhla	1.58
Surat Thani	1.72
Trang	1.75

Note: 1) The detailed data is shown in Chapter 2.
2) Bangkok and Chob Buri(Laem Chabang): based on data of Port Authority and their policy which is Freight demand of Bangkok Port will not increase because of space limitations in the Chao Praya River, reversely, one of the Laem Chabang Port will increase due to a new deep sea port.
3) Phuket,Songkhla: based on data of Harbor Department
Other province : based on report of Harbor Department

Table 4.3.1.13 Number of Fishing Boats in the Year 2011

Type of boat	Number of Boats
Fishing boat	13,263

Table 4.3.1.14 Number of trips of Small Boats in the Chao Phraya River in the Year 2011

Unit: trips/day

Type of small boat	Number of trips
Express boat	542
Ferry boat	8,097
Long-tailed boat	2,787

Table 4.3.1.15 Growth Rate of Tourist Forecast

Item	Growth Rate(Year2011/Year2000)
Tourist Forecast	2.0

Note: The detailed data is shown in Chapter 2.

3) Emission Factor

The method to estimate the fuel consumption and SOx emission of vessels, fishing boats and small boats is the same as the one used for the Year 2000, which is based on the "NOx Manual (Ministry of Environment, Japan)".

The sulfur contents of Fuel Oil and the specific gravity of High Speed Diesel and Fuel Oil for the Year 2011 are the same as the ones used for the Year 2000, which is shown in Table 4.3.1.16. The sulfur contents of fuel (High Speed Diesel) for the Year 2011, which are based on the actual sulfur contents of the Euro market (sulfur contents : 300 ppm for EURO3 regulation), are shown in Table 4.3.1.16.

Table 4.3.1.16 Sulfur Contents in Fuel and Specific Gravity

Type of Fuel	Type of fuel	Sulfur Contents (wt%)	Specific gravity
Diesel	High Speed	0.0300	0.8358
Fuel Oil	No.1	1.7	0.9402
	No.2	1.7	0.9487

Source: Sulfur Contents of High Speed Diesel :
Average of actual sulfur contents in Euro market based on Auto Oil II Program
Sulfur Contents of Fuel Oil and Specific gravity of both fuel : DCR,2000

4) Estimated Emission

The estimated fuel consumption and SOx emission of vessels, fishing boats and small boats of the Year 2011 in the whole Thailand are shown in Table 4.3.1.17 - 4.3.1.20.

The total fuel consumption of vessels, fishing boats and small boats is about 227 kton/year in year 2011. The total SOx emission is about 7,700 ton/year in year 2011.

The fuel consumptions of the ports in Bangkok, Chon Buri and Rayong account for about 22%, 30%, and 28% of the total fuel consumption of vessels in the whole Thailand respectively. The share of Bangkok, Chon Buri, Rayong in the total SOx emission of vessels in the whole Thailand is the same as the share of fuel consumption.

The SOx emissions of vessels and small boats account for 97% and 3% of the total SOx emission of ships in the whole Thailand respectively.

Table 4.3.1.17 Fuel Consumption of Vessels in the Year 2011

Unit: kton/year

Province	Liquid Bulk	Solid Bulk	Fully Cellular Container	Semi-Container	Ro-Ro	Conventional	Others	Total
Bangkok	7	4	18	2	1	17	1	50
Samut Sakhon	0	1				0	1	2
Chachoengsao	4	0	0	0		2	0	7
Chanthaburi							0	0
Chon Buri	17	5	9	2	5	29	0	68
Chumporn						0		0
Krabi	0	1			0	2	0	4
Nakhon Si Thammarat	1	0		0		1	0	3
Phetchaburi						0		0
Phuket	3	0	0		1	1	0	5
Prachuap Khiri Khan		1				5	0	5
Rayong	51	2	0	0	0	9	0	63
Satun						0	0	0
Songkhla	8	2	4	1	0	2	0	17
Surat Thani						0		0
Trang	0	2				1	1	4
Total	91	18	31	5	8	70	4	227

Table 4.3.1.18 SOx emissions of Vessels in the Year 2011

Unit: ton/year

Province	Liquid Bulk	Solid Bulk	Fully Cellular Container	Semi-Container	Ro-Ro	Conventional	Others	Total
Bangkok	246	141	607	61	41	595	17	1,707
Samut Sakhon	7	18				12	22	59
Chachoengsao	148	0	2	0		68	5	224
Chanthaburi							0	0
Chon Buri	572	186	300	70	178	992	9	2,306
Chumporn						1		1
Krabi	2	24			7	81	6	120
Nakhon Si Thammarat	35	11		1		44	3	93
Phetchaburi						1		1
Phuket	106	5	5		20	35	14	185
Prachuap Khiri Khan		21				161	1	183
Rayong	1,720	78	11	12	3	302	3	2,129
Satun						7	5	12
Songkhla	265	75	142	19	10	72	10	592
Surat Thani						0		0
Trang	0	53				20	47	120
Total	3,102	613	1,067	161	259	2,388	141	7,731

Table 4.3.1.19 Fuel Consumption and SOx emission of Fishing Boats in the Year 2011

Type of boat	Fuel Consumption (kton/year)	SOx Emission (ton/year)
Fishing boat	58	35

Table 4.3.1.20 Fuel Consumption and SOx emission of Small Boats in the Year 2011

Type of small boat	Fuel Consumption (kton/year)	SOx Emission (ton/year)
Express boat	2	71
Ferry boat	4	140
Long-tailed boat	4	3
Total	10	214

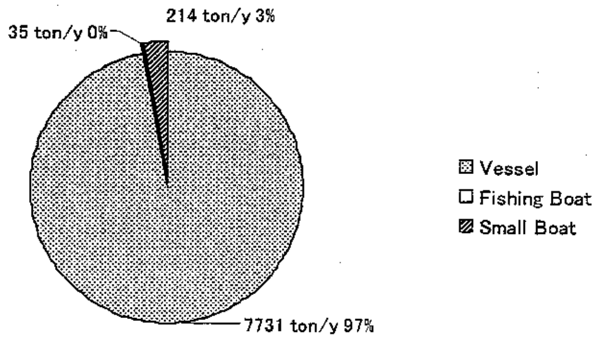


Figure 4.3.1.10 Share of SOx Emission of Ships in the whole Thailand in the Year 2011

4.3.1.4 Aircrafts

1) Outline

The flow of SOx emission estimation of aircraft for the Year 2011(BAU Case) in the whole Thailand is shown in Figure 4.3.1.11.

In the BAU Case, the demand forecasts of the Airport Authority and the Department of Aviation are considered. The policy concerning the Bangkok International Airport is considered, in which the Second Bangkok International Airport (SBIA) will be used, but, the Don Muang Airport will not be in operation in the year 2011.

The actual sulfur contents of jet fuel are the same as for the year 2000.

The SOx emission of aircraft by airport is estimated using the number of flights for the Year 2011 by aircraft type and the SOx emission factor in the LTO cycle based on USEPA.

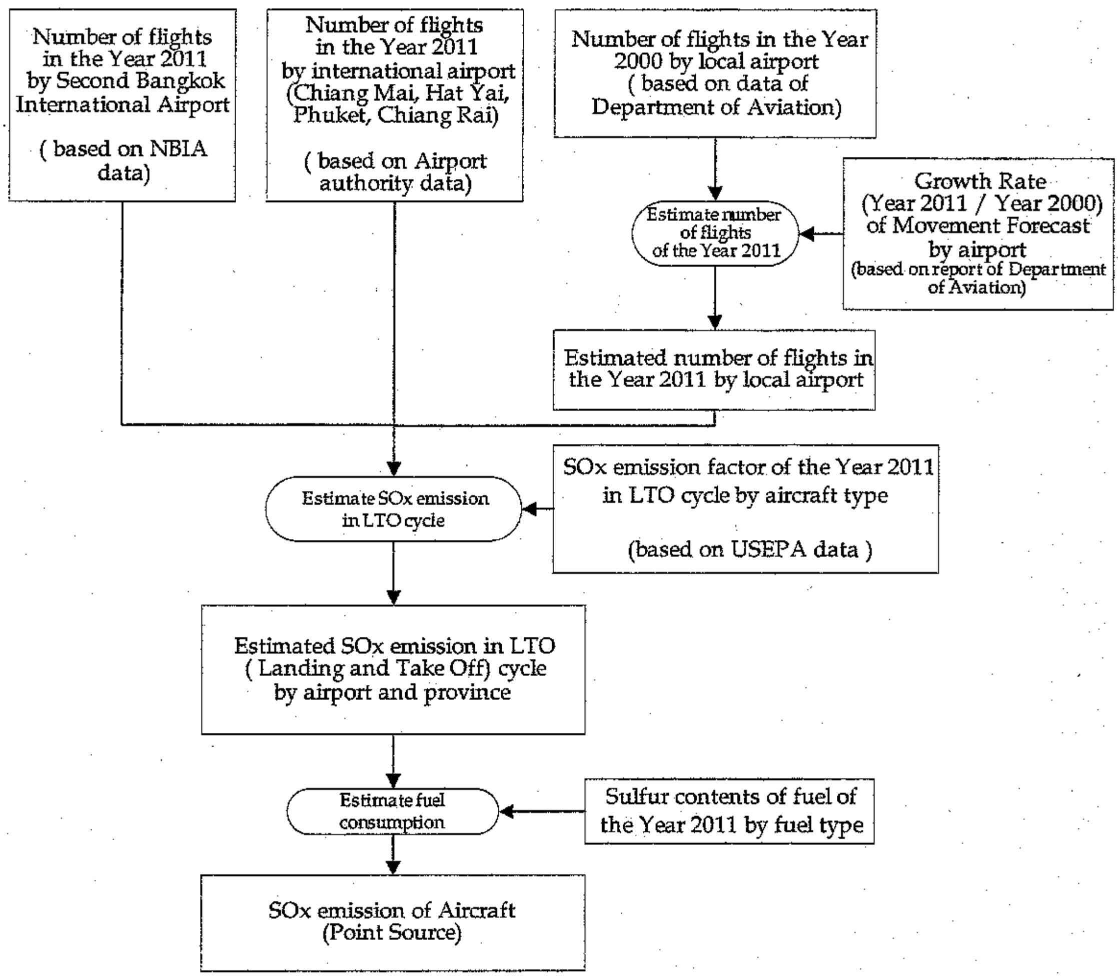


Figure 4.3.1.11 Flow of SOx emission estimation of aircraft for the Year 2011 in the whole Thailand

The number of flights of the Second Bangkok International Airport (SBIA) for the Year 2011 is based on the data of the New Bangkok International Airport Co.,Ltd (NBIA). The number of flights of the international airports (Chiang Mai, Hat Yai, Phuket, Chiang Rai) for the Year 2011 is based on the data of the Airport Authority.

The number of flights of the local airports for the Year 2011 is estimated using the one for the Year 2000 and the growth rate of movement forecast by airport based on "The Study on Airport Development Master Plan(2000)" report of the Department of Aviation. The fuel consumption is estimated using the sulfur contents of fuel for the Year 2011 and the estimated SOx emission.

2) Traffic Data

The annual aircraft movement in the year 2011 is shown in Table 4.3.1.21.

Table 4.3.1.21 Annual Aircraft Movement in the Year 2011

Airport		Movement(Flight/year)
International airport	Bangkok (SBIA)	309,295
	Chiangmai	39,153
	Hatyai	19,706
	Phuket	40,213
	Chiang Rai	6,010
Local airport	Betong	1,460
	Buri Ram	2,191
	Chantaburi	730
	Chumphon	491
	Hua Hin	17,881
	Khon Kaen	8,681
	Krabi	6,054
	Lampang	3,456
	Loei	2,409
	Mae Hong Son	4,561
	Mae Sariang	730
	Mae Sot	2,380
	Nakhon Phanom	1,707
	Nakon Ratchasima(korat)	4,368
	Nakhon Si Thammarat	3,986
	Nan	2,979
	Narathiwat	1,827
	Pattani	26
	Phechabun	1,703
	Phitsanulok	11,028
	Pharae	6,079
	Ranong	2,319
	Roi Et	1,804
	Sakhon Nakhon	2,917
	Surat Thani	2,866
	Sukhothai	2,083
	Samui	15,998
	Tak	15
	Trang	8,527
	Ubon Ratchathani	4,029
	Udon Thani	5,183
	Mukdahan	2,190
	Utapao	5,480
Total		552,515

Note: SBIA and Betong,Chantaburi,Mae Sariang,Mukdahan : New airport
Don Muang Airport is planed to be used for few unscheduled charter flight

The number of flights of the international airports (Chiang Mai, Hat Yai, Phuket, Chiang Rai) and SBIA for the Year 2011 is based on the data of the Airport Authority and NBIA.

The number of flights of the local airports for the Year 2011 is estimated using the one of the Year 2000 and the growth rate of movement forecast by airport based on the report of the Department of Aviation, which is shown in Table 4.3.1.22.

The annual aircraft movement is about 553,000 flights/year in the year 2011. The annual aircraft movement in the Second Bangkok International Airport (SBIA) accounts for more than 50% of the total annual aircraft movement in the whole Thailand.

The location of airports is shown in Figure 4.3.1.2.

Table 4.3.1.22 Growth Rate of Annual Movement

Airport		Growth Rate (Year2011/Year2000)
Local airport	Buri Ram	3.3
	Chumphon	1.1
	Hua Hin	1.1
	Khon Kaen	2.2
	Krabi	2.2
	Lampang	1.8
	Loei	3.3
	Mae Hong Son	1.7
	Mae Sot	2.2
	Nakhon Phanom	2.2
	Nakon Ratchasima(korat)	2.6
	Nakhon Si Thammarat	4.4
	Nan	2.2
	Narathiwat	1.1
	Pattani	1.1
	Phechabun	3.3
	Phitsanulok	1.6
	Pharae	3.3
	Ranong	2.2
	Roi Et	2.8
	Sakhon Nakhon	3.3
	Surat Thani	1.4
	Sukhothai	1.3
	Samui	1.3
	Tak	1.0
	Trang	3.3
	Ubon Ratchathani	1.7
	Udon Thani	2.2
	Utapao	2.0

Note:Sukhothai,Samui,Tak,Utapao : based on trend of annual movement
Others : based on report of Department of Aviation

3) Emission Factor

The method to estimate the SOx emission of aircraft is the same as the one used for the Year 2000, which is based on the "Evaluation of Air Pollutant Emissions from Subsonic Commercial Jet Aircraft(USEPA)".

The sulfur contents and the specific gravity of fuel for the Year 2011 are the same as the ones for the Year 2000, which are shown in Table 4.2.1.27.

4) Estimated Emission

The estimated fuel consumption and SOx emission of aircraft for the Year 2011 in the whole Thailand are shown in Table 4.3.1.23 and Figure 4.3.1.12.

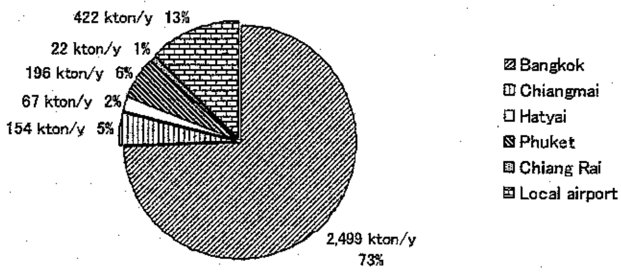
The fuel consumption and SOx emission of aircraft in the whole Thailand are about 3,400 kton/year, about 4,200 ton/year in year 2011 respectively.

The fuel consumption in the Second Bangkok International Airport accounts for 74% of the total fuel consumption of aircraft. 74 % of SOx emission of aircraft in the whole Thailand is emitted from the Second Bangkok International Airport.

Table 4.3.1.23 Fuel Consumption and SOx Emission of Aircraft in the Year 2011

Airport		Fuel Consumption kton/year	SOx Emission ton/year
International airport	Bangkok(SBIA)	2,499	3,098
	Chiangmai	154	191
	Hatyai	67	83
	Phuket	196	243
	Chiang Rai	22	27
Local airport	Betong	2	2
	Buri Ram	2	3
	Chantaburi	1	1
	Chumphon	0	0
	Hua Hin	24	29
	Khon Kaen	49	61
	Krabi	13	16
	Lampang	17	21
	Loei	5	6
	Mae Hong Son	27	33
	Mae Sariang	1	1
	Mae Sot	2	2
	Nakhon Phanom	5	6
	Nakon Ratchasima(korat)	19	24
	Nakhon Si Thammarat	12	14
	Nan	5	7
	Narathiwat	4	5
	Pattani	0	0
	Phechabun	3	4
	Phitsanulok	45	56
	Pharae	15	18
	Ranong	7	8
	Roi Et	5	6
	Sakhon Nakhon	9	11
	Surat Thani	17	21
	Sukhothai	5	6
	Samui	36	45
	Tak	0	0
	Trang	25	31
	Ubon Ratchathani	22	27
	Udon Thani	26	32
	Mukdahan	6	8
	Utapao	16	20
Total		3,360	4,166

Note: For ATMOS2, height of Climb-out and Approach is 6,000m.



Fuel Consumption

SOx Emission

Figure 4.3.1.12 Fuel Consumption and SOx emission of Aircraft in the Whole Thailand in the Year 2011

4.3.1.5 SOx Emission of Mobile Sources for the Year 2011(BAU Case) in the Whole Thailand

The Summary of SOx emission of mobile sources for the Year 2011(BAU Case) in the whole Thailand is shown in Table 4.3.1.24. The estimated total annual SOx emission of mobile sources is about 23,300 ton/year. The share of each region in the total SOx emission is shown in Figure 4.3.1.13. The SOx emission of the BMR is about 8,400 ton/y, which accounts for about 36% of the total SOx emission.

The share of each mobile source in the total SOx emission is shown in Figure 4.3.1.13. The share is 46% for vehicles on roads, 34% for ships, 18% for aircraft, 0.7% for railways and 1% for area sources like traffic in local areas.

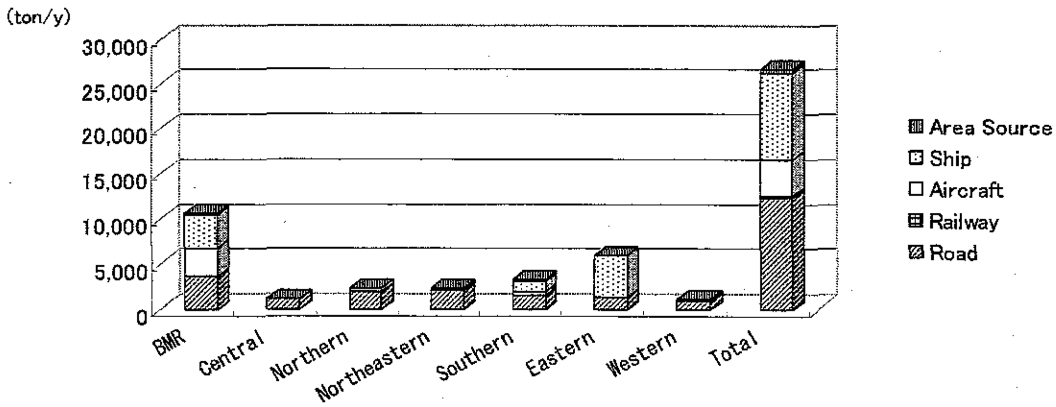


Figure 4.3.1.13 SOx Emission of Mobile Sources for the Year 2011 in the Whole Thailand

Table 4.3.1.24 SOx Emission of Mobile Sources for the Year 2011 in the Whole Thailand

Unit: ton/year

Region	Vehicle			Rail-way	Air-craft	Ship			Other	Total
	Gasoline	HSD	total	HSD	Jet Fuel	HSD	Fuel Oil	total	Area Source	
BMR	740	2,389	3,129	15	3,098	11	1,977	1,988	205	8,436
Central	107	828	935	21					15	970
Northern	287	1,306	1,594	28	367					1,989
Northeastern	311	1,462	1,773	30	182					1,986
Southern	228	1,043	1,272	29	469	13	1,123	1,137	66	2,972
Eastern	128	992	1,120	11	21	8	4,659	4,666	39	5,857
Western	102	706	808	18	29	5	183	188	10	1,054
Total	1,904	8,727	10,631	153	4,166	37	7,942	7,979	335	23,265

Note: Aircraft emission is estimated in LTO Cycle from 0m to 6000m.
HSD: High Speed Diesel

The Summary of fuel consumption of mobile sources for the Year 2011(BAU Case) in the whole Thailand is shown in Table 4.3.1.25 and Figure 4.3.1.14.

The estimated total annual fuel consumption of mobile sources is 27,000 kton/year. The fuel consumption of vehicles is about 21,900 ton/y, which accounts for about 80% of the total fuel consumption.

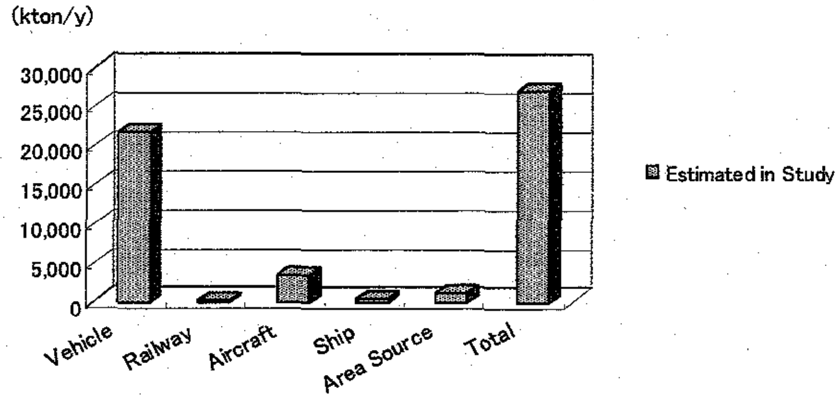


Figure 4.3.1.14 Fuel Consumption of Mobile Sources for the Year 2011 in the Whole Thailand

Table 4.3.1.25 Fuel Consumption of Mobile Sources for the Year 2011 in the Whole Thailand

Unit: kton/year

Item	Vehicle	Railway	Aircraft	Ship	Area Source	Total
Estimated in Study	21,867	256	3,360	296	1,231	27,009

4.3.1.6 Comparison of SOx Emission between the Year 2000 and 2011(BAU Case) in the Whole Thailand

The SOx emission and fuel consumption of mobile sources for the Year 2000 and 2011(BAU Case) in the whole Thailand are shown in Figure 4.3.1.15 - 4.3.1.16.

The total SOx emission for the Year 2011 increases by 29% on the Year 2000. As for the increase of SOx emission by the mobile sector, although the SOx emission of gasoline vehicles decreases by 41%, the one of diesel vehicles increases by 33%, aircraft by 80% and ship by 50% respectively.

The total fuel consumption for the Year 2011 increases by 62% on the Year 2000. As for the increase of fuel consumption by the mobile sector, the fuel consumption of gasoline vehicles increases by 74%, diesel vehicles by 55%, aircraft by about 80% and ships by about 40% respectively.

The sulfur contents of gasoline of year 2011 is reduced by 66% from 382 ppm to 130 ppm and that of diesel oil is reduced by 14 % from 348 ppm to 300 ppm. This is the reason why the SOx emission of gasoline vehicle of year 2011 is reduced although that of diesel vehicle is not reduced.

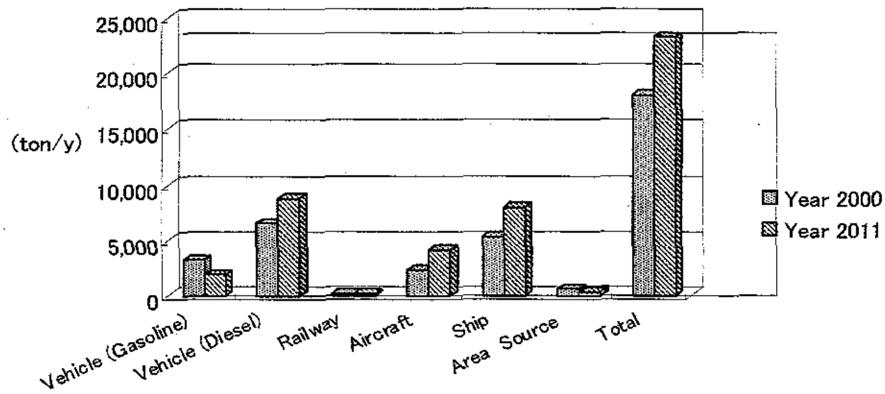


Figure 4.3.1.15 SOx Emission of Mobile Sources for the Year 2000 and 2011 in the Whole Thailand

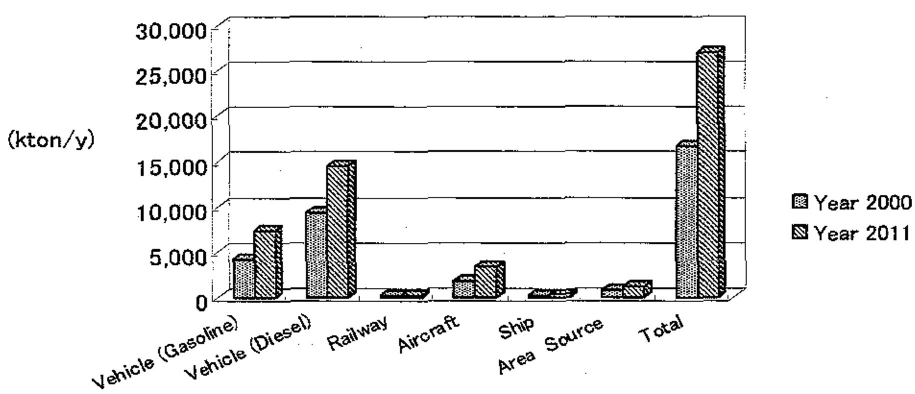


Figure 4.3.1.16 Fuel Consumption of Mobile Sources for the Year 2000 and 201 in the Whole Thailand

4.3.2 Mobile Sources Inventory for the Year 2011(BAU Case) in the BMR

4.3.2.1 Vehicles

1) Outline

The flow of NOx and SOx emission estimations of vehicles for the Year 2011 in the BMR (Bangkok Metropolitan Region) is shown in Figure 4.3.2.1.

In the BAU Case, the Trasnport Project and MRT project (based on URMAP of OCMLT) in the BMR are considered. The EURO3 NOx emission standard for vehicles and level 5 for motorcycles are adopted. The actual sulfur contents of fuel (gasoline and high speed diesel) which is suitable to the EURO3 regulation are adopted.

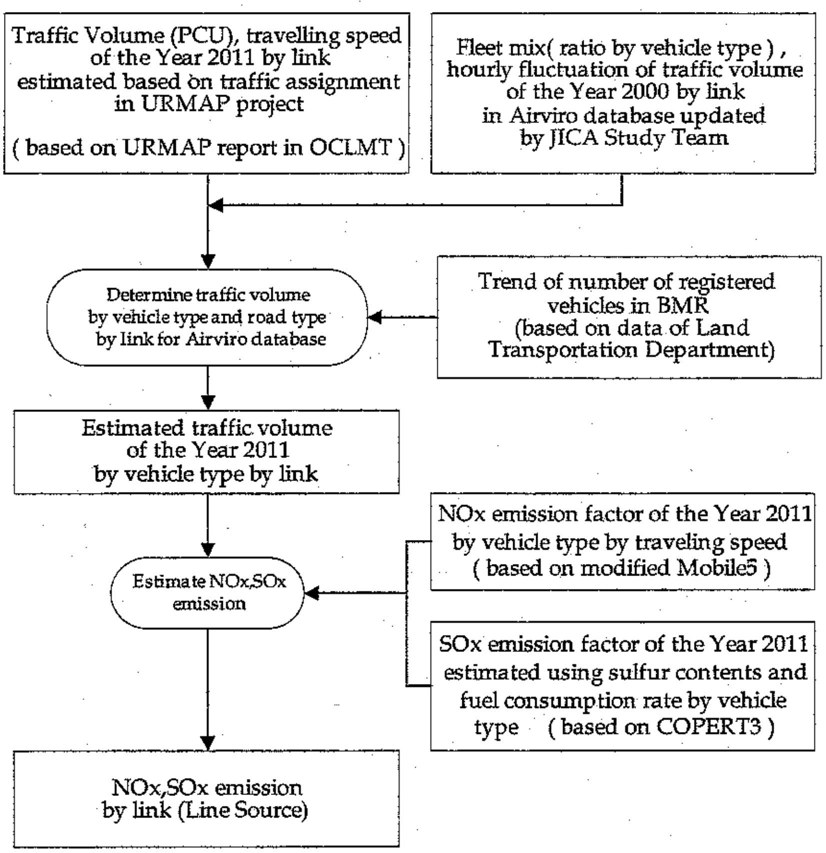


Figure 4.3.2.1 Flow of SOx and NOx emission estimation of vehicles for the Year 2011 in the BMR

The database of the traffic data and the emission factor in the Airviro system is updated using the traffic volume and the traveling speed for the Year 2011 by link estimated based on the traffic assignment of the "Urban Rail Transportation Master Plan (URMAP, 2001) "report in OCMLT, and using the fleet mix (ratio by vehicle type) for the Year 2011 by link, which is estimated based on the one for the Year 2000 and the trend of the number of registered vehicles in the BMR.

The details of the updated Airviro database are explained in Chapter 6 "Model Simulation".

The SOx emission of vehicles in the BMR is estimated using the vehicle kilometers for the Year 2011 by link calculated by traffic volume and link length in the updated database of the Airviro system, and using the SOx emission factor based on the sulfur contents of fuel for the Year 2011 and the fuel consumption rate calculated by COPERT3.

The NOx emission of vehicles in the BMR is estimated using the vehicle kilometers for the Year 2011 by link and the NOx emission factor for the Year 2011 by vehicle type by the traveling speed calculated based on the vehicular NOx standard enforcement plan and Mobile5.

2) Traffic Data

The vehicle kilometers for the Year 2011 by vehicle type in the BMR are shown in Table 4.3.2.2, which are estimated using the Airviro database updated based on the traffic assignment data in the URMAP report of OCMLT. The transport projects considered in the BMR for 2011 (BAU Case) are shown in Table 4.3.2.1 and the location of roads is shown in Figure 4.3.2.2.

Table 4.3.2.1 Transport Projects considered in the BMR for 2011(BAU Case)

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

The annual vehicle kilometers of the BMR is about 70,000 million vehicle-kilometers/year in the year 2011, which is about 1.5 times of that of year 2000. The share of Bangkok is 47% of the total vehicle kilometers of the BMR. As for the share of each vehicle type in the total vehicle kilometers, the share is 45% for gasoline passenger cars, 4% for diesel passenger cars, 14% for motorcycles, 16% for light trucks, 10% for heavy trucks and 7% for buses.

The average vehicle speed of the year 2011 is 33 km/h, which is slower than that of the year 2000, 36 km/h.

Table 4.3.2.2 Vehicle Kilometers by Vehicle Type in the BMR in the Year 2011

Province	Vehicle Kilometers by vehicle type (Million Vehicle-Kilometers/year)									
	PS(G)	Taxis (G)	Taxis (LPG)	PS(D)	Light Trucks	Buses	Heavy Trucks	MCs	Tuk-Tuks	total
Bangkok	16,183	503	352	1,290	4,650	2,098	3,054	4,491	187	32,809
Nonthaburi	2,916	91	64	286	862	523	741	791	33	6,307
Pathum Thani	4,505	140	98	544	1,243	769	1,007	1,132	47	9,485
Samut Prakan	3,680	114	80	334	1,105	571	832	1,078	45	7,840
Nakhon Pathom	2,805	87	61	384	2,349	641	1,268	1,940	81	9,616
Samut Sakhon	1,738	54	38	220	777	293	440	755	31	4,347
BMR	31,827	989	693	3,058	10,987	4,896	7,341	10,187	424	70,403

Note: Estimated based on traffic assignment data of URMAP report in OCMLT

Figure 4.3.2.2 Location of Mobile Source of the Year 2011 in the BMR

3) Emission Factor

(1) Method

In the same way as for SOx, the emission factors for NOx in 2011 (BAU Case) were calculated basically in the same way as for 2000, except the EURO 3 and Level 5 planned to be implemented up to 2011 as shown in Table 4.3.2.3.

Table 4.3.2.3 Emission Control considered in the BAU Case

Emission Control	
	More Stringent Emission Standard Enforcement (EURO 3, Level 5) - LDGV, LDDV, LDDT (EURO3: 2004-) - HDDV (EURO3: 2006-) - MC (Level 5: 2004-)

However some of the calculation conditions needed to be estimated apart from 2000 since all of them were based on the estimates, therefore the following issues are focused upon here,

- The different methods from 2000, which were applied to 2011 (BAU Case),
- The different calculation conditions from 2000, which has not been discussed in the part of 2000, and
- The other necessary conditions for 2011 (BAU Case), which have not been discussed in the part of 2000.

Figure 4.2.2.3 shows the general workflow of the NOx emission factor calculation. For predicting the future emission factors for 2011 (BAU Case), the age distribution and 2/4 strokes ratio of MCs were mainly modified from the calculation for the year 2000. The modification of the age distribution reflected both effects of aged vehicles in retirement and new ones introduced which were produced on the emission factors' levels, and the 2/4 strokes ratio brought about the emission factor consolidated into the average MC level.

Table 4.2.2.4, the reduction rate of the NOx emission factor in the EURO 2 onward from EURO 1, shows the reduction rates from EURO 2 to EURO 3 for the emission factors of LDGV, LDDV, LDDT and HDDV. The emission factors of those vehicles in EURO 3 were calculated with the reduction rates, as shown in Table 4.2.2.4.

(2) Motorcycles and Tuk-tuks, Taxis(LPG)

As shown in Figure 4.2.2.8, the detailed workflow of the NOx emission factors calculation for MCs, Tuk-tuks and Taxis(LPG), the future emission factors (Table 4.2.2.10), which would comply with the future emission standard, Level 5, were calculated with the reduction rate from Level 4 shown in Table 4.2.2.8.

Table 4.3.2.4 shows the shares of 2 or 4 strokes in MCs up to 2011. After the enforcement of Level 5 at year 2004, MCs with 2 stroke engine would no longer be in production, due to its stringent emission level, and only MCs with 4 stroke would be sold.

Table 4.3.2.4 Shares of 2 or 4 Strokes in MCs

Year	Registered MC Number (Share of 4-storke:%)		New MC Number (Share of 4-storke:%)	
1976-1993	7,260,665	13%	-	-
1994	8,248,303	13%	1,091,216	13%
1995	9,314,840	14%	1,339,076	14%
1996	10,713,678	14%	1,247,906	18%
1997	11,649,959	15%	987,343	26%
1998	12,464,499	16%	533,848	44%
1999	13,244,961	17%	497,422	54%
2000	13,816,560	20%	682,929	70%
2001	14,717,485	24%	900,925	**82%**
2002	15,618,410	27%	900,925	88%
2003	16,519,335	31%	900,925	94%
2004	17,420,260	34%	900,925	**100%**
2005	18,321,185	38%	900,925	100%
2006	19,222,110	41%	900,925	100%
2007	20,123,035	43%	900,925	100%
2008	21,023,960	46%	900,925	100%
2009	21,924,885	48%	900,925	100%
2010	22,825,810	50%	900,925	100%
2011	23,726,735	52%	900,925	100%

NOx emission factors, which were consolidated from MCs 2/4 stroke by their shares in each year, are shown in Table 4.3.2.5.

Table 4.3.2.5 NOx Emission Factor of MCs

unit:g/km

	2 st. shr	4 st. shr	2 st. EF	4 st. EF	2 + 4 st.
1976-1993	87%	13%	0.02	0.26	0.05
1994	87%	13%	0.02	0.26	0.05
1995	86%	14%	0.02	0.26	0.05
1996	82%	18%	0.02	0.26	0.06
1997	74%	26%	0.02	0.24	0.08
1998	56%	44%	0.02	0.24	0.12
1999	46%	54%	0.02	0.24	0.14
2000	30%	70%	0.02	0.24	0.17
2001	18%	82%	0.02	0.23	0.19
2002	12%	88%	0.02	0.23	0.20
2003	6%	94%	0.02	0.23	0.22
2004-2011	0%	100%	0.02	0.23	0.23

(3) Emission Factor

The emission factors of NOx, for each speed range from 5 to 100 km/h, are shown in Table 4.3.2.6.

Table 4.3.2.6 NOx Emission Factors of All Vehicle Types and Motorcycles

SPEED	NOx Emission of year 2011 (g/km)								
(Km/Hr)	LDGV	TAXI (G)	TAXI (L)	LDDV	LDDT	H-truck	Bus	MC	TUKTUK
5	1.60	0.73	0.59	1.75	1.52	28.10	28.10	0.12	0.40
10	1.51	0.69	0.56	1.59	1.38	25.49	25.49	0.12	0.40
15	1.45	0.66	0.53	1.44	1.25	23.16	23.16	0.12	0.40
20	1.39	0.63	0.51	1.31	1.14	21.10	21.10	0.12	0.40
25	1.34	0.61	0.50	1.20	1.05	19.32	19.32	0.12	0.40
30	1.30	0.59	0.48	1.11	0.97	17.81	17.81	0.12	0.40
35	1.27	0.58	0.47	1.03	0.90	16.58	16.58	0.12	0.40
40	1.25	0.57	0.47	0.97	0.85	15.62	15.62	0.13	0.40
45	1.25	0.57	0.47	0.92	0.82	14.94	14.94	0.13	0.40
50	1.25	0.57	0.47	0.90	0.80	14.53	14.53	0.14	0.40
55	1.27	0.58	0.47	0.89	0.79	14.40	14.40	0.15	0.40
60	1.29	0.59	0.48	0.90	0.80	14.54	14.54	0.15	0.40
65	1.33	0.61	0.50	0.92	0.83	14.96	14.96	0.16	0.40
70	1.37	0.63	0.52	0.96	0.87	15.65	15.65	0.17	0.40
75	1.43	0.65	0.54	1.02	0.92	16.62	16.62	0.18	0.40
80	1.49	0.68	0.57	1.10	0.99	17.86	17.86	0.19	0.40
85	1.57	0.72	0.60	1.19	1.08	19.38	19.38	0.20	0.40
90	1.66	0.76	0.63	1.30	1.18	21.17	21.17	0.21	0.40
95	1.76	0.80	0.67	1.42	1.29	23.24	23.24	0.23	0.40
100	1.87	0.85	0.71	1.57	1.42	25.58	25.58	0.24	0.40

Figure 4.3.2.3 shows a comparison between the emission factors of 2000 and 2011. The differences observed in each vehicle type are explained as follows,

- The emission factors of all vehicle types, except Taxi s(LPG) and Tuk-tuks, were changed by the vehicle fleet transition, the old giving way to the new. The emission factors of them except MCs were reduced due to the retirement of the high emitting ones and the ones of MCs were increased by approx. 90% due to the increase of the 4-stroke MC's share.
- In the case of Taxis (G), it causes a considerable reduction of approx. 60%, and vehicles of the 1993 model year, which have the emission factor of PRE ECE level and consist of 40% of the total registered in 2000, would retire before 2011. All Taxi (G) in 2011 would consist of vehicles in the EURO2 onward.
- LDGVs tend to deteriorate the ability of their catalytic converters sooner than diesel vehicles such as LDDVs, LDDTs and HDDVs (expressed by the higher deterioration rate in MOBILE5). This caused the LDGVs to have the same or a smaller reduction (approx. 20%) by the old vehicles in retirement than the diesel vehicles (LDDVs: approx. 20% LDDTs: approx. 40% HDDVs: approx. 45%), which could maintain a smaller deterioration to the emission level.

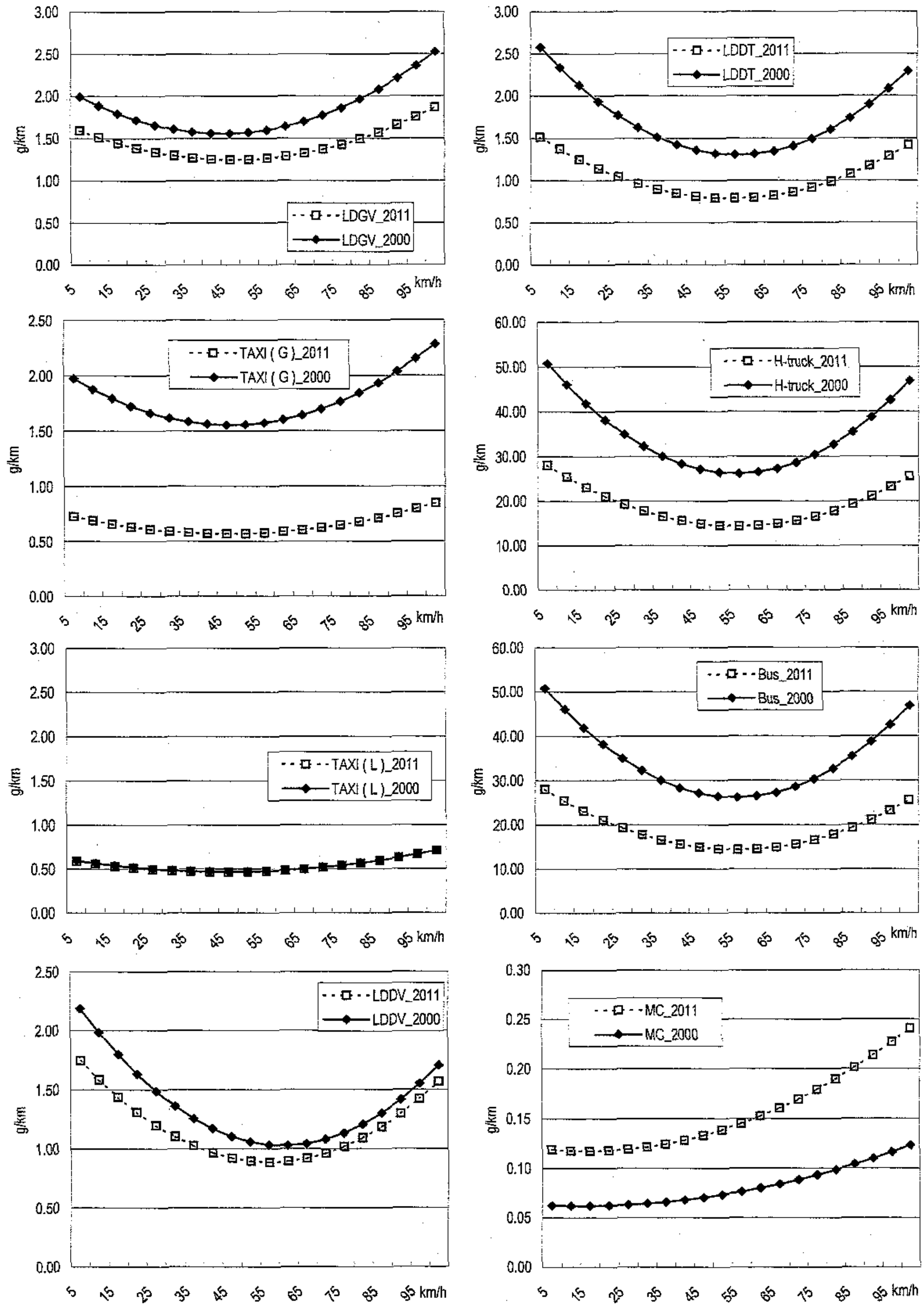


Figure 4.3.2.3 Comparison of NOx Emission Factors for the years 2000 and 2011(BAU Case)

4) Estimated Emission

The estimated NOx and SOx emissions of vehicles for the Year 2011 in the BMR are shown in Table 4.3.2.7 and Figure 4.3.2.4, 4.3.2.5.

The NOx and SOx emissions of vehicles in the BMR is about 291,000 ton/year, 3,300ton/year in the year 2011 respectively. The NOx and SOx emission of Bangkok are the biggest in the BMR and account for 48%, 51% of the total emission of the BMR respectively. 80% of NOx emission is emitted from diesel vehicles, about 15% from gasoline vehicles and 0.2% from LPG vehicles. 72% of SOx is emitted from diesel vehicles and about 22% from gasoline vehicles.

Table 4.3.2.7 Estimated NOx and SOx Emissions of vehicles in the BMR in the Year 2011

Province	NOx Emission(ton/year)					SOx Emission(ton/year)			
	Vehicle				Traffic in Area	Vehicle			Traffic in Area
	Gasoline	HSD	LPG	total		Gasoline	HSD	total	
Bangkok	22,789	102,250	252	125,291	13,098	407	1,081	1,488	198
Nonthaburi	4,000	23,640	44	27,684	473	65	234	299	6
Pathum Thani	6,105	29,656	67	35,827	164	80	271	351	0
Samut Prakan	5,212	25,976	59	31,247	225	78	254	332	1
Nakhon Pathom	4,006	37,579	62	41,648	169	73	415	488	0
Samut Sakhon	2,369	12,853	31	15,252	92	38	134	172	0
Total	44,480	231,954	515	276,949	14,222	740	2,389	3,129	205

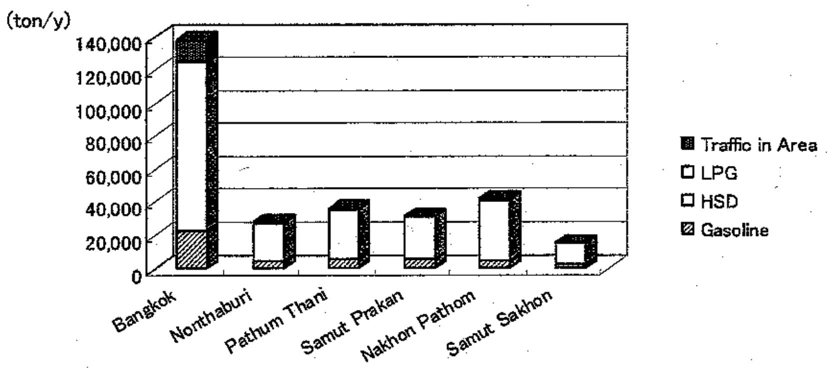


Figure 4.3.2.4 Estimated NOx Emission of vehicles in BMR in the Year 2011

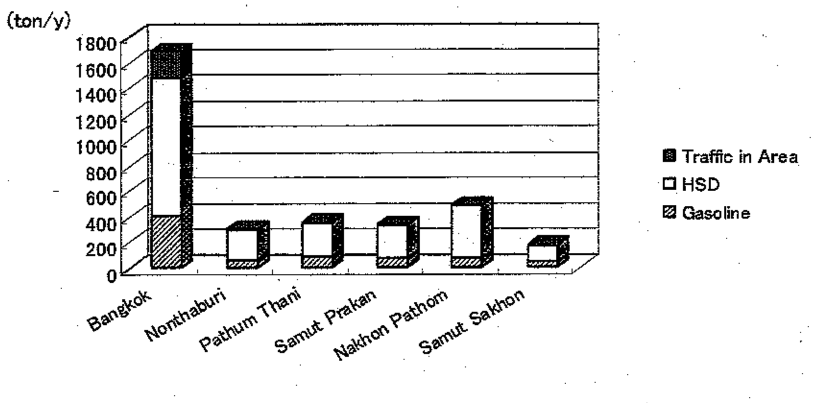


Figure 4.3.2.5 Estimated SOx Emission of vehicles in BMR in the Year 2011

4.3.2.2 Railways

1) Outline

The flow of NOx and SOx emission estimation of railways for the Year 2011(BAU Case) in the BMR are shown in Figure 4.3.2.6.

In the BAU Case, the Track Doubling Project of SRT is considered. The actual sulfur contents of fuel (high speed diesel) which is suitable to the EURO3 regulation are adopted.

The NOx emission of railways by line and by province is estimated using the number of operations of trains for the Year 2011 based on the "Investment of Capacity Constraints and Determination of the Need for Track Doubling of SRT Network (2002) " report of the State Railway of Thailand (SRT) and the NOx emission factor is estimated based on the AP-42 of USEPA. The SOx emission of railways by line and by province is estimated using the number of operations of trains for the Year 2011 and the SOx emission factor, which is calculated by the sulfur contents of fuel for the Year 2011 and the fuel consumption rate of trains based on data of the SRT.

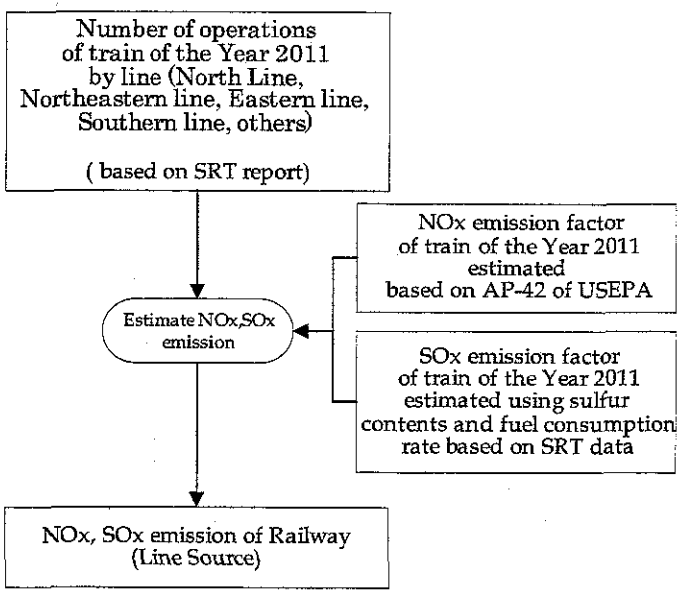


Figure 4.3.2.6 Flow of SOx and NOx emission estimation of railways for the Year 2011 in the BMR

2) Traffic Data

The traffic data of railway sis shown in Chapter 4.3.1.2 "Railways 2) Traffic Data".

The location of the railwaylines is shown in Figure 4.3.2.2.

3) Emission Factor

The NOx emission factor of railways for the Year 2011 are the same as the ones for the year 2000, which are shown in Table 4.2.2.14. The SOx emission factor of railways is shown in Table 4.3.1.9.

4) Estimated Emission

The estimated SOx and NOx emission of railways for the year 2011 in the BMR are shown in Table 4.3.2.8.

The NOx emission of railways in the BMR is about 1,800 ton/year and 15 ton/year for SOx emission.

Table 4.3.2.8 NOx and SOx Emission of Railways in the BMR in the Year 2011

Line	NOx Emission (ton/year)	SOx Emission (ton/year)
Line in BMR	1,779	15

4.3.2.3 Ships

1) Outline

The flow of NOx and SOx emission estimations for ships for the year 2011 in the BMR is shown in Figure 4.3.2.7.

In the BAU Case, demand forecasts of the Port Authority and the Harbor Department are considered. The Port Authority's policy is considered, which is that the freight demand of Bangkok Port will not increase due to space limitation in the Chao Praya River, reversely, the one for the Laem Chabang Port will increase due to a new deep sea port.

The actual sulfur contents of high speed diesel which is suitable to the EURO3 regulation are adopted. The actual sulfur contents of fuel oil are the same as for the year 2000.

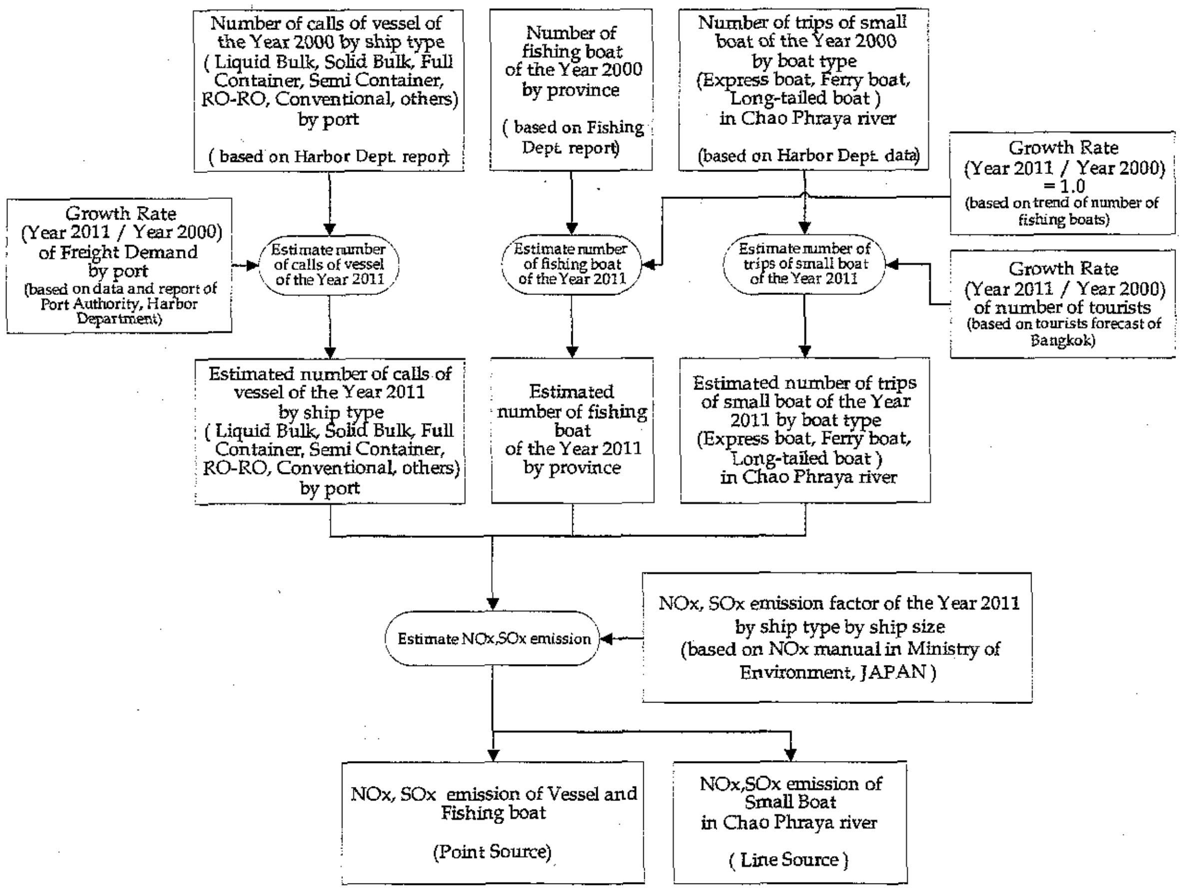


Figure 4.3.2.7 Flow of SOx and NOx emission estimation of ships for the Year 2011 in the BMR

The NOx emission of vessels in loading, arrival and departure is estimated using the number of calls of vessels for the year 2011 by port in the BMR and the NOx emission factor based on the NOx manual in Japan. The number of calls of vessels of the year 2011 is estimated using the one for the year 2000 and the growth rate of freight demand based on data of the Port Authority, the Harbor Department and "The Master Plan Study for the Coastal Channels and Ports Development (2001)" report of the Harbor Department.

For fishing boats, the NOx emission is estimated using the number of fishing boats for the year 2011 and the NOx emission factor of the NOx manual. The number of fishing boats for the year 2011 is the same as the one for the year 2000 because of the trend of the number of fishing boats based on the "Thai Fishing Vessels Statistics (1999)" of the Fisheries Department.

For small boats, the NOx emission is estimated using the number of trips of express boats, ferry boats and long-tailed boats for the year 2011 in the Chao Phraya River and the NOx emission factor of the NOx manual. The number of trips of express boats, ferry boats and long-tailed boats of the year 2011 is estimated using the one for the year 2000 and the growth rate of tourists forecast for Bangkok.

In the same way as the NOx emission estimation, the SOx emission of vessels, fishing boats and small boats is estimated using the number of calls of vessels, the number of fishing boats and the number of trips of express boats, ferry boats and long-tailed boats respectively and using the SOx emission factor, which is calculated based on the sulfur contents of fuel for the year 2011 and the fuel consumption rate of the NOx manual in Japan.

2) Traffic Data

The number of calls of vessels for the year 2011 by port in the BMR is shown in Table 4.3.2.9, which is estimated using the one for the Year 2000 and the growth rate of freight demand as shown in Table 4.3.1.12. The calls of vessels in private wharves and the Klong Toey wharf of Bangkok port account for 46%, 39% of total calls of vessels in the BMR respectively.

The share of each ship type in the total calls of vessels in the BMR is 36% for Full Cellular Containers and 26% for Conventional.

As for fishing boats, the number of boats for the year 2011 in the BMR is shown in Table 4.3.2.10, which is the same as the one for the year 2000. The number of fishing boats in the whole Thailand is about 1,700 boats in the year 2011, which is the same as the one for the year 2000.

The number of trips of small boats in the Chao Phraya River for the year 2011 is shown in Table 4.3.2.11, which is estimated using the one for the year 2000 and the growth rate of tourists forecast shown in Table 4.3.1.14. The number of trips of small boats in the Chao Phraya River is about 11,400 trips/day.

The location of ports and routes of small boats is shown in Figure 4.3.2.2.

Table 4.3.2.9 Number of Calls of Vessels on Arrival & Departure in the BMR in the Year 2011

Unit: calls of vessel/year

Port		Liquid Bulk	Solid Bulk	Fully Cellular Container	Semi-Container	Ro-Ro	Conventional	Others	Total
Bangkok	Klong Toey Wharf	0	35	2,325	234	87	819	10	3,509
	Klong Toey Pole	0	49	0	1	0	198	0	248
	Bang Hua Suer Pole	0	36	0	8	0	123	3	169
	Sathupradit Buoy	0	263	0	0	0	187	17	467
	Tmn Wharf	0	12	0	0	0	19	24	55
	Private Wharves	909	713	1,055	110	25	1,060	276	4,147
	Others	15	18	12	5	0	20	11	82
Samut Sakhon	Mahachai	7	145	0	0	0	21	230	403
	Thachalom	0	0	0	0	0	2	0	2
	Others	21	28	0	0	0	28	325	403
Total		952	1299	3,392	358	112	2,477	896	9,485

Note: The number of calls shows the total sum of calls on arrival and departure.
Vessels in Samut prakan are included in Bangkok.
Ro-Ro : cargo ships for vehicles.

Table 4.3.2.10 Number of Fishing Boats in the BMR in the Year 2011

Province	Number of Boats
Bangkok	0
Samut Prakan	830
Samut Sakhon	897
Total	1,727

Table 4.3.2.11 Number of trips of Small Boats in the Chao Phraya River in the Year 2011

Unit: trips/day

Type of small boat	Number of trips
Express boat	542
Ferry boat	8,097
Long-tailed boat	2,787
Total	11,426

3) Emission Factor

The NOx and SOx emission factors of ships of the Year 2011 are shown in Chapter 4.3.1.3 "Ships 3) Emission Factor".

4) Estimated Emission

The estimated NOx and SOx emissions of vessels, fishing boats and small boats for the year 2011 in the BMR are shown in Table 4.3.2.12 – 4.3.2.15.

The NOx emission of vessels, fishing boats and small boats in the BMR are about 3,100 ton/year, 450 ton/year and 360 ton/year respectively. The SOx emission of vessels, fishing boats and small boats in the BMR is about 1,800 ton/year, 9 ton/year and 220 ton/year respectively.

The NOx emissions of private wharves and the Klong Toey wharf of Bangkok port account for 47% and 40% of the total NOx emission of vessels in the BMR respectively. The SOx emissions of private wharves and the Klong Toey wharf of Bangkok port account for 47% and 40% of the SOx emission of vessels in the BMR respectively.

The NOx emissions of vessels and fishing boats account for 79% and 11% of the NOx emission total for ships in the BMR respectively. The SOx emissions of vessels and small boats account for 89% and 11% of the total SOx emission of ships in the BMR respectively.

Table 4.3.2.12 NOx emission of Vessels in the BMR in the Year 2011

Unit: ton/year

Port		Liquid Bulk	Solid Bulk	Fully Cellular Container	Semi-Container	Ro-Ro	Conventional	Others	Total
Bangkok	Klong Toey Wharf		7	764	66	57	341	1	1,236
	Klong Toey Pole		10		0		82		93
	Bang Hua Suer Pole		7		2		48	0	57
	Sathupradit Buoy		59				81	2	141
	Tmn Wharf		3				8	2	13
	Private Wharves	463	146	334	31	16	436	21	1,448
	Others	8	4	4	2		8	1	27
Samut Sakhon	Mahachai	3	25				8	14	51
	Thachalom						1		1
	Others	10	5				11	20	46
Total		485	266	1,102	101	73	1,025	61	3,112

Table 4.3.2.13 SOx emission of Vessels in the BMR in the Year 2011

Unit: ton/year

Port		Liquid Bulk	Solid Bulk	Fully Cellular Container	Semi-Container	Ro-Ro	Conventional	Others	Total
Bangkok	Klong Toey Wharf		4	420	40	32	202	0	698
	Klong Toey Pole		6		0		49		55
	Bang Hua Suer Pole		4		1		29	0	34
	Sathupradit Buoy		35				48	1	84
	Tmn Wharf		2				5	1	8
	Private Wharves	242	88	184	18	9	258	14	813
	Others	4	2	2	1		5	1	15
Samut Sakhon	Mahachai	2	15				5	9	31
	Thachalom						1		1
	Others	5	3				6	13	27
Total		253	160	607	61	41	606	39	1,766

Table 4.3.2.14 Estimated NOx and SOx emission of Fishing Boats in the BMR in the Year 2011

Province	NOx Emission (ton/year)	SOx Emission (ton/year)
Bangkok	0	0
Samut Prakan	249	5
Samut Sakhon	198	4
Total	447	9

Table 4.3.2.15 Estimated NOx and SOx emission of Small Boats in the BMR in the Year 2011

Type of small boat	NOx Emission (ton/year)	SOx Emission (ton/year)
Express boat	71	71
Ferry boat	144	140
Long-tailed boat	142	3
Total	357	214