3.2.7

Emission Factors of Current Motor Vehicles

Emission factors of current motor vehicles were established from the results of the chassis dynamometer tests and published data in the USA and Japan. Five pollutants that are being considered are HC, CO, NOx, SOx and PM. SOx emission factor is calculated from the following formula which uses known fuel consumption (liters/km) and sulphur content in fuel (% wt).

$$SOx\ (g/km) = \text{fuel consumption rate}\ (\ell/km) \times \text{specific gravity}\ (g/m\ell) \times \text{sulphur content}\ (\%) \times \frac{\text{molecular weight of SO2}}{\text{molecular weight of S}} \times 1000\ (m\ell/\ell) \times 1/100$$

Selected values of specific gravity and sulphur content of petrol and diesel oil obtained from the fuel analyses are given in Table 1.

Table 1 Fuel Characteristics

Fuel Type	Specific Gravity	Sulphur Content (weight %)
Petrol	0.78	0.003
Diesel oil	0.85	0.323

PM emission factors are established for individual types of vehicle irrespective of their mileage. Vehicle speed is taken into consideration only on the emission factors for buses.
In Fig. 1 the procedure for obtaining the emission factors of current motor vehicles is shown.

(1) Classification of Vehicle Types and Engine Types

Based on RTD's annual statistical bulletin (#6006), the numbers of various types of registered vehicles in Kuala Lumpur and State of Selangor is shown in Table 2. Motor cars are assumed to petrol fuelled and buses to be diesel fuelled. Taxis are both petrol and diesel fuelled.

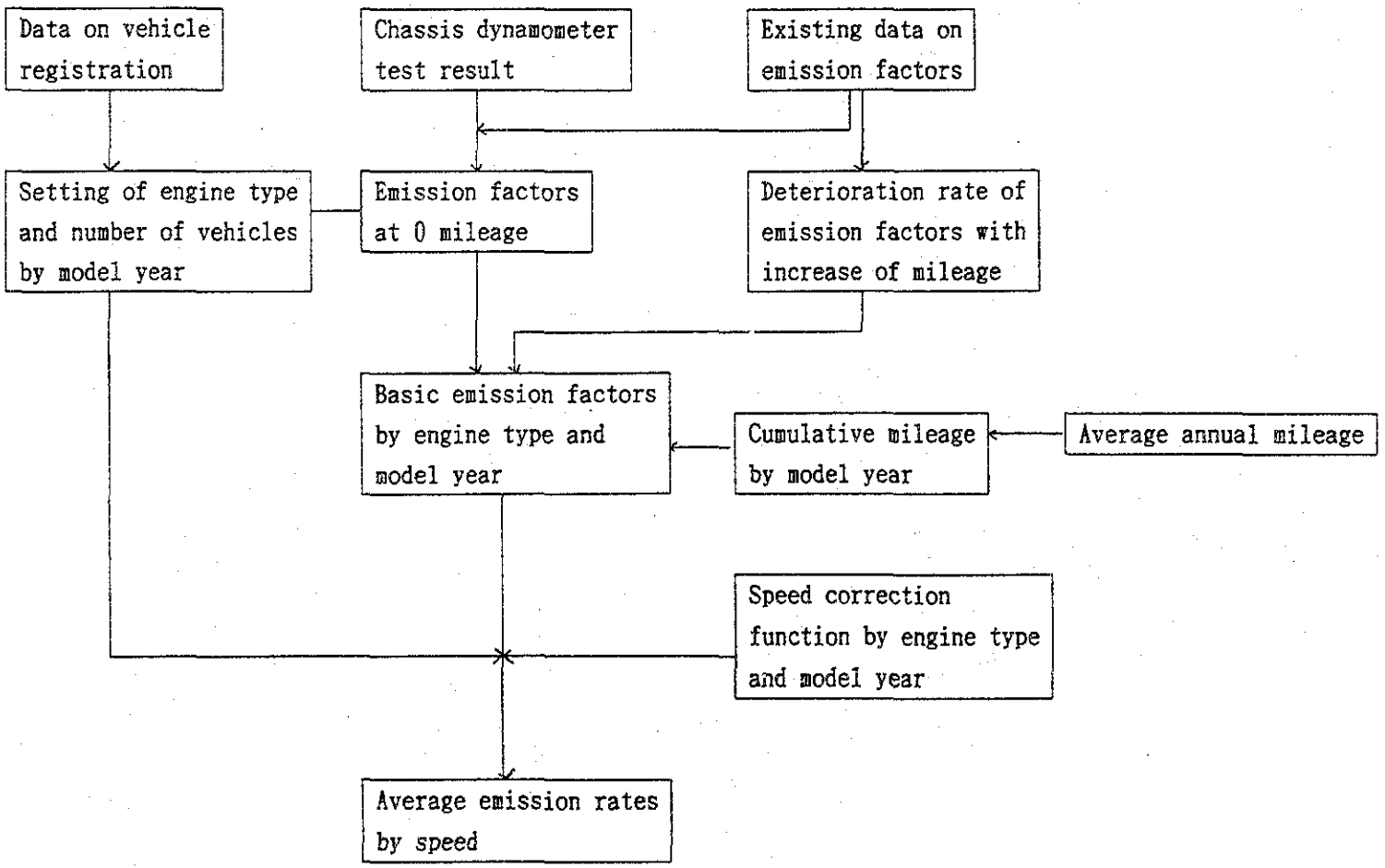


Fig. 1 Process of Setting Vehicular Emission Factors

Table 2 Number of Registered Vehicles in Kuala Lumpur and State of Selangor as at End of 1991

Vehicle Type	Petrol	Diesel	Total
Motorcycle	689036	0	689036
	(100.0)		(100.0)
Motor car	653207	17965	671172
	(97.3)	(2.7)	(100.0)
Taxi	5888	5682	11570
	(50.9)	(49.1)	(100.0)
Rental Car	2886	244	3130
	(92.2)	(7.8)	(100.0)
Bus	516	8031	8547
	(6.0)	(94.0)	(100.0)
Lorry	66118	57600	123718
	(53.4)	(46.6)	(100.0)
Others	8285	52844	61129
	(13.6)	(86.4)	(100.0)
Total	1425936	142366	1568302
	(90.9)	(9.1)	(100.0)

Source: RTD(#6006、1991)

The number of different types of vehicles registered in Peninsular Malaysia according to their engine type and capacity are shown in Table 3. Van consists of both petrol and diesel engine types.

Table 3 Number of Registered Vehicles in Peninsular Malaysia by Type, Engine and Engine Capacity (1986-1988)

Vehicle Type		Engine Capacity(c.c.)										
		-1000	1001-1500	1501-2000	2001-2500	2501-3000	3001-3500	3501-4000	4001-4500	4501-5000	5001-	Total
Motor Car	Petrol	6002	114716	24071	3978	1181	103	62	24	10	5	150152
	Diesel	4	30	180	845	69	11	3	1		6	1149
	Total	6006	114746	24251	4823	1250	114	65	25	10	11	151301
Van	Petrol	2354	16593	2404	241	29	3	11			7	21642
	Diesel	0	44	655	2648	353	39	30	1	1	65	3836
	Total	2354	16637	3059	2889	382	42	41	1	1	72	25478
Taxi	Petrol	12	308	25	3							348
	Diesel	1	5	593	523	3						1125
	Total	13	313	618	526	3						1473
Bus	Petrol		1	5	5	5		1				17
	Diesel			8	358	105	34	69	1	9	1525	2109
	Total		1	13	363	110	34	70	1	9	1525	2126
Truck	Petrol	393	303	1903	269	90	14	4	1		20	2997
	Diesel	235	54	295	5271	4160	294	157	25	18	1864	12373
	Total	628	357	2198	5540	4250	308	161	26	18	1884	15370

Source: Annual Statistical Bulletin, 1986-1988, RTD(#6006)

In Table 4 the number of motorcycles registered in Kuala Lumpur and State of Selangor from 1986 to 1988 according to engine capacity is shown. Motorcycles with engine capacity less than 100cc occupies around 73% of the total.

Table 4 Total Number of Registered Motorcycles by Engine Capacity
(Kuala Lumpur and State of Selangor, 1986-1988)

	Engine Capacity(c.c.)				
	- 75	76-100	101-250	250-	Total
Kuala Lumpur	2669	6162	2968	95	11894
Selangor	2620	9577	4556	57	16810
Total	5289	15739	7524	152	28704
(%)	18.4	54.9	26.2	0.5	(100.0)

Source: Annual Statistical Bulletin, 1987-1988, RTD(#6006)

Based on the above Tables 2, 3 and 4, in Table 5 is assigned engine types to nine types of vehicle surveyed for traffic volume. Light duty trucks are assumed to be petrol fuelled, and medium and heavy (or large) duty trucks are diesel fuelled. Engine capacity less than 5000cc is considered as medium truck and more than 5001cc is considered as the large truck. The ratio of medium and large trucks registered is given in Table 6. Table 7 shows the ratio of engine type for van and taxi obtained from values presented in Tables 2 and 3 respectively.

Table 5 Classification of Motor Vehicles by Engine Type

No.	Vehicle Type	Petrol	Diesel
1	Motorcycle	○	
2	Motor car	○	
3	Van	○	○
4	Taxi	○	○
5	Mini bus		○
6	Medium/Large bus		○
7	Small truck	○	
8	Medium		○
9	Large truck		○
10	Lorry/Trailer		○

Note Engine capacity
Medium truck; 5000cc or less
Large truck ; 5501cc or more

Table 6 Ratio of Medium and Large Trucks to the Total Number of Trucks

	Ratio
Medium Truck	0.849
Large Truck	0.151

Table 7 Ratio of Van and Taxi according to Their Engine Type

Engine Type	Van	Taxi
Petrol	0.849	0.509
Diesel	0.151	0.491

Table 8 was prepared using data from RTD's document (#6006) for the number of petrol fuelled taxis registered in Kuala Lumpur and State of Selangor from 1986 to 1991. Together with these data and the registered number of vehicles at the end of 1991 given in Table 2, the number of petrol taxis registered in different years is shown in Table 9.

Table 8 Registration of Petrol Taxi (1986-1991)
(Kuala Lumpur and State of Selangor)

Year	1986	1987	1988	1989	1990	1991	Total
Taxi	47	81	66	230	1020	917	2361

Source: Annual Statistical Bulletin, RTD(#6006)

Table 9 Ratio of Petrol Taxi by Registration Year Registered during Different Years

Registered Year	pre-1985	1986-1991
Taxi	0.599	0.401

(2) Number of Different Types of Vehicles Registered in Each Year

The vehicle emission factors depend on the year the vehicle was initially registered. Therefore, the number of vehicles registered each year must be estimated to calculate average emission factors for current vehicles.

According to RTD's Data, the number of vehicles initially registered from 1986 to 1991 in Kuala Lumpur and State of Selangor is shown in Table 10. Based on Tables 2 and 10, the total number of each vehicles registered from 1972 to 1985 is calculated as shown in Table 11. In Table 12 is given the total number of vehicles registerd between 1972 and 1991. The number of vehicles registered from 1972 to 1976 is obtained by taking the difference between the number of registered until 1991 and the number of vehicles registered from 1977 to 1991. It is assumed that between 1972 and 1976 equal number of vehicles were registered each year.

Table 10 Number of Newly registered Motor Vehicles by Type
(Kuala Lumpur and State of Selangor, 1986-1991)

Registered Year	Motorcycle	Motor Car	Bus	Goods Vehicles		Total
				Petrol	Diesel	
1986	23924	24585	396	4549	2438	57637
1987	13342	20222	325	1217	1574	37891
1988	16606	28919	278	1339	2303	51419
1989	32283	44745	371	2230	4579	88486
1990	46824	60470	454	3436	7486	126107
1991	53147	69230	636	3473	9709	143867
Total	186126	248171	2460	16244	28089	505407

Table 11 Total Number of Motor Vehicles Registered by Type and year

Year	Motorcycle	Motor Car	Bus	Goods Vehicles	Total
1972-1985	502910	423001	6087	79385	1062895
1986-1991	186126	248171	2460	73844	505407
Total	689036	671172	8547	123718	1568302

Table 12 Annual Total Number of Newly registered Motor Vehicles
(Kuala Lumpur and State of Selangor)

Registered Year	Total Number
1972	54254
1973	54255
1974	54255
1975	54255
1976	54255
Sub-total	271274
1977	55702
1978	67986
1979	70604
1980	98764
1981	100184
1982	100473
1983	107696
1984	104138
1985	86074
Sub-total	791621
1986-1991	505407
Total	1568302

1) Vehicles Registered before 1992

DOE's data (#5004) shows average life is 7 years for motorcycles, 5 years for taxis and 10 years for other types of vehicles. If motorcycles registered 14 years ago are condemned and other types of vehicles excluding taxis registered 20 years ago are condemned, then the registered number of each type of vehicles from 1972 to 1985 can be obtained by distributing the number registered by 1985 in Table 11 proportionally to the registered numbers between 1978 and 1985 for motorcycles and 1972 and 1985 for other types of vehicles excluding taxis in Table 12.

2) Vehicles Registered in 1992

Based on the previous study by JICA (#6007) and Table 2.2.2 in the Main Report, the annual growth rate of registered vehicles are set as shown in Table 13.

If motorcycles registered 14 years ago are condemned and other types of vehicles excluding taxis registered 20 years ago are condemned, then the registered number

of vehicles in 1992 could be calculated from the following equation.

$$Nv(t) = Tv(t-1) \times (t) + Nv(t-vl)$$

where;

t : year

Nv: number of registered vehicles

Tv: total number of registered vehicles

r : annual growth rate of number of vehicles

vl: vehicle life

14 for motorcycle

20 for other type of vehicles except for taxi

Thus, the total number of registered vehicles that will still be in use in the year 1992 according to their types and year first registered are calculated as shown in Table 14.

Table 13 Average Annual Growth Rate of Motor Vehicles

Vehicle Type	Average Annual Growth Rate 1985-1995	1996-2005
Motorcycle	2.6	2.6
Motor Car	6.8	6.2
Taxi	6.8	5.5
Goods Vehicles	5.1	5.1
Bus	2.6	2.6

Source; Table 2.2.2 in the Main Report for bus and motorcycle, (#6007) for others

Table 14 Number of Newly Registered Vehicles by Type
(1972-1992)

Year	Motorcycle	Motor Car	Bus	Goods Vehicles		
				Petrol	Diesel	Total
1972		21592	310	2546	1506	4052
1973		21592	311	2546	1506	4052
1974		21592	311	2546	1506	4052
1975		21592	311	2546	1506	4052
1976		21592	311	2546	1507	4053
1977		22168	319	2614	1547	4161
1978	46460	27056	389	3190	1888	5078
1979	48249	28098	404	3313	1960	5273
1980	67493	39305	566	4634	2742	7376
1981	68463	39870	574	4701	2782	7483
1982	68661	39985	575	4714	2790	7504
1983	73597	42860	617	5053	2990	8043
1984	71166	41444	596	4886	2891	7777
1985	58821	34255	493	4039	2390	6429
1986	23924	24585	396	4549	2438	6987
1987	13342	20222	325	1217	1574	2791
1988	16606	28919	278	1339	2303	3642
1989	32283	44745	371	2230	4579	6809
1990	46824	60470	454	3436	7486	10922
1991	53147	69230	636	3473	9709	13182
1992	64651	67232	536	5918	4444	10362

(3) Travelling Speed

The speed of vehicles has a close relation to the amount of emission. Generally at slower speed vehicles emit more HC, CO and SOx, and less NOx. This means there are differences in emission amount from a car on a crowded road and on a less crowded one. The average speeds in four zones , determined from the travel speed survey are listed in Table 15. The four zones are as follows.

Zone 1: Inside Inner Ring Road
Zone 2: Zone between Inner Ring Road and Middle Ring Road
Zone 3: Kuala Lumpur (outside of Middle Ring Road) and Petaling Jaya
Zone 4: Kelang Valley Region (outside of Kuala Lumpur and Petaling Jaya)

For expressways (Federal Highway, KL-Seremban Expressway and KL-Karal Highway), different speeds from general roads are set in Zone 4. Average speed of motorcycles was assumed to be 40 km/h or less.

Table 15 Classification of Regional Average Speed

(Unit: km/h)

		Weekdays				Holidays			
Time Zone		07-09	10-15	16-20	21-06	07-09	10-15	16-20	21-06
General Roads	Zone 1	20	20	15	20	35	25	25	35
	Zone 2	25	25	20	25	35	30	30	35
	Zone 3	30	35	25	35	45*	40	40	45*
	Zone 4	35	40	35	40	50*	45*	45*	50*
Express Way	Zone 4 F.H	40	50*	40	50*	60*	55*	55*	60*
	KL.S KL.K	50*	65*	50*	65*	65*	55*	55*	60*

*: Motorcycle : 40 km/h

Classification of Zone

Zone 1: Inside Inner Ring Road
Zone 2: Zone between Inner Ring Road and Middle Ring Road
Zone 3: Kuala Lumpur (outside of Middle Ring Road) and Petaling Jaya
Zone 4: Kelang Valley Region (outside of Kuala Lumpur and Petaling Jaya)

(4) Chassis Dynamometer Test

Thanks to PROTON, 17 petrol fuelled vehicles were tested for their exhaust emissions. The particulars of the tests were as follows.

a) Tested cars: Petrol fuelled
b) Fuel: Unleaded petrol
c) No. of cars: 17
d) Test modes: ECE mode (ECE), Japanese ten mode (J-10), Constant speed (60)
(Average speed) ECE (18.7 km/h), J-10 (17.8 km/h), 60 (60 km/h)
e) Measured: Emission factors of HC, CO and NOx and Fuel economy
f) Air conditioner: On/Off effects on emission factors for three cars out of 17.

1) Air Conditioner Off

The results of chassis dynamometer test with the air conditioner off are given in Table 16. The results for the ECE mode tests for engine capacities of 1500cc or less according to the model year are summarized in Table 17.

Table 17 Emission Rates of Motor Car by Model Year (ECE Mode)

Model Year	HC (g/km)	CO (g/km)	NOx (g/km)	Fuel Economy (km/ℓ)	Mileage (km)
1978	2.08	18.50	0.71	11.16	424672
1983	2.83	21.49	1.22	9.80	276417
1984	3.82	24.10	1.77	11.94	421328
1986	2.40	10.68	1.36	11.12	127546
1988	3.08	5.25	3.39	11.94	100276
1989	2.75	15.57	2.93	9.73	43115
1990	2.47	6.36	3.03	10.34	34573
1991	2.76	8.43	2.77	10.64	15037
1992	2.35	4.98	2.19	10.11	852

The emission factors are further arranged into three groups based on the year of manufacture (before 1985, 1986-1991 and 1992) and the results of this grouping are shown in Table 18.

Table 16 Chassis Dynamometer Test Result

Vehicle No.	Engine (cc)	Model Year	Mileage (km)	HC(g/km)			CO(g/km)			NOx(g/km)			Fuel Economy(km/l)			Vehicle Name
				ECE	10	60	ECE	10	60	ECE	10	60	ECE	10	60	
1	1300	1988	100276	3.08	3.43	0.17	5.25	6.03	0.45	3.39	3.53	3.49	11.94	11.99	22.05	PROTON SAGA
2	1300	1990	48261	2.75	3.28	0.17	5.67	6.62	0.42	3.83	3.65	3.50	10.52	11.20	20.58	PROTON SAGA
3	1500	1989	42440	2.86	3.35	0.86	15.80	17.27	3.39	3.90	4.01	3.97	9.83	10.11	18.24	PROTON SAGA
4	1000	1986	100404	2.19	2.35	0.63	11.99	10.34	5.46	1.39	1.28	1.13	12.42	12.42	27.79	CHARADE
5	1500	1992	977	2.26	3.01	0.68	4.50	5.01	0.34	2.66	2.77	2.88	10.34	10.44	18.97	ISWARA
6	1500	1983	186660	3.04	3.40	0.85	17.93	18.50	4.34	1.17	1.27	0.95	9.05	9.31	18.98	F. LASER
7	1400	1983	366173	2.61	2.56	1.02	25.04	24.76	13.93	1.27	1.61	1.48	10.75	10.78	16.55	M. TREDIA
8	1200	1978	424672	2.08	2.46	0.80	18.50	19.65	9.88	0.71	0.76	0.62	11.16	11.32	18.93	H. CIVIC
9	1500	1986	154688	2.61	3.09	0.61	9.37	11.79	2.54	1.33	1.39	1.05	9.82	9.42	21.12	PROTN SAGA
10	1800	1991	22113	0.77	0.77	0.04	4.79	5.26	0.22	1.30	1.48	0.85	7.49	7.09	13.03	RENAULT
11	1500	1990	20884	2.19	2.80	0.59	7.05	8.41	1.13	2.23	2.72	2.83	10.15	10.37	18.77	PROTON SAGA
12	2000	1987	70966	0.31	0.26	0.02	2.34	2.68	0.04	0.33	0.25	0.38	9.95	10.79	19.74	H. ACCCORD
13	1500	1989	43789	2.63	3.43	0.81	15.34	16.45	3.11	1.96	2.00	1.86	9.63	11.69	25.51	PROTON SAGA
14	1000	1984	421328	3.82	3.72	0.88	24.10	18.48	9.97	1.77	2.12	0.77	11.94	14.67	28.59	CHARADE
15	1500	1991	15037	2.76	3.37	0.86	8.43	8.88	0.94	2.77	2.99	3.21	10.64	12.80	25.81	PROTON SAGA
16	1500	1992	80	2.36	2.96	0.67	3.34	3.87	0.49	1.23	1.33	1.21	9.86	10.29	18.97	PROTON ISWARA
17	1500	1992	1500	2.42	3.13	0.72	7.09	7.64	0.82	2.69	2.79	3.04	10.14	10.54	24.56	PROTON SAGA

Engine Capacity: less than 1500cc

Vehicle No.	Engine (cc)	Model Year	Mileage (km)	HC(g/km)			CO(g/km)			NOx(g/km)			Fuel Economy(km/l)			Vehicle Name
				ECE	10	60	ECE	10	60	ECE	10	60	ECE	10	60	
8	1200	1978	424672	2.08	2.46	0.80	18.50	19.65	9.88	0.71	0.76	0.62	11.16	11.32	18.93	H. CIVIC
7	1400	1983	366173	2.61	2.56	1.02	25.04	24.76	13.93	1.27	1.61	1.48	10.75	10.78	16.55	M. TREDIA
14	1000	1984	421328	3.82	3.72	0.88	24.10	18.48	9.97	1.77	2.12	0.77	11.94	14.67	28.59	CHARADE
4	1000	1986	100404	2.19	2.35	0.63	11.99	10.34	5.46	1.39	1.28	1.13	12.42	12.42	27.79	CHARADE
1	1300	1988	100276	3.08	3.43	0.17	5.25	6.03	0.45	3.39	3.53	3.49	11.94	11.99	22.05	PROTON SAGA
2	1300	1990	48261	2.75	3.28	0.17	5.67	6.62	0.42	3.83	3.65	3.50	10.52	11.20	20.58	PROTON SAGA

Engine Capacity: 1500cc

Vehicle No.	Engine (cc)	Model Year	Mileage (km)	HC(g/km)			CO(g/km)			NOx(g/km)			Fuel Economy(km/l)			Vehicle Name
				ECE	10	60	ECE	10	60	ECE	10	60	ECE	10	60	
6	1500	1983	186660	3.04	3.40	0.85	17.93	18.50	4.34	1.17	1.27	0.95	9.05	9.31	18.98	F. LASER
9	1500	1986	154688	2.61	3.09	0.61	9.37	11.79	2.54	1.33	1.39	1.05	9.82	9.42	21.12	PROTON SAGA
3	1500	1989	42440	2.86	3.35	0.86	15.80	17.27	3.39	3.90	4.01	3.97	9.83	10.11	18.24	PROTON SAGA
13	1500	1989	43789	2.63	3.43	0.81	15.34	16.45	3.11	1.96	2.00	1.86	9.63	11.69	25.51	PROTON SAGA
11	1500	1990	20884	2.19	2.80	0.59	7.05	8.41	1.13	2.23	2.72	2.83	10.15	10.37	18.77	PROTON SAGA
15	1500	1991	15037	2.76	3.37	0.86	8.43	8.88	0.94	2.77	2.99	3.21	10.64	12.80	25.81	PROTON SAGA
17	1500	1992	1500	2.42	3.13	0.72	7.09	7.64	0.82	2.69	2.79	3.04	10.14	10.54	24.56	PROTON SAGA
5	1500	1992	977	2.26	3.01	0.68	4.50	5.01	0.34	2.66	2.77	2.88	10.34	10.44	18.97	PROTON ISWARA
16	1500	1992	80	2.36	2.96	0.67	3.34	3.87	0.49	1.23	1.33	1.21	9.86	10.29	18.97	PROTON ISWARA

Engine Capacity: more than 1500cc

Vehicle No.	Engine (cc)	Model Year	Mileage (km)	HC(g/km)			CO(g/km)			NOx(g/km)			Fuel Economy(km/l)			Vehicle Name
				ECE	10	60	ECE	10	60	ECE	10	60	ECE	10	60	
12	2000	1987	70966	0.31	0.26	0.02	2.34	2.68	0.04	0.33	0.25	0.38	9.95	10.79	19.74	H. ACCCORD
10	1800	1991	22113	0.77	0.77	0.04	4.79	5.26	0.22	1.30	1.48	0.85	7.49	7.09	13.03	RENAULT

Table 18 Average Emission Rates of Motor Car by Model Year

Model Year	HC (g/km)	CO (g/km)	NOx (g/km)	Fuel Economy (km/ℓ)	Cumulative Mileage (km)
~ 1985	2.91	21.36	1.23	10.97	374139
1986 ~ 1991	2.69	9.26	2.70	10.75	64109
1992	2.35	4.98	2.19	10.11	852

2) Cumulative Mileage and Emission Factors

Cars tend to emit more pollutants with more mileage. Table 19 was taken from the compilation by US EPA (#5008) for the mileage deterioration rates that need to be added to the factor 1.0 of the new car. Although the rate for HC shown in the table is 0.031, around 10% of it, i.e. 0.003, seems appropriate judging from the data given in Table 18. Thus, the deterioration rates in Malaysia are established as shown in Table 20. The emission factors of new cars shipped directly from factories in the past are obtained as shown in Table 21 by using the deterioration rates given in Table 20.

Table 19 Deterioration Rate of Emission Factors with Cumulative Mileage (Motor Car)

Pollutant	Deterioration Rate per 10000 km	Note
HC	0.031	LDGV
CO	0.037	1972-1974
NOx	0.0	

Source: U.S.EPA(#5008)

Table 20 Deterioration Rate of Emission Factors with Cumulative Mileage in Malaysia (motor car)

Pollutant	Deterioration Rate per 10000 km
HC	0.003
CO	0.037
NOx	0.0

Table 21 Emission Factors for Motor Car
(zero mileage)

Model Year	pre-1985	1986-1991	1992
HC	2.62	2.64	2.35
CO	8.96	7.49	4.96
NOx	1.23	2.70	2.19

3) Effects of Air Conditioners

Effects of keeping air conditioners on to the emission factors were analyzed with three cars. The results of this test are given in Tables 22 and 23, and a summary of keeping the air conditioner on is as follows;

HC: no change
CO: 15% increase
NOx: 30% increase
Fuel economy: 10% decrease

Table 22 Influence of Air-conditioning on Emission Factors

Item	Vehicle No.	13			14			15		
	Mode	ECE	J-10	60	ECE	J-10	60	ECE	J-10	60
HC	Off(g/km)	2.63	3.43	0.81	3.82	3.72	0.88	2.76	3.37	0.86
	On (g/km)	2.35	2.85	0.85	3.40	3.92	0.89	2.18	2.88	1.02
	Change(%)	-10.6	-16.9	4.9	-11.0	5.4	1.1	-21.0	-14.5	18.6
CO	Off(g/km)	15.34	16.45	3.11	24.10	18.48	9.97	8.43	8.88	0.94
	On (g/km)	16.46	18.56	3.91	21.93	17.80	10.21	10.19	13.12	1.38
	Change(%)	7.3	12.8	25.7	-9.0	-3.7	2.4	20.9	47.7	46.8
NOx	Off(g/km)	1.96	2.00	1.86	1.77	2.12	0.77	2.77	2.99	3.21
	On (g/km)	2.59	2.63	2.45	2.74	2.99	0.94	1.86	4.26	3.94
	Change(%)	32.1	31.5	31.7	54.8	41.0	22.1	-32.9	42.5	22.7
Fuel	Off(km/ℓ)	9.63	11.69	25.51	11.94	14.67	28.59	10.64	12.80	25.81
Economy	On (km/ℓ)	8.61	10.52	23.56	10.65	13.35	26.82	8.89	10.59	22.60
	Change(%)	-10.6	-10.0	-7.6	-10.8	-9.0	-6.2	-16.4	-17.3	-12.4

Table 23 Change of Emission Rates by Air-conditioning

Vehicle No.		13	14	15	Ave.
HC	ECE	-10.6	-11.0	-21.0	-14.2
(%)	J-10	-16.9	5.4	-14.5	-8.7
	60	4.9	1.1	18.6	8.2
	Ave.	-7.5	-1.5	-5.6	-4.9
CO	ECE	7.3	-9.0	20.9	6.4
(%)	J-10	12.8	-3.7	47.7	18.9
	60	25.7	2.4	46.8	25.0
	Ave.	15.3	-3.4	38.5	16.8
NOx	ECE	32.1	54.8	-32.9	18.0
(%)	J-10	31.5	41.0	42.5	38.4
	60	31.7	22.1	22.7	25.5
	Ave.	31.8	39.3	10.4	27.2
Fuel	ECE	-10.6	-10.8	-16.4	-12.6
Economy	J-10	-10.0	-9.0	-17.3	-12.1
(%)	60	-7.6	-6.2	-12.4	-8.7
	Ave.	-9.4	-8.7	-15.4	-11.1

(5) Annual Mileage and Cumulative Mileage

Because of differences in emission factors by model years, it is necessary to organize contributions of annual mileages (travel fractions) in order to calculate average emission factors. For each types of vehicles the travel fractions can be calculated from the vehicle compositions by registration years and annual mileages.

In Table 24 the average life and annual mileage covered by different types of vehicles cited from DOE documents (#5004) is presented.

Table 24 Average Life and Annual Mileage by Various Types of Vehicles

Vehicle Type	Average Life (Year)	Annual Mileage (x1000 Km/year)
Motorcycle	7	11.27
Private Car	10	19.32
Taxi	5	96.60
Bus	10	104.65
Van & Lorry	10	48.30

Source: PEMBAKARAN BAHANAPI PUNCA BERGERAK, DOE(#5009)

By assuming no change of annual mileages by model years, motorcycles first registered in 1978 and 1992 and other types of vehicles (excluding taxis) registered in 1972 and 1992 travel in 1992 in average on the half distance of those registered in the intermediate years. By employing the value of the petrol goods vehicles in Table 14 for those of petrol fuelled vans and small trucks and also the value of diesel goods vehicles in the table for those of diesel fuelled vans, medium and large trucks, lorries and trailers, travel fractions for each type of vehicles according to registration year are calculated as shown in Tables 25(1) to 25(5).

Cumulative mileages given in these tables are obtained from annual mileages of vehicles by types shown in Table 24. For taxis, average life of petrol engine cars is assumed to be 7 years for those registered before 1986 and 3 years for those registered in 1986 and after. For diesel taxis, their average life is assumed to be 5 years (Table 25(6)). As the travel fractions for petrol taxis according to registration years, the ratios in Table 9 were used.

Table 25(1) Travel Weighting Fraction Calculation and Cumulative mileage for Motorcycle

Model Years	Fleet Registration (A)	Annual mileage (1979~1991:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1978	0.0616	0.5	0.0333	154.96	13.75
1979	0.0640	1	0.0691	146.51	13
1980	0.0896	1	0.0967	135.24	12
1981	0.0908	1	0.0981	123.97	11
1982	0.0911	1	0.0983	112.70	10
1983	0.0976	1	0.1054	101.43	9
1984	0.0944	1	0.1019	90.16	8
1985	0.0780	1	0.0843	78.89	7
1986	0.0317	1	0.0343	67.62	6
1987	0.0177	1	0.0191	56.35	5
1988	0.0220	1	0.0238	45.08	4
1989	0.0428	1	0.0462	33.81	3
1990	0.0621	1	0.0671	22.54	2
1991	0.0705	1	0.0761	11.27	1
1992	0.0858	0.5	0.0463	2.82	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 25(2) Travel Weighting Fraction Calculation and Cumulative Mileage for Motor Car

Model Years	Fleet Registration (A)	Annual mileage (1973~1991:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1972	0.0292	0.5	0.0156	381.57	19.75
1973	0.0292	1	0.0311	367.08	19
1973	0.0292	1	0.0311	347.76	18
1975	0.0292	1	0.0311	328.44	17
1976	0.0292	1	0.0311	309.12	16
1977	0.0300	1	0.0319	289.80	15
1978	0.0366	1	0.0390	270.48	14
1979	0.0381	1	0.0405	251.16	13
1980	0.0532	1	0.0566	231.84	12
1981	0.0540	1	0.0575	212.52	11
1982	0.0542	1	0.0576	193.20	10
1983	0.0580	1	0.0618	173.88	9
1984	0.0561	1	0.0597	154.56	8
1985	0.0464	1	0.0494	135.24	7
1986	0.0333	1	0.0354	115.92	6
1987	0.0274	1	0.0291	96.60	5
1988	0.0392	1	0.0417	77.28	4
1989	0.0606	1	0.0645	57.96	3
1990	0.0819	1	0.0871	38.64	2
1991	0.0938	1	0.0998	19.32	1
1992	0.0911	0.5	0.0484	4.83	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 25(3) Travel Weighting Fraction Calculation and Cumulative Mileage for Mini Bus, Medium/Large Bus

Model Years	Fleet Registration (A)	Annual mileage (1973~1991:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1972	0.0341	0.5	0.0179	2066.84	19.75
1973	0.0342	1	0.0359	1988.35	19
1973	0.0342	1	0.0359	1883.70	18
1975	0.0342	1	0.0359	1779.05	17
1976	0.0342	1	0.0359	1674.40	16
1977	0.0351	1	0.0368	1569.75	15
1978	0.0428	1	0.0449	1465.10	14
1979	0.0445	1	0.0467	1360.45	13
1980	0.0623	1	0.0654	1255.80	12
1981	0.0632	1	0.0663	1151.15	11
1982	0.0633	1	0.0664	1046.50	10
1983	0.0679	1	0.0712	941.85	9
1984	0.0656	1	0.0688	837.20	8
1985	0.0543	1	0.0569	732.55	7
1986	0.0436	1	0.0457	627.90	6
1987	0.0358	1	0.0375	523.25	5
1988	0.0306	1	0.0321	418.60	4
1989	0.0408	1	0.0428	313.95	3
1990	0.0500	1	0.0524	209.30	2
1991	0.0700	1	0.0734	104.65	1
1992	0.0590	0.5	0.0309	26.16	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 25(4) Travel Weighting Fraction Calculation and Cumulative Mileage for Petrol Van and Small Truck

Model Years	Fleet Registration (A)	Annual mileage (1973~1991:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1972	0.0353	0.5	0.0188	953.93	19.75
1973	0.0353	1	0.0375	917.70	19
1973	0.0353	1	0.0375	869.40	18
1975	0.0353	1	0.0375	821.10	17
1976	0.0353	1	0.0375	772.80	16
1977	0.0363	1	0.0386	724.50	15
1978	0.0443	1	0.0470	676.20	14
1979	0.0460	1	0.0489	627.90	13
1980	0.0643	1	0.0683	579.60	12
1981	0.0653	1	0.0693	531.30	11
1982	0.0654	1	0.0695	483.00	10
1983	0.0701	1	0.0745	434.70	9
1984	0.0678	1	0.0721	386.40	8
1985	0.0561	1	0.0596	338.10	7
1986	0.0631	1	0.0671	289.80	6
1987	0.0169	1	0.0179	241.50	5
1988	0.0186	1	0.0197	193.20	4
1989	0.0310	1	0.0329	144.90	3
1990	0.0477	1	0.0507	96.60	2
1991	0.0482	1	0.0512	48.30	1
1992	0.0822	0.5	0.0436	12.08	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 25(5) Travel Weighting Fraction Calculation and Cumulative Mileage for Diesel Van, Medium/Large Truck and Lorry/Trailer

Model Years	Fleet Registration (A)	Annual mileage (1973~1991:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1972	0.0243	0.5	0.0127	953.93	19.75
1973	0.0243	1	0.0255	917.70	19
1973	0.0243	1	0.0255	869.40	18
1975	0.0243	1	0.0255	821.10	17
1976	0.0243	1	0.0255	772.80	16
1977	0.0249	1	0.0262	724.50	15
1978	0.0304	1	0.0320	676.20	14
1979	0.0316	1	0.0332	627.90	13
1980	0.0442	1	0.0464	579.60	12
1981	0.0448	1	0.0471	531.30	11
1982	0.0450	1	0.0472	483.00	10
1983	0.0482	1	0.0506	434.70	9
1984	0.0466	1	0.0489	386.40	8
1985	0.0385	1	0.0405	338.10	7
1986	0.0393	1	0.0413	289.80	6
1987	0.0254	1	0.0266	241.50	5
1988	0.0371	1	0.0390	193.20	4
1989	0.0738	1	0.0775	144.90	3
1990	0.1207	1	0.1267	96.60	2
1991	0.1565	1	0.1644	48.30	1
1992	0.0716	0.5	0.0376	12.08	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 25(6) Travel Weighting Fraction Calculation and Cumulative Mileage for Taxi

Engine Type	Model Year	Travel Fraction	Cumulative Mileage (1000km)	Average Age
Petrol	-1985	0.599	676.2	7
	1986-1992	0.401	289.8	3
Diesel	-	1.0	483.0	5

(6) Emission Factors for New Vehicles

Using the chassis dynamometer test results, and data in USA and Japan, emission factors for HC, CO and NOx and fuel consumption rates for new vehicles (at 0 mileage) were established as shown in Table 26. With emission factors for motor cars registered in 1986 and after, they were divided into two groups; Proton cars and other cars. The share of Proton according to registered years is given in Table 27.

Table 27 Share of Proton in Motor Car Sales in Malaysia

	1986-1991	1992
Proton's share	0.557	0.593

Source: Proton

(7) Deterioration of Emission Factor with Cumulative Mileage

Using the chassis dynamometer test results and data from the US EPA (#5008), the mileage deterioration rates of emission factors for HC, CO and NOx that has to be added to the factor 1.0 of the new car was established and is given in Table 28. No deterioration with increase of mileage is assumed on fuel consumption rate.

Table 28 Deterioration Rate of Emission Factors with Increase of Cumulative Mileage

Engine Type	Vehicle Type	Pollutant	Deterioration Rate per 10000 km	Note
Petrol	Motorcycle	HC	0.054	Motorcycle
		CO	0.045	Pre-1978
		NOx	0.186	
	Motor Car	HC	0.003	Chassis Dynamometer Test
	Van	CO	0.037	LDGV
	Taxi	NOx	0.0	1972-1974
	Small Truck	HC	0.031	LDGT1
		CO	0.037	1972
		NOx	0.0	
Diesel	Van	HC	0.038	LDDV
	Taxi	CO	0.030	Pre-1975
	Mini Bus	NOx	0.017	
	Medium Truck	HC	0.058	LDDT
		CO	0.032	Pre-1978
		NOx	0.027	
	Medium/large Bus	HC	0.009	HDDV
	Large Truck	CO	0.009	1972-1974
	Lorry/Trailer	NOx	0.0	

Note Emission factor of 0 mileage is assumed to be 1.
No deterioration was assumed for fuel consumption rate.

Source: COMPILATION OF AIR POLLUTANT EMISSION FACTORS, VOL. II Mobile Sources, U.S. EPA, 1985(#5008)

Table 26 Current Emission Factors and Fuel Consumption Rates for Motor Vehicles
(at 0 mileage)

Vehicle Type	Fuel	Model Year	Item	Emission Factor	Base Speed	Source
Motorcycle	Petrol	78-92	HC	9.9		U.S. EPA(#5007)
			CO	17.0		
			NOx	0.075	31.5	
			FC	0.04		
Motor Car	Petrol	72-85	HC	2.62		Chassis dynamometer test
			CO	19.82		Japan(#5010), motor car(uncontrolled)
			NOx	1.23	18.7	Chassis dynamometer test
			FC	0.091		
		86-92 Proton	HC	2.64		
			CO	7.49		
			NOx	2.70	18.7	Chassis dynamometer test
			FC	0.093		
		86-92 Others	HC	2.62		Chassis dynamometer test
			CO	19.82		Japan(#5010), motor car(uncontrolled)
			NOx	1.23	18.7	Chassis dynamometer test
			FC	0.091		
Van	Petrol	72-92	HC	2.07		
			CO	19.73		
			NOx	3.06	18.7	Japan(#5010), LDGT(uncontrolled)
			FC	0.13		
	Diesel	72-92	HC	0.81		U.S. EPA(#5008)
			CO	1.68		LDDV, pre-1975
			NOx	0.91	31.5	
			FC	0.10		U.S. EPA(#5007), LDDV
Taxi	Petrol	72-85	HC	2.62		Chassis dynamometer test
			CO	19.82		Japan(#5010), motor car(uncontrolled)
			NOx	1.23	18.7	Chassis dynamometer test
			FC	0.091		
		86-92	HC	2.64		
			CO	7.49		
			NOx	2.70	18.7	Chassis dynamometer test
			FC	0.093		
	Diesel	72-92	HC	0.29		
			CO	1.1		U.S. EPA(#5008)
			NOx	0.99	31.5	LDDV, pre-1973
			FC	0.10		U.S. EPA(#5007), LDDV
Mini Bus	Diesel	72-92	HC	0.78		U.S. EPA(#5008)
			CO	1.54		LDDT, pre-1972
			NOx	1.39	31.5	
			FC	0.23		SAE(#5012)
Medium/Large Bus	Diesel	72-92	HC	2.63		U.S. EPA(#5008)
			CO	7.62	31.3	HDDV, pre-1972
			NOx	15.87		
			FC	0.50	29.0	U.S. EPA(#5007), HDDV
Small Truck	Petrol	72-92	HC	2.07		
			CO	19.73		
			NOx	3.06	18.7	Japan(#5010), LDGT(uncontrolled)
			FC	0.13		
Medium Truck	Diesel	72-92	HC	0.78		U.S. EPA(#5008)
			CO	1.54		LDDT, pre-1972
			NOx	1.39	31.5	
			FC	0.23		SAE(#5012)
Large Truck	Diesel	72-92	HC	2.63		U.S. EPA(#5008)
			CO	7.62	31.3	HDDV, pre-1972
			NOx	15.87		
			FC	0.50	29.0	U.S. EPA(#5007), HDDV
Lorry/Trailer	Diesel	72-92	HC	2.63		U.S. EPA(#5008)
			CO	7.62	31.3	HDDV, pre-1972
			NOx	15.87		
			FC	0.50	29.0	U.S. EPA(#5007), HDDV

Note FC: Fuel consumption rate
Unit HC, CO, NOx : g/km
FC : liter/km
Base speed : km/h

(8) Establishment of Basic Emission Factors

Basic emission factors for different types of vehicles and engines (Table 29) were obtained using the emission factors for new vehicles (Table 26), cumulative mileages of different types of vehicles (Table 25), deterioration rates of emission factors (Table 28) and share of Proton in sales of motor cars (Table 27). The following is the equation to calculate the basic emission factors.

$$BEf = Ef \times (1 + r \times Cm)$$

where:

BEf: basic emission factor

Ef : emission factor at 0 mileage

r : deterioration rate

Cm : cumulative mileage

Table 29(1) Current Basic Emission Factors for Petrol Vehicles (HC, CO, NOx and SOx)

Vehicle Type	Model Years	Item	Emission Factor	Base Speed	Travel Fraction	Average Cumulative Mileage(1000 km/unit)
Motorcycle	1978-1992	HC	14.54	31.5	1.0	87
		CO	23.63			
		NOx	0.20			
		SOx	0.002			
Motor Car	1972-1985	HC	2.81	18.7	0.594	238
		CO	37.24			
		NOx	1.23			
		SOx	0.004			
	1986-1991	HC	2.67	18.7	0.358	54
		CO	15.52			
		NOx	2.05			
		SOx	0.004			
	1992	HC	2.64	18.7	0.048	5
		CO	12.73			
		NOx	2.10			
		SOx	0.004			
Van	1972-1992	HC	2.36	18.7	1.0	466
		CO	35.75			
		NOx	3.06			
		SOx	0.006			
Taxi	1972-1985	HC	3.15	18.7	1.0	676
		CO	69.41			
		NOx	1.23			
		SOx	0.004			
	1986-1992	HC	2.87	18.7	1.0	290
		CO	15.52			
		NOx	2.70			
		SOx	0.004			
Small Truck	1972-1992	HC	5.06	18.7	1.0	466
		CO	53.75			
		NOx	3.06			
		SOx	0.006			

Unit HC, CO, NOx: g/km
Base speed : km/h

Table 29(2) Basic Emission Factors for Diesel Vehicles
(HC, CO, NOx and SOx)

Vehicle Type	Model Years	Item	Emission Factor	Base Speed	Travel Fraction	Average Cumulative Mileage(1000 km/unit)
Van	1972-1992	HC	1.88			
		CO	3.43	31.5	1.0	347
		NOx	1.55			
		SOx	0.549			
Taxi	1972-1992	HC	0.82			
		CO	2.69	31.5	1.0	483
		NOx	1.80			
		SOx	0.549			
Mini Bus	1972-1992	HC	3.67			
		CO	6.05	31.5	1.0	976
		NOx	3.70			
		SOx	1.263			
Medium/Large Bus	1972-1992	HC	4.94			
		CO	14.31	31.3	1.0	976
		NOx	15.87			
		SOx	2.745	29.0		
Medium Truck	1972-1992	HC	2.35			
		CO	3.25	31.5	1.0	347
		NOx	2.69			
		SOx	1.263	29.0		
Large Truck Lorry/Trailer	1972-1992	HC	3.45			
		CO	10.00	31.5	1.0	347
		NOx	15.87			
		SOx	2.745	29.0		

Unit HC, CO, NOx: g/km
Base speed : km/h

(9) Average Speed and Emission Factors

Emission rate from a car changes with its speed. The change can be calculated by using equations given in Tables 30(1) and (2). Equations with separate correction factor coefficients according to vehicle type and engine type were derived using published data in the USA and Japan (#5008, #5010).
Using the equation, the relation between the vehicle speed and emission rate is expressed in the following equation;

$$Ef(v2) = Ef(v1) \times sf(v2) / Sf(v1)$$

where:

v1, v2: average speed

Ef(v) : emission factor at speed (v)

Emission factors for petrol and diesel vehicles given in Tables 31(1) and (2) were calculated using these informations; ratio of medium and large trucks (Table 6), ratio of petrol taxi registered in different years (Table 9), basic emission factors and travel fractions (Table 29) and speed correction equations (Table 30).

(10) Average Emission Factors

Table 30(1) Speed Correction Factor Coefficients for Petrol Vehicles
(HC, CO, NOx and SOx)

$SF(s) = Exp(a + b*s + c*s^2 + d*s^3 + e*s^4 + f*s^5)$ for HC and CO

$SF(s) = a + b*s + c*s^2 + d*s^3 + e*s^4 + f*s^5$ for NOx

$SF(s) = a/s + b$ for SOx

Vehicle Type		a	b	c	d	e	f	Note
Motorcycle	HC	0.231026E 1	-0.289572E 0	0.152990E-1	-0.446689E-3	0.648183E-5	-0.363456E-7	pre-1978
	CO	0.233989E 1	-0.296978E 0	0.160071E-1	-0.477396E-3	0.706752E-5	-0.403978E-7	
	NOx	0.168635E 1	-0.118303E 0	0.654975E-2	-0.137139E-3	0.100849E-5	0.0	
	SOx	0.620800E 0	0.439100E-1					
Motor Car	HC	0.268382E 1	-0.344633E 0	0.195417E-1	-0.625720E-3	0.978442E-5	-0.583369E-7	LDGV
	CO	0.283929E 1	-0.368756E 0	0.210782E-1	-0.676438E-3	0.106267E-4	-0.636405E-7	1973-1974
	NOx	0.783838E 0	0.328549E-3	0.106029E-2	-0.319350E-4	0.290389E-6	0.0	
	SOx	0.725200E 0	0.615200E-1					
Van	HC	0.268382E 1	-0.344633E 0	0.195417E-1	-0.625720E-3	0.978442E-5	-0.583369E-7	LDGV
	CO	0.283929E 1	-0.368756E 0	0.210782E-1	-0.676438E-3	0.106267E-4	-0.636405E-7	1973-1974
	NOx	0.783838E 0	0.328549E-3	0.106029E-2	-0.319350E-4	0.290389E-6	0.0	
	SOx	0.725200E 0	0.615200E-1					
Taxi	HC	0.268382E 1	-0.344633E 0	0.195417E-1	-0.625720E-3	0.978442E-5	-0.583369E-7	LDGV
	CO	0.283929E 1	-0.368756E 0	0.210782E-1	-0.676438E-3	0.106267E-4	-0.636405E-7	1973-1974
	NOx	0.783838E 0	0.328549E-3	0.106029E-2	-0.319350E-4	0.290389E-6	0.0	
	SOx	0.725200E 0	0.615200E-1					
Small Truck	HC	0.239540E 1	-0.335781E 0	0.211609E-1	-0.731550E-3	0.120715E-4	-0.748566E-7	LDGT1
	CO	0.248747E 1	-0.391562E 0	0.270721E-1	-0.976178E-3	0.165270E-4	-0.104317E-6	1972
	NOx	0.942131E 0	-0.423240E-1	0.386253E-2	-0.939853E-4	0.753883E-6	0.0	
	SOx	0.769500E 0	0.761500E-1					

Where :

s = average speed(mph for HC, CO and NOx, km/h for SOx)

For motorcycle, the speed correction factor coefficients for SOx is that of small motor car.

Source: U.S.EPA(#5008) for HC, CO and NOx and Tokyo Metropolitan Government(#5010) for SOx

Table 30(2) Speed Correction Factor Coefifcients for Diesel Vehicles
(HC, CO, NOx and SOx)

$SF(s) = Exp(a + b*s + c*s^2)$ for HC, CO and NOx
$SF(s) = a/s + b$ for SOx

Vehicle Type		a	b	c	Note
Van	HC	0.90900	-0.05500	0.00044	LDDV
	CO	1.37520	-0.08800	0.00091	pre-1975
	NOx	0.66800	-0.04800	0.00071	
	SOx	1.35500	0.08848		
Taxi	HC	0.90900	-0.05500	0.00044	LDDV
	CO	1.37520	-0.08800	0.00091	pre-1975
	NOx	0.66800	-0.04800	0.00071	
	SOx	1.35500	0.08848		
Mini Bus	HC	0.90900	-0.05500	0.00044	LDDV
	CO	1.37520	-0.08800	0.00091	pre-1975
	NOx	0.66800	-0.04800	0.00071	
	SOx	1.28000	0.18280		
Medium/Large	HC	0.92400	-0.05500	0.00044	HDDV
Bus	CO	1.39600	-0.08800	0.00091	
	NOx	0.67600	-0.04800	0.00071	
	SOx	1.28000	0.18280		
Medium Truck	HC	0.90900	-0.05500	0.00044	HDDV
	CO	1.37520	-0.08800	0.00091	
	NOx	0.66800	-0.04800	0.00071	
	SOx	1.14500	0.16360		
Large Truck	HC	0.92400	-0.05500	0.00044	HDDV
	CO	1.39600	-0.08800	0.00091	
	NOx	0.67600	-0.04800	0.00071	
	SOx	1.14500	0.16360		
Lorry/Trailer	HC	0.92400	-0.05500	0.00044	HDDV
	CO	1.39600	-0.08800	0.00091	
	NOx	0.67600	-0.04800	0.00071	
	SOx	1.14500	0.16360		

Where :
s = average speed(mph for HC, CO and NOx, km/h for SOx)

Source: U.S.EPA(#5008) and Tokyo Metropolitan Government(#5010)

Average emission factors for various types of vehicles operating in KVR are given in Table 32. This was derived from engine type ratios for different types of vehicles (Tables 2 and 7) and emission factors for petrol and diesel vehicles (Table 31).

(11) PM Emission Factors

PM emission factors were assumed to be independent of cumulative mileage. Effect of speed change on PM emission rate was taken into consideration only for buses which have sharp accelerations and decelerations.

The PM emission factors set by the U.S.EPA (#5008) for various types of vehicles is summarized in Table 33.

The U.S.EPA's report (#5013) shows differences in PM emission rates between trailers and large buses (Table 34). PM emission factor for medium/large buses at 15 km/h and 25 km/h and more is set by multiplying PM emission rate for bus at 14.1 km/h and 30.1km/h by 1.389/1.209 (PM emission factor ratio for lorry/trailer in Table 33 to that in Table 34) respectively. PM emission factor for medium/large buses at 20 km/h is the average of those at 15km/h and 25 km/h. PM emission factors for mini buses are calculated by multiplying those for medium/large buses by 0.497/1.389 (the ratio of PM emission factor for medium truck to that for lorry/trailer). PM emission rates for buses are given in Table 35.

Average PM emission factors shown in Table 36 are derived from ratios of medium and large trucks (Table 6), engine type ratios for vans and taxis (Table 7) and PM emission factors in Tables 33 and 35.

Table 33 An Example of Average Particulate Emission Factors for Motor Vehicles

Vehicle Type	PM Emission Factor (g/km)	Note
Motorcycle	0.205	2 stroke
Motor Car	0.043	LDGV, 1970-1974
Van (petrol)	0.043	ditto
Van (diesel)	0.435	LDDV, Pre-1981
Taxi (petrol)	0.043	LDGV, 1970-1974
Taxi (diesel)	0.435	LDDV, Pre-1981
Small Truck	0.043	LDGT, 1970-1974
Medium Truck	0.497	LDGT, Pre-1981
Large Truck	1.389	HDDV
Lorry/Trailer	1.389	HDDV

Note PM emission factor for large truck and lorry/trailer was calculated by the following equation.

$$Ef = 0.700(g/Bhp\text{-}hr) \times Cf$$

where;
Ef: PM emission factor for large truck and lorry/trailer
Cf: conversion factor for emissions in g/Bhp-hr to g/km
3.1917 for HDDV for 1972-1974

Source: U.S.EPA(#5008)

Table 31(1) Emission Factors for Petrol Vehicles

(HC, CO, NOx and SOx)

(Unit:g/km)

Vehicle Type		Average Travel Speed(km/h)										
		15	20	25	30	35	40	45	50	55	60	65
Motorcycle	HC	27.18	20.79	17.30	15.12	13.52	12.35	11.34	10.47	9.74	9.16	8.72
	CO	44.19	34.03	28.12	24.58	21.98	19.85	18.20	16.78	15.60	14.65	13.94
	NOx	0.21	0.19	0.19	0.19	0.20	0.21	0.22	0.23	0.23	0.24	0.24
	SOx	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Motor Car	HC	3.47	2.57	2.07	1.75	1.50	1.32	1.15	1.02	0.90	0.80	0.73
	CO	36.04	26.44	21.05	17.68	15.16	13.30	11.62	10.27	9.09	8.25	7.58
	NOx	1.51	1.58	1.65	1.74	1.81	1.88	1.93	1.99	2.02	2.07	2.11
	SOx	0.005	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003
Van	HC	2.97	2.20	1.77	1.50	1.29	1.13	0.99	0.87	0.77	0.69	0.63
	CO	68.47	50.23	39.99	33.59	28.79	25.27	22.08	19.52	17.28	15.68	14.40
	NOx	2.96	3.09	3.23	3.40	3.54	3.68	3.78	3.89	3.95	4.06	4.13
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.004
Taxi	HC	3.83	2.84	2.28	1.93	1.66	1.45	1.27	1.12	0.99	0.88	0.81
	CO	60.89	44.67	35.57	29.87	25.61	22.48	19.63	17.36	15.36	13.94	12.80
	NOx	1.76	1.84	1.92	2.02	2.11	2.19	2.25	2.31	2.35	2.41	2.45
	SOx	0.005	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003
Small Truck	HC	6.14	4.79	4.05	3.51	3.10	2.73	2.40	2.13	1.89	1.69	1.55
	CO	64.04	51.08	44.22	39.26	35.45	31.64	27.83	24.40	21.73	19.82	18.68
	NOx	2.95	3.10	3.31	3.57	3.82	4.08	4.30	4.52	4.66	4.81	4.92
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Table 31(2) Emission Factor for Diesel Vehicles

(HC, CO, NOx and SOx)

(Unit:g/km)

Vehicle Type		Average Travel Speed(km/h)										
		15	20	25	30	35	40	45	50	55	60	65
Van	HC	2.89	2.52	2.20	1.95	1.73	1.56	1.41	1.30	1.18	1.11	1.03
	CO	6.45	5.21	4.32	3.60	3.09	2.67	2.37	2.13	1.95	1.82	1.71
	NOx	1.92	1.74	1.59	1.48	1.39	1.33	1.29	1.26	1.26	1.26	1.29
	SOx	0.750	0.654	0.599	0.562	0.532	0.511	0.499	0.486	0.474	0.465	0.457
Taxi	HC	1.27	1.10	0.96	0.86	0.76	0.68	0.62	0.57	0.52	0.49	0.45
	CO	5.06	4.09	3.39	2.83	2.42	2.10	1.86	1.67	1.54	1.43	1.35
	NOx	2.40	2.16	1.98	1.84	1.73	1.66	1.60	1.57	1.57	1.57	1.60
	SOx	0.750	0.654	0.599	0.562	0.532	0.511	0.499	0.486	0.474	0.465	0.457
Mini Bus	HC	5.66	4.92	4.30	3.82	3.38	3.05	2.76	2.53	2.31	2.17	2.02
	CO	11.37	9.20	7.62	6.35	5.45	4.72	4.17	3.75	3.45	3.21	3.03
	NOx	4.92	4.44	4.07	3.77	3.55	3.40	3.29	3.22	3.22	3.22	3.29
	SOx	1.518	1.399	1.325	1.274	1.240	1.218	1.195	1.178	1.167	1.155	1.144
Large Bus	HC	7.60	6.59	5.76	5.09	4.55	4.07	3.68	3.39	3.10	2.91	2.71
	CO	26.68	21.68	17.79	14.87	12.79	11.12	9.73	8.76	8.06	7.50	7.09
	NOx	21.06	19.01	17.44	16.18	15.24	14.46	13.98	13.83	13.67	13.83	14.14
	SOx	3.300	3.041	2.881	2.770	2.696	2.647	2.598	2.561	2.536	2.512	2.487
Medium Truck	HC	3.62	3.15	2.75	2.44	2.16	1.95	1.76	1.62	1.48	1.39	1.29
	CO	6.11	4.94	4.09	3.41	2.92	2.53	2.24	2.01	1.85	1.72	1.62
	NOx	3.58	3.23	2.96	2.75	2.58	2.48	2.40	2.34	2.34	2.34	2.40
	SOx	1.516	1.396	1.320	1.276	1.238	1.212	1.193	1.175	1.162	1.156	1.143
Large Truck	HC	5.31	4.60	4.03	3.55	3.18	2.84	2.57	2.37	2.17	2.03	1.89
	CO	18.64	15.14	12.43	10.39	8.93	7.77	6.80	6.12	5.63	5.24	4.95
	NOx	21.06	19.01	17.44	16.18	15.24	14.46	13.98	13.83	13.67	13.83	14.14
	SOx	3.246	2.989	2.827	2.732	2.651	2.597	2.556	2.516	2.489	2.475	2.448
Lorry/Trailer	HC	5.31	4.60	4.03	3.55	3.18	2.84	2.57	2.37	2.17	2.03	1.89
	CO	18.64	15.14	12.43	10.39	8.93	7.77	6.80	6.12	5.63	5.24	4.95
	NOx	21.06	19.01	17.44	16.18	15.24	14.46	13.98	13.83	13.67	13.83	14.14
	SOx	3.246	2.989	2.827	2.732	2.651	2.597	2.556	2.516	2.489	2.475	2.448

Table 32 Average Emission Rate for Motor Vehicles
(HC, CO, NOx and SOx)

(Unit: g/km)

Vehicle Type		Average Speed(km/h)										
		15	20	25	30	35	40	45	50	55	60	65
Motorcycle	HC	27.18	20.79	17.30	15.12	13.52	12.35	11.34	10.47	9.74	9.16	8.72
	CO	44.19	34.03	28.12	24.58	21.98	19.85	18.20	16.78	15.60	14.65	13.94
	NOx	0.21	0.19	0.19	0.19	0.20	0.21	0.22	0.23	0.23	0.24	0.24
	SOx	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Motor Car	HC	3.47	2.57	2.07	1.75	1.50	1.32	1.15	1.02	0.90	0.80	0.73
	CO	36.04	26.44	21.05	17.68	15.16	13.30	11.62	10.27	9.09	8.25	7.58
	NOx	1.51	1.58	1.65	1.74	1.81	1.88	1.93	1.99	2.02	2.07	2.11
	SOx	0.005	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003
Van	HC	2.96	2.25	1.83	1.57	1.36	1.19	1.05	0.93	0.83	0.75	0.69
	CO	59.10	43.43	34.60	29.06	24.91	21.86	19.10	16.89	14.97	13.59	12.48
	NOx	2.80	2.89	2.98	3.11	3.22	3.33	3.40	3.49	3.54	3.64	3.70
	SOx	0.119	0.104	0.096	0.089	0.085	0.081	0.080	0.078	0.076	0.074	0.072
Taxi	HC	2.57	1.99	1.63	1.40	1.22	1.07	0.95	0.85	0.76	0.69	0.63
	CO	33.48	24.75	19.77	16.59	14.22	12.47	10.90	9.66	8.57	7.80	7.18
	NOx	2.07	2.00	1.95	1.93	1.92	1.93	1.93	1.95	1.97	2.00	2.03
	SOx	0.371	0.323	0.296	0.278	0.263	0.252	0.247	0.240	0.234	0.230	0.226
Mini Bus	HC	5.66	4.92	4.30	3.82	3.38	3.05	2.76	2.53	2.31	2.17	2.02
	CO	11.37	9.20	7.62	6.35	5.45	4.72	4.17	3.75	3.45	3.21	3.03
	NOx	4.92	4.44	4.07	3.77	3.55	3.40	3.29	3.22	3.22	3.22	3.29
	SOx	1.518	1.399	1.325	1.274	1.240	1.218	1.195	1.178	1.167	1.155	1.144
Medium/Large	HC	7.60	6.59	5.76	5.09	4.55	4.07	3.68	3.39	3.10	2.91	2.71
Bus	CO	26.68	21.68	17.79	14.87	12.79	11.12	9.73	8.76	8.06	7.50	7.09
	NOx	21.06	19.01	17.44	16.18	15.24	14.46	13.98	13.83	13.67	13.83	14.14
	SOx	3.300	3.041	2.881	2.770	2.696	2.647	2.598	2.561	2.536	2.512	2.487
Small Truck	HC	6.14	4.79	4.05	3.51	3.10	2.73	2.40	2.13	1.89	1.69	1.55
	CO	64.04	51.08	44.22	39.26	35.45	31.64	27.83	24.40	21.73	19.82	18.68
	NOx	2.95	3.10	3.31	3.57	3.82	4.08	4.30	4.52	4.66	4.81	4.92
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Medium/Large	HC	3.88	3.37	2.94	2.61	2.31	2.08	1.88	1.73	1.58	1.49	1.38
Truck	CO	8.00	6.48	5.35	4.46	3.83	3.32	2.93	2.63	2.42	2.25	2.12
	NOx	6.22	5.61	5.15	4.78	4.49	4.29	4.15	4.07	4.05	4.07	4.17
	SOx	2.201	2.026	1.916	1.852	1.797	1.760	1.733	1.706	1.687	1.678	1.659
Lorry/Trailer	HC	5.31	4.60	4.03	3.55	3.18	2.84	2.57	2.37	2.17	2.03	1.89
	CO	18.64	15.14	12.43	10.39	8.93	7.77	6.80	6.12	5.63	5.24	4.95
	NOx	21.06	19.01	17.44	16.18	15.24	14.46	13.98	13.83	13.67	13.83	14.14
	SOx	3.246	2.989	2.827	2.732	2.651	2.597	2.556	2.516	2.489	2.475	2.448

The U.S.EPA's report (#5013) shows differences in PM emission rates between trailers and large buses (Table 34). PM emission factor for medium/large buses at 15 km/h and 25 km/h and more is set by multiplying PM emission rate for bus at 14.1 km/h and 30.1km/h by 1.389/1.209 (PM emission factor ratio for lorry/trailer in Table 33 to that in Table 34) respectively. PM emission factor for medium/large buses at 20 km/h is the average of those at 15km/h and 25 km/h. PM emission factors for mini buses are calculated by multiplying those for medium/large buses by 0.497/1.389 (the ratio of PM emission factor for medium truck to that for lorry/trailer). PM emission rates for buses are given in Table 35.
Average PM emission factors shown in Table 36 are derived from ratios of medium and large trucks (Table 6), engine type ratios for vans and taxis (Table 7) and PM emission factors in Tables 33 and 35.

Table 34 Particulate Emission Factor for Bus and Trailer

Vehicle Type	Emission Rate (g/km) Average Speed (km/h) 14.1	30.1	Average
Trailer	-	1.3	1.209
Bus	3.9	2.5	

Source: U.S.EPA (#5013)

Table 35 Particulate Emission for Buses

	Vehicle Speed (km/h) 15	20	25-	Note
Mini Bus	1.603	1.408	1.028	from medium truck
M/Large Bus	4.481	3.425	2.872	from lorry/trailer

Table 36 Average Particulate Emission Factor for Motor Vehicles

(Unit: g/km)

Vehicle Type	Average Speed(km/h)		
	15	20	25-
Motorcycle	0.205	0.205	0.205
Motor Car	0.043	0.043	0.043
Van	0.102	0.102	0.102
Taxi	0.235	0.235	0.235
Mini Bus	1.603	1.408	1.028
Medium/Large Bus	4.481	3.935	2.872
Small Truck	0.043	0.043	0.043
Medium/Large Truck	0.632	0.632	0.632
Lorry/Trailer	1.389	1.389	1.389

3.2.8

Emission Factors of Motor Vehicles in the Future

(1) Exhaust Gas Emission Controls

The Malaysian government implemented Regulation ECE.No. 15.04 (Table 1) to petrol vehicles and Regulation No. 49 (Table 2) and No. 24 (PM concentration) on diesel vehicles in June, 1992. Also in 1994, Regulation 91/441/EEC (Table 3) will be enforced on petrol vehicles. These regulations were taken into consideration in formulating emission factors in the future. The regulations have limits for both type approval and checks on production conformity, of which the latter limit is observed in this study. Regulation 91/441/EEC is assumed to be in effect on Jan. 1, 1995. In Table 4 a summary of the types of vehicles and regulations considered for the establishment of the emission factors in future is shown.

Table 1 Regulation No. 15.04

	Limit Value			
	Type approval		Checks on production conformity	
Reference mass RW(kg)	CO (g/test)	HC + NOx (g/test)	CO	HC + NOx
RW≦1020	58	19.0	70	23.8
1020<RW≦1250	67	20.5	80	25.6
1250<RW≦1470	76	22.0	91	27.5
1470<RW≦1700	84	23.5	101	29.4
1700<RW≦1930	93	25.0	112	31.3
1930<RW≦2150	101	26.5	121	33.1
2150<RW	110	28.0	132	35.0

ECE mode (average speed: 18.7 km/h)
4.0521km/test

Table 2 Regulation No. 49

Pollutant	Limit Value (g/kWh)
HC	3.5
CO	14
NOx	18

Table 3 Regulation 91/441/EEC

Pollutant	Limit Value (g/km)	
	for type approval	for conformity of production checks
CO	2.72	3.16
HC + NOx	0.97	1.13

Test mode: urban cycle + extra-urban cycle
Average speed: 33.6 km/h

Table 4 Regulation by Vehicle Type Considered in Setting Future Emission Factors

Petrol	1993 - 1994	1995-2005
Motor Car Taxi Van Small Truck	R15.04	91/441/EEC
Diesel Taxi Van Mini Bus Medium/Large Bus Medium/Large Truck Lorry/Trailer	R49	R49

(2) Procedure for Setting Emission Factors

The technique to determine emission factors in the future (1997 and 2005) is the same as the one applied to current emission factors, as illustrated in Fig. 1.

(3) Types of Vehicle and Engine

The type of engine used by different vehicles are given in Table 5. The ratios of type of engine used by taxis and vans are in Table 6, and the ratios of medium and large trucks are shown in Table 7. These values are assumed to be the same as at present.

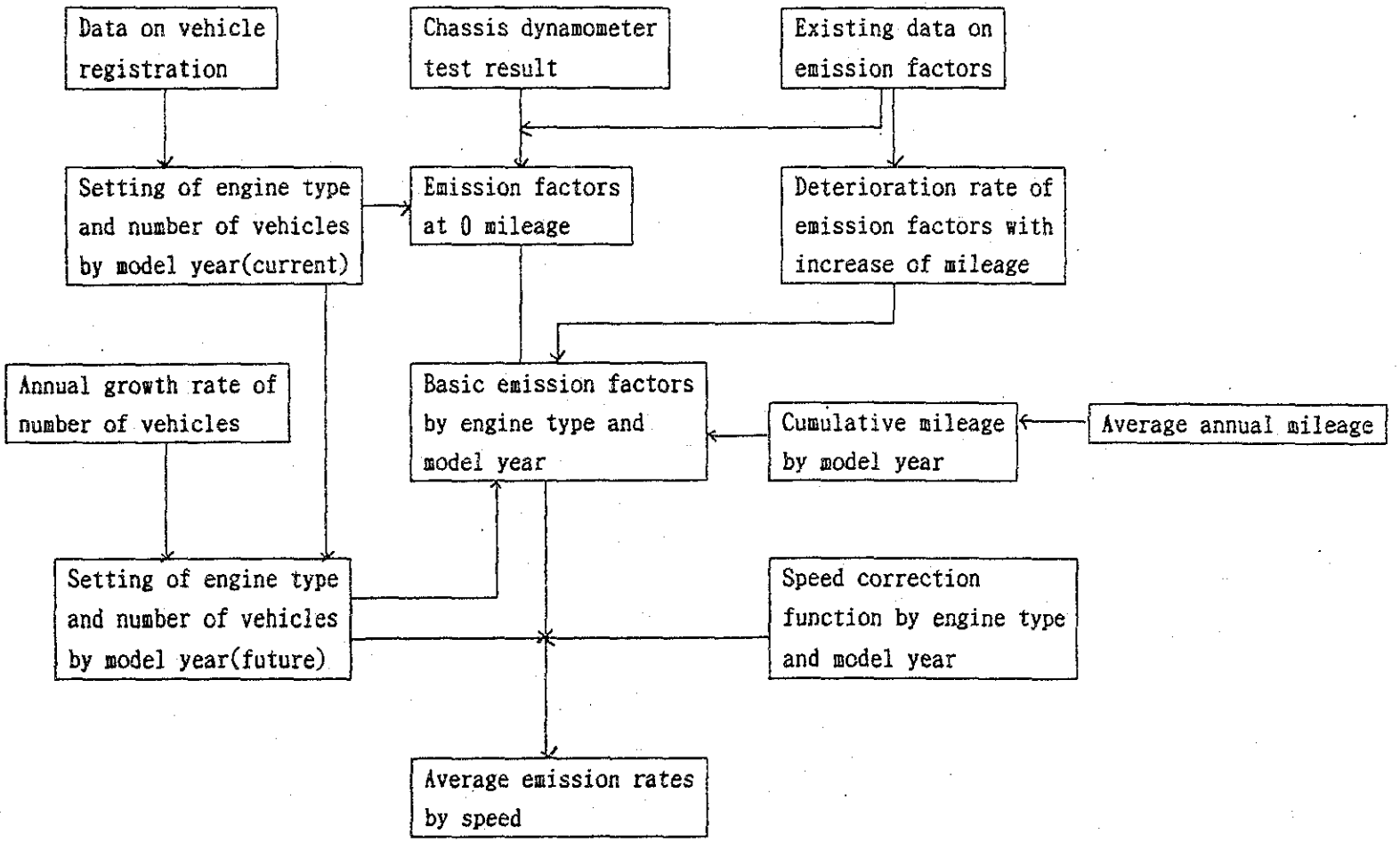


Fig. 1 Process of Setting Vehicular Emission Factors

Table 5 Classification of Motor Vehicles by Type of Engine

No.	Vehicle Type	Petrol	Diesel
1	Motorcycle	○	
2	Motor car	○	
3	Van	○	○
4	Taxi	○	○
5	Mini bus		○
6	Medium/Large bus		○
7	Small truck	○	
8	Medium		○
9	Large truck		○
10	Lorry/Trailer		○

Note Engine capacity

Medium truck; 5000cc or less

Large truck ; 5501cc or more

Table 6 Ratio of Van and Taxi by Type of Engine

Engine Type	Van	Taxi
Petrol	0.849	0.509
Diesel	0.151	0.491

Table 7 Ratio of Medium and Large Trucks to Total Number of Trucks

Truck Type	Ratio
Medium Truck	0.849
Large Truck	0.151

(4) The Number of Different Types of Vehicles Registered in Each Years

The vehicle emission factors depends on the year the vehicle was initially registered. Therefore, the number of vehicles registered each year must be estimated to calculate average emission factors in the future. In Table 8 the number of vehicles initially registered from 1972 to 1992 is given. The annual growth rate of registered vehicles are as in Table 9. If motorcycles registered 14 years ago and other type of vehicles (exclusive of taxi) 20 years ago are

condemned, then, the registered number of vehicles in year t could be calculated from the following equation. The total number of vehicles registered from 1993 to 2005 according to their types and year first registered are estimated as shown in Table 10.

$$Nv(t) = Tv(t-1) * r(t) + Nv(t-vl)$$

Where;

t: year

Nv: number of registered vehicles

Tv: total number of registered vehicles

r : annual growth rate of number of vehicles

vl : vehicle life

14 for motorcycle

20 for other vehicles except for taxi

Table 8 Number of Newly Registered Vehicles by Type (1972-1992)

Year	Motorcycle	Motor Car	Bus	Goods Vehicles		
				Petrol	Diesel	Total
1972		21592	310	2546	1506	4052
1973		21592	311	2546	1506	4052
1974		21592	311	2546	1506	4052
1975		21592	311	2546	1506	4052
1976		21592	311	2546	1507	4053
1977		22168	319	2614	1547	4161
1978	46460	27056	389	3190	1888	5078
1979	48249	28098	404	3313	1960	5273
1980	67493	39305	566	4634	2742	7376
1981	68463	39870	574	4701	2782	7483
1982	68661	39985	575	4714	2790	7504
1983	73597	42860	617	5053	2990	8043
1984	71166	41444	596	4886	2891	7777
1985	58821	34255	493	4039	2390	6429
1986	23924	24585	396	4549	2438	6987
1987	13342	20222	325	1217	1574	2791
1988	16606	28919	278	1339	2303	3642
1989	32283	44745	371	2230	4579	6809
1990	46824	60470	454	3436	7486	10922
1991	53147	69230	636	3473	9709	13182
1992	64651	67232	536	5918	4444	10362

Table 9 Average Annual Growth Rate of Motor Vehicles

Vehicle Type	Average Annual Growth Rate 1985-1995	1996-2005
Motorcycle	2.6	2.6
Motor Car	6.8	6.2
Taxi	6.8	5.5
Goods Vehicles	5.1	5.1
Bus	2.6	2.6

Source; Table 2.2.2 in the Main Report for bus and motorcycle, (#6007) for others

Table 10 Number of Newly Registered Vehicles by Type (1977-2005)

Year	Motorcycle	Motor Car	Bus	Goods Vehicles		
				Petrol	Diesel	Total
1972		21592	310	2546	1506	4052
1973		21592	311	2546	1506	4052
1974		21592	311	2546	1506	4052
1975		21592	311	2546	1506	4052
1976		21592	311	2546	1507	4053
1977		22168	319	2614	1547	4161
1978	46460	27056	389	3190	1888	5078
1979	48249	28098	404	3313	1960	5273
1980	67493	39305	566	4634	2742	7376
1981	68463	39870	574	4701	2782	7483
1982	68661	39985	575	4714	2790	7504
1983	73597	42860	617	5053	2990	8043
1984	71166	41444	596	4886	2891	7777
1985	58821	34255	493	4039	2390	6429
1986	23924	24585	396	4549	2438	6987
1987	13342	20222	325	1217	1574	2791
1988	16606	28919	278	1339	2303	3642
1989	32283	44745	371	2230	4579	6809
1990	46824	60470	454	3436	7486	10922
1991	53147	69230	636	3473	9709	13182
1992	64651	67232	536	5918	4444	10362
1993	66920	70335	543	6090	4593	10683
1994	86657	73650	549	6271	4751	11022
1995	88133	77190	555	6461	4916	11377
1996	88850	75731	561	6660	5091	11751
1997	94319	79664	576	6938	5314	12252
1998	92435	88116	653	7735	5847	13582
1999	80651	92944	675	8090	6121	14211
2000	46331	108172	844	9654	7115	16769
2001	36340	113006	859	9977	7378	17355
2002	40211	117656	868	10259	7621	17880
2003	56512	125346	918	10881	8067	18948
2004	71692	129045	905	11011	8227	19238
2005	78672	127287	810	10477	7998	18475

(5) Emission Factors of New Vehicles

All newly registered vehicles are assumed to be new vehicles (with zero cumulative mileage). Current (after 1986) emission factors of petrol fuelled vehicles such as motor cars, vans and small trucks, which are regulated from June, 1992 for their emission are assumed to meet the limit values of Table 1. The emission factors of diesel vehicles registered from 1993 which are under the Regulation ECE.No. 29 are chosen from those around 1982 published in the USA.

1) Motorcycles

The current factors that are employed for motorcycles will continue to remain.

2) Motor Cars

Emission factors of motor cars were established in groups based on years, namely 1986-1991, 1992, 1993-1994, and 1995 onwards. Proton's share in motor cars from 1986 to 1994 is assumed as shown in Table 11. The factors in the fourth group were cited from the values found in Regulation No.83 (Table 3). Since in this regulation HC and NOx are summed together, the given values must be separated. From the results of Japanese ten mode (average speed 17.8 km/h) tests, the ratio of HC to NOx is around 1:3 (HC = 0.08 & NOx = 0.24 g/km). Since the average speed of Regulation No.83 test is 33.6 km/h, the Japanese values were extrapolated using equations (Table 21(1)) derived from the data of US.EPA (#5008). The relations of HC and NOx emissions with the speeds are listed in Table 12.

Table 11 Share of Proton in Motor Car Sales

	1986-1991	1992-1994
Proton's share	0.557	0.593

Table 12 Change of Emission Rates of HC and NOx with Speed

Pollutant	Average Speed(km/h)	
	17.8	33.6
HC	1.49	0.95
NOx	1.15	0.98

Now, HC emission at the average speed of 33.6km/h is given by the following equation.

$$\frac{\frac{1.49}{0.95} X}{\frac{1.15}{0.98}(1.13 - X)} = \frac{1}{3}$$

Hence, HC emission X is 0.23 and NOx is 0.90 g/km (Table 13(1)).

3) Vans

Emission factors of petrol fueled vans were devided into two groups by the registrated year; before 1995 and 1995 onwards. Current emission factors are applied to those for petrol vans registered before 1995. The emission factors for petrol vans registered after 1995 is the same as those for motor cars registered after 1995. Although factors of diesel vans were similarly kept as the same with the current values for vehicles registered between 1986 and 1992, for the vehicles after 1993, the factors were selected from the data given in the U.S. EPA report (#5008).

4) Taxis

Emission factors for petrol taxis were devided into three groups by the registered year; 1987-1992,1993-1994, and 1995 onwards. For the first two groups, current emission factors are used. The emission factors for the third group is the same as those for motor cars registered after 1995. the factors of diesel vehicles were determined by the same way as those of diesel fuelled vans.

5) Buses

Emission factors for mini buses, and medium/large buses were set by the same way as those of vans.

6) Small Trucks

Emission factors for small trucks were determined by the same way as those of

Table 13(1) Future Emission Factors and Fuel Consumption Rates for Petrol Vehicles
(at 0 mileage)

Vehicle Type	Model Year	Item	Emission Factor	Base Speed	Source
Motorcycle	1982-2005	HC	9.9		U.S.EPA(#5007)
		CO	17.0		
		NOx	0.075	31.5	
		FC	0.04		
Motor Car	1977-1985	HC	2.62		Chassis dynamometer test
		CO	19.82		Japan(#5010), motor car(uncontrolled)
		NOx	1.23	18.7	Chassis dynamometer test
		FC	0.091		
	1986-1992 Proton	HC	2.64		
		CO	7.49		
		NOx	2.70	18.7	Chassis dynamometer test
		FC	0.093		
	1986-1992 Others	HC	2.62		Chassis dynamometer test
		CO	19.82		Japan(#5010), motor car(uncontrolled)
		NOx	1.23	18.7	Chassis dynamometer test
		FC	0.091		
	1993-1994 Proton	HC	2.35		
		CO	4.96		
		NOx	2.19	18.7	Chassis dynamometer test
		FC	0.099		
	1993-1994 Others	HC	2.62		Chassis dynamometer test
		CO	19.82		Japan(#5010), motor car(uncontrolled)
		NOx	1.23	18.7	Chassis dynamometer test
		FC	0.091		
	1995-2005	HC	0.23		
		CO	3.16	33.6	R83
		NOx	0.90		
		FC	0.099	18.7	Chassis dynamometer test
Van	1977-1994	HC	2.07		
		CO	19.73		
		NOx	3.06	18.7	Japan(#5010), LDGT(uncontrolled)
		FC	0.13		
	1995-2005	HC	0.23		
		CO	3.16	33.6	R83
		NOx	0.90		
		FC	0.13	18.7	Japan(#5010), LDGT(uncontrolled)
Taxi	1987-1992 Proton	HC	2.64		
		CO	7.49		
		NOx	2.70	18.7	Chassis dynamometer test
		FC	0.093		
	1993-1994 Proton	HC	2.35		
		CO	4.96		
		NOx	2.19	18.7	Chassis dynamometer test
		FC	0.099		
	1995-2005	HC	0.23		
		CO	3.16	33.6	R83
		NOx	0.90		
		FC	0.099	18.7	Chassis dynamometer test
Small Truck	1977-1994	HC	2.07		
		CO	19.73		
		NOx	3.06	18.7	Japan(#5010), LDGT(uncontrolled)
		FC	0.13		
	1995-2005	HC	0.23		
		CO	3.16	33.6	R83
		NOx	0.90		
	FC	0.13	18.7	Japan(#5010), LDGT(uncontrolled)	

Note FC: Fuel consumption rate
Unit HC, CO, NOx : g/km
FC : liter/km

Table 13(2) Future Emission Factors and Fuel Consumption Rates for Diesel Vehicles
(at 0 mileage)

Vehicle Type	Model Year	Item	Emission Factor	Base Speed	Source
Van	1977-1992	HC	0.81		U.S.EPA(#5008)
		CO	1.68		LDDV, pre-1975
		NOx	0.91	31.5	
		FC	0.10		U.S.EPA(#5007), LDDV
	1993-2005	HC	0.18		U.S.EPA(#5008)
		CO	0.71		LDDV, post-1980
		NOx	0.81	31.5	
		FC	0.10		U.S.EPA(#5007), LDDV
Taxi	1987-1992	HC	0.29		U.S.EPA(#5008)
		CO	1.1		LDDV, pre-1973
		NOx	0.99	31.5	
		FC	0.10		U.S.EPA(#5007), LDDV
	1993-2005	HC	0.18		U.S.EPA(#5008)
		CO	0.71		LDDV, post-1980
		NOx	0.81	31.5	
		FC	0.10		U.S.EPA(#5007), LDDV
Mini Bus	1977-1992	HC	0.78		U.S.EPA(#5008)
Medium Truck		CO	1.54		LDDT, pre-1972
		NOx	1.39	31.5	
		FC	0.23		SAE(#5012)
	1993-2005	HC	0.27		U.S.EPA(#5008)
		CO	0.83		LDDT, post-1981
		NOx	0.92	31.5	
		FC	0.23		SAE(#5012)
Medium/Large Bus	1977-1992	HC	2.63		U.S.EPA(#5008)
Large Truck		CO	7.62	31.3	HDDV, pre-1972
Lorry/Trailer		NOx	15.87		
		FC	0.50	29.0	U.S.EPA(#5007), HDDV
	1993-2005	HC	2.02		U.S.EPA(#5008)
		CO	5.44	31.3	HDDV, 1982-1984
		NOx	11.73		
		FC	0.50	29.0	U.S.EPA(#5007), HDDV

Note FC: Fuel consumption rate

Unit HC, CO, NOx : g/km

FC : liter/km

Base speed : km/h

petrol vans.

7) Medium/Large Trucks and Lorries/Trailers

Emission factors were set by the same way as those of diesel vans.

In Tables 13(1) and (2) the emission factors of new vehicles in the future by type of vehicle and engine are shown.

(5) Cumulative Mileage and Emission Factors

In Table 14 the deterioration rates of emission factors with increase of cumulative mileage is given.

Table 14 Deterioration Rate of Emission Factors with Increase of Cumulative Mileage (per 10000 km)

Vehicle Type	Engine Type	Model Years	HC	CO	NOx	FC	Note
Motorcycle	Petrol	1982-2005	0.054	0.045	0.186	0.0	Current
Motor Car	Petrol	1977-1994	0.003	0.037	0.0	0.0	Current
		1995-2005	0.025	0.025	0.025	0.0	UN.ECE(#5013)
Van	Petrol	1977-1994	0.003	0.037	0.0	0.0	Current
		1995-2005	0.025	0.025	0.025	0.0	UN.ECE(#5013)
	Diesel	1977-1992	0.038	0.030	0.017	0.0	Current
		1993-2005	0.038	0.022	0.014	0.0	U.S.EPA(#5008)
Taxi	Petrol	1987-1994	0.003	0.037	0.000	0.0	UN.ECE(#5013)
		1995-2005	0.025	0.025	0.025	0.0	UN.ECE(#5013)
	Diesel	1977-1992	0.038	0.030	0.017	0.0	Current
	Diesel	1993-2005	0.038	0.022	0.014	0.0	U.S.EPA(#5008)
Mini Bus	Diesel	1977-1992	0.038	0.030	0.017	0.0	Current
		1993-2005	0.038	0.022	0.014	0.0	U.S.EPA(#5008)
Medium/Large Bus	Diesel	1977-1992	0.009	0.009	0.0	0.0	Current
		1993-2005	0.010	0.009	0.0	0.0	U.S.EPA(#5008)
Small Truck	Petrol	1977-1994	0.031	0.037	0.0	0.0	Current
		1995-2005	0.025	0.025	0.025	0.0	UN.ECE(#5013)
Medium Truck	Diesel	1977-1992	0.058	0.032	0.027	0.0	Current
		1993-2005	0.058	0.019	0.013	0.0	U.S.EPA(#5008)
Large Truck	Diesel	1977-1992	0.009	0.009	0.0	0.0	Current
Lorry/Trailer		1993-2005	0.010	0.009	0.0	0.0	U.S.EPA(#5008)

Note FC: Fuel consumption rate(km/ℓ)

(6) Annual and Cumulative Mileages

Annual mileage of each type of vehicle is the same as the current one (Table 15). Except for taxis, the annual and cumulative mileages are calculated by the same way as were used for current ones. With taxis, they are calculated as follows. From RTD's data (#6006), the number of registered taxis according to different years is obtained as shown in Table 16. Referring to this information, their annual and cumulative mileages for the year 1997 are set. For the year 2005, in-use taxis are assumed to be those registered only after 1995. Travel fractions and cumulative mileages of various types of vehicles in 1997 and 2005 are shown in Tables 17 and 18 respectively.

Table 15 Average Life and Annual Mileage by Vehicle Type

Vehicle Type	Average Life (Year)	Annual Mileage (x1000 Km/year)
Motorcycle	7	11.27
Private Car	10	19.32
Taxi	5	96.60
Bus	10	104.65
Van & Lorry	10	48.30

Source: PEMBAKARAN BAHANAPI PUNCA BERGERAK, DOE(#5009)

Table 16 Number of Taxi by Registration Year
(at the end of the year 1991)

Model Year	Number	Ratio
-1987	8344	0.721
1988-1989	583	0.050
1990-1991	2643	0.229
Total	11570	

Table 17(1) Travel Weighting Fraction Calculation and Cumulative mileage for Motorcycle (1997)

Model Years	Fleet Registration (A)	Annual mileage (1984~1996:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1983	0.0943	0.5	0.0518	154.96	13.75
1984	0.0911	1	0.1002	146.51	13
1985	0.0753	1	0.0828	135.24	12
1986	0.0306	1	0.0337	123.97	11
1987	0.0171	1	0.0188	112.70	10
1988	0.0213	1	0.0234	101.43	9
1989	0.0413	1	0.0455	90.16	8
1990	0.0600	1	0.0659	78.89	7
1991	0.0681	1	0.0748	67.62	6
1992	0.0828	1	0.0910	56.35	5
1993	0.0802	1	0.0882	45.08	4
1994	0.0826	1	0.0908	33.81	3
1995	0.0851	1	0.0936	22.54	2
1996	0.0835	1	0.0918	11.27	1
1997	0.0867	0.5	0.0477	2.82	0.25

Note Cumulative mileage(D) = average age(E) X annual mileage

Table 17(2) Travel Weighting Fraction Calculation and Cumulative Mileage for Motor Car (1997)

Model Years	Fleet Registration (A)	Annual mileage (1978~1996:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1977	0.0220	0.5	0.0116	381.57	19.75
1978	0.0269	1	0.0283	367.08	19
1979	0.0279	1	0.0294	347.76	18
1980	0.0390	1	0.0411	328.44	17
1981	0.0396	1	0.0417	309.12	16
1982	0.0397	1	0.0418	289.80	15
1983	0.0426	1	0.0448	270.48	14
1984	0.0412	1	0.0433	251.16	13
1985	0.0340	1	0.0358	231.84	12
1986	0.0244	1	0.0257	212.52	11
1987	0.0201	1	0.0212	193.20	10
1988	0.0287	1	0.0302	173.88	9
1989	0.0444	1	0.0468	154.56	8
1990	0.0600	1	0.0632	135.24	7
1991	0.0687	1	0.0724	115.92	6
1992	0.0668	1	0.0703	96.60	5
1993	0.0698	1	0.0736	77.28	4
1994	0.0731	1	0.0770	57.96	3
1995	0.0767	1	0.0807	38.64	2
1996	0.0752	1	0.0792	19.32	1
1997	0.0791	0.5	0.0417	4.83	0.25

Note Cumulative mileage(D) = average age(E) X annual mileage

Table 17(3) Travel Weighting Fraction Calculation and Cumulative Mileage for Mini Bus, Medium/Large Bus (1997)

Model Years	Fleet Registration (A)	Annual mileage (1978~1996:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1977	0.0309	0.5	0.0162	2066.84	19.75
1978	0.0377	1	0.0394	1988.35	19
1979	0.0392	1	0.0410	1883.70	18
1980	0.0549	1	0.0574	1779.05	17
1981	0.0557	1	0.0582	1674.40	16
1982	0.0558	1	0.0583	1569.75	15
1983	0.0598	1	0.0625	1465.10	14
1984	0.0578	1	0.0604	1360.45	13
1985	0.0478	1	0.0500	1255.80	12
1986	0.0384	1	0.0401	1151.15	11
1987	0.0315	1	0.0329	1046.50	10
1988	0.0270	1	0.0282	941.85	9
1989	0.0360	1	0.0376	837.20	8
1990	0.0440	1	0.0460	732.55	7
1991	0.0617	1	0.0645	627.90	6
1992	0.0520	1	0.0543	523.25	5
1993	0.0527	1	0.0550	418.60	4
1994	0.0532	1	0.0556	313.95	3
1995	0.0538	1	0.0563	209.30	2
1996	0.0544	1	0.0569	104.65	1
1997	0.0559	0.5	0.0292	26.16	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 17(4) Travel Weighting Fraction Calculation and Cumulative Mileage for Petrol Van and Small Truck (1997)

Model Years	Fleet Registration (A)	Annual mileage (1978~1996:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1977	0.0285	0.5	0.0150	953.93	19.75
1978	0.0348	1	0.0367	917.70	19
1979	0.0361	1	0.0381	869.40	18
1980	0.0505	1	0.0533	821.10	17
1981	0.0513	1	0.0541	772.80	16
1982	0.0514	1	0.0542	724.50	15
1983	0.0551	1	0.0581	676.20	14
1984	0.0533	1	0.0562	627.90	13
1985	0.0440	1	0.0465	579.60	12
1986	0.0496	1	0.0523	531.30	11
1987	0.0133	1	0.0140	483.00	10
1988	0.0146	1	0.0154	434.70	9
1989	0.0243	1	0.0256	386.40	8
1990	0.0375	1	0.0395	338.10	7
1991	0.0379	1	0.0399	289.80	6
1992	0.0645	1	0.0681	241.50	5
1993	0.0664	1	0.0700	193.20	4
1994	0.0684	1	0.0721	144.90	3
1995	0.0704	1	0.0743	96.60	2
1996	0.0726	1	0.0766	48.30	1
1997	0.0756	0.5	0.0399	12.08	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 17(5) Travel Weighting Fraction Calculation and Cumulative Mileage for Diesel Van, Medium/Large Truck and Lorry/Trailer (1997)

Model Years	Fleet Registration (A)	Annual mileage (1978~1996:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1977	0.0195	0.5	0.0102	953.93	19.75
1978	0.0238	1	0.0249	917.70	19
1979	0.0248	1	0.0259	869.40	18
1980	0.0346	1	0.0362	821.10	17
1981	0.0351	1	0.0367	772.80	16
1982	0.0352	1	0.0368	724.50	15
1983	0.0378	1	0.0395	676.20	14
1984	0.0365	1	0.0382	627.90	13
1985	0.0302	1	0.0316	579.60	12
1986	0.0308	1	0.0322	531.30	11
1987	0.0199	1	0.0208	483.00	10
1988	0.0291	1	0.0304	434.70	9
1989	0.0578	1	0.0605	386.40	8
1990	0.0945	1	0.0988	338.10	7
1991	0.1226	1	0.1282	289.80	6
1992	0.0561	1	0.0587	241.50	5
1993	0.0580	1	0.0606	193.20	4
1994	0.0600	1	0.0627	144.90	3
1995	0.0621	1	0.0649	96.60	2
1996	0.0643	1	0.0672	48.30	1
1997	0.0671	0.5	0.0351	12.08	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 17(6) Travel Weighting Fraction and Average Cumulative Mileage by Model Year for Taxi

(1997)

Model Year	Travel Fraction	Cumulative Mileage (1000km)	Average Age
1987-1992	0.600	628	6.5
1993-1994	0.200	338	3.5
1995-1997	0.200	145	1.5

Table 18(1) Travel Weighting Fraction Calculation and Cumulative mileage for Motorcycle (2005)

Model Years	Fleet Registration (A)	Annual mileage (1992~2004:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1991	0.0444	0.5	0.0237	154.96	13.75
1992	0.0508	1	0.0542	146.51	13
1993	0.0523	1	0.0558	135.24	12
1994	0.0538	1	0.0575	123.97	11
1995	0.0555	1	0.0593	112.70	10
1996	0.0544	1	0.0581	101.43	9
1997	0.0565	1	0.0604	90.16	8
1998	0.0630	1	0.0673	78.89	7
1999	0.0657	1	0.0703	67.62	6
2000	0.0787	1	0.0840	56.35	5
2001	0.0811	1	0.0866	45.08	4
2002	0.0831	1	0.0888	33.81	3
2003	0.0880	1	0.0941	22.54	2
2004	0.0888	1	0.0949	11.27	1
2005	0.0839	0.5	0.0448	2.82	0.25

Note Cumulative mileage(D) = average age(E) X annual mileage

Table 18(2) Travel Weighting Fraction Calculation and Cumulative Mileage for Motor Car (2005)

Model Years	Fleet Registration (A)	Annual mileage (1986~2004:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1985	0.0210	0.5	0.0111	381.57	19.75
1986	0.0151	1	0.0159	367.08	19
1987	0.0124	1	0.0131	347.76	18
1988	0.0178	1	0.0187	328.44	17
1989	0.0275	1	0.0289	309.12	16
1990	0.0371	1	0.0391	289.80	15
1991	0.0425	1	0.0448	270.48	14
1992	0.0413	1	0.0435	251.16	13
1993	0.0432	1	0.0455	231.84	12
1994	0.0452	1	0.0476	212.52	11
1995	0.0474	1	0.0499	193.20	10
1996	0.0465	1	0.0490	173.88	9
1997	0.0489	1	0.0515	154.56	8
1998	0.0541	1	0.0570	135.24	7
1999	0.0571	1	0.0601	115.92	6
2000	0.0665	1	0.0699	96.60	5
2001	0.0694	1	0.0730	77.28	4
2002	0.0723	1	0.0761	57.96	3
2003	0.0770	1	0.0810	38.64	2
2004	0.0793	1	0.0834	19.32	1
2005	0.0782	0.5	0.0411	4.83	0.25

Note Cumulative mileage(D) = average age(E) X annual mileage

Table 18(3) Travel Weighting Fraction Calculation and Cumulative Mileage for Mini Bus, Medium/Large Bus (2005)

Model Years	Fleet Registration (A)	Annual mileage (1986~2004:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1985	0.0385	0.5	0.0203	2066.84	19.75
1986	0.0309	1	0.0326	1988.35	19
1987	0.0254	1	0.0267	1883.70	18
1988	0.0217	1	0.0229	1779.05	17
1989	0.0290	1	0.0305	1674.40	16
1990	0.0355	1	0.0374	1569.75	15
1991	0.0497	1	0.0523	1465.10	14
1992	0.0419	1	0.0441	1360.45	13
1993	0.0424	1	0.0447	1255.80	12
1994	0.0429	1	0.0452	1151.15	11
1995	0.0433	1	0.0457	1046.50	10
1996	0.0438	1	0.0462	941.85	9
1997	0.0450	1	0.0474	837.20	8
1998	0.0510	1	0.0537	732.55	7
1999	0.0527	1	0.0555	627.90	6
2000	0.0659	1	0.0694	523.25	5
2001	0.0671	1	0.0707	418.60	4
2002	0.0678	1	0.0714	313.95	3
2003	0.0717	1	0.0755	209.30	2
2004	0.0707	1	0.0745	104.65	1
2005	0.0633	0.5	0.0333	26.16	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 18(4) Travel Weighting Fraction Calculation and Cumulative Mileage for Petrol Van and Small Truck (2005)

Model Years	Fleet Registration (A)	Annual mileage (1986~2004:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1985	0.0295	0.5	0.0156	953.93	19.75
1986	0.0333	1	0.0351	917.70	19
1987	0.0089	1	0.0094	869.40	18
1988	0.0098	1	0.0103	821.10	17
1989	0.0163	1	0.0172	772.80	16
1990	0.0251	1	0.0265	724.50	15
1991	0.0254	1	0.0268	676.20	14
1992	0.0433	1	0.0457	627.90	13
1993	0.0445	1	0.0470	579.60	12
1994	0.0459	1	0.0484	531.30	11
1995	0.0473	1	0.0499	483.00	10
1996	0.0487	1	0.0514	434.70	9
1997	0.0508	1	0.0536	386.40	8
1998	0.0566	1	0.0598	338.10	7
1999	0.0592	1	0.0625	289.80	6
2000	0.0706	1	0.0746	241.50	5
2001	0.0730	1	0.0771	193.20	4
2002	0.0750	1	0.0793	144.90	3
2003	0.0796	1	0.0841	96.60	2
2004	0.0805	1	0.0851	48.30	1
2005	0.0766	0.5	0.0405	12.08	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 18(5) Travel Weighting Fraction Calculation and Cumulative Mileage for Diesel Van, Medium/Large Truck and Lorry/Trailer (2005)

Model Years	Fleet Registration (A)	Annual mileage (1986~2004:1) (B)	Travel Fraction (C) (A*B/ΣA*B)	Cumulative Mileage (1000 km)(D)	Average Age (E)
1985	0.0203	0.5	0.0106	953.93	19.75
1986	0.0207	1	0.0216	917.70	19
1987	0.0133	1	0.0140	869.40	18
1988	0.0195	1	0.0204	821.10	17
1989	0.0388	1	0.0406	772.80	16
1990	0.0635	1	0.0664	724.50	15
1991	0.0823	1	0.0861	676.20	14
1992	0.0377	1	0.0394	627.90	13
1993	0.0389	1	0.0407	579.60	12
1994	0.0403	1	0.0421	531.30	11
1995	0.0417	1	0.0436	483.00	10
1996	0.0432	1	0.0451	434.70	9
1997	0.0450	1	0.0471	386.40	8
1998	0.0496	1	0.0518	338.10	7
1999	0.0519	1	0.0543	289.80	6
2000	0.0603	1	0.0631	241.50	5
2001	0.0625	1	0.0654	193.20	4
2002	0.0646	1	0.0676	144.90	3
2003	0.0684	1	0.0715	96.60	2
2004	0.0697	1	0.0730	48.30	1
2005	0.0678	0.5	0.0355	12.08	0.25

Note Cumulative mileage(D) = average age(E) x annual mileage

Table 18(6) Travel Weighting Fraction and Average Cumulative Mileage by Model Year for Taxi

(2005)

Model Year	Travel Fraction	Cumulative Mileage (1000km)	Average Age
-	1	483	5

(7) Basic Emission Factors

Basic emission factors and travel fractions for the year 1997 and 2005 as shown in Tables 19 and 20 were obtained from the emission factors for new vehicles (Table 13), the cumulative mileages of various types of vehicles (Tables 17 and 18), the deterioration rates of emission factors (Table 14), and Proton's share to the total number of motor cars (Table 11). No deterioration with increase of mileage is assumed on fuel consumption rate.

Table 19(1) Future Basic Emission Factors for Petrol Vehicles (1997)
(HC, CO, NOx and SOx)

Vehicle Type	Model Years	Item	Emission Factor	Base Speed	Travel Fraction	Average Cumulative Mileage(1000km/unit)
Motorcycle	1982-1997	HC	13.77			
		CO	22.54	31.5	1.0	72
		NOx	0.18			
		SOx	0.002			
Motor Car	1977-1985	HC	2.85			
		CO	41.70	18.7	0.318	298
		NOx	1.23			
		SOx	0.004			
	1986-1991	HC	2.75			
		CO	20.15	18.7	0.259	150
		NOx	2.05			
		SOx	0.004			
	1992	HC	2.71			
		CO	16.98	18.7	0.070	97
		NOx	2.10			
		SOx	0.004			
	1993-1994	HC	2.51			
		CO	13.75	18.7	0.151	67
		NOx	1.80			
		SOx	0.004			
	1995-1997	HC	0.24			
		CO	3.35	33.6	0.202	24
		NOx	0.95			
		SOx	0.005	18.7		
Van	1997-1994	HC	2.40			
		CO	57.98	18.7	0.809	524
		NOx	3.06			
		SOx	0.006			
	1995-1997	HC	0.26			
		CO	3.63	33.6	0.191	60
		NOx	1.03			
		SOx	0.006	18.7		
Taxi	1987-1992	HC	3.14			
		CO	24.89	18.7	0.600	676
		NOx	2.70			
		SOx	0.004			
	1993-1994	HC	2.59			
		CO	11.16	18.7	0.200	290
		NOx	2.19			
		SOx	0.005			
	1995-1997	HC	0.31			
		CO	4.30	33.6	0.200	290
		NOx	1.23			
		SOx	0.005	18.7		
Small Truck	1977-1994	HC	5.43			
		CO	57.98	18.7	0.809	524
		NOx	3.06			
		SOx	0.006			
	1995-1997	HC	0.26			
		CO	3.63	33.6	0.191	60
		NOx	1.03			
		SOx	0.006	18.7		

Unit HC, CO, NOx: g/km
Base speed : km/h

Table 19(2) Future Basic Emission Factors for Diesel Vehicles (1997)
(HC, CO, NOx and SOx)

Vehicle Type	Model Years	Item	Emission Factor	Base Speed	Travel Fraction	Average Cumulative Mileage(1000km/unit)
Van	1977-1992	HC	2.36			
		CO	4.22	31.5	0.710	504
		NOx	1.69			
		SOx	0.549			
	1993-1997	HC	0.25			
		CO	0.88	31.5	0.290	106
		NOx	0.93			
		SOx	0.549			
Taxi	1987-1992	HC	0.98			
		CO	3.17	31.5	0.600	628
		NOx	2.05			
		SOx	0.549			
	1993-1997	HC	0.51			
		CO	1.46	31.5	0.400	242
		NOx	1.36			
		SOx	0.549			
Mini Bus	1977-1992	HC	4.58			
		CO	7.46	31.5	0.747	1282
		NOx	4.42			
		SOx	1.263			
	1993-1997	HC	0.51			
		CO	1.26	31.5	0.253	233
		NOx	1.22			
		SOx	1.263			
Medium/Large Bus	1977-1992	HC	5.66			
		CO	16.41	31.3	0.747	1282
		NOx	15.87			
		SOx	2.745	29.0		
	1993-1997	HC	2.49			
		CO	6.58	31.3	0.253	233
		NOx	11.73			
		SOx	2.745	29.0		
Medium Truck	1977-1992	HC	3.06			
		CO	4.02	31.5	0.809	504
		NOx	3.28			
		SOx	1.263	29.0		
	1993-1997	HC	0.44			
		CO	1.00	31.5	0.191	106
		NOx	1.05			
		SOx	1.263	29.0		
Large Truck Lorry/Trailer	1977-1992	HC	3.82			
		CO	11.07	31.5	0.809	504
		NOx	15.87			
		SOx	2.745	29.0		
	1993-1997	HC	2.23			
		CO	5.96	31.5	0.191	106
		NOx	11.73			
		SOx	2.745	29.0		

Unit HC, CO, NOx: g/km
Base speed : km/h

Table 20(1) Future Basic Emission Factors for Petrol Vehicles (2005)
(HC, CO, NOx and SOx)

Vehicle Type	Model Years	Item	Emission Factor	Base Speed	Travel Fraction	Average Cumulative Mileage(1000km/unit)
Motorcycle	1991-2005	HC	13.61			
		CO	22.31	31.5	1.0	69
		NOx	0.17			
		SOx	0.002			
Motor Car	1985	HC	2.92			
		CO	47.80	18.7	0.011	382
		NOx	1.23			
		SOx	0.004			
	1986-1991	HC	2.87			
		CO	27.56	18.7	0.160	305
		NOx	2.05			
		SOx	0.004			
	1992	HC	2.83			
		CO	24.13	18.7	0.044	251
		NOx	2.10			
		SOx	0.004			
	1993-1994	HC	2.62			
		CO	20.05	18.7	0.093	222
		NOx	1.80			
		SOx	0.004			
	1995-2005	HC	0.28			
		CO	3.87	33.6	0.692	90
		NOx	1.10			
		SOx	0.005	18.7		
Van	1985-1994	HC	2.50			
		CO	70.47	18.7	0.282	695
		NOx	3.06			
		SOx	0.006			
	1995-2005	HC	0.36			
		CO	4.95	33.6	0.718	227
		NOx	1.41			
		SOx	0.006	18.7		
Taxi	1995-2005	HC	0.51			
		CO	6.98	33.6	1.0	483
		NOx	1.99			
		SOx	0.005	18.7		
Small Truck	1985-1994	HC	6.53			
		CO	70.47	18.7	0.282	695
		NOx	3.06			
		SOx	0.006			
	1995-2005	HC	0.36			
		CO	4.95	33.6	0.718	227
		NOx	1.41			
		SOx	0.006	18.7		

Unit HC, CO, NOx: g/km
Base speed : km/h

Table 20(2) Future Basic Emission Factors for Diesel Vehicles (2005)
(HC, CO, NOx and SOx)

Vehicle Type	Model Years	Item	Emission Factor	Base Speed	Travel Fraction	Average Cumulative Mileage(1000km/unit)
Van	1985-1992	HC	3.09			
		CO	5.41	31.5	0.299	740
		NOx	2.05			
		SOx	0.549			
	1993-2005	HC	0.36			
		CO	1.13	31.5	0.701	266
		NOx	1.11			
		SOx	0.549			
Taxi	1995-2005	HC	0.51			
		CO	1.46	31.5	1.0	483
		NOx	1.36			
		SOx	0.549			
Mini Bus	1985-1992	HC	5.71			
		CO	9.23	31.5	0.267	1665
		NOx	5.32			
		SOx	1.263			
	1993-2005	HC	0.87			
		CO	1.89	31.5	0.733	581
		NOx	1.67			
		SOx	1.263			
Medium/Large Bus	1985-1992	HC	6.57			
		CO	19.04	31.3	0.267	1665
		NOx	15.87			
		SOx	2.745	29.0		
	1993-2005	HC	3.19			
		CO	8.29	31.3	0.733	581
		NOx	11.73			
		SOx	2.745	29.0		
Medium Truck	1985-1992	HC	4.13			
		CO	5.19	31.5	0.299	740
		NOx	4.17			
		SOx	1.263			
	1993-2005	HC	0.69			
		CO	1.25	31.5	0.701	266
		NOx	1.24			
		SOx	1.263	29.0		
Large Truck Lorry/Trailer	1985-1992	HC	4.38			
		CO	12.69	31.5	0.299	740
		NOx	15.87			
		SOx	2.745	29.0		
	1993-2005	HC	2.56			
		CO	6.74	31.5	0.701	266
		NOx	11.73			
		SOx	2.745	29.0		

Unit HC, CO, NOx: g/km
Base speed : km/h

(8) Average Speed and Emission Factors

Using published data in the USA and Japan, speed correction equations and coefficients according to vehicle type and engine type were set as shown in Tables 21(1) and (2).

Emission factors for petrol and diesel vehicles according to various speeds shown in Tables 22 (for the year 1997) and 23 (for the year 2005) were obtained using the following informations; ratio of medium and large trucks (Table 7), basic emission factors and travel fractions (Tables 19 and 20) and speed correction equations (Table 21).

(9) Average Emission Factors

Average emission factors for various types of vehicles operating in KVR in 1997 and 2005 are given in Tables 24 and 25. This was derived from engine type ratios for different types of vehicles (Tables 5 and 7) and emission factors for petrol and diesel vehicles (Tables 22 and 23).

(10) PM Emission Factors

PM emission factors were assumed to be independent of cumulative mileage. Effect of speed change on PM emission rate was taken into consideration only for buses.

Using the same method as was used in setting current PM emission factors, the future emission factors for petrol and diesel vehicles were set as shown in Tables 26(1) and (2) respectively.

The emission factors for mini buses and medium/large buses were calculated from those for medium truck and trailer respectively, using the same method as was used for their current emission factors.

PM emission factors for various types of vehicles in 1997 and 2005 shown in Tables 28 and 29 were derived from ratios medium and large trucks (Table 7), engine type ratios for vans and taxis (Table 6), travel fractions for various types of vehicles (Tables 18 and 19) and PM emission factors in Tables 26 and 27.

Table 26(1) Particulate Emission Factors for Petrol Vehicles

Vehicle Type	PM Emission Factor (g/km)		Note for 1995-2005
	-1994	1995-2005	
Motorcycle	0.205	0.205	2 stroke
Motor Car	0.043	0.023	LDGV, 1975+, CAT
Van	0.043	0.023	ditto
Taxi	0.043	0.023	ditto
Small Truck	0.043	0.023	LDGT, 1975+, CAT

Table 21(1) Future Speed Correction Factor Coefficients for Petrol Vehicles
(HC, CO, NOx and SOx)

$SF(s) = Exp(a + b*s + c*s^2 + d*s^3 + e*s^4 + f*s^5)$ for HC, CO and NOx(post-1995)

$SF(s) = a + b*s + c*s^2 + d*s^3 + e*s^4 + f*s^5$ for NOx, pre-1995

$SF(s) = a/s + b$ for SOx

Vehicle Type		a	b	c	d	e	f	Note
Motorcycle	HC	0.231026E 1	-0.289572E 0	0.152990E-1	-0.446689E-3	0.648183E-5	-0.363456E-7	Current
1983-2005	CO	0.233989E 1	-0.296978E 0	0.160071E-1	-0.477396E-3	0.706752E-5	-0.403978E-7	
	NOx	0.168635E 1	-0.118303E 0	0.654975E-2	-0.137139E-3	0.100849E-5	0.0	
	SOx	0.620800E 0	0.439100E-1					
Motor Car	HC	0.268382E 1	-0.344633E 0	0.195417E-1	-0.625720E-3	0.978442E-5	-0.583369E-7	Current
1977-1994	CO	0.283929E 1	-0.368756E 0	0.210782E-1	-0.676438E-3	0.106267E-4	-0.636405E-7	
	NOx	0.783838E 0	0.328549E-3	0.106029E-2	-0.319350E-4	0.290389E-6	0.0	
	SOx	0.725200E 0	0.615200E-1					
1995-2005	HC	0.984090E 0	-0.567319E-1	0.332320E-3				LDGV
	CO	0.858419E 0	-0.437969E-1					1981+
	NOx	0.386041E 0	-0.262961E-1	0.336740E-3				
	SOx	0.725200E 0	0.615200E-1					
Van	HC	0.268382E 1	-0.344633E 0	0.195417E-1	-0.625720E-3	0.978442E-5	-0.583369E-7	Current
1977-1994	CO	0.283929E 1	-0.368756E 0	0.210782E-1	-0.676438E-3	0.106267E-4	-0.636405E-7	
	NOx	0.783838E 0	0.328549E-3	0.106029E-2	-0.319350E-4	0.290389E-6	0.0	
	SOx	0.725200E 0	0.615200E-1					
1995-2005	HC	0.984090E 0	-0.567319E-1	0.332320E-3				LDGV
	CO	0.858419E 0	-0.437969E-1					1981+
	NOx	0.386041E 0	-0.262961E-1	0.336740E-3				
	SOx	0.725200E 0	0.615200E-1					
Taxi	HC	0.984090E 0	-0.567319E-1	0.332320E-3				LDGV
1987-1994	CO	0.858419E 0	-0.437969E-1					1981+
	NOx	0.386041E 0	-0.262961E-1					
	SOx	0.725200E 0	0.615200E-1					
1995-2005	HC	0.984090E 0	-0.567319E-1	0.332320E-3				LDGV
	CO	0.858419E 0	-0.437969E-1					1981+
	NOx	0.386041E 0	-0.262961E-1	0.336740E-3				
	SOx	0.725200E 0	0.615200E-1					
Small Truck	HC	0.239540E 1	-0.335781E 0	0.211609E-1	-0.731550E-3	0.120715E-4	-0.748566E-7	Current
1977-1994	CO	0.248747E 1	-0.391562E 0	0.270721E-1	-0.976178E-3	0.165270E-4	-0.104317E-6	
	NOx	0.942131E 0	-0.423240E-1	0.386253E-2	-0.939853E-4	0.753883E-6	0.0	
	SOx	0.769500E 0	0.761500E-1					
1995-2005	HC	0.984090E 0	-0.567319E-1	0.332320E-3				LDGT1
	CO	0.858419E 0	-0.437969E-1					1987+
	NOx	0.386041E 0	-0.262961E-1	0.336740E-3				
	SOx	0.725200E 0	0.615200E-1					

Where :

s = average speed(mph for HC, CO and NOx, km/h for SOx)

Source: U.S.EPA(#5008) for HC, CO and NOx, Japan(#5010) for SOx

Table 21(2) Speed Correction Factor Coefifcients for Diesel Vehicles (HC, CO, NOx and SOx)

$SF(s) = Exp(a + b*s + c*s^2)$ for HC, CO and NOx

$SF(s) = a/s + b$ for SOx

Vehicle Type		a	b	c	Note
Van	HC	0.90900	-0.05500	0.00044	Current
	CO	1.37520	-0.08800	0.00091	
	NOx	0.66800	-0.04800	0.00071	
	SOx	1.35500	0.08848		
Taxi	HC	0.90900	-0.05500	0.00044	Current
	CO	1.37520	-0.08800	0.00091	
	NOx	0.66800	-0.04800	0.00071	
	SOx	1.35500	0.08848		
Mini Bus	HC	0.90900	-0.05500	0.00044	Current
	CO	1.37520	-0.08800	0.00091	
	NOx	0.66800	-0.04800	0.00071	
	SOx	1.28000	0.18280		
Medium/Large Bus	HC	0.92400	-0.05500	0.00044	Current
	CO	1.39600	-0.08800	0.00091	
	NOx	0.67600	-0.04800	0.00071	
	SOx	1.28000	0.18280		
Medium Truck	HC	0.90900	-0.05500	0.00044	Current
	CO	1.37520	-0.08800	0.00091	
	NOx	0.66800	-0.04800	0.00071	
	SOx	1.14500	0.16360		
Large Truck	HC	0.92400	-0.05500	0.00044	Current
	CO	1.39600	-0.08800	0.00091	
	NOx	0.67600	-0.04800	0.00071	
	SOx	1.14500	0.16360		
Lorry/Trailer	HC	0.92400	-0.05500	0.00044	Current
	CO	1.39600	-0.08800	0.00091	
	NOx	0.67600	-0.04800	0.00071	
	SOx	1.14500	0.16360		

Where :

s = average speed(mph for HC, CO and NOx, km/h for SOx)

Source: U.S.EPA(#5008) for HC, CO and NOx, Japan(#5010) for SOx

Table 22(1) Emission Factors for Petrol Vehicles by Average Speed (1997)

(HC, CO, NOx and SOx)

(Unit: g/km)

Vehicle Type		Average Travel Speed(km/h)										
		15	20	25	30	35	40	45	50	55	60	65
Motorcycle	HC	25.75	19.69	16.39	14.32	12.81	11.70	10.74	9.91	9.23	8.68	8.26
	CO	42.15	32.46	26.82	23.44	20.96	18.93	17.35	16.00	14.88	13.97	13.30
	NOx	0.18	0.17	0.17	0.17	0.18	0.19	0.20	0.20	0.21	0.21	0.22
	SOx	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Motor Car	HC	2.84	2.12	1.71	1.45	1.24	1.09	0.95	0.84	0.75	0.66	0.61
	CO	28.82	21.30	17.03	14.33	12.30	10.79	9.42	8.32	7.37	6.67	6.11
	NOx	1.53	1.58	1.62	1.69	1.74	1.80	1.84	1.88	1.91	1.95	1.98
	SOx	0.005	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003
Van	HC	2.53	1.88	1.52	1.29	1.11	0.97	0.85	0.75	0.66	0.59	0.54
	CO	60.90	44.84	35.77	30.08	25.79	22.63	19.77	17.47	15.46	14.02	12.86
	NOx	2.63	2.73	2.83	2.96	3.06	3.17	3.25	3.32	3.38	3.46	3.52
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.004
Taxi	HC	3.13	2.33	1.88	1.60	1.37	1.20	1.05	0.93	0.82	0.73	0.67
	CO	23.29	17.29	13.85	11.67	10.02	8.79	7.68	6.78	6.00	5.42	4.96
	NOx	2.29	2.36	2.44	2.54	2.62	2.71	2.77	2.84	2.88	2.95	3.00
	SOx	0.005	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003
Small Truck	HC	5.42	4.23	3.58	3.10	2.74	2.42	2.12	1.88	1.67	1.49	1.37
	CO	57.03	45.58	39.46	35.02	31.60	28.19	24.79	21.73	19.35	17.63	16.59
	NOx	2.63	2.73	2.90	3.09	3.29	3.49	3.66	3.84	3.95	4.07	4.16
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Table 22(2) Emission Factors for Diesel Vehicles by Average Speed (1997)

(HC, CO, NOx and SOx)

(Unit: g/km)

Vehicle Type		Average Travel Speed(km/h)										
		15	20	25	30	35	40	45	50	55	60	65
Van	HC	2.69	2.34	2.05	1.82	1.61	1.45	1.31	1.21	1.10	1.03	0.96
	CO	6.11	4.94	4.09	3.41	2.92	2.53	2.24	2.01	1.85	1.72	1.62
	NOx	1.95	1.76	1.62	1.50	1.41	1.35	1.31	1.28	1.28	1.28	1.31
	SOx	0.750	0.654	0.599	0.562	0.532	0.511	0.499	0.486	0.474	0.465	0.457
Taxi	HC	1.22	1.06	0.93	0.83	0.73	0.66	0.59	0.55	0.50	0.47	0.44
	CO	4.68	3.78	3.14	2.61	2.24	1.94	1.72	1.54	1.42	1.32	1.24
	NOx	2.36	2.13	1.95	1.81	1.70	1.63	1.58	1.54	1.54	1.54	1.58
	SOx	0.750	0.654	0.599	0.562	0.532	0.511	0.499	0.486	0.474	0.465	0.457
Mini Bus	HC	5.47	4.76	4.15	3.69	3.27	2.95	2.66	2.45	2.24	2.09	1.95
	CO	11.08	8.96	7.43	6.19	5.30	4.60	4.07	3.65	3.36	3.12	2.95
	NOx	4.80	4.33	3.97	3.68	3.47	3.32	3.21	3.14	3.14	3.14	3.21
	SOx	1.518	1.399	1.325	1.274	1.240	1.218	1.195	1.178	1.167	1.155	1.144
Large Bus	HC	7.48	6.48	5.67	5.00	4.48	4.00	3.62	3.34	3.05	2.86	2.67
	CO	25.96	21.09	17.31	14.47	12.44	10.82	9.46	8.52	7.84	7.30	6.90
	NOx	19.67	17.76	16.29	15.12	14.24	13.50	13.06	12.91	12.77	12.91	13.21
	SOx	3.300	3.041	2.881	2.770	2.696	2.647	2.598	2.561	2.536	2.512	2.487
Medium Truck	HC	3.54	3.08	2.69	2.39	2.11	1.91	1.72	1.58	1.45	1.36	1.26
	CO	5.91	4.78	3.96	3.30	2.83	2.45	2.17	1.95	1.79	1.67	1.57
	NOx	3.50	3.16	2.89	2.68	2.53	2.42	2.34	2.29	2.29	2.29	2.34
	SOx	1.516	1.396	1.320	1.276	1.238	1.212	1.193	1.175	1.162	1.156	1.143
Large Truck	HC	5.17	4.48	3.92	3.46	3.10	2.77	2.50	2.31	2.11	1.98	1.85
Lorry/Trailer	CO	17.87	14.52	11.92	9.96	8.56	7.45	6.52	5.86	5.40	5.03	4.75
	NOx	19.46	17.57	16.12	14.96	14.09	13.36	12.93	12.78	12.64	12.78	13.07
	SOx	3.246	2.989	2.827	2.732	2.651	2.597	2.556	2.516	2.489	2.475	2.448

Table 23(1) Emission Factors for Petrol Vehicles by Average Speed (2005)

(HC, CO, NOx and SOx)

(Unit: g/km)

Vehicle Type		Average Travel Speed(km/h)										
		15	20	25	30	35	40	45	50	55	60	65
Motorcycle	HC	25.45	19.46	16.20	14.15	12.66	11.57	10.62	9.80	9.12	8.57	8.17
	CO	41.72	32.13	26.55	23.20	20.75	18.74	17.18	15.84	14.72	13.83	13.16
	NOx	0.18	0.17	0.17	0.17	0.18	0.18	0.19	0.20	0.20	0.21	0.21
	SOx	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Motor Car	HC	1.42	1.09	0.89	0.76	0.66	0.58	0.51	0.45	0.40	0.36	0.33
	CO	14.46	11.22	9.21	7.85	6.78	5.93	5.18	4.55	4.03	3.59	3.24
	NOx	1.51	1.48	1.46	1.46	1.45	1.46	1.46	1.46	1.47	1.48	1.50
	SOx	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003
Van	HC	1.33	1.04	0.86	0.73	0.63	0.56	0.49	0.43	0.39	0.34	0.32
	CO	31.19	23.69	19.24	16.31	14.05	12.30	10.74	9.46	8.37	7.52	6.82
	NOx	2.06	2.03	2.01	2.00	2.00	2.01	2.02	2.03	2.03	2.05	2.07
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.004
Taxi	HC	0.87	0.74	0.64	0.56	0.49	0.43	0.38	0.34	0.30	0.27	0.25
	CO	11.53	10.06	8.74	7.64	6.68	5.80	5.07	4.41	3.89	3.38	2.94
	NOx	2.41	2.27	2.15	2.05	1.97	1.91	1.87	1.82	1.80	1.78	1.78
	SOx	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003
Small Truck	HC	2.68	2.12	1.80	1.56	1.38	1.21	1.06	0.94	0.84	0.75	0.69
	CO	29.55	24.01	20.80	18.41	16.51	14.65	12.87	11.26	10.02	9.05	8.40
	NOx	2.06	2.03	2.03	2.05	2.08	2.12	2.16	2.20	2.23	2.26	2.30
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.004

Table 23(2) Emission Factors for Diesel Vehicles by Average Speed (2005)

(HC, CO, NOx and SOx)

(Unit: g/km)

Vehicle Type		Average Travel Speed(km/h)										
		15	20	25	30	35	40	45	50	55	60	65
Van	HC	1.81	1.58	1.38	1.22	1.08	0.98	0.88	0.81	0.74	0.69	0.65
	CO	4.53	3.66	3.03	2.53	2.17	1.88	1.66	1.49	1.37	1.28	1.20
	NOx	1.85	1.67	1.53	1.42	1.34	1.28	1.24	1.21	1.21	1.21	1.24
	SOx	0.750	0.654	0.599	0.562	0.532	0.511	0.499	0.486	0.474	0.465	0.457
Taxi	HC	0.79	0.68	0.60	0.53	0.47	0.42	0.38	0.35	0.32	0.30	0.28
	CO	2.75	2.23	1.85	1.54	1.32	1.14	1.01	0.91	0.83	0.78	0.73
	NOx	1.81	1.63	1.49	1.38	1.30	1.25	1.21	1.18	1.18	1.18	1.21
	SOx	0.750	0.654	0.599	0.562	0.532	0.511	0.499	0.486	0.474	0.465	0.457
Mini Bus	HC	3.33	2.89	2.53	2.25	1.99	1.79	1.62	1.49	1.36	1.27	1.19
	CO	7.24	5.85	4.85	4.04	3.46	3.00	2.66	2.39	2.19	2.04	1.92
	NOx	3.52	3.17	2.91	2.70	2.54	2.43	2.35	2.30	2.30	2.30	2.35
	SOx	1.518	1.399	1.325	1.274	1.240	1.218	1.195	1.178	1.167	1.155	1.144
Large Bus	HC	6.30	5.46	4.78	4.22	3.77	3.37	3.05	2.81	2.57	2.41	2.25
	CO	20.79	16.89	13.86	11.59	9.96	8.66	7.58	6.82	6.28	5.85	5.52
	NOx	17.03	15.38	14.11	13.09	12.33	11.69	11.31	11.18	11.06	11.18	11.44
	SOx	3.300	3.041	2.881	2.770	2.696	2.647	2.598	2.561	2.536	2.512	2.487
Medium Truck	HC	2.64	2.30	2.01	1.78	1.58	1.42	1.29	1.18	1.08	1.01	0.94
	CO	4.56	3.69	3.06	2.55	2.18	1.89	1.67	1.50	1.38	1.29	1.21
	NOx	2.81	2.54	2.33	2.16	2.03	1.95	1.88	1.84	1.84	1.84	1.88
	SOx	1.5165	1.396	1.320	1.276	1.238	1.212	1.193	1.175	1.162	1.156	1.143
Large Truck	HC	4.78	4.14	3.62	3.19	2.86	2.56	2.31	2.13	1.95	1.83	1.70
Lorry/Trailer	CO	15.89	12.91	10.59	8.85	7.61	6.62	5.79	5.21	4.80	4.47	4.22
	NOx	17.20	15.53	14.25	13.22	12.45	11.81	11.43	11.30	11.17	11.30	11.55
	SOx	3.246	2.989	2.827	2.732	2.651	2.597	2.556	2.516	2.489	2.475	2.448

Table 24 Average Emission Factors for Motor Vehicles by Average Speed (1997)
(HC, CO, NOx and SOx)

(Unit: g/km)

Vehicle Type		Average Travel Speed(km/h)										
		15	20	25	30	35	40	45	50	55	60	65
Motorcycle	HC	25.75	19.69	16.39	14.32	12.81	11.70	10.74	9.91	9.23	8.68	8.26
	CO	42.15	32.46	26.82	23.44	20.96	18.93	17.35	16.00	14.88	13.97	13.30
	NOx	0.18	0.17	0.17	0.17	0.18	0.19	0.20	0.20	0.21	0.21	0.22
	SOx	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Motor Car	HC	2.84	2.12	1.71	1.45	1.24	1.09	0.95	0.84	0.75	0.66	0.61
	CO	28.82	21.30	17.03	14.33	12.30	10.79	9.42	8.32	7.37	6.67	6.11
	NOx	1.53	1.58	1.62	1.69	1.74	1.80	1.84	1.88	1.91	1.95	1.98
	SOx	0.005	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003
Van	HC	2.55	1.95	1.60	1.37	1.19	1.04	0.92	0.82	0.73	0.66	0.60
	CO	52.63	38.82	30.99	26.05	22.34	19.59	17.12	15.14	13.40	12.16	11.16
	NOx	2.53	2.58	2.65	2.74	2.81	2.90	2.96	3.01	3.06	3.13	3.19
	SOx	0.119	0.104	0.096	0.089	0.085	0.081	0.080	0.078	0.076	0.074	0.072
Taxi	HC	2.19	1.71	1.41	1.22	1.06	0.93	0.82	0.74	0.66	0.60	0.56
	CO	14.15	10.66	8.59	7.22	6.20	5.43	4.75	4.21	3.75	3.41	3.13
	NOx	2.32	2.25	2.20	2.18	2.17	2.18	2.19	2.20	2.22	2.26	2.30
	SOx	0.371	0.323	0.296	0.278	0.263	0.253	0.247	0.240	0.234	0.230	0.226
Mini Bus	HC	5.47	4.76	4.15	3.69	3.27	2.95	2.66	2.45	2.24	2.09	1.95
	CO	11.08	8.96	7.43	6.19	5.30	4.60	4.07	3.65	3.36	3.12	2.95
	NOx	4.80	4.33	3.97	3.68	3.47	3.32	3.21	3.14	3.14	3.14	3.21
	SOx	1.518	1.399	1.325	1.274	1.240	1.218	1.195	1.178	1.167	1.155	1.144
Medium/Large	HC	7.48	6.48	5.67	5.00	4.48	4.00	3.62	3.34	3.05	2.86	2.67
Bus	CO	25.96	21.09	17.31	14.47	12.44	10.82	9.46	8.52	7.84	7.30	6.90
	NOx	19.67	17.76	16.29	15.12	14.24	13.50	13.06	12.91	12.77	12.91	13.21
	SOx	3.300	3.041	2.881	2.770	2.696	2.647	2.598	2.561	2.536	2.512	2.487
Small Truck	HC	5.42	4.23	3.58	3.10	2.74	2.42	2.12	1.88	1.67	1.49	1.37
	CO	57.03	45.48	39.46	35.02	31.60	28.19	24.79	21.73	19.35	17.63	16.59
	NOx	2.63	2.73	2.90	3.09	3.29	3.49	3.66	3.84	3.95	4.07	4.16
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Medium/Large	HC	3.79	3.29	2.88	2.55	2.26	2.04	1.84	1.69	1.55	1.45	1.35
Truck	CO	7.72	6.25	5.16	4.31	3.70	3.20	2.83	2.54	2.34	2.18	2.05
	NOx	5.91	5.34	4.89	4.53	4.28	4.07	3.94	3.87	3.85	3.87	3.96
	SOx	1.777	1.637	1.548	1.496	1.451	1.422	1.400	1.377	1.362	1.355	1.340
Lorry/Trailer	HC	5.17	4.48	3.92	3.46	3.10	2.77	2.50	2.31	2.11	1.98	1.85
	CO	17.87	14.52	11.92	9.96	8.56	7.45	6.52	5.86	5.40	5.03	4.75
	NOx	19.46	17.57	16.12	14.96	14.09	13.36	12.93	12.78	12.64	12.78	13.07
	SOx	3.246	2.989	2.827	2.732	2.651	2.597	2.556	2.516	2.489	2.475	2.448

Table 25 Average Emission Factors for Motor Vehicles by Average Speed (2005)
(HC, CO, NOx and SOx)

(Unit: g/km)

Vehicle Type		Average Travel Speed(km/h)										
		15	20	25	30	35	40	45	50	55	60	65
Motorcycle	HC	25.45	19.46	16.20	14.15	12.66	11.57	10.62	9.80	9.12	8.57	8.17
	CO	41.72	32.13	26.55	23.20	20.75	18.74	17.18	15.84	14.72	13.83	13.16
	NOx	0.18	0.17	0.17	0.17	0.18	0.18	0.19	0.20	0.20	0.21	0.21
	SOx	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Motor Car	HC	1.42	1.09	0.89	0.76	0.66	0.58	0.51	0.45	0.40	0.36	0.33
	CO	14.46	11.22	9.21	7.85	6.78	5.93	5.18	4.55	4.03	3.59	3.24
	NOx	1.51	1.48	1.46	1.46	1.45	1.46	1.46	1.46	1.47	1.48	1.50
	SOx	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003
Van	HC	1.40	1.12	0.94	0.80	0.70	0.62	0.55	0.49	0.44	0.39	0.37
	CO	27.16	20.67	16.79	14.23	12.26	10.73	9.37	8.26	7.31	6.58	5.97
	NOx	2.03	1.98	1.94	1.91	1.90	1.90	1.90	1.91	1.91	1.92	1.94
	SOx	0.119	0.104	0.096	0.089	0.085	0.081	0.080	0.078	0.076	0.074	0.072
Taxi	HC	0.83	0.71	0.62	0.55	0.48	0.43	0.38	0.34	0.31	0.28	0.26
	CO	7.22	6.22	5.36	4.64	4.05	3.51	3.08	2.69	2.39	2.10	1.85
	NOx	2.12	1.96	1.83	1.72	1.64	1.59	1.55	1.51	1.50	1.49	1.50
	SOx	0.371	0.324	0.296	0.278	0.263	0.253	0.247	0.241	0.234	0.230	0.226
Mini Bus	HC	3.33	2.89	2.53	2.25	1.99	1.79	1.62	1.49	1.36	1.27	1.19
	CO	7.24	5.85	4.85	4.04	3.46	3.00	2.66	2.39	2.19	2.04	1.92
	NOx	3.52	3.17	2.91	2.70	2.54	2.43	2.35	2.30	2.30	2.30	2.35
	SOx	1.518	1.399	1.325	1.274	1.240	1.218	1.195	1.178	1.167	1.155	1.144
Medium/Large	HC	6.30	5.46	4.78	4.22	3.77	3.37	3.05	2.81	2.57	2.41	2.25
Bus	CO	20.79	16.89	13.86	11.59	9.96	8.66	7.58	6.82	6.28	5.85	5.52
	NOx	17.03	15.38	14.11	13.09	12.33	11.69	11.31	11.18	11.06	11.18	11.44
	SOx	3.300	3.041	2.881	2.770	2.696	2.647	2.598	2.561	2.536	2.512	2.487
Small Truck	HC	2.68	2.12	1.80	1.56	1.38	1.21	1.06	0.94	0.84	0.75	0.69
	CO	29.55	24.01	20.80	18.41	16.51	14.65	12.87	11.26	10.02	9.05	8.40
	NOx	2.06	2.03	2.03	2.05	2.08	2.12	2.16	2.20	2.23	2.26	2.30
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.004
Medium/Large	HC	2.96	2.58	2.25	1.99	1.77	1.59	1.44	1.32	1.21	1.13	1.05
Truck	CO	6.27	5.08	4.20	3.50	3.00	2.60	2.29	2.06	1.90	1.77	1.66
	NOx	4.98	4.50	4.13	3.83	3.60	3.44	3.32	3.27	3.25	3.27	3.34
	SOx	1.776	1.636	1.547	1.495	1.451	1.421	1.399	1.376	1.362	1.354	1.340
Lorry/Trailer	HC	4.78	4.14	3.62	3.19	2.86	2.56	2.31	2.13	1.95	1.83	1.70
	CO	15.89	12.91	10.59	8.85	7.61	6.62	5.79	5.21	4.80	4.47	4.22
	NOx	17.20	15.53	14.25	13.22	12.45	11.81	11.43	11.30	11.17	11.30	11.55
	SOx	3.246	2.989	2.827	2.732	2.651	2.597	2.556	2.516	2.489	2.475	2.448

Table 26(2) Particulate Emission Factors for Diesel Vehicles

Vehicle Type	PM Emission Factor (g/km)		Note for 1993-2005
	-1992	1993-2005	
Van	0.435	0.186	LDDV, 1981-1986
Taxi	0.435	0.186	LDDV, 1981-1986
Medium Truck	0.497	0.186	LDGT, 1981-1986
Large Truck	1.389	1.113	HDDV 1982-1984
Lorry/Trailer	1.389	1.113	ditto

Note PM emission factor for large truck and lorry/trailer was calculated by the following equation.

$$Ef = 0.700(g/Bhp\text{-}hr) \times Cf$$

where;

Ef: PM emission factor for large truck and lorry/trailer

Cf: conversion factor for emissions in g/Bhp-hr to g/km

3.1917 for HDDV for -1992

2.5580 for HDDV for 1993-2005

Source: U.S.EPA(#5008)

Table 27 Particulate Emission for Buses

	-1992			1993-2005		
Vehicle Speed	15	20	25-	15	20	25-
Mini Bus	1.603	1.408	1.028	0.600	0.527	0.385
M/Large Bus	4.481	3.425	2.872	3.590	3.153	2.301

Table 28 Average Particulate Emission Factor for Motor Vehicles (1997)

(Unit: g/km)

Vehicle Type	Average Speed(km/h)		
	15	20	25
Motorcycle	0.205	0.205	0.205
Motor Car	0.039	0.039	0.039
Van	0.086	0.086	0.086
Taxi	0.209	0.209	0.209
Mini Bus	1.349	1.185	0.865
Medium/Large Bus	4.256	3.737	2.728
Small Truck	0.039	0.039	0.039
Medium/Large Truck	0.543	0.543	0.543
Lorry/Trailer	1.309	1.309	1.309

Table 29 Average Particulate Emission Factor for Motor Vehicles (2005)

(Unit: g/km)

Vehicle Type	Average Speed(km/h)		
	15	20	25
Motorcycle	0.205	0.205	0.205
Motor Car	0.027	0.027	0.027
Van	0.069	0.069	0.069
Taxi	0.103	0.103	0.103
Mini Bus	0.995	0.874	0.638
Medium/Large Bus	3.941	3.461	2.526
Small Truck	0.032	0.032	0.032
Medium/Large Truck	0.402	0.402	0.402
Lorry/Trailer	1.182	1.182	1.182

Part 4 AIR QUALITY SIMULATION

4.1 Air Quality Simulation by Dispersion Model

4.1.1 Dispersion Equation

(1) Point source Equation

When windy (u > 0.4 m/s), the following plume equation is used.

$$C(R,\ z)=\frac{Q_p}{\sqrt{2\pi}\ \frac{\pi}{8}R\sigma_z u}\cdot\left\{\exp\left\{-\frac{(z-He)^2}{2\sigma_z^2}\right\}+\exp\left\{-\frac{(z+He)^2}{2\sigma_z^2}\right\}\right\}$$

C(R,z) : Concentration at the location (R,z)

R : Horizontal distance (m) from a point source to a computation point

z : z coordinates (m) of the computation point (along height)

Qp : Point source intensity (Nm^3/s)

u : Wind speed (m/s)

He : Effective stack height (m)

σ_z : Vertical diffusion parameter (m) (using the Pasquill-Gifford chart)

When calm ($u \leq 0.4$ m/s), the following puff equation is used.

$$C(x,y,T)=\frac{1}{(2\pi)}\int_0^T\frac{2Q_p}{\sigma_y^2\sigma_z}\exp\left(-\frac{(x-ut)^2}{2\sigma_y^2}-\frac{y^2}{2\sigma_y^2}-\frac{He^2}{2\sigma_z^2}\right)dt$$

A steady-state solution for the calm condition was applied after integrating the above equation up to $t = \infty$, with $u = 0$, $\sigma_y = \alpha t$, and $\sigma_z = \gamma t$.

$$C(R,z)=\frac{Qp}{(2\pi)^{3/2}\gamma}\cdot\left\{\frac{1}{R^2+\frac{\alpha^2}{\gamma^2}(z-He)^2}+\frac{1}{R^2+\frac{\alpha^2}{\gamma^2}(z+He)^2}\right\}$$

$$R^2=x^2+y^2$$

α , γ : Diffusion parameters for calm

$\sigma x=\sigma y=\alpha\cdot t$

$\sigma z=\gamma\cdot t$

t : Time lapse (s)

(2) Area Source Equation

When windy, the plume equation applicable to long-term average concentration is used, assuming that a square area source with a side 2a long is present in isolation.

$$C=\frac{Q_A}{\sqrt{2\pi}\,u}\int_{x-a}^{x+a}\frac{2a}{\left(\frac{\pi}{8}\xi+2a\right)\sigma z(\xi)}\cdot\{F\}\,d\xi$$

$$\{F\}=\exp\left\{-\frac{(z-He)^2}{2\sigma z(\xi)^2}\right\}+\exp\left\{-\frac{(z+He)^2}{2\sigma z(\xi)^2}\right\}$$

QA : Area source intensity (Nm^3/s)

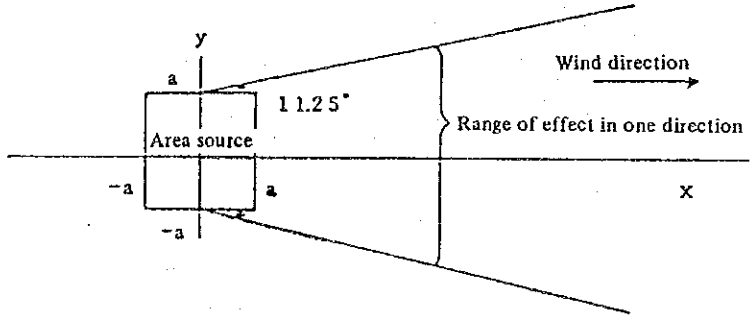
u : Wind speed (m/s)

He : Effective stack height (m)

σ z : Vertical diffusion parameter (m)

2a : Length (m) of a side of a square area source

A conceptual diagram of area source dispersion model is shown below.



When calm, the following equation is used by applying the simplified puff equation (steady-state solution) to a circular area source that has the same area as a square area source with a side 2a long.

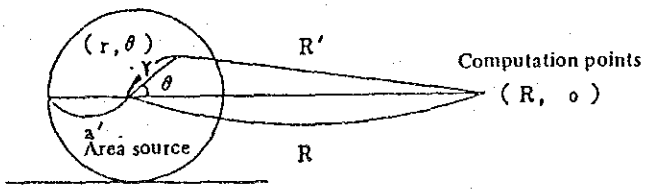
$$C = \frac{Q_A}{(2\pi)^{3/2} r} \int_0^{a'} \int_0^{2} \left(\frac{1}{R'^2 + b_1^2} + \frac{1}{R'^2 + b_2^2} \right) r \cdot d\theta \cdot dr$$

$$a' = \frac{2a}{\sqrt{\pi}}$$

$$R' = (r^2 + R^2 - 2rR\cos\theta)^{1/2}$$

$$b_1 = \frac{\alpha}{r}(z - He), \quad b_2 = \frac{\alpha}{r}(z + He)$$

A conceptual diagram of area source diffusion model is shown below.



(3) Line Source Equation

When windy, the 2π/16 equation which brings uniform concentration in the direction of y is used.

$$C = \int_{r_1}^{r_2} \frac{Q_L}{\sqrt{2\pi} \cdot \frac{\pi}{8} r \sigma z(r) u} \cdot \left\{ \exp\left\{ -\frac{(z - He)^2}{2\sigma z(r)^2} \right\} + \exp\left\{ -\frac{(z + He)^2}{2\sigma z(r)^2} \right\} \right\} \cdot dr$$

z : z coordinate (m) at the computation point

r : Distance (m) from the computation point to a line source

r1, r2: Integration interval (m) of a line source

QL : Line source intensity (Nm^3 / s.m)

u : Wind speed (m/s)

He : Effective stack height (m)

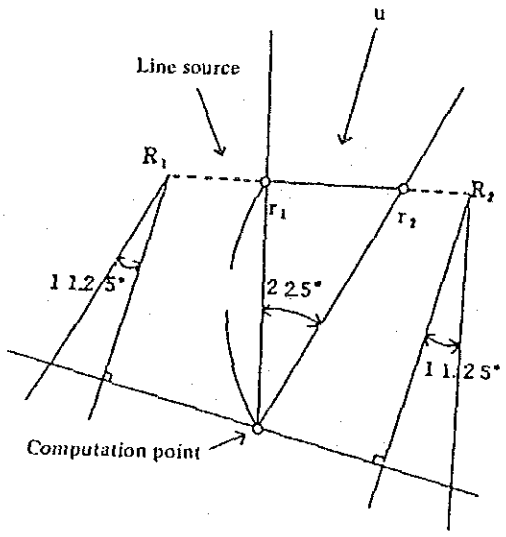
σz : Vertical diffusion parameter (m)

When calm, the following equation is used.

$$C = \int_{R_1}^{R_2} \frac{Q_L}{(2\pi)^{\frac{3}{2}} r} \left(\frac{1}{r^2 + b_1^2} + \frac{2}{r^2 + b_2^2} \right) dr$$

$$b_1 = \frac{\alpha}{r}(z - He) \qquad b_2 = \frac{\alpha}{r}(z + He) \qquad r^2 = x^2 + y^2$$

R1, R2: Integration interval (m) of a line source as shown below



(2) Plane Distribution of Contribution Concentratin by Air Pollution Sources

1) Present State

Estimated plane distribution of contribution concentration of present state by sources is shown in Fig. 4.1.1 - Fig. 4.1.4

2) In Future

Predicted plane distribution of contribution concentration in future by sources is shown in Fig 4.1.5 - Fig. 4.1.8.

3) With Control Measure

Predicted plane distribution of contribution concentration with control measure by sources is shown in Fig. 4.1.9 - Fig. 4.1.12.

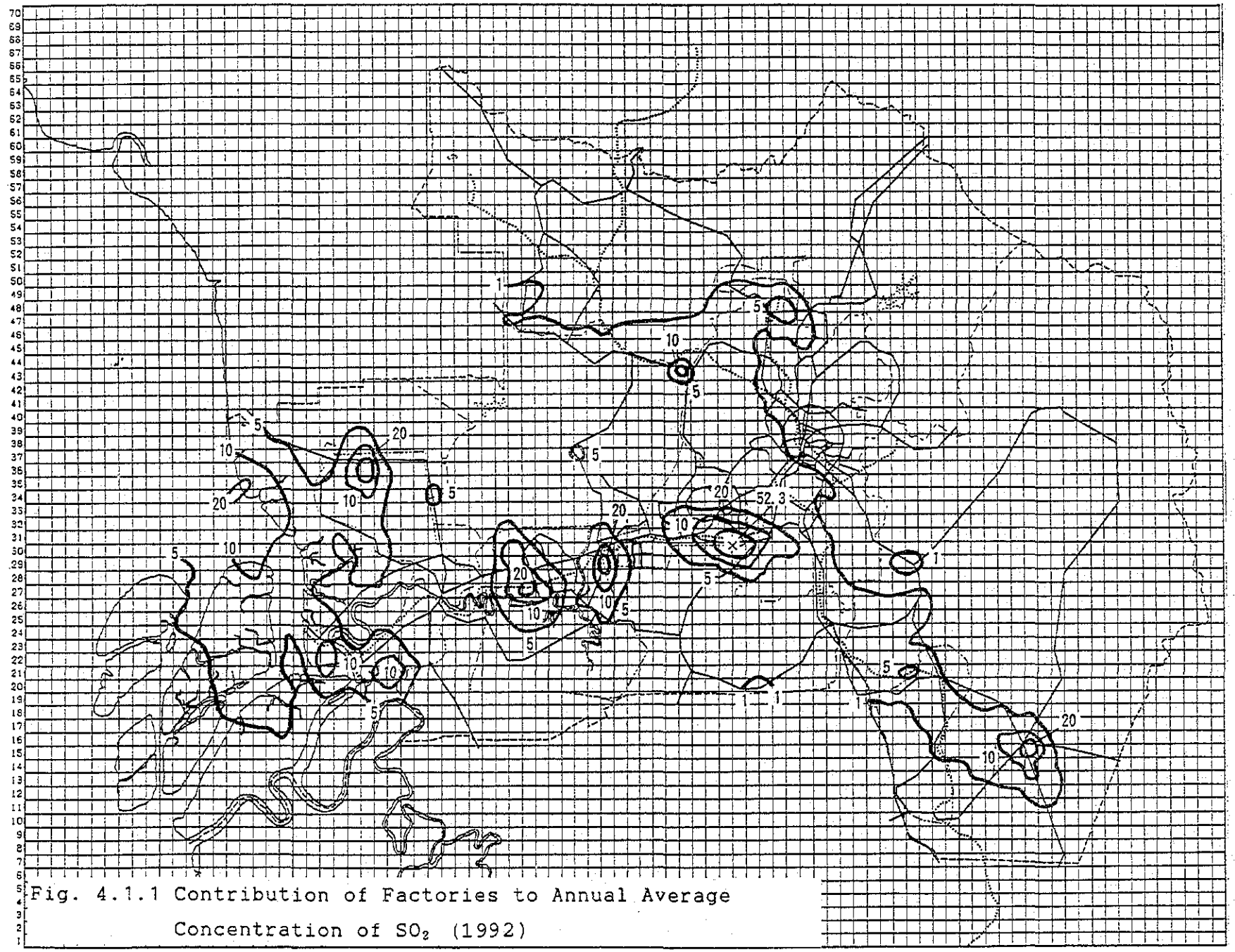


Fig. 4.1.1 Contribution of Factories to Annual Average Concentration of SO_2 (1992)

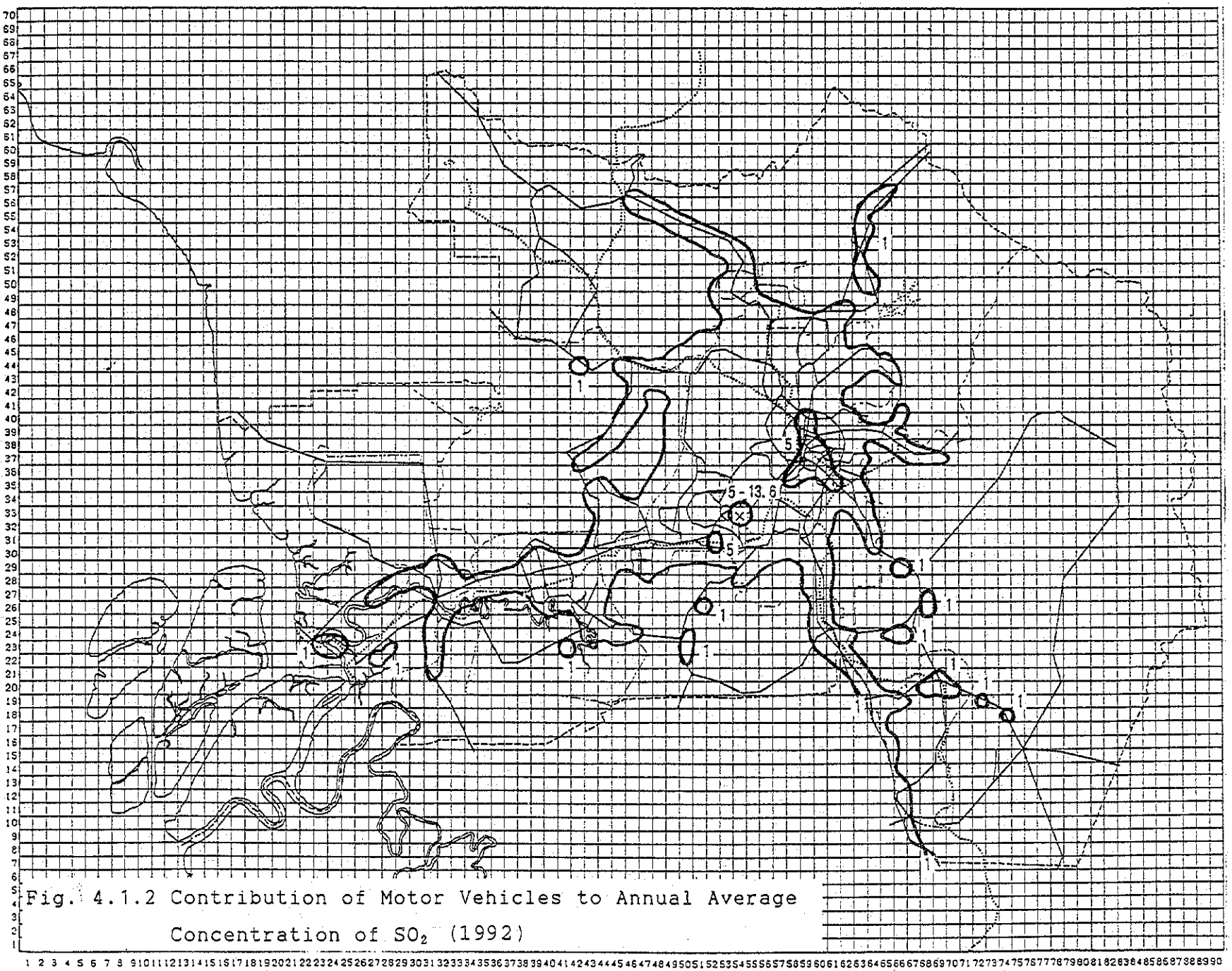


Fig. 4.1.2 Contribution of Motor Vehicles to Annual Average Concentration of SO_2 (1992)

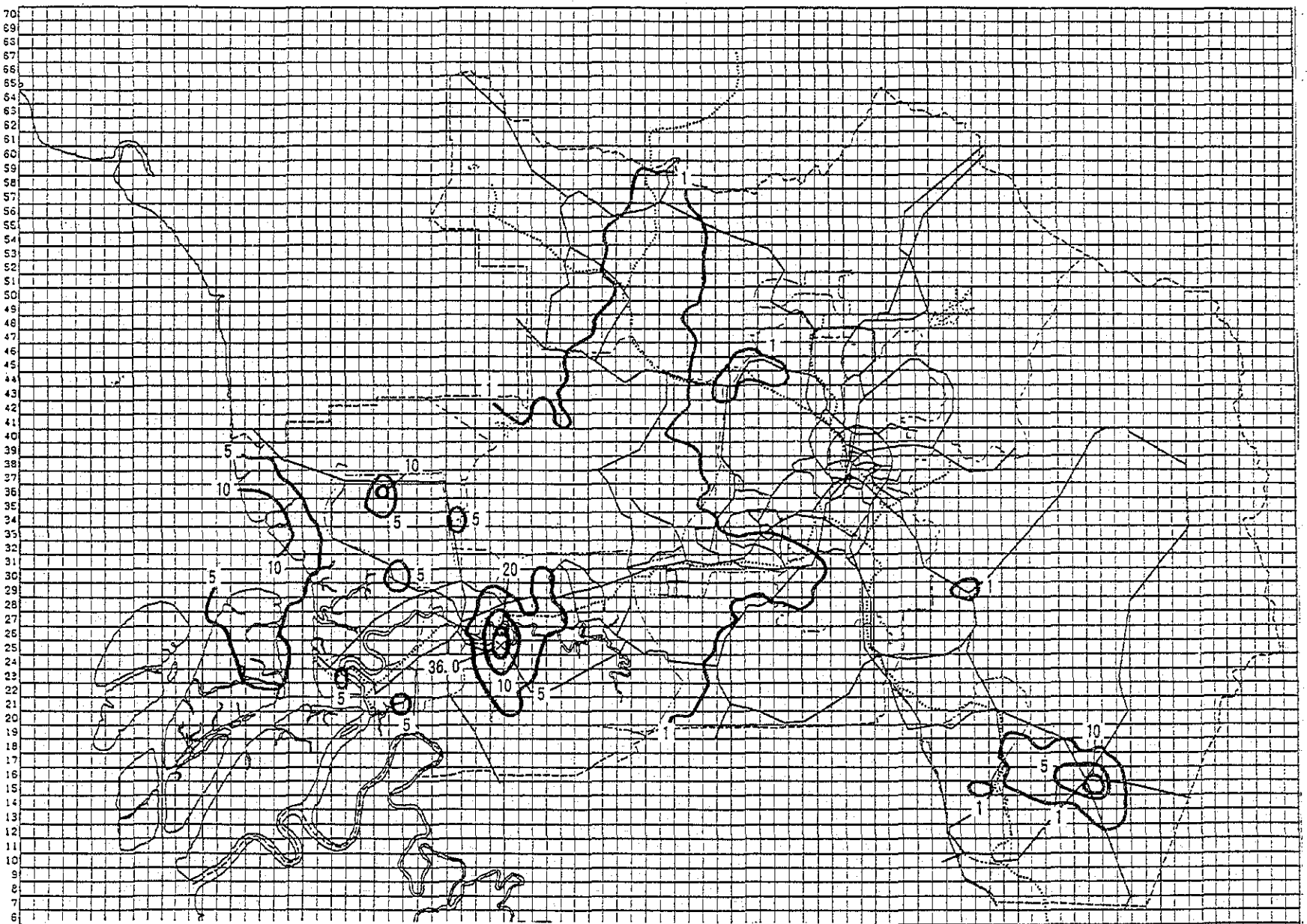


Fig. 4.1.3 Contribution of Factories to Annual Average Concentration of NO_x (1992)

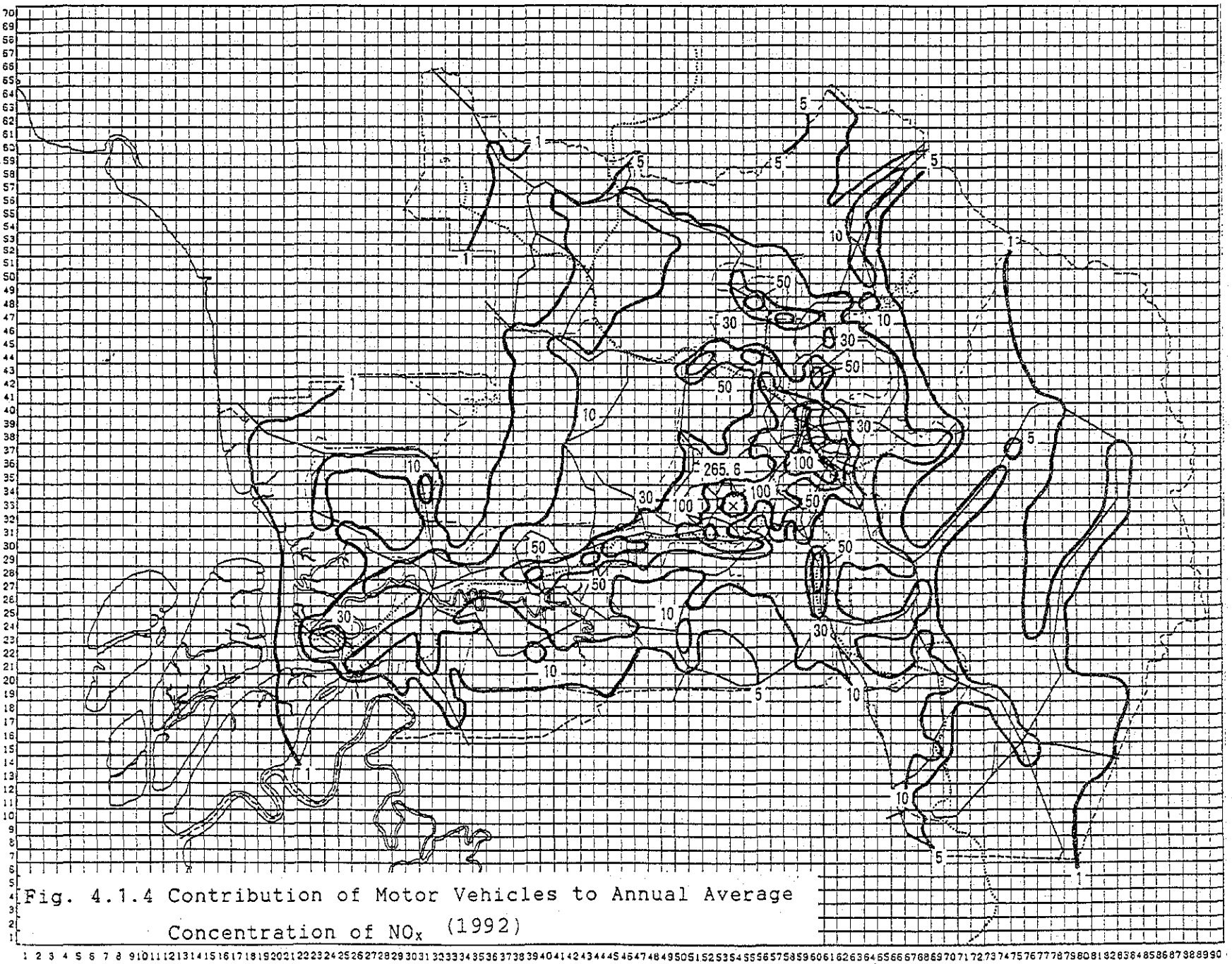


Fig. 4.1.4 Contribution of Motor Vehicles to Annual Average Concentration of NO_x (1992)

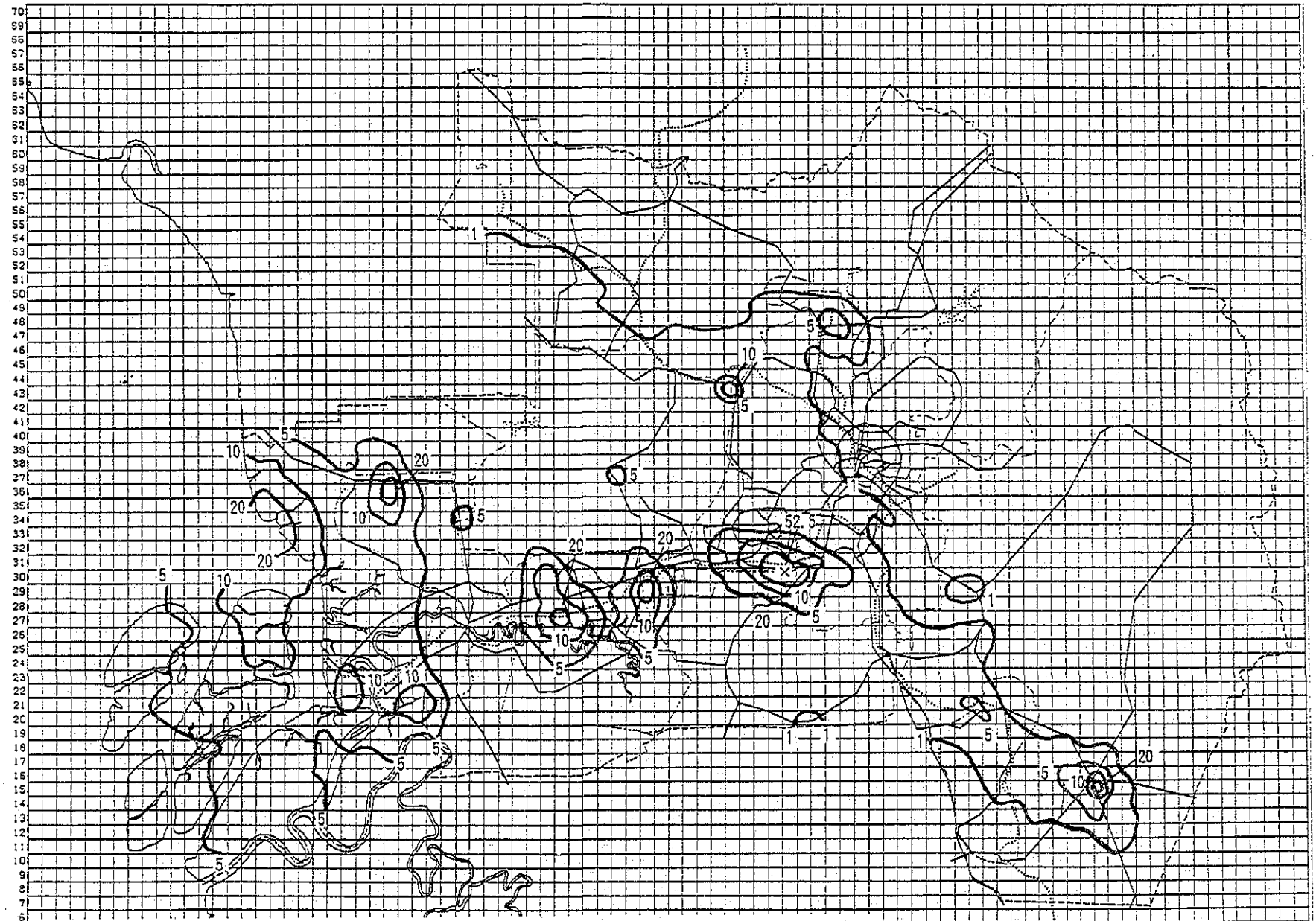


Fig. 4.1.5 Contribution of Factories to Annual Average Concentration of SO_2 (2005)(without Control Meusures)

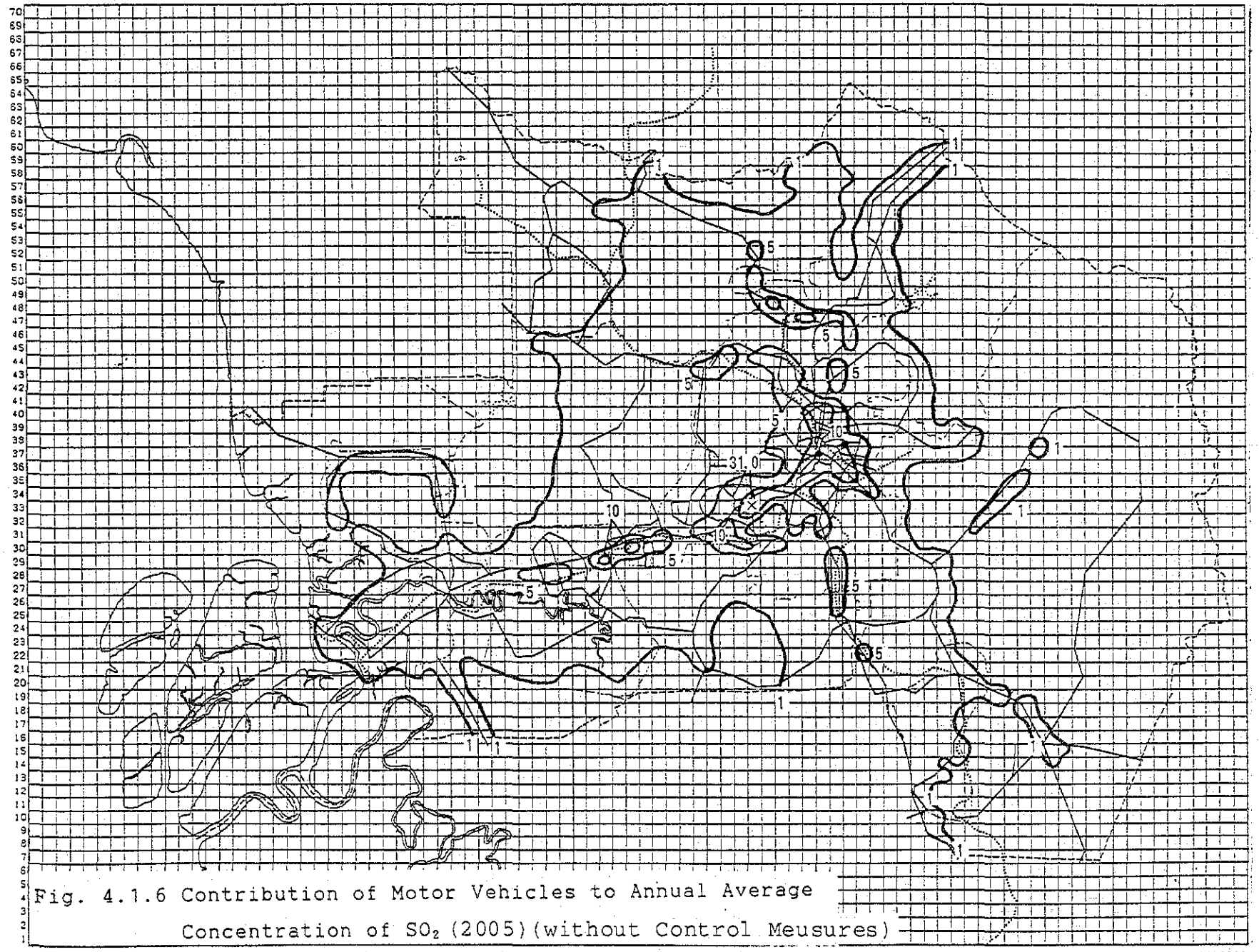


Fig. 4.1.6 Contribution of Motor Vehicles to Annual Average Concentration of SO_2 (2005)(without Control Meusures)

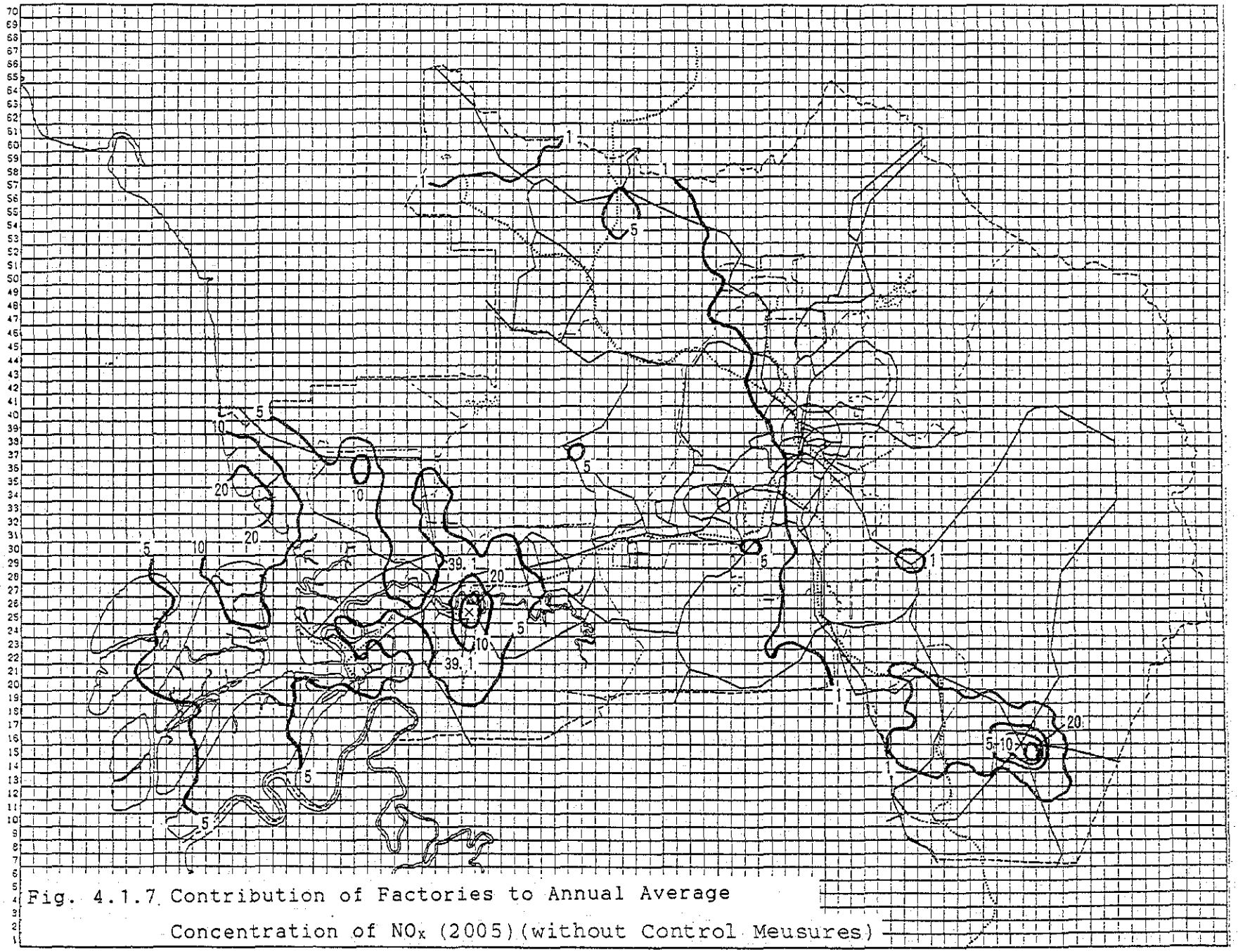


Fig. 4.1.7 Contribution of Factories to Annual Average Concentration of NO_x (2005)(without Control Meusures)

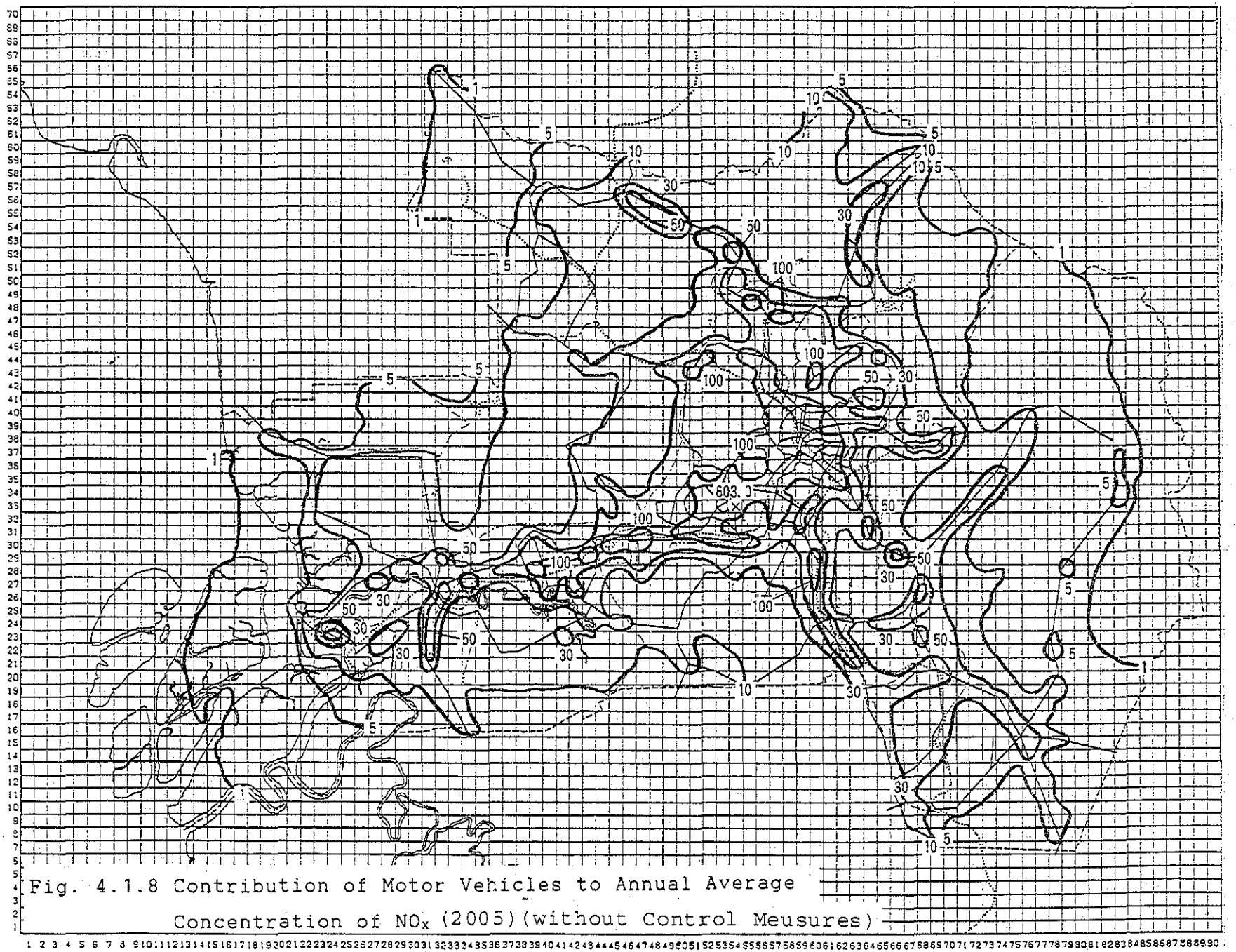


Fig. 4.1.8 Contribution of Motor Vehicles to Annual Average Concentration of NO_x (2005)(without Control Meusures)

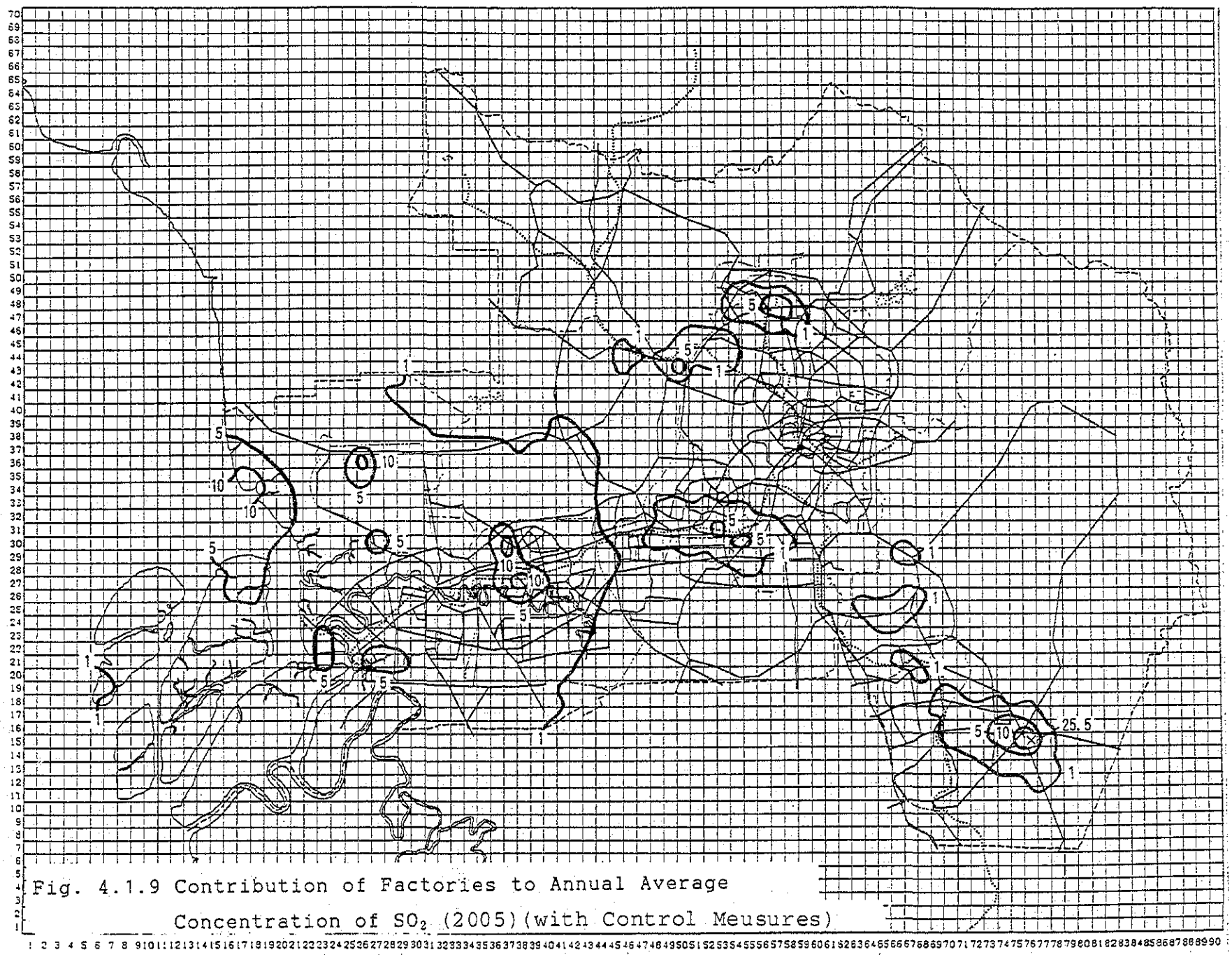


Fig. 4.1.9 Contribution of Factories to Annual Average Concentration of SO_2 (2005)(with Control Meusures)

Fig. 4.1.10 Contribution of Motor Vehicles to Annual Average Concentration of SO_2 (2005)(with Control Meusures)

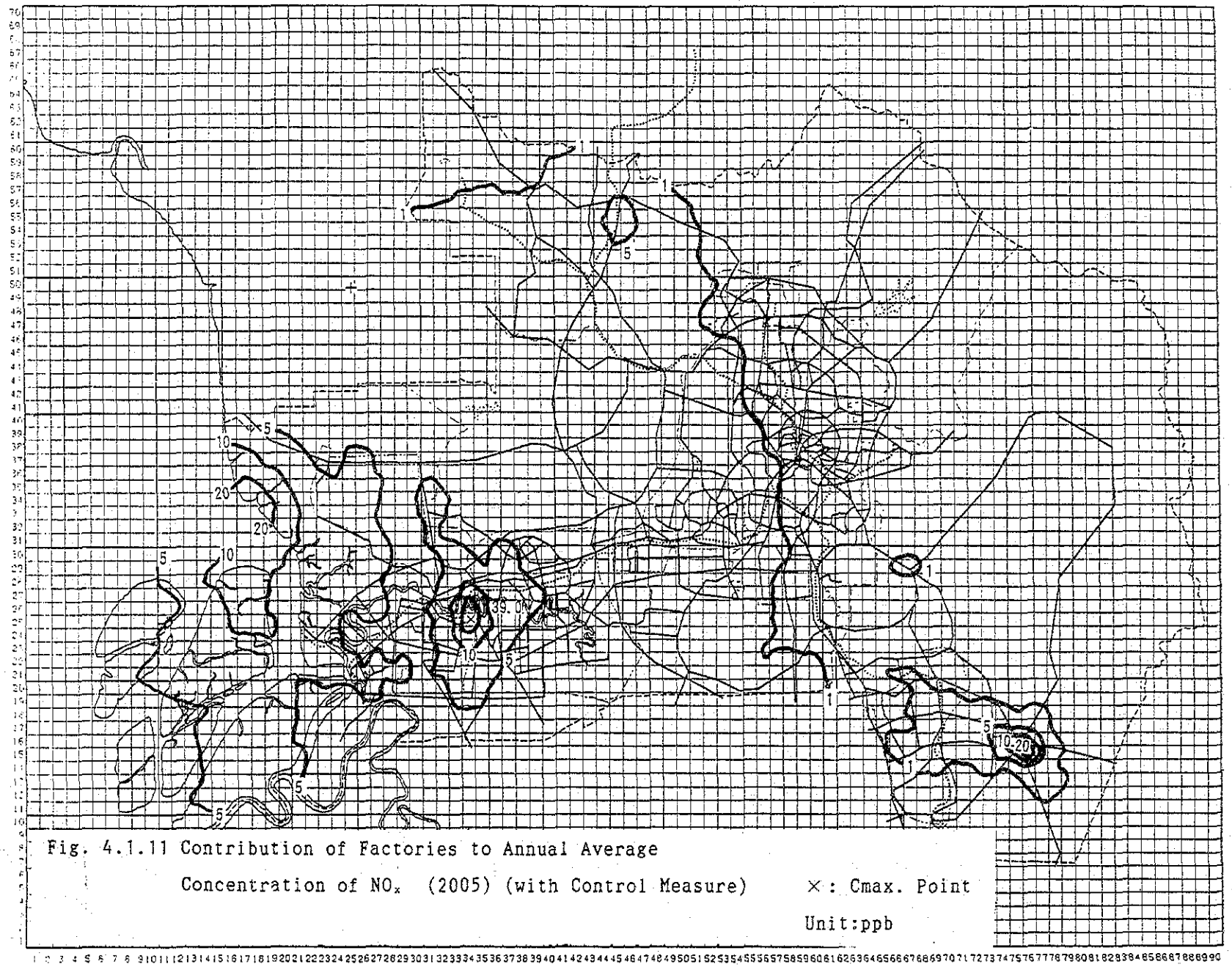


Fig. 4.1.11 Contribution of Factories to Annual Average Concentration of NO_x (2005) (with Control Measure)

× : Cmax. Point

Unit:ppb

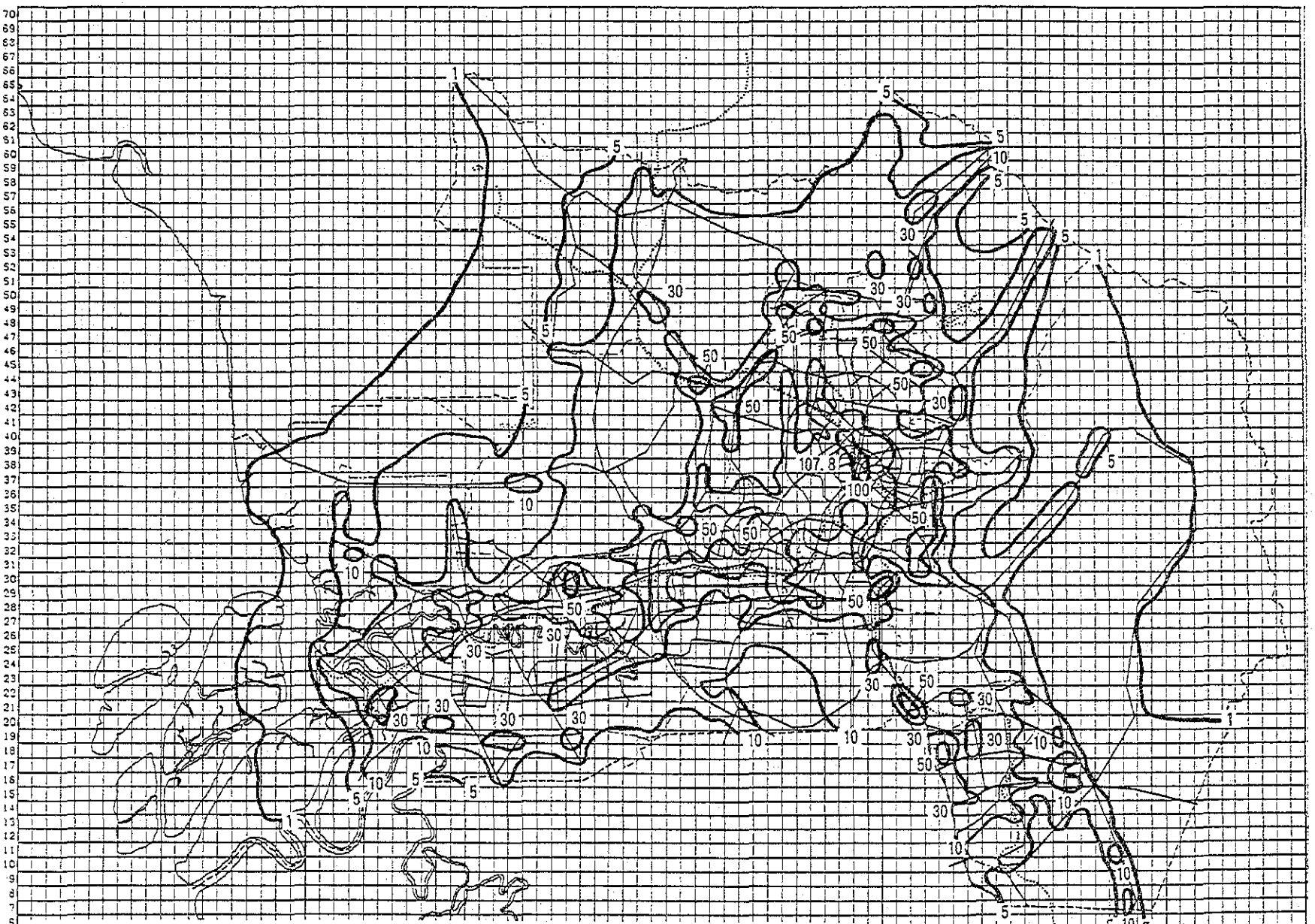


Fig. 4.1.12 Contribution of Motor Vehicles to Annual Average Concentration of NO_x (2005)(with Control Meusures)

4.1.2 Calculation Method for Correlation Coefficient and Coefficient of Variation

Calculation Method for Correlation Coefficient is as follows.

$$r = \frac{Sxy}{\sqrt{Sxx \cdot Syy}}$$ Correlation Coefficient

$$\overline{Y} = \frac{1}{n}\sum_{i=1}^{n} Yi$$

$$\overline{X} = \frac{1}{n}\sum_{i=1}^{n} Xi$$

$$Sxy = \sum_{i=1}^{n} (Xi-\overline{X}) \cdot (Yi-\overline{Y})$$

$$Syy = \sum_{i=1}^{n} (Yi-\overline{Y})^2$$

$$Sxx = \sum_{i=1}^{n} (Xi-\overline{X})^2$$

Calculation Method for Coefficient of Variation is as follows.

$$Ei = Yi - Y'i$$ ---------- Error

$$S'\varepsilon = \sum_{i=1}^{n} (Yi-Y'i)^2$$ ---------- Sum of error squares

$$= \sum_{i=1}^{n} \left\{ Yi - (a_0 + Xi) \right\}^2$$

$$= \sum_{i=1}^{n} \left\{ Yi - (\overline{Y} - \overline{X} + Xi) \right\}^2$$

$$= \sum_{i=1}^{n} \left\{ (Yi-\overline{Y}) - (Xi-\overline{X}) \right\}^2$$

$$= \sum_{i=1}^{n} (Yi-\overline{Y})^2 - 2\sum_{i=1}^{n} (Yi-\overline{Y}) \cdot (Xi-\overline{X}) + \sum_{i=1}^{n} (Xi-\overline{X})^2$$

$$= Syy - 2\,Sxy + Sxx$$

$$s'\varepsilon = \frac{S'\varepsilon}{n-2}$$ ---------- Unbiased variance of error

$$s' = \sqrt{s'\varepsilon}$$ ---------- Coefficient of variation

4.1.3 Setting of Background Concentration

Background concentration was set as shown in Table 4.1.1 in estimating the concentration of present state, in future and with control measure.

Part of background concentration excluding in natural in future and with control measure was supposed to change according to the change of air pollutant volume from all sources.

Table 4.1.1 Background Concentration

Estimating case	Item	Air pouutant volume (1 (ton/yaer)	Background concentration (2		
			In natural	Unknown	Total
Present state	SO_2	35,666	2.0	1.1	3.1
	NO_x	54,388	3.0	2.9	5.9
	CO	290,930	0.5	0.5	1.0
In future	SO_2	51,620	2.0	1.6	3.6
	NO_x	115,263	3.0	6.2	9.2
	CO	660,411	0.5	1.2	1.7
With control measure	SO_2	33,181	2.0	1.1	3.1
	NO_x	79,738	3.0	4.3	7.3
	CO	322,032	0.5	0.6	1.1

Note: (1 Volume is from all sources.

(2 Units are SO_2 → ppb, NO_x → ppb, CO → ppm.