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Technical Report

Localized Air Quality Impacts of Diesel Particulate Emissions

by

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Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air, Noise and Radiation
U.S. Environmental Protection Agency

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Introduction

A number of studies are available which attempt to predict the level of diesel exhaust particulate along the roadway resulting from the increased use of diesel engines as power plants for light-and heavy-duty vehicles. Among these are reports prepared by EPA,1/2/ the Southwest Research Institute,3/ General Motors Corporation,4/ Toyota Motor Co.,5/ and the Aerospace Corporation.6/

When trying to evaluate the results of these studies, problems arise due to the lack of a consistent set of assumptions made by the individual groups. The rate of diesel penetration into the market, vehicle emission factors, traffic density and meteorological conditions are among the variables encountered. This report attempts to establish a broader base of comparison among these studies than presently exists.

To effect this, each study will be altered so that all use the same rate of dieselization and particulate emission factor. The modification process simply consists of replacing the values of these two parameters used in each study with the following set of assumptions (based on the year 1990):

Light-duty emission factor:	1.0 gram particulate/mile
Heavy-duty emission factor:	2.0 grams particulate/mile
Light-duty dieselization level:	Low - 9.6% of urban VMT High - 15.9% of urban MVT
Heavy-duty dieselization level:	Low - 3.7% of urban VMT High - 5.2% of urban VMT

This report consists of three basic sections; the first provides a brief description of the various studies, the second incorporates the standardizing assumptions in the modification procedure, and the third compares the studies based on the changes made in section two.

In order to facilitate reading of this report, only the most essential tables have been included in the body of the text. Other, supporting tables are located in the appendix and are identified by the prefix A.

Section I: Summaries of Roadside Impact Studies

A. EPA: "Reply to Request for Concentration Estimates near Roadways Due to Mobile Source Emissions of Sulfuric Acid and Diesel Particulates (TSP and BaP)".1/

Model Used: HIWAY7/

Traffic Characterization: The traffic volume used in this study assumed 100,000 vehicles per day for the Monday through Friday work period. By applying the SAPPOLUT model,8/ hourly vehicle distribution characteristics were determined for a suburban freeway in an area with a population greater than 500,000. (See Table A-1).

Receptor Locations: Five receptors were chosen in the EPA study, each located on the inbound side of the freeway. This choice of locations was done in order to maximize the effect of peak hour (0700) traffic. (See Figure 1).

Meteorological Data: By studying CO concentrations measured in Oakbrook, Illinois, Patterson9/ determined that maximum 8-hour average concentrations occur for the eight consecutive hours ending about 6 P.M. Corresponding meteorological data were: 2-5 m/sec wind speeds, 0° - 50° wind fluctuations, and D-stability. For the 24-hour periods with highest concentrations, winds were 2-7 m/sec, direction variability was 0° - 50°, and atmospheric stability was nearly constant.

Summary of Meteorological Conditions

One-hour

Wind speed: 1 m/sec road-wind angle: 7°
Stability class: D: Initial mixing:* 5m

8-hour Worst Case

Wind speed (by hour): 4, 3, 2, 2, 2, 2, 2, 2 m/sec

Road-wind angle (by hour): 45°, 40°, 30°, 20°, 12°, 7°, 12°, 15°

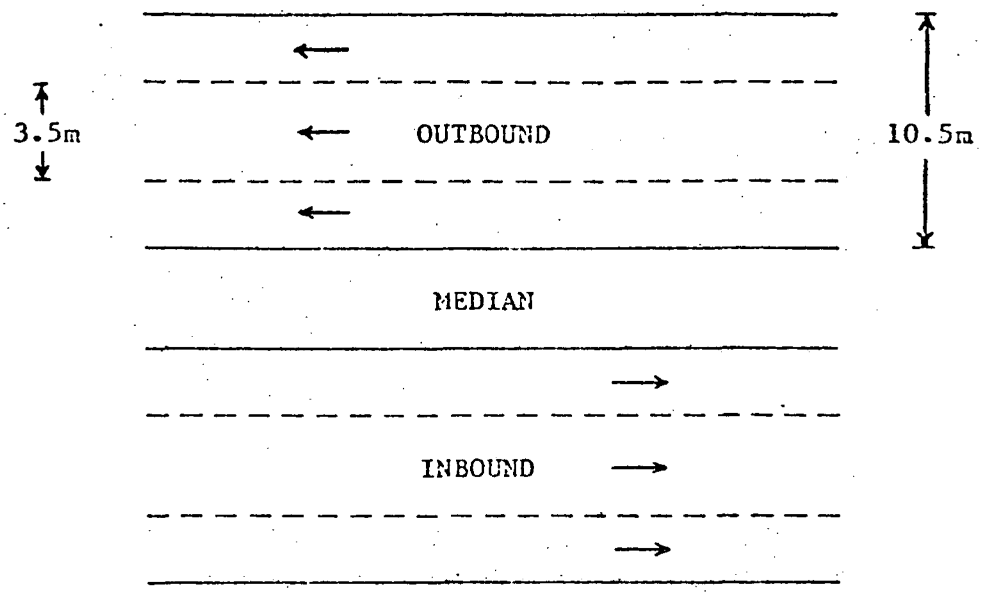
Stability class: D

Initial mixing:* 5m

24-hour Worst case

Wind speed (by hour): 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 3, 4, 3, 2, 2, 2, 2, 2, 2, 2, 2, 2, 3, 4, m/sec

*Initial mixing refers to the region of space immediately after the point of pollutant release in which turbulence is the predominant mode of dispersion.



Receptor Number	Distance to Curb (meters)
1	4.75
2	24.75
3	44.75
4	64.75
5	94.75

Figure 1. Source-Receptor Configuration

Source: Reference 1/

Road-wind angle (by hour): 20°, 30°, 30°, 20°, 30°, 30°, 20°, 12°, 15°, 30°, 40°, 45°, 40°, 30°, 20°, 12°, 7°, 12°, 15°, 15°, 20°, 30°, 40°, 45°

Stability class: D

Initial mixing: 5m

Emission Factors: Emissions by vehicle class are in Table A-2.

Dieselization Rate: The breakdown of urban VMT for 1990 by vehicle class was taken from a PEDCo report.10/ Table A-2 presents this analysis.

Results: (See Table 1) The terms best and max refer to the different dieselization rates found in Table 1. The low and high terms refer to the HDVD (heavy-duty vehicle diesel) emission factors in Table A-2. The first set of 8-hour concentration estimates are obtained by multiplying 1-hour values by 0.7, as suggested in the Indirect Source Guidelines.11/

B. Southwest Research Institute Study:3/ "Study of Particulate Emission from Motor Vehicles - A Report to Congress" (Draft)

Four separate scenarios were considered by SwRI in order to analyze exposures at the local level. For the purposes of this report, these scenarios will be referred to as: on a crowded expressway, beside an expressway, in a street canyon and in a parking area. The last of these will not be described due to its highly specialized nature, making it difficult to compare with other studies.

On a Crowded Expressway

Model Used: Chock's Simple Line Source Model12/

Traffic Characterization: A portion of I-45 at Houston, Texas with a 5:30 p.m. vehicle count of 1494 vehicles per lane was used for this study. (See Figure 2)

Receptor Location: Concentrations were computed for the outside downwind lane.

Meteorological Data: An examination of recent five-year meteorological data revealed that at 6 p.m., the wind was from the ESE at 4 to 16 knots (2.06 to 8.23 m/sec) at 2.75° to 25.25° relative to the road and stability was within plus or minus 1 class of neutral 15% of the time. These conditions were chosen as model inputs.

Table 1

Particulate Concentrations

One-Hour Concentrations (milligrams per cubic meter)

Receptor #	Best, Low	Best, High	Max, Low	Max, High
1	.155	.191	.294	.345
2	.096	.118	.182	.214
3	.072	.089	.137	.160
4	.058	.071	.110	.129
5	.042	.052	.080	.093
Eight-Hour Concentrations (using conversion factor = .7)				
1	.109	.134	.207	.242
2	.067	.082	.127	.149
3	.050	.062	.095	.111
4	.040	.049	.076	.089
5	.029	.036	.055	.064
Eight-Hour Reasonable Case Scenario				
1	.032	.039	.061	.071
2	.023	.028	.044	.051
3	.018	.022	.034	.040
4	.016	.020	.030	.036
5	.013	.016	.025	.029
24-Hour Scenario				
1	.020	.025	.038	.044
2	.015	.018	.028	.033
3	.012	.015	.023	.027
4	.010	.012	.019	.022
5	.008	.011	.017	.020

Source: Reference 1/.

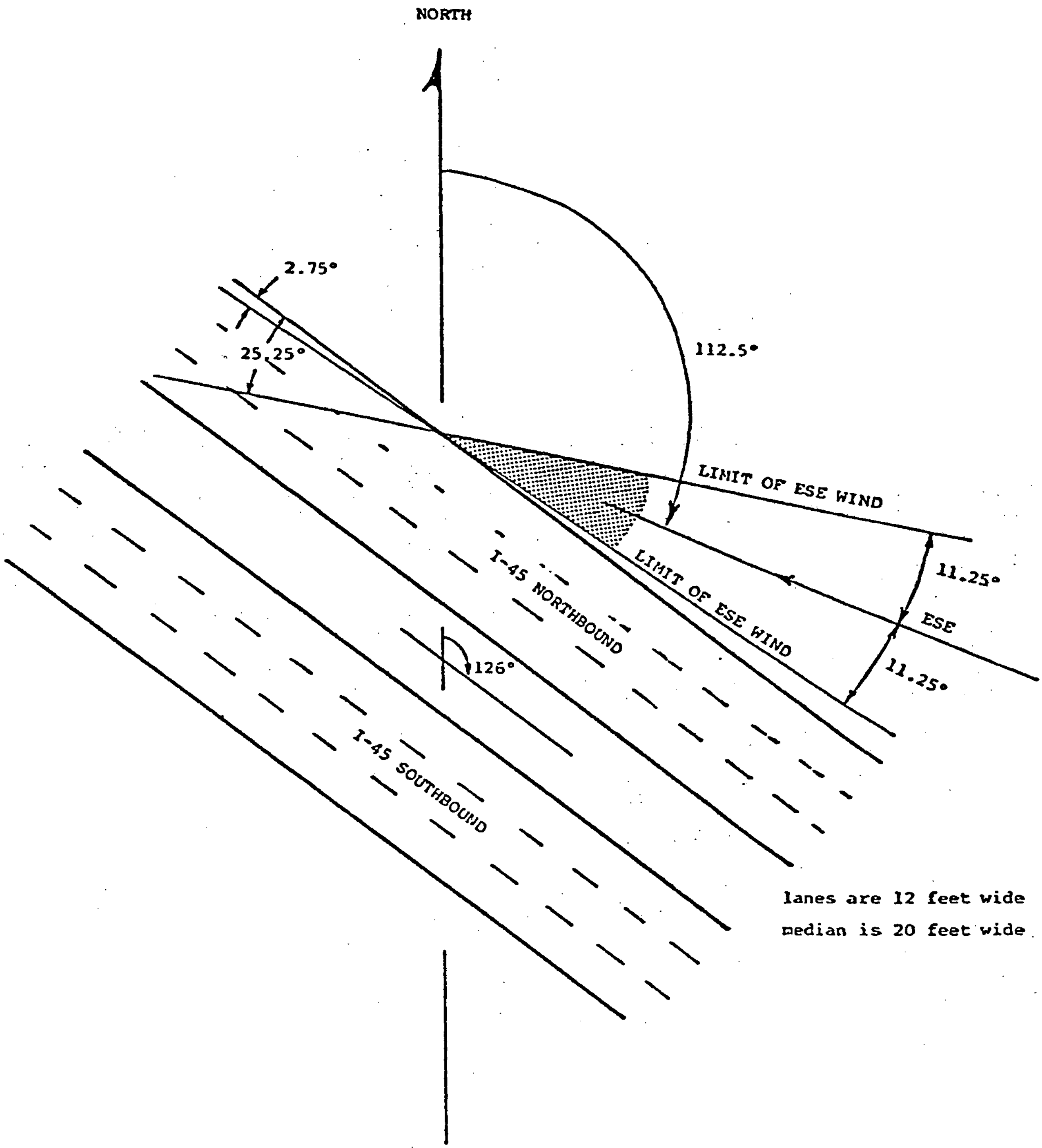


Figure 2 . I-45 AT JOPLIN, HOUSTON, TEXAS, SHOWING WIND ANGLE LIMITS WITH ROAD FOR ESE WIND.

Source: Reference 3/

Emission Factors: Two sets of emission factors were considered; one scenario which assumed that the proposed light-duty diesel standard (Federal Register 2/1/79) will be adopted as proposed and another which considered the effect of no diesel particulate regulations. The light-duty diesel emission factors used for the first situation were 0.6 g/mile for 1981 and 1982 model years and 0.2 g/mile for 1983 and beyond. Emission factors for the latter scenario were developed by considering the amount of pollutants from individual vehicle models (see Table A-3), their corresponding projected sales (Table A-4), and a breakdown of annual travel. Tables A-5 and A-6 show the computed particulate emission factors for a crowded expressway by model year. Composite emission factors are found in Table A-7.

Dieselization Rate: Three estimates of the rate of diesel penetration were used in this study. The "best" estimate assumes that in 1985, 25% of GM's light duty sales will be diesel. Also, it is assumed that 25% of total sales will be diesel in 1995. A low estimate was prepared which considered the possibility of the manufacturers not being able to meet the proposed light duty diesel standards. This scenario held the diesel sales at the 1982 level. A third "high" estimate dealt with the possibility of more stringent fuel economy requirements by D.O.T. This would, according to their projections, result in greater production of more fuel efficient diesels. Sales would follow the "best" estimate growth rates until 1983, where a linear increase leading to a 1995 diesel sales penetration figure of 50% would begin. From 1995 through 2000, the diesel fraction of sales remains constant at 50%.

Results: Table 2 shows the results of the "On Expressway" study.

Beside an Expressway

Model Used: Chock's line source model, modified by Sievers to yield annual arithmetic means, was used.13/

Traffic Characterization: The study site was I-10 at Silber Road on the west side of Houston. This portion of I-10 runs due east-west with four lanes in each direction. The average traffic count for 1977 was 167,860 vehicles per day.

Receptor Location: The contributions to annual TSP levels at 1, 10, 30, 100, 200 and 500 meters from the road's northern edge were computed.

Meteorological Data: Ambient particulate concentrations were computed for each of 576 meteorological conditions. This number was arrived at by considering the possible combinations of 16 wind directions, six stability classes and six wind speed classes. The frequency of occurrence of each particular meteorological combination was multiplied by the corresponding concentration in order

TABLE 2 VEHICLE CONTRIBUTION TO AMBIENT AIR PARTICULATE CONCENTRATIONS ON AN EXPRESSWAY (I-45 at Joplin Dr.) IN HOUSTON, TEXAS

		Vehicle Contributions, $\mu g/m^3$			
Year	Diesel Part. Regulations	4 kts ** at 2.75°	4 kts at 25.25	16 kts at 2.75°	16 kts at 25.25
		baseline			
1977		78.1	49.6	56.6	16.5
		Low Estimate of Light Duty Dieselization			
1985	yes	57.4	36.5	41.6	12.1
1985	no	62.0	39.4	44.9	13.1
1990	yes	47.1	29.9	34.1	9.9
1990	no	62.0	39.4	44.9	13.1
2000	yes	47.9	30.4	34.7	10.1
2000	no	70.8	45.0	51.3	15.0
		Best Estimate of Light Duty Dieselization			
1985	yes	57.8	36.7	41.9	12.2
1985	no	63.9	40.6	46.3	13.5
1990	yes	49.8	31.6	36.1	10.5
1990	no	70.1	44.5	50.8	14.8
2000	yes	53.6	34.0	38.8	11.3
2000	no	90.4	57.4	65.5	19.1
		High Estimate of Light Duty Dieselization			
1985	yes	58.2	37.0	42.2	12.3
1985	no	64.7	41.1	46.9	13.7
1990	yes	52.1	33.1	37.7	11.0
1990	no	78.5	49.8	56.9	16.6
2000	yes	61.6	39.1	44.7	13.0
2000	no	116.8	74.2	84.6	24.7

* at outside, downwind lane

** wind speed and direction relative to expressway

Source: Reference 3/

to weight the prediction. Houston wind data indicates that vehicle emissions will be dispersed northward approximately 60% of the time.

Emission Factors and Dieselization Rate: The same scenarios from the on expressway study were used here.

Results: Table 3 shows the results of the "Beside an Expressway" study.

In a Street Canyon

Model Used: The street canyon model by Johnson, et. al.14/ was the basis for this study. The model is based on helical air circulation patterns over a street with buildings on both sides.

Traffic Characterization: The test city was San Antonio. The street being modeled was Houston Street (eastbound one-way) between cross streets Navarro and St. Mary's. "Canyon" width was 61 feet and the leeward side average building height was 111 feet. Average daily traffic was approximately 15,300 vehicles per day. For receptors 3 and 4 (residents), vehicle rate = 0.177 vehicles per second. For receptors 1 and 2 (pedestrians), a peak rate of 0.354 vehicles per second was used.

Receptor Location: (Refer to Figure 3.) $X_1 = X_2$ = street center-to-receptor 1 or 2 (pedestrian) distance = 28.8 feet. $X_3 = X_4$ = street center-to-receptor 3 or 4 (resident) distance = 30.5 feet.

Meteorological Data: U = rooftop wind speed = 10 mph (4.5 meters/sec). Wind direction is from the south-southeast (58° to street direction).

Emission Factors:

Vehicle Type	National Fraction of VMT	Total Particulate Emission Factor g/mile
Light-duty gasoline	0.925	0.27
Light-duty diesel	0.001	0.99
Medium-duty truck	0.007	0.56
Heavy-duty gasoline	0.022	1.01
Heavy-duty diesel	0.040	2.84
Motorcycles	0.005	0.08

Dieselization Rate: The same three low, best and high estimates used in the on and beside an expressway studies were used here.

Results: Table 4 contains the "Street Canyon" projections.

TABLE 3 . Annual Arithmetic Mean Vehicle Contribution To Ambient Air Particulate Beside an Expressway (I-10 at Silber) in Houston, Texas

Year	Diesel Part. Regulations	Vehicle particulate contribution, annual arithmetic mean, μg/m³ — Distance from road edge: 1m	10m	30m	100m	200m	500m
				Baseline			
1977		12.4	9.7	6.2	3.0	1.8	0.8
		Low estimate of light duty dieselization					
1985	Yes	9.1	7.2	4.5	2.2	1.3	0.6
1985	No	9.8	7.7	4.9	2.4	1.4	0.6
1990	Yes	7.5	5.9	3.7	1.8	1.1	0.5
1990	No	9.8	7.7	4.9	2.4	1.4	0.6
2000	Yes	7.6	6.0	3.8	1.8	1.1	0.5
2000	No	11.2	8.8	5.6	2.7	1.6	0.7
		Best estimate of light duty dieselization					
1985	Yes	9.2	7.2	4.6	2.2	1.3	0.6
1985	No	10.1	8.0	5.1	2.4	1.4	0.7
1990	Yes	7.9	6.2	3.9	1.9	1.1	0.5
1990	No	11.1	8.7	5.5	2.7	1.6	0.7
2000	Yes	8.5	6.7	4.2	2.0	1.2	0.6
2000	No	14.3	11.3	7.2	3.4	2.0	0.9
		High estimate of light duty dieselization					
1985	Yes	9.2	7.3	4.6	2.2	1.3	0.6
1985	No	10.2	8.1	5.1	2.5	1.5	0.7
1990	Yes	8.2	6.5	4.1	2.0	1.2	0.5
1990	No	12.4	9.8	6.2	3.0	1.8	0.8
2000	Yes	9.8	7.7	4.9	2.3	1.4	0.6
2000	No	18.5	14.6	9.2	4.4	2.6	1.2

[a] On northside of the expressway which runs east-west

Source: Reference 3/

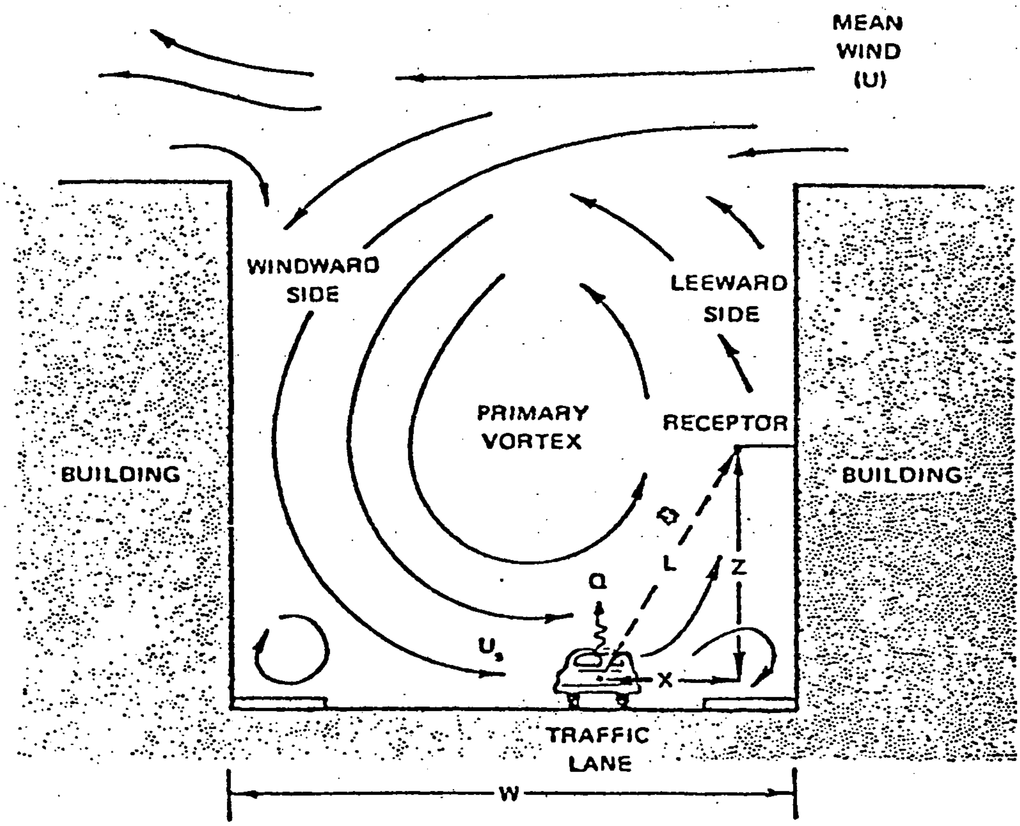


Figure 3 . Physical characteristics of street canyon

Source: Reference 3/

TABLE 4 Estimated Motor Vehicle Contributions to Total Particulate Concentrations in a Street Canyon, Houston Street between Navarro and St. Mary's, San Antonio, Texas

				Leeward side concentrations (ΔX_L), $\mu g/m^3$		Windward side concentrations (ΔX_W), $\mu g/m^3$	
Year	Regulations in effect	Dieselization estimate	Composite emission factor, g/veh. mi	receptor 1 pedestrian	receptor 3 resident	receptor 2 pedestrian	receptor 4 resident
1977	No	as is	0.39	13.	4.8	6.2	2.5
1985	Yes	low	0.26	8.6	3.2	4.1	1.7
		best	0.26	8.6	3.2	4.1	1.7
		high	0.26	8.6	3.2	4.1	1.7
	No	low	0.30	9.9	3.7	4.7	1.9
		best	0.31	10.	3.8	4.9	2.0
		high	0.32	11.	4.0	5.1	2.1
1990	Yes	low	0.22	7.3	2.7	3.5	1.4
		best	0.24	7.9	3.0	3.8	1.5
		high	0.26	8.6	3.2	4.1	1.7
	No	low	0.31	10.	3.8	4.9	2.0
		best	0.37	12.	4.6	5.9	2.4
		high	0.43	14.	5.3	6.8	2.8
2000	Yes	low	0.19	6.3	2.4	3.0	1.2
		best	0.24	7.9	3.0	3.8	1.5
		high	0.31	10.	3.8	4.9	2.0
	No	low	0.31	10.	3.8	4.9	2.0
		best	0.46	15.	5.7	7.3	2.9
		high	0.66	22.	8.2	10.	4.2

Source: Reference 3/

C. Toyota Motor Co.: Toyota Comment on the EPA Proposed Particulate Regulation for Light-Duty Diesel Vehicles.5/

Model Used: A diffusion factor of $\sigma_z = \alpha x^{\gamma}$ was used; where, for level areas, $\alpha = 1.09$, $\gamma = 0.49$ and for areas between "average" city buildings, $\alpha = 1.14$ and $\gamma = 0.55$.

Traffic Characterization: An hourly average traffic of 2,500 light-duty diesel vehicles was assumed. This figure is one fourth of the most crowded traffic level in Japan: the area where National Road Route 43 and Hanshin Express Highway run in parallel.

Receptor Location: Concentrations were computed for distances from 10 to 100 meters from the edge of the road.

Meteorological Data: The wind velocity assumed was 1 m/sec with a road angle of 90°.

Emission Factors: Two particulate emission rates were used: 0.6 g/mile and 0.2 g/mile.

Dieselization Rate: A set rate of 2,500 diesel vehicles per hour was used when receptor distance was varied. In another portion of the study, vehicle traffic was varied and receptor location held constant at the "roadside." The term "roadside", however, was not clearly defined.

Results: Figures 4 thru 7 describe their findings.

D. GM: "General Motors' Response to EPA Notice of Proposed Rulemaking on Particulate Regulation for Light-Duty Diesel Vehicles."4/

Scenario 1

Model Used: Chock's Simple Line Source Model.12/

Traffic Characterization: A four-lane road carrying 25,000 vehicles per day was considered.

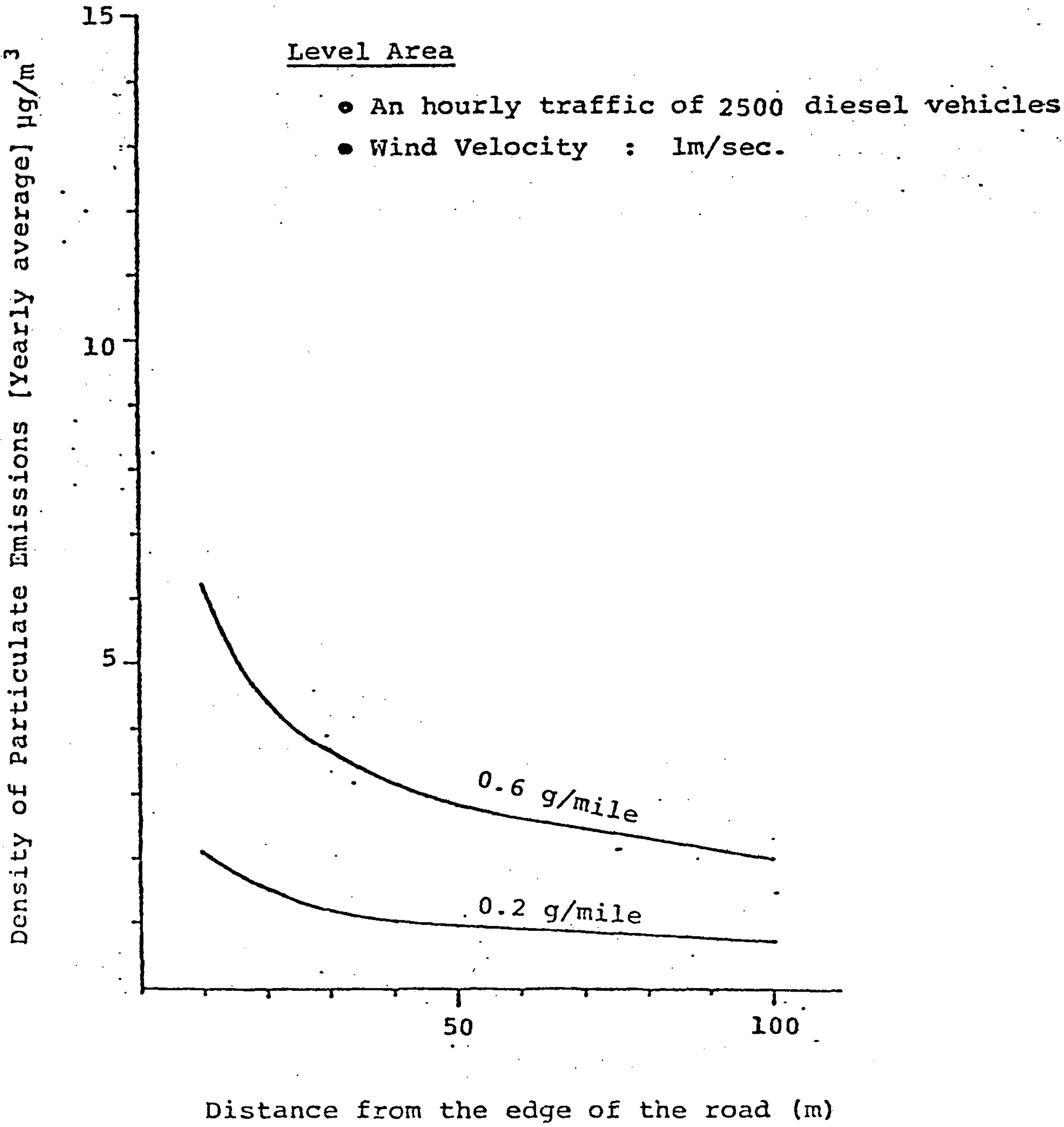
Receptor Location: 3 meters above ground and 3.8 meters from the road.

Meteorological Conditions: 1 mph winds, parallel to the road under very stable conditions.

Emission Factor: 1.0 g/mile.

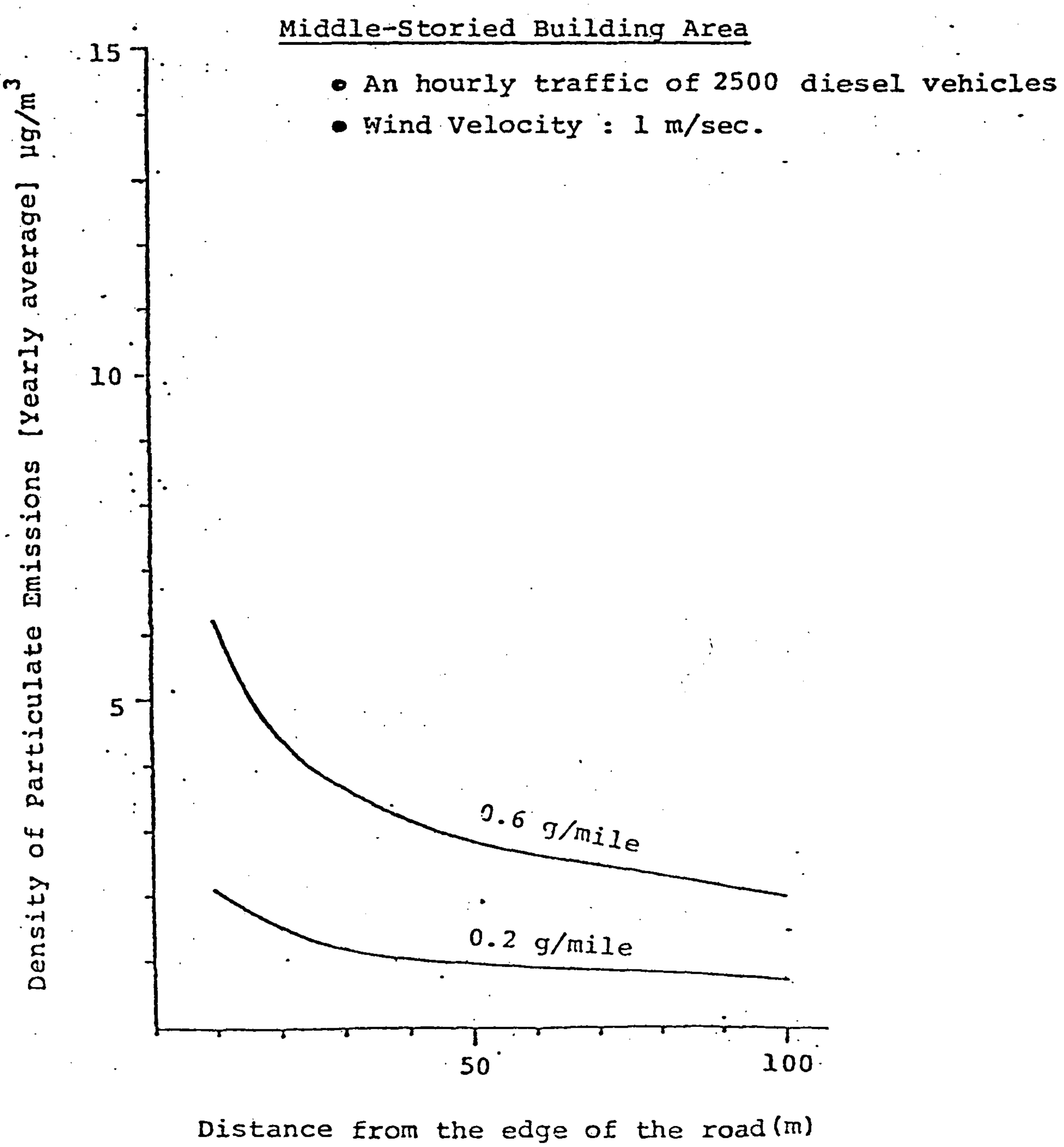
Dieselization Rate: 25% of the vehicles were assumed to be light-duty diesels.

Fig. 4 Relation between the distance from the edge of the road and the density of the particulate emissions



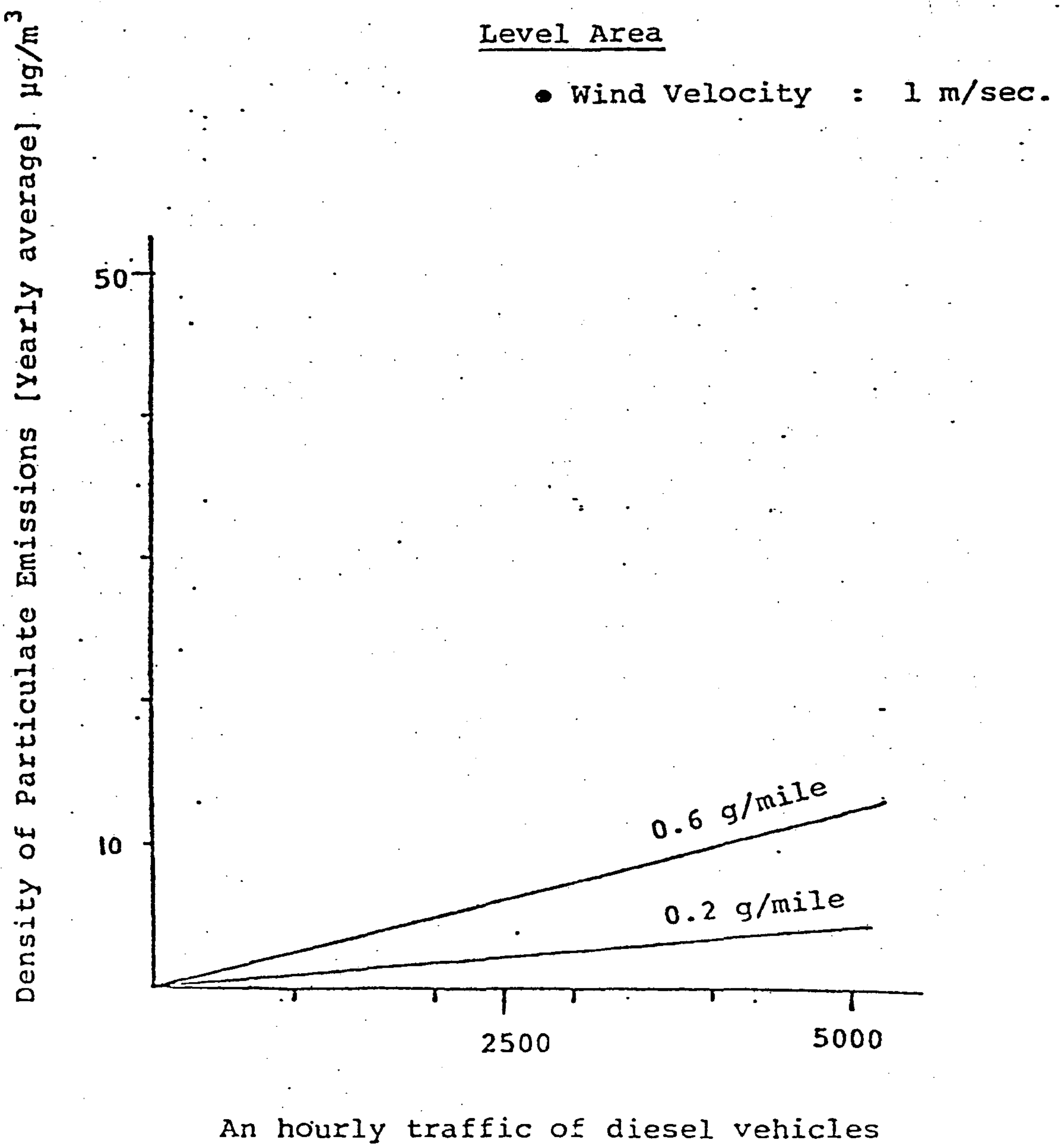
Source: Reference 3/

Fig. 5 . Relation between the distance from the edge of the road and the density of the particulate emissions



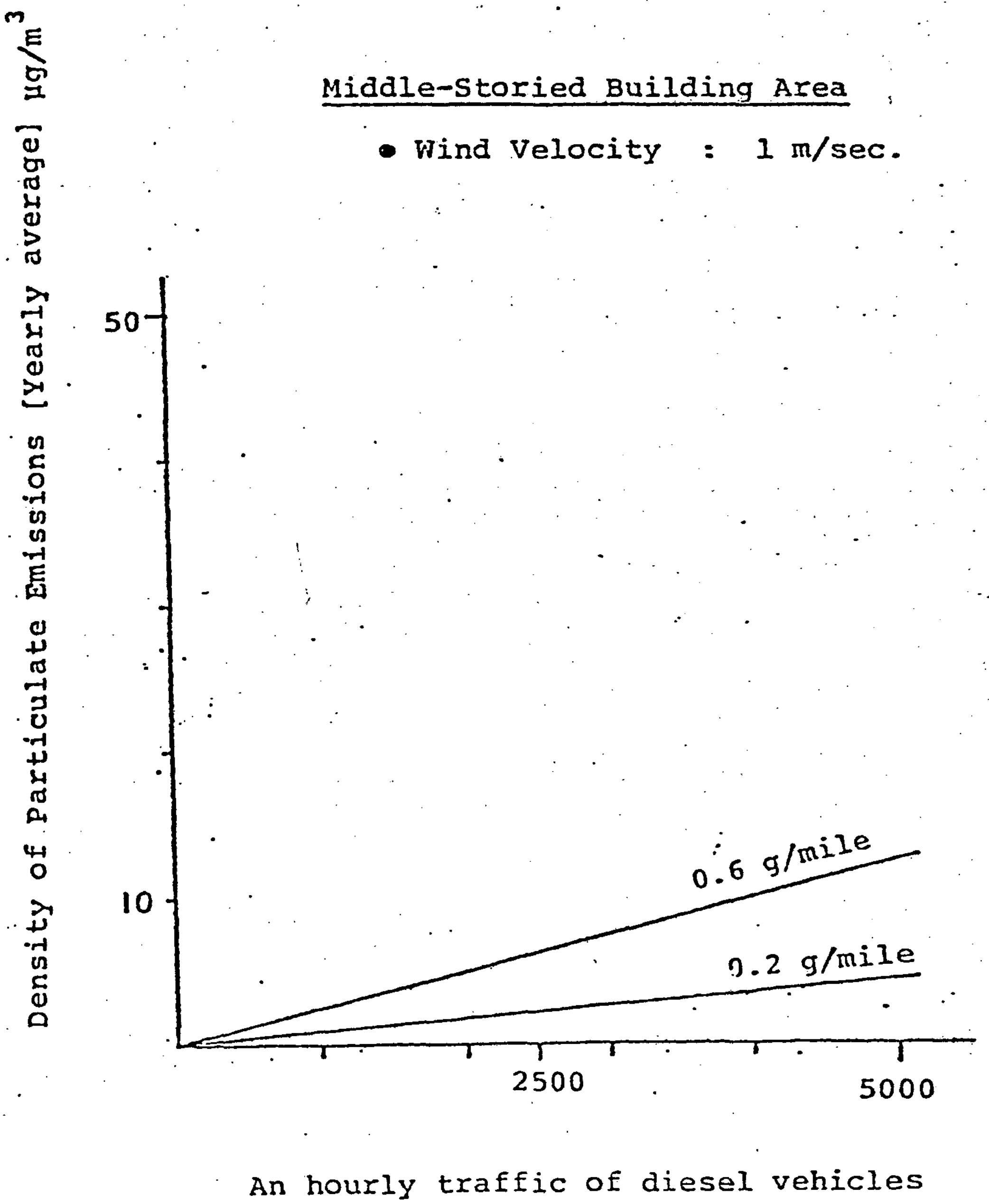
Source: Reference 5/

Fig. 6 Relation between the density of the particulate emissions at the road side and the traffic of diesel vehicles.



Source: Reference 5/

Fig. 7 Relation between the density of the particulate emissions at the road side and the traffic of diesel vehicles.



Source: Reference 5/

Results: 13.5 micrograms per cubic meter.

GM states that since the worst case meteorology cannot be sustained for a 24-hour period, the highest 24-hour concentration would be approximately one-half of this hourly value, or 6.8 mg/m^3.

Scenario 2: This analysis is based on case B from Chapter IV of the Draft Regulatory Analysis.15/

Traffic Characterization: 25% of the light-duty fleet is assumed to be diesel for the year 2000; 1% per year growth rate for VMT is used.

Receptor Location: "Roadside".

Meteorological Conditions: No details available.

Emission Factor: 0.2 g/mile.

Results: 24-hour roadside maximum: Major cities - 8.8 micrograms per cubic meter; Mid-size cities - 2.5 micrograms per cubic meter.

The 24-hour roadside estimates are based on the highest observed 24-hour CO measurement (e.g., for a major city: 33 ppm in Chicago in 1966).16/ No details of the methodology employed in this correlation are provided.

Worst-case Scenario: This evaluation describes Manhattan if all its taxis were diesel.

Model: Street Canyon Model.14/

Traffic Characterization: Six-lane roadway with traffic density of 500 cars per hour per lane.

Meteorological Conditions: No details available other than "adverse."

Emission Factor: 1.0 g/mile

Dieselization Rate: 60% of total traffic (100% of taxis).

Results: 127 micrograms per cubic meter for a 1-hour average; 71 micrograms for a 24-hour average.

E. Aerospace Corporation: "Assessment of Environmental Impacts of Light-Duty Vehicle Dieselization".6/

Localized air quality impact analyses were performed to determine effects from an urban freeway, an urban street canyon and an enclosed parking garage. The last of these is mentioned for completeness and will not be discussed here since its scope is specialized beyond the needs of this study.

Urban Freeway:

Approach: Impact estimates were based on an empirical parameter Ψ, referred to as the pollutant concentration index. It is defined as $\Psi_{XZ} = \frac{(C_{XZ} - C_b)}{Q}$, where C_{XZ} is the concentration of a measured pollutant at distance X horizontally from the roadway and distance Z vertically above the ground, C_b is the background concentration and Q is the vehicle source emission flux (product of emission factor and traffic count). The assumption is made that diesel particulate will disperse in the same manner as gases. Thus, Ψ values obtained from CO and tracer gas measurements can be used to determine diesel particulate concentrations by substituting the appropriate diesel emission factor. Several studies to determine the roadside distribution of CO and tracer gases were used by Aerospace in order to determine Ψ values. These are listed in Table A-8 together with a brief description of each.

Traffic Characterization: In connection with the 50 percentile Ψ values (meant to represent typical dispersion conditions) a maximum traffic density of 12,000 vehicles per hour was used. To determine 24-hour maximum concentrations occurring once a year, different Ψ values were chosen. These corresponded to the 99.73 Ψ percentile $((1 - \frac{1}{365}) \times 100)$. Data from GM was used to obtain these values because they were the most extensive available. The traffic count for this scenario was 7,850 vehicles/hour based on a 24-hour integration of traffic flow on an 8-lane urban freeway in Los Angeles.

Receptor Locations: Monitoring data were analyzed at or near three locations: 1) the roadway median, 2) 100 feet from the roadway, and 3) 300 feet from the roadway. These sites were chosen to represent exposures to highway users, people employed by roadside businesses and inhabitants of nearby homes.

Emission Factors: Composite emission factors were based on Manhattan data and were calculated from the following equation:

$$EF = \frac{\sum_{e,c} (Dump)_{cnpe}}{\sum_{e,c} (VMT)_{cnpe}}$$, where p denotes the pollutant for

class c vehicles with engine type e in calendar year n. Table A-9 lists the emission factors so determined.

Dieselization Rate: Three rates of light-duty vehicle dieselization were investigated: the 1% base case, 10% and 25% rates for the year 2000.

Results: Urban freeway exhaust particulate projections using the 50 percentile ψ and the 99.73 percentile ψ (worst case) are in Tables 5 and 6. Note that the latter is in terms of the annual geometric mean and maximum annual 24-hour concentrations.

Street Canyon

Approach: The same basic methodology used in the urban freeway analysis was used here. The data base (used to determine the pollutant concentration index) consisted of four studies, each designed to determine the CO distribution in the urban street canyon. SRI International performed two of these studies at sites in St. Louis, Missouri22/ and San Jose, California.23/ Vanderbilt University 24/ and the city of New York25/ conducted the remaining two investigations.

Traffic Characterization: Traffic counts of 500, 1,000, 1,500 and 2,000 vehicles per hour were used to evaluate the 1975 base year (50 percentile ψ values were used). When the effects of changes in the rate of diesel penetration were studied, the traffic count was held constant at 2,000 vehicles per hour. Annual maximum 24-hour and annual geometric mean values were determined at a traffic count of 936 vehicles per hour. This traffic density as well as the 99.7 percentile ψ values were based on the St. Louis study referenced earlier.

Receptor Locations: For the base 1975 year, pollutant levels at heights of 6, 15, 30, 60 and 120 feet were determined. Concentrations were evaluated for other scenarios at heights of 6, 30 and 90 feet above street level. A special worst case street level scenario was also evaluated based on a CO monitor in downtown Manhattan.

Emission Factors: The same factors used in the urban freeway scenario were applied to this portion of the study.

Dieselization Rate: The three scenarios used in the urban freeway analysis were applied here.

Results: Tables 7 through 10 give the results of this study.

Table 5 — Urban Freeway Exhaust Particulate Concentrations, Projection Years

LDV Dieselization Rate	Projection Year	Roadway Median		Distance From Edge of Roadway, Ft					
				13		100		300	
		Diesel	Total*	Diesel	Total*	Diesel	Total*	Diesel	Total*
B/C (1%)	1975	12.2	86.7	17.8	126.4	6.6	46.6	2.8	19.9
	1985	19.6	38.3	28.6	55.9	10.5	20.6	4.5	8.8
	1990	27.1	39.5	39.5	57.5	14.6	21.2	6.2	9.0
	2000	42.0	46.9	61.3	68.5	22.6	25.2	9.6	10.8
10%	1985	24.7	43.5	36.1	63.4	13.3	23.4	5.7	10.0
	1990	33.1	45.2	48.3	65.9	17.8	24.3	7.6	10.4
	2000	48.1	52.7	70.1	76.9	25.9	28.3	11.0	12.1
25%	1985	34.0	52.1	49.6	76.0	18.3	28.0	7.8	11.9
	1990	43.5	54.7	63.4	79.8	23.4	29.4	10.0	12.5
	2000	57.9	61.9	84.4	90.3	31.1	33.3	13.3	14.2
25% + 100% Taxis	1985	55.2	73.7	80.6	107.5	29.7	39.6	12.7	16.9
	1990	55.2	66.5	80.6	97.0	29.7	35.7	12.7	15.2
	2000	67.4	71.4	98.3	104.2	38.4	38.4	15.5	16.3

50th Percentile values based on generalized ψ profile (Figure 3.2-2), $\mu g/m^3$ above ambient, traffic count = 12,000 veh/hr.

*Total mobile source exhaust emission contribution.

Source: Reference 6/

Table 6 Urban Freeway Exhaust Particulate Concentrations, Maximum Annual 24-Hour and Annual Geometric Means, Best Estimate

Diesel-ization Rate	Pro-jection Year	Roadway Median				Distance From Roadway Edge, Ft											
						13				100				300			
		Diesel Exhaust Particulates		Total Exhaust Particulates		Diesel Exhaust Particulates		Total Exhaust Particulates		Diesel Exhaust Particulates		Total Exhaust Particulates		Diesel Exhaust Particulates		Total Exhaust Particulates	
		24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual
Base Case (1%)	1975	21.0	7.0	148.8	49.6	27.1	9.0	191.8	64.0	10.7	3.6	76.1	25.4	7.0	2.3	49.6	16.5
	1985	33.6	11.2	65.7	21.9	43.3	14.4	84.8	28.3	17.2	5.7	33.6	11.2	11.2	3.7	21.9	7.3
	1990	46.5	15.5	67.6	22.6	60.0	20.0	87.3	29.1	23.8	7.9	34.6	11.5	15.5	5.2	22.6	7.5
	2000	72.2	24.1	80.6	26.9	93.0	31.0	103.9	34.6	36.9	12.3	41.2	13.7	24.1	8.0	26.9	9.0
10% LDV	1985	42.5	14.2	74.6	24.9	54.7	18.2	96.2	32.1	21.7	7.2	38.2	12.7	14.2	4.7	24.9	8.3
	1990	56.8	19.0	77.6	25.9	73.4	24.4	100.0	33.3	29.1	9.7	39.7	13.2	19.0	6.3	25.9	8.6
	2000	82.6	27.6	90.4	30.1	106.4	35.5	116.7	38.8	42.2	14.1	46.2	15.4	27.6	9.2	30.1	10.1
25% LDV	1985	58.4	19.5	89.5	29.8	75.2	25.1	115.4	38.5	29.8	9.9	45.8	15.3	19.5	6.5	29.8	9.9
	1990	74.6	24.9	94.0	31.4	96.3	32.1	121.1	40.3	38.2	12.7	48.0	16.0	24.9	8.3	31.4	10.4
	2000	99.4	33.2	106.3	35.4	128.1	42.7	137.1	45.6	50.8	16.9	54.3	18.1	33.2	11.0	35.4	11.8
25%LDV + 100% Taxis	1985	95.0	31.7	126.5	42.2	122.4	40.8	163.2	54.5	48.6	16.2	64.7	21.6	31.7	10.6	42.2	14.1
	1990	95.0	31.7	114.2	38.1	122.4	40.8	147.2	49.0	48.6	16.2	58.4	19.4	31.7	10.6	38.1	12.7
	2000	115.7	38.6	122.6	40.9	149.1	49.7	158.1	52.6	59.2	19.7	62.7	20.8	38.6	12.9	40.9	13.6

Values referenced to representative ψ characteristic (Figure 3.2-2), $\mu g/m^3$ above ambient, traffic count = 7850 veh/hr.

TSP Air Quality Standards

	24-Hr	Annual Geometric Mean
Federal Primary/Secondary	260/150	75/60
California	100	60

Source: Reference 6/

Table 7 . Street Canyon Exhaust Particulate Concentrations, 1975 Baseline Year

	Height Above Street, ft									
	6		15		30		60		120	
Traffic Count (Veh/Hr)	Diesel	Total*	Diesel	Total*	Diesel	Total*	Diesel	Total*	Diesel	Total*
2000	4.3	30.7	3.9	27.7	3.1	22.3	2.3	16.2	1.2	8.4
1500	3.3	23.0	2.9	20.8	2.4	16.7	1.7	12.2	0.9	6.3
1000	2.2	15.4	2.0	13.8	1.6	11.1	1.2	8.1	0.6	4.2
500	1.1	7.7	1.0	6.9	0.8	5.6	0.6	4.1	0.3	2.1

50th percentile values, based on generalized ψ profile (Figure 3.3-2); $\mu g/m^3$ above ambient
*Total mobile source exhaust emission contribution

Source: Reference 6/

Table 8 Street Canyon Exhaust Particulate Concentrations, Projection Years

LDV Dieselization Rate	Projection Year	Height Above Street, ft					
		6		30		90	
		Diesel	Total*	Diesel	Total*	Diesel	Total*
Baseline (1%)	1975	4.3	30.7	3.1	22.3	1.7	12.0
	1985	6.9	13.6	5.0	9.8	2.7	5.3
	1990	9.6	14.0	7.0	10.1	3.8	5.5
	2000	14.9	16.6	10.8	12.1	5.8	6.5
10%	1985	8.8	15.4	6.4	11.2	3.4	6.0
	1990	11.7	16.0	8.5	11.6	4.6	6.3
	2000	17.0	18.7	12.4	13.5	6.7	7.3
25%	1985	12.0	18.5	8.7	13.4	4.7	7.2
	1990	15.4	19.4	11.2	14.1	6.0	7.6
	2000	20.5	21.9	14.9	15.9	8.0	8.6
25% PC + 100% Taxis	1985	19.6	26.1	14.2	18.9	7.7	10.2
	1990	19.6	23.6	14.2	17.1	7.7	9.2
	2000	23.9	25.3	17.3	18.4	9.4	9.9

50th percentile values, based on generalized ψ profile (Figure 3.3-2), $\mu g/m^3$ above ambient; traffic count = 2000 veh/hr

*Total mobile source exhaust emission contribution

Source: Reference 6/

Table 9 Street Canyon Exhaust Particulate Concentrations, Worst Case Metropolitan Geometry

LDV Dieselization Rate	Projection Year	Particulate Concentration ($\mu g/m^3$ above ambient)	
		Diesel	Total*
Baseline (1%)	1975	6.9	48.9
	1985	11.0	21.6
	1990	15.3	22.2
	2000	23.7	26.5
10%	1985	14.0	24.5
	1990	18.7	25.5
	2000	27.1	29.7
25%	1985	19.2	29.4
	1990	24.5	30.9
	2000	32.6	34.9
25% PC + 100% Taxis	1985	31.2	41.6
	1990	31.2	37.5
	2000	38.0	40.3

Based on 50th percentile CO concentrations at curb-side receptor at 110 East 45th Street, Manhattan

*Total mobile source exhaust emission contribution

Source: Reference 6/

Table 10 Street Canyon Exhaust Particulate Concentrations, Maximum Annual 24-Hour and Annual Geometric Means at Various Elevations

		Height Above Street											
		6				30				90			
		Diesel Particulates		Total Particulates		Diesel Particulates		Total Particulates		Diesel Particulates		Total Particulates	
Dieselization Rate	Projection Year	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual
25% LDV	1985	21.3	7.1	32.5	10.8	17.1	5.7	26.2	8.8	10.3	3.4	15.7	5.2
	1990	27.2	9.0	34.1	11.4	21.9	7.3	27.7	9.2	13.1	4.4	16.5	5.5
	2000	36.2	12.0	38.6	12.9	29.1	9.7	31.2	10.4	17.4	5.8	18.7	6.2
25% LDV + 100% Taxis	1985	34.5	11.5	46.0	15.3	27.9	9.3	37.1	12.4	16.7	5.6	22.3	7.4
	1990	34.5	11.5	41.5	13.8	27.9	9.3	33.5	11.2	16.7	5.6	20.1	6.7
	2000	42.1	14.0	44.6	14.9	33.9	11.3	36.0	12.0	20.4	6.8	21.6	7.2

Values based on St. Louis field study data, $\mu g/m^3$ above ambient.

TSP Air Quality Standards

	24-Hr	Annual Geometric Mean
Federal Primary/Seconary	260/150	75/60
California	100	60

Source: Reference 6/

F. CAMP-site Evaluation - EPA "Relative Impact of CO and Particulate on Urban Air Quality"2/

Approach: Carbon monoxide monitoring records at CAMP-sites in seven major cities were used as a data base for this study. Since 82 - 97% of the CO in these cities originates from mobile sources, replacing the appropriate CO emission factor with the desired diesel particulate emission factor (weighted for VMT) converts CO concentrations into particulate concentrations.

Receptor Locations: See Table A-10.

Emission Factor and Traffic Characterization: See Table A-11. In order to convert 1967 ambient CO levels to 1990 ambient particulate levels, it was necessary to assume growth in the urban vehicle miles traveled parameter. An increase of 41.4% was assumed based on a 1.5% per year increase, compounded.

Results: The ratio of urban diesel particulate emissions (1990) to CO emission (1967) should be 0.0018, based on the above procedure. The CO and TSP levels for the seven cities of interest are in Table 11.

Table 11

Ambient CO and Diesel Particulate Levels in Seven Selected Cities

City	1967 Ambient CO Level (Milligrams Per Cubic Meter)* 16/	1990 Ambient Diesel Part. Levels (Micrograms per Cubic Meter)
Chicago	13.5	24.3
Philadelphia	7.2	13.0
Denver	7.1	12.8
St. Louis	5.7	10.3
San Francisco	5.0	9.0
Cincinnati	4.9	8.8
Washington, D.C.	3.8	6.8

* Annual geometric mean of 24-hour averages.

Section II: Standardization of Roadside Impact Studies

As stated in the introduction, attempts to place the studies on more common ground center around substituting the same level of dieselization and exhaust particulate emission factor for the values of these parameters used in each study. These standardizing quantities, listed below, represent expected conditions for the year 1990.

Light-duty emission factor: 1.0 gram/mile
Heavy-duty emission factor: 2.0 grams/mile

Light-duty dieselization level:
- Low estimate - 9.6% of urban VMT
- High estimate - 15.9% of urban VMT

Heavy-duty dieselization level:
- Low estimate - 3.7% of urban VMT
- High estimate - 5.2% of urban VMT

Urban VMT growth rate (where applicable) - 1 % per year, compounded.

The roadside diesel particulate concentrations reported in the Tables 12-16 reflect the use of these numbers. The basic assumption has been made, as has been done in all of the studies being examined here, that the air quality impact is proportional to the emission level. For example, if the emission factors and VMT breakdown (low estimate) shown above are combined, the average diesel particulate emission factor is 0.17 gram per urban VMT for the low estimate case. In the last study examined in the previous section (EPA, 2/), the average diesel particulate emission factor was 0.121 gram per urban VMT (see Table A-11). For this reason, the impacts shown in Table 11 should be increased by 41%. However, the EPA study assumed a 1.5% per year growth rate for urban VMT, while the standard scenario above specifies a 1% per year growth rate. Over the 23 years in question (1967-1990), this difference would result in a 12% difference in the projected impacts. Combining the two impacts shown in Table 11 should be increased by 25% to convert the previous results in the standard scenario.

Toyota represented two scenarios in their comment, one for a "level area" and another for a "middle storied building area". However, the two graphs depicting their respective conclusions are identical (refer to Figures 4 and 5 of this document). Since it is unreasonable to expect these data to be the same, an inadvertant error on the part of Toyota personnel is probably the cause. Because Toyota did not provide details of the conversion from hourly averages to yearly averages it was not possible to determine which of the two scenarios was properly labeled and which was not. Thus, modification of their results are not included in this report.

Table 12

Modified Results of
"Reply to Request for Concentration Estimates
Near Roadways Due to Mobile Source Emissions of
Sulfuric Acid and Diesel Particulates (TSP and BaP)" - EPA 1/

Projected 1990 1-Hour Concentration (micrograms per cubic meter)

Receptor #	Light-Duty	Heavy-Duty
1 (4.75 m to curb)	95-155	72-101
2 (24.75 m to curb)	58-96	45-63
3 (44.75 m to curb)	43-72	33-47
4 (64.75 m to curb)	34-58	27-38
5 (94.75 m to curb)	26-42	19-27

Projected 1990 8-Hour Reasonable Case (micrograms per cubic meter)

Receptor #	Light-Duty	Heavy-Duty
1 (4.75 m to curb)	20-33	15-21
2 (24.75 m to curb)	14-23	11-15
3 (44.75 m to curb)	11-18	8-12
4 (64.75 m to curb)	10-16	7-10
5 (94.75 m to curb)	8-13	6-8

Projected 1990 24-Hour Concentration (micrograms per cubic meter)

Receptor #	Light-Duty	Heavy-Duty
1 (4.75 m to curb)	12-20	9-13
2 (24.75 m to curb)	9-15	7-10
3 (44.75 m to curb)	7-12	6-8
4 (64.75 m to curb)	6-10	5-7
5 (94.75 m to curb)	5-8	4-5

Table 13

Modified Results of "Study of Particulate Emissions from Motor Vehicles - A Report to Congress" - SwRI 3/

Projected 1990 On-Expressway Concentrations (micrograms per cubic meter)

	4 Kts* at 2.75°	4 Kts at 25.25°	16 Kts at 2.75°	16 Kts at 25.25°
Light-Duty	36.7-61.1	23.3-38.8	26.5-42.2	7.7-12.9
Heavy-Duty	28.4-39.8	18.0-25.3	20.6-28.8	6.0- 8.4

* Wind speed and direction relative to road

Projected 1990 Beside-Expressway Concentrations (annual arithmetic mean, micrograms per cubic meter)

	Distance From Roadway (Meters)					
	1 m	10 m	30 m	100 m	200 m	500 m
Light-Duty	5.8-9.6	4.6-7.6	2.9-4.8	1.4-2.4	.8-1.4	.4-.6
Heavy-Duty	4.5-6.3	3.5-5.0	2.2-3.1	1.1-1.5	.6- .9	.3-.4

Projected 1990 Street Canyon Concentrations (micrograms per cubic meter)

	Leeward Side		Windward Side	
	Receptor #1 (Pedestrian)	Receptor #2 (Resident)	Receptor #3 (Pedestrian)	Receptor #4 (Resident)
Light-Duty	5.8-14.1	2.2-5.4	2.8-6.9	1.1-2.8
Heavy-Duty	4.5- 9.2	1.7-3.5	2.2-4.5	.9-1.8

Table 14

Modified Results of
"General Motors Response to EPA Notice
of Proposed Rulemaking on Particulate
Regulations for Light-Duty Diesel Vehicles" - GM 4/

Projected 1990 Hourly Maximum Concentration at Three Meters Above Ground, 3.8 Meters from Road (micrograms per cubic meter)

Light-Duty: 5.2 - 8.6

Heavy-Duty: 1.0 - 5.6

Projected 1990 24-Hour Roadside Maximum - Based on CO Measurements (micrograms per cubic meter)*

	Major Cities	Mid-Size Cities
Light-Duty	15.2 - 25.3	4.3 - 7.2
Heavy-Duty	11.7 - 16.5	3.3 - 4.7

* A factor of 0.9 was used to convert the traffic count for the year 2000 (GM basis) to the 1990 scenario.

The GM worst case (Manhattan-Taxi) scenario was not modified due to its highly specialized nature.

Table 15

Modified Results of
"Assessment of Environmental Impacts of
Light-Duty Vehicle Dieselization" - Aerospace Corporation 6/

Projected 1990 Off-Expressway Concentrations
(Micrograms Per Cubic Meter)

	24-Hour Max	Annual Geo. Mean
30 Meters from Road:		
Light-Duty	24.1 - 40.3	8.1 - 13.4
Heavy-Duty	18.7 - 26.3	6.2 - 8.8
91 Meters from Road:		
Light-Duty	15.8 - 26.3	5.3 - 8.7
Heavy-Duty	12.2 - 17.1	4.1 - 5.7

Projected 1990 Street Canyon Concentrations
(Micrograms Per Cubic Meter)

	24-Hour Max	Annual Geo. Mean
1.8 Meters above Street:		
Light-Duty	17.3 - 28.7	5.7 - 9.6
Heavy-Duty	13.3 - 18.7	4.4 - 6.2
9.1 Meters above Street:		
Light-Duty	13.9 - 23.2	4.6 - 7.7
Heavy-Duty	10.7 - 15.1	3.6 - 5.0
27.4 Meters above Street:		
Light-Duty	8.3 - 13.9	2.8 - 4.6
Heavy-Duty	6.4 - 9.0	2.1 - 3.0

Table 16

Modified Results of
"Relative Impact of CO and
Particulate on Urban Air Quality" - EPA 2/

Projected 1990 CAMP Site Concentrations
(annual geometric means,* micrograms per cubic meter)

City	Light-Duty	Heavy-Duty
Chicago	17.0 - 28.4	13.2 - 18.5
Philadelphia	9.1 - 15.1	7.0 - 9.9
Denver	9.0 - 14.9	6.9 - 9.7
St. Louis	7.2 - 12.0	5.6 - 7.8
San Francisco	6.3 - 10.5	4.9 - 6.8
Cincinnati	6.2 - 10.3	4.8 - 6.7
Washington, D.C.	4.8 - 8.0	3.7 - 5.2

* An increase in VMT of 25.7% (based on a compounded 1% per year growth rate) from the baseline 1967 year was assumed.

Section III: Summary and Conclusions

The purpose of this report was to make the various studies on the localized air quality impact of diesel particulate emissions more comparable with one another. This was done by focusing on the year 1990 and applying certain standardizing assumptions. These included using low and high estimates of dieselization, 9.6 and 15.9%, for the light-duty fraction of urban vehicle miles travelled (VMT) and 3.7 and 5.2% for the heavy-duty instead of the corresponding values used in each study. Further, emission factors originally implemented were replaced by the following: 1.0 gram per mile for light-duty diesel vehicles and 2.0 grams per mile for heavy-duty diesels. From the studies so modified one can see a range of predicted concentrations which varies both with the exposure duration and receptor location (refer to Section I). It is noted that most studies investigated off-expressway and street canyon concentrations; these then are the focal points for comparisons in this summary. All concentrations cited hereafter (except the GM worst case study) reflect modifications made in Section II.

A. Off-Expressway The EPA report yielded predictions on 1-hour, 8-hour, and 24-hour bases at locations from 4.75 to 94.75 meters from the roadway.1/ The traffic count in this study was 100,000 vehicles per day. It was determined that a 1-hour concentration of 58-96 micrograms per cubic meter would occur approximately 25 meters from the roadway due to light-duty diesels alone. Similarly, 8-hour and 24-hour light-duty particulate concentrations of 14-23 and 9-15 micrograms per cubic meter were projected for the 25 meter site. The same receptor location, approximately 25 meters from the roadway, was used in other reports as well.

Southwest Research Institute3/ estimated diesel particulate concentrations at distances from 1-500 meters from the curb (in addition to a street canyon study and an on-expressway evaluation). At a distance of 30 meters from a roadway carrying 9000 vehicles per hour, the annual arithmetic mean particulate concentration from light-duty diesels was 2.9-4.8 micrograms per cubic meter. Aerospace's off-expressway study, based on actual monitoring data, found annual maximum 24-hour concentrations of 24.2-40.3 micrograms per cubic meter and annual geometric mean values of 8.1-13.4 micrograms per cubic meter at the 30 meter distance.6/

The role of meteorology cannot be overlooked when explaining discrepancies among the three aforementioned off-expressway studies. The EPA report attempted to duplicate conditions which led to high CO concentrations measured in Oakbrook, Illinois. Southwest used a composite of 576 meteorlogical conditions at the study site (Houston); each weighted according to its frequency of occurrence. Such procedure led to the use of a typical meteorological scenario in their study. However, the Houston test site was selected partly because of its perpendicular orientation to prevailing winds (a condition which maximizes off-expressway concentrations). Not necessarily Thus, both the EPA and Southwest studies were designed to represent adverse - yet different - meteorological conditions. Since the Aerospace study draws upon several independent tracer gas experiments, it does not represent a specific meteorological scenario; rather, an average scenario resulting from contributions by each constituent experiment is built into the study's framework. From the above discussion, it cannot be concluded that any single report used meteorological conditions more viable than another's since each represents conditions that could easily occur at other locations.

In addition to obvious differences in traffic volume, much of the disparity among the three off-expressway studies can be explained by the inherent differences among the various dispersion modeling aproaches taken. EPA's study was based on the HIWAY line source dispersion model;7/ Southwest Research Institute used a modified version of GM's line source model developed by Chock;12/ and Aerospace Corporation relied on tracer gas surrogate to establish the relationship between concentration and source strength. In a study performed for EPA by the New York Department of Environmental Conservation in which eight line source dispersion models were evaluated, GM's yielded the best correlation with tracer gases (HIWAY was one of the models investigated).26/ One would therefore expect the Southwest study to yield more reliable results than the EPA report since the former was based on GM's model. Aerospace's findings should be superior to either since their study was based directly on measured tracer gas dispersion characteristics rather than an empirical representation of idealized dispersion.

B. Street Canyon Projected street canyon concentrations of light-duty diesel particulate were determined in reports by GM, Southwest Research, and the Aerospace Corporation.4/,3/,6/ GM attempted to evaluate the impact on Manhattan air quality of an all diesel taxi fleet. Using Dabberdt's Gaussian Street Canyon Model,18/ they estimated a 24-hour average diesel particulate concentration of 71 micrograms per cubic meter associated with a traffic volume of 3,000 vehicles per hour (60 percent diesel). Since their report did not include a discussion of meteorological inputs (other than the word "adverse"), receptor location, or street geometry, it cannot be fully evaluated or compared with the other street canyon studies.

Southwest also used the Dabberdt model, but they provided sufficient details to allow adequate interpretation. In their study, it was estimated that pedestrians on the leeward side of the street would be exposed to a continual concentration of 5.8-14.1 micrograms of light-duty diesel particulate per cubic meter (given a traffic flow of approximately 1,274 vehicles per hour).

The Aerospace report yielded similar pedestrian exposure results, even though their methodology was entirely different: an annual geometric mean of 5.7-9.6 micrograms per cubic meter (based on a traffic volume of 936 vehicles per hour. As was the case with their off-expressway study, Aerospace relied on tracer gas experiments to determine the relationship between source strength and receptor concentration. By not relying totally on the rigid nature of a mathematically simulated source-receptor relationship, conditions more representative of everyday exposure scenarios are represented. The simple technique of substituting diesel emission factors for those of the tracer gases should be superior to the more complex Gaussian dispersion approach.

C. Others The remaining two reports (Toyota's could not be modified, see Section II), GM's roadside study4/ and the EPA CAMP-site study, 2/ represent exposure estimates generally closer to the roadway than the 25-30 meter range. GM looked at a location 3 meters above ground and 3.8 meters from the road. For a 4-lane road carrying 25,000 vehicles per day, 5.2-8.6 micrograms per cubic meter of diesel particulate from light-duty vehicles would occur at this location over a 24-hour period. It should be noted that parallel wind conditions were used to arrive at this estimation (a condition which maximizes on-expressway concentrations but minimizes the off-roadway levels).

Concentrations in the EPA CAMP-site study2/ were based on CO monitoring data. Annual geometric mean values for the 7 cities studied ranged from 4.8-8.0 micrograms per cubic meter for Washington, D.C. to 17.0-28.4 micrograms per cubic meter in Chicago. A further description of monitoring sites of this study are in Table A-10.

Upon reviewing all the studies, the localized impact off an expressway and in a street canyon was best evaluated by the Aerospace report as their methodology avoided such assumptions as constant wind velocity and atmospheric stability. On the expressway, SwRI was most thorough in their evaluation, basing such parameters as wind speed and direction and traffic counts on real world data. The CAMP-site study is also noteworthy because the data base (CO monitors at CAMP-sites in 7 major U.S. cities) was obtained over a long period of time, thus adding validity to the predictions obtained.

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Appendix

Table A-1

Vehicle Distribution and Roadway Split in Percentage by Hour of Day for a Suburban Freeway

HOUR	PERCENT ADT	PERCENT IN-BOUND	PERCENT OUT-BOUND
0	1.5	44	56
01	1.0	46	54
02	0.5	48	52
03	0.5	54	46
04	1.0	60	40
05	1.5	68	32
06	4.5	68	32
07	8.5	64	36
08	6.5	58	42
09	5.0	54	46
10	5.0	52	48
11	4.5	50	50
12	4.5	50	50
13	4.5	52	48
14	5.5	52	48
15	7.0	48	52
16	8.5	42	58
17	8.5	40	60
18	5.5	44	56
19	4.5	48	52
20	3.5	48	52
21	3.0	44	56
22	2.5	46	54
23	2.5	44	56

Source: SAPPOLUT8/
Taken from Reference 1/.

Table A-2

Particulate Emission Rate (by class) 1/

Vehicle Class*	Particulates (gm/mi)
LDV-G	0.0087
LDT-G	0.0087
HDV-G	0.029
LDV-D	0.9
LDT-D	0.9
HDV-D	Low 2.0 High 3.0

Vehicle-type Split by Fraction of Urban VMT 1/

	Best Estimate	Max Estimate
LDV-G	0.754	0.639
LDT-G	0.098	0.084
HDV-G	0.025	0.010
LDV-D	0.076	0.191
LDT-D	0.010	0.024
HDV-D	0.037	0.052

*Key:
LD = Light-Duty
HD = Heavy-Duty
V = Vehicle
T = Truck
-G = Gasoline-fueled
-D = Diesel-fueled

TABLE A-3 Light Duty Diesel Emission Factors by Engine Model

Year(s)	Emission Factors, g/km											
	M-B							GM				
	200D & 200D	240D	300D, 300SD, 300CD	Pengeot 504D	VW Rabbit	IH Scout	Chrysler Mitsubishi	350	350 pickup	260	projected V6	projected I4
Thru 1980	0.38	0.28	0.36	0.26	0.18	0.24	0.38	0.55	0.38	0.56	0.35	----
'81-'82 controlled	----	0.28	0.36	0.26	0.18	0.24	0.37	0.37	0.37	0.37	0.35	0.27
'81-'82 not controlled	----	0.28	0.36	0.26	0.18	0.24	0.38	0.55	0.28	0.56	0.35	0.27
'83 & later controlled	----	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
'83 & later not controlled	----	0.28	0.36	0.26	0.18	0.24	0.38	0.55	0.38	0.56	0.35	0.37

Source: Reference 3/

TABLE A-4 Percent of Total Diesel Sales for Various Models

	Percent of Diesel Sales											
	M-B							GM				
Year(s)	200D & 200D	240D	300D, 300SD, 300CD	Pengeot 504D	VW Rabbit	IH Scout	Chrysler Mitsubishi	350	350 pickup	260	projected V6	projected I4
1973 & earlier	100											
1974		100										
1975		90		10								
1976		33	46	17		4						
1977		28	32	14	22	4						
1978		4	13	3	18	1		44	17			
1979		2	7	2	31	<1	2	33	9	14		
1980		2	4	1	21	<1	2	27	6	13	24	
1981		1	3	1	16	<1	1	21	5	10	29	13
1982		1	3	1	14	<1	1	18	4	8	31	19
1983		1	3	1	12	<1	1	16	3	8	32	23
1984		1	2	1	12	<1	1	15	3	7	31	27
1985		1	2	1	10	<1	1	13	3	7	32	30

Source: Reference 3/

TABLE A-5 Exhaust Particulate Emission Factors for a Crowded Expressway by Model Year With Diesel Particulate Regulations

Particulate Emissions g/km

Model Year	≤69	70	71	72	73	74	75	76	77	78	79	80
for 1985 estimates												
Light-duty gasoline	0.11	0.06	0.06	0.06	0.06	0.06	0.04	0.04	0.03	0.03	0.03	0.03
Light-duty diesel	0.27	0.27	0.27	0.27	0.27	0.25	0.23	0.22	0.22	0.26	0.27	0.27
Medium-duty truck	0.31	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.17	0.17
Heavy-duty gasoline	0.52	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.24	0.24
Heavy-duty diesel	1.31	1.12	1.12	1.12	1.12	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Motorcycles	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.02
for 1990 and 2000 estimates (assumes no leaded gasoline)												
Light -duty gasoline	0.06	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Light-duty diesel	0.27	0.27	0.27	0.27	0.27	0.25	0.23	0.22	0.22	0.26	0.27	0.27
Medium-duty truck	0.16	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13
Heavy-duty gasoline	0.25	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.12	0.12
Heavy-duty diesel	1.31	1.12	1.12	1.12	1.12	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Motorcycles	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01

Model Year	81	82	83	84	85	86	87	88	89	90	91	≥92
for 1985 estimates												
Light-duty gasoline	0.01	0.01	0.01	0.01	0.01							
Light-duty diesel	0.22	0.22	0.08	0.08	0.08							
Medium-duty truck	0.17	0.23	0.23	0.23	0.27							
Heavy-duty gasoline	0.24	0.24	0.04	0.04	0.04							
Heavy-duty diesel	0.99	0.99	0.81	0.81	0.81							
Motorcycles	0.02	0.02	.006	.006	.006							
for 1990 and 2000 estimates (assumes no leaded gasoline)												
Light -duty gasoline	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Light-duty diesel	0.22	0.22	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Medium-duty truck	0.13	0.19	0.19	0.19	0.22	0.19	0.19	0.19	0.24	0.24	0.24	0.28
Heavy-duty gasoline	0.12	0.12	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Heavy-duty diesel	0.99	0.99	0.81	0.81	0.81	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Motorcycles	0.01	0.01	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003

Source: Reference 3/

TABLE A-6 Exhaust Particulate Emission Factors for a Crowded Expressway by Model Year Without Diesel Particulate Regulations

Particulate Emissions g/km

Model Year	≤69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	≥92
for 1985 estimates																								
Light-duty gasoline	0.11	0.06	0.06	0.06	0.06	0.06	0.04	0.04	0.03	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01							
Light-duty diesel	0.27	0.27	0.27	0.27	0.27	0.25	0.23	0.22	0.22	0.26	0.27	0.27	0.26	0.25	0.25	0.25	0.24							
Medium-duty truck	0.31	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.17	0.17	0.17	0.23	0.24	0.26	0.28							
Heavy-duty gasoline	0.52	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.24	0.24	0.24	0.24	0.04	0.04	0.04							
Heavy-duty diesel	1.31	1.12	1.12	1.12	1.12	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99							
Motorcycles	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.02	0.02	0.02	.006	.006	.006							
for 1990 and 2000 estimates (assumes no leaded gasoline)																								
Light-duty gasoline	0.06	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Light-duty diesel	0.27	0.27	0.27	0.27	0.27	0.25	0.23	0.22	0.22	0.26	0.27	0.27	0.26	0.25	0.25	0.25	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Medium-duty truck	0.16	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.19	0.22	0.26	0.26	0.32	0.32	0.32	0.38	0.38	0.38	0.44
Heavy-duty gasoline	0.25	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.12	0.12	0.12	0.12	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Heavy-duty diesel	1.31	1.12	1.12	1.12	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Motorcycles	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003

Source: Reference 3/

Table A-7

Comparison of On-Freeway Emission Factors for Houston, Texas

Year	Diesel Particulate Regulations	Composite Emission Factor g/mile		
		Low est. of dieselization	Best est. of dieselization	High est. dieselization
1977			0.204	
1985	yes	0.150	0.151	0.152
1985	no	0.162	0.167	0.169
1990	yes	0.123	0.130	0.136
1990	no	0.162	0.183	0.205
2000	yes	0.125	0.140	0.161
2000	no	0.185	0.236	0.305

Source: Reference 3/.

Table A-8

Urban Freeway Data Base

Organization	Date of Measurements	Measurements per Receptor	Roadway Characteristics: Location	Type	Surrounding Terrain	Emissions from Vehicles not on Roadway	Species Measured	Reference
GM1/	Sept-Oct 1975	66	GM Proving Ground, Milford, Mi.	at-grade	nearly level lightly wooded rural	no	sulfate particulate; tracer gas (SF_6)	17
SRI2/	Jan-Feb 1975	45	Highway 101 near Santa Clara, Ca.	at-grade	level, open	no	CO; tracer gases (SF_6 and Freon)	18 19
SRI	Aug-Sept 1975	47	I-280 in San Jose, Ca.	above-grade (elevated on columns, not a solid fill)	urban streets and low buildings (near CBD)	yes	CO; tracer gases (SF_6 and Freon)	19
ANL3/	June-July 1973	49	I-55 in suburbs of Chicago, Ill.	at-grade	level, open	no	CO	20
ANL	Aug 1973	31	I-90, in suburbs of Chicago, Ill.	below-grade	level, residential	"not significant"	CO	20

Table A-8 (cont.)

Urban Freeway Data Base

Organization	Date of Measurements	Measurements per Receptor	Roadway Characteristics: Location	Type	Surrounding Terrain	Emissions from Vehicles not on Roadway	Species Measured	Reference
VH TRC4/	June 1973 - July 1974	21	I-495, in Fairfax County, Va.	at-grade	level rural	No	CO	21
VH TRC	Jan-Aug 1974	15	I-64, in Norfolk, Va.	at-grade	uncomplicated scattered 1-story residential	No	CO	21

Source: Reference 6/

1/ General Motors Corporation
2/ SRI International
3/ Argonne National Laboratory
4/ Virginia Highway & Transporation Research Council

Table A-9. Composite Emission Factors for Urban Freeway and Street Canyon Analyses

LDV Dieselization Rate	Projection Year	Diesel Exhaust Particulates (g/mi)*	Total Exhaust Particulates (g/mi)*
B/C (1%)	1975	0.0425	0.301
	1985	0.0680	0.133
	1990	0.0941	0.137
	2000	0.146	0.163
10%	1985	0.0859	0.151
	1990	0.115	0.157
	2000	0.167	0.183
25%	1985	0.118	0.181
	1990	0.151	0.190
	2000	0.201	0.215
25% + 100% Taxis	1985	0.192	0.256
	1990	0.192	0.231
	2000	0.234	0.248

*Based on total VMT, all vehicle classes.

Source: Reference 6/

Table A-10

Information Concerning CO Probes at CAMP sites 2/

CAMP site	Height Above Ground, Meter (ft.)	Distance from Nearest Large Road, Meter (ft.)	Vehicle Count (vehicles/day)	Comments
Chicago	4.12 (13.5)	6.94 (22.75)	46,000	Humidity not compensated - may enhance to twice as much East on Congress - 22,000 vehicles/day West on Congress - 24,000 vehicles/day
Cincinnati	4.57 (15)	6.1 (20)	8,558	30.5 meter (100 ft.) to the north is Lincoln Pkwy, 9643 cars/day. Central Pkwy to the east, 19,570 vehicles/day.
Denver	5.18 (17)	6.41 (21)	17,000	
Philadelphia	4.57 (15)	61 from 20th st. (200) and 21st st.	10,578 (20th st.) 3,576 (21st st.)	
St. Louis	4.57 (15)	12.2 (40)	17,950	9.15 m (30 ft.) from parking lot of 193 spaces - mid Dec. to mid Feb.
San Francisco	1.83 above ground (6) 3.66 above street (12)	3.05 (10)		
Washington, D.C.	3.36 (11)	15.25 (50)	14,740	

Table A-11

Traffic Characterization 2/

	Vehicle Class			
	LDV	LDT	HDV-G	HDV-D
CO Emission Factor (g/mile)-1967	89	91	298	35
Particulate Emission Factor (g/mile)	0.5	0.5	0	2.0
Fraction of Urban VMT				
1974	0.83	0.108	0.036	0.026
1990	0.83	0.108	0.025	0.037
Diesel Fraction - 1990	0.1	0.1	0	1.0