Development of Criteria for Reserving Exclusive Bus Lanes

C. C. Miesse, U.S. Environmental Protection Agency, Philadelphia

The reservation of an existing traffic lane for the exclusive use of buses and car pools results in increased congestion and slower speeds on the remaining lanes until a sufficient number of automobile drivers have been diverted to buses. Equations are developed to determine the variation of the resultant emissions with the percentage of diversion for various values of initial speed, number of lanes, and directional split (for counterflow lanes). Results of the analysis indicate that minimum diversion percentages exist below which carbon monoxide emission rates and total hydrocarbon emissions are greater with than without the exclusive bus lanes for both in-lane and counterflow configurations.

The reservation of existing traffic lanes for the exclusive use of express buses and car pools has been proposed and promulgated as a technique for encouraging the use of public transit on the assumption that air quality will be improved by a decrease in the number of private automobiles. Various transportation agencies have noted that implementation of this measure along specific corridors would impede traffic to the extent that pollutant concentrations may even increase; the following analysis was therefore undertaken to quantify the anticipated results, based on empirical relations between traffic flow, average speed, and pollutant emission rates.

The analysis is based on the following assumptions:

1. Variation of traffic flow with operating speed, for both the peak-flow (inbound) and counterflow (outbound) directions is determined by the volume-speed curves given in the Highway Capacity Manual (1).
2. Variation of pollutant emission rates with average speed is determined by equations developed by the U.S. Environmental Protection Agency (EPA) (2).
3. Automobile drivers who have not been diverted to buses will be evenly distributed over the remaining lanes in such a way that the resulting total traffic density is maintained.
4. Free-flow conditions are assumed to be such that level of service F (1) is not considered except where it occurs because of resulting congestion in the remaining traffic lanes.
5. Additional emissions caused by buses or car pools that are permitted to use the exclusive lanes are disregarded as negligible.
6. For the counterflow bus-lane configuration, flow in the outbound (less congested) lanes will remain constant during the peak period.

NOMENCLATURE

The following terms are used in the analysis (for those terms in the equations that are formulated in customary units, no SI equivalents are given):

- D = number of automobile drivers per mile diverted to buses,
- E = emission rate for carbon monoxide (CO) (g/mile·h),
- e = composite CO emission factor (g/mile),
- F = lane volume (traffic flow) (vehicles/h),
- f = f(V) = speed factor for CO emissions,
- g = g(V) = speed factor for hydrocarbon (HC) emissions,
- H = total HC emissions (g),
- h = composite HC emission factor (g/mile),
- k = $(N_o - D)/N_o$ = fraction of automobile drivers not diverted to buses,
- L = average trip length (miles),
- M = number of inbound lanes,
- N(M) = total traffic density for M lanes (automobiles/mile),
- P = number of peak-period automobiles,
- q = (100 - y)/y = ratio of outbound to inbound traffic flow,
- T = length of peak period (h),
- V = average traffic speed during peak period (mph),
- y = percentage of total traffic flow on inbound lanes,
- ϕ = M/(M - 1) = ratio of number of traffic lanes before and after reservation of bus lane,
- o = before reservation of exclusive lane,
- 1 = after reservation of exclusive lane,
- $^{-}$ = inbound lanes after reservation of counterflow bus lane, and
- $'$ = outbound lanes in counterflow configuration.

ANALYSIS

The effect of reserving one lane of a four-, six-, or eight-lane highway for the exclusive use of express buses is analyzed by using relations between traffic volume and operating speed observed on limited-access highways across the country and reported in the Highway Capacity Manual (1). The typical variation of traffic volume with operating speed, which is used as a basis for the following equations, is shown in Figure 1. Figure 1 shows that the traffic flow (F), lane volume in vehicles per hour, for a design speed of 112 km/h (70 mph) can be approximated by

$$F = 1.633V(V_d - V) \tag{1}$$

where V_d is the design speed for the highway (112 km/h or 70 mph in Figure 1).

Because traffic flow equals the product of speed (V) and traffic density (N) in automobiles per mile, traffic density for a single lane can obviously be represented by

$$N(1) = 1.633(V_d - V) \tag{2}$$

For M lanes, the total traffic density is thus represented by

$$N(M) = N_x = 1.633M(V_d - V) \tag{2a}$$

In the analyses that follow, it is assumed that the original N automobiles per mile will reduce to N - D automobiles per mile (evenly distributed over the remaining inbound lanes), where D is the number of automobile drivers per mile diverted to buses. In Figure 2, a schematic diagram of the assumed in-lane traffic density before and after reservation of the exclusive

Figure 1. Variation of traffic volume per lane with expressway operating speed.

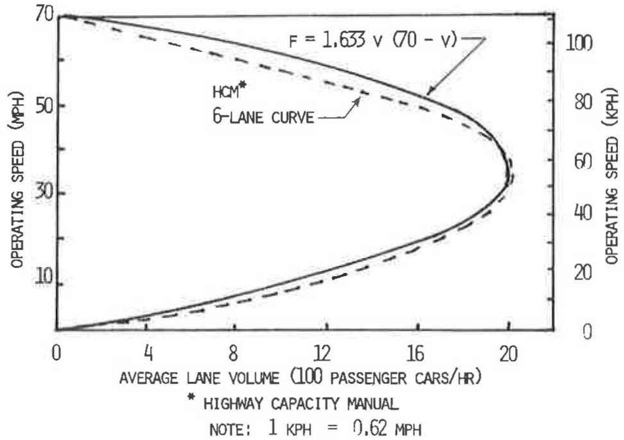
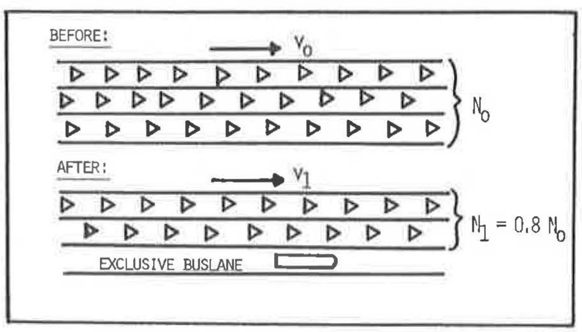


Figure 2. In-lane configuration: 20 percent diversion from automobiles to buses.



lane indicates an assumed 20 percent diversion for three lanes (M = 3) in the peak-flow direction.

Emissions

Because the air quality impact of CO emissions is local and dependent on the instantaneous emission rate, the appropriate equation for M lanes can be written as follows:

$$\begin{aligned} E &= F \times M \times e \times f(V) \\ &= N(M) \times V \times e \times f(V) \\ &= 1.633MV(V_d - V)e[f(V)] \end{aligned} \tag{3}$$

in grams per mile per hour where e is the base emission factor and V is assumed to remain constant through the peak period. The impact of HC emissions, however, is regionwide and is dependent on the total emissions during the morning peak period. The critical measure of HC emissions is thus expressed by

$$\begin{aligned} H &= F \times M \times T \times L \times h \times g(V) \\ &= 1.633MV(V_d - V)T \times L \times h \times g(V) \\ &= P \times L \times h \times g(V) \end{aligned} \tag{4}$$

in grams, where T is the time required to discharge the reservoir of P peak-period automobiles.

In-Lane Exclusive Bus Lanes

The initial traffic density is represented by

$$N_o = 1.633M(70 - V_o) \tag{5}$$

If $k = (N_o - D)/N_o$ represents the fraction of automobile drivers who are not diverted to the express buses, then the traffic density on the (M - 1) lanes remaining is represented by

$$\begin{aligned} N_l &= kN_o \\ &= 1.633(M - 1)(70 - V_l) \end{aligned} \tag{6}$$

where k is the decimal fraction of automobiles remaining in the traffic lanes. Simultaneous consideration of Equations 5 and 6 reveals that

$$V_l = 70 - k\phi(70 - V_o) \tag{7}$$

where

$$\phi = M/(M - 1) \tag{8}$$

Corresponding values of the CO emission rates before and after implementation of the exclusive bus lane are determined from Equations 3, 5, and 6, as follows:

$$E_o = 1.633MV_o(70 - V_o)e[f(V_o)] \tag{9}$$

and

$$\begin{aligned} E_l &= N_l \times V_l \times e \times f(V_l) \\ &= k \times N_o \times V_l \times e \times f_l \\ &= (k \times E_o \times V_l \times f_l)/V_o f_o \end{aligned} \tag{10}$$

where the subscripts o and l represent conditions before and after implementation and f_o and f_l represent $f(V_o)$ and $f(V_l)$ respectively. Thus, the effectiveness of the exclusive bus lanes with respect to CO emissions is determined by the ratio

$$E_l/E_o = kV_l f_l/V_o f_o \tag{11}$$

Table 1 gives the pertinent input variables and the resulting emission ratios for the following factors: V_o = 64 km/h (40 mph), M = 3, $\phi = M/(M - 1) = 1.5$, N_o = 1.633 M $(70 - V_o) = 147$, $f_o = f(V_o) = 0.461$, and $g_o = g(V_o) = 0.617$. The table indicates that the emission ratios are always greater than k and exceed unity for k > 0.96 (CO) and k > 0.86 (HC). The additional emissions resulting from express buses operating in the exclusive lanes were found to be less than 2 percent of the automobile emissions and were omitted from further consideration.

The resulting variation of the minimum percentage diversion with the number of inbound lanes for reduction of CO emissions (emission-reducing effectiveness equals unity) is shown in Figure 3. The figure shows that, for an average pre-bus-lane speed of 56 km/h (35 mph), the installation of an exclusive bus lane will result in increased CO emissions unless 8 to 10 percent of the automobile drivers change to the transit mode.

Equations for total HC emissions, before and after reservation of a single lane for express buses, are derived from Equations 4, 5, and 6:

$$\begin{aligned} H_o &= N_o \times V_o \times T_o \times L \times h \times g(V_o) \\ &= P_o \times L \times h \times g_o \end{aligned} \tag{12}$$

and

$$\begin{aligned} H_l &= N_l \times V_l \times T_l \times L \times h \times g(V_l) \\ &= P_l \times L \times h \times g_l \end{aligned} \tag{13}$$

Table 1. Input variables and emission ratios for in-lane exclusive bus lane.

k	$V_1 = 70 - k\phi(70 - V_o)$	$f_1 = f(V_1)$	kV_1f_1	kV_1f_1/V_of_o	kg_1	kg_1/g_o
1.0	25.00	0.773	19.33	1.048	0.825	1.316
0.95	27.25	0.711	18.24	0.990	0.787	1.276
0.90	29.50	0.630	17.01	0.924	0.678	1.099
0.85	31.75	0.586	15.94	0.866	0.609	0.992
0.80	34.00	0.547	14.88	0.810	0.548	0.894
0.75	36.25	0.514	13.88	0.756	0.494	0.808
0.70	38.50	0.485	12.90	0.704	0.445	0.730
0.65	40.75	0.461	11.99	0.655	0.401	0.660

Figure 3. Minimum percentage diversion versus number of inbound lanes for in-lane CO emissions.

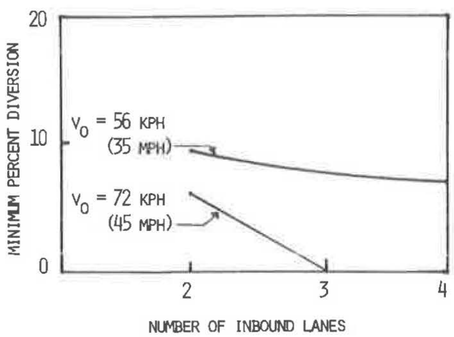
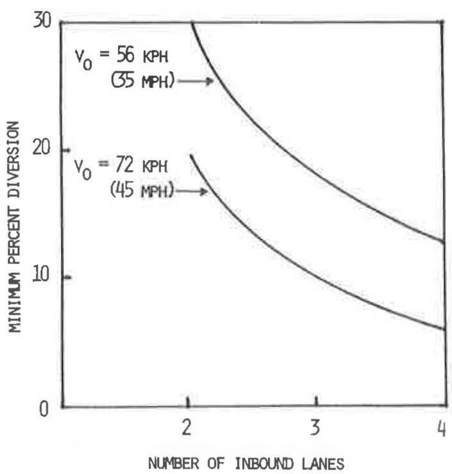


Figure 4. Minimum percentage diversion versus number of inbound lanes for in-lane HC emissions.



Under the assumption of steady-state traffic densities during the peak period, it is apparent that the traffic densities (N) are proportional to the total numbers of peak-period automobiles (P). Thus, $P_1/P_o = N_1/N_o = k$, and Equation 13 can be expressed by

$$H_1 = k \times P_o \times L \times h \times g_1 \tag{13a}$$

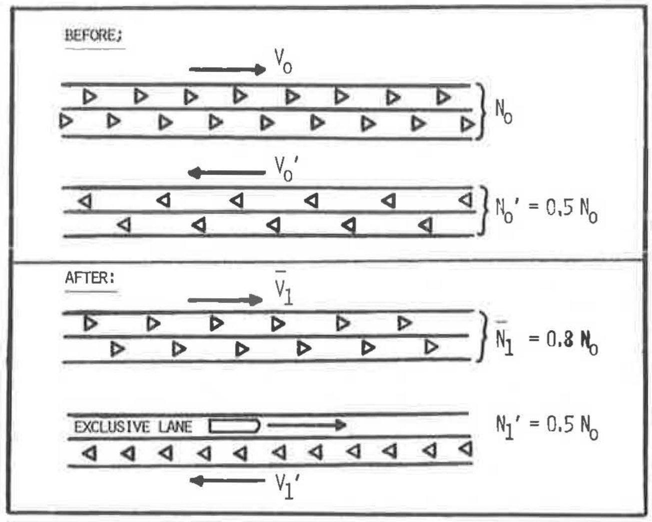
The emission-reducing effectiveness for HC of the in-lane exclusive bus lane is thus determined by

$$H_1/H_o = kg_1/g_o \tag{14}$$

The pertinent variables and the resulting ratios for V_o = 64 km/h (40 mph) and M = 3 are given in Table 1.

Figure 4 shows the variation of minimum percentage diversion with the number of inbound lanes (M) for reduction in HC emissions. The figure shows that reduction of HC emissions requires a diversion of 14 to 30 percent of automobile drivers on a highway where the

Figure 5. Counterflow configuration: 20 percent diversion from automobiles to buses and 60-40 directional split.



normal peak-period speed is 56 km/h (35 mph).

Counterflow Exclusive Bus Lanes

Basic relations for the peak-flow direction in the counterflow configuration (Figure 5) are equivalent or similar to Equations 5 and 6 for the in-lane exclusive bus lanes:

$$\bar{N}_1 = kN_o = 1.633M(70 - \bar{V}_1) \tag{15}$$

where it is noted that, because the bus lane is now assigned to the less congested, outbound portion of the highway, the number of inbound lanes (M) remains the same after implementation of the exclusive lane. Simultaneous consideration of Equations 5 and 15 results, therefore, in the following equation for $\bar{V}_1$:

$$\bar{V}_1 = 70 - k(70 - V_o) \tag{16}$$

The relation of the initial outbound speed (V_o') to V_o is established by the directional split [y : (100 - y)]:

$$q = (100 - y)/y \tag{17}$$

where y is the percentage of total traffic flow (MF_o + $M'F_o'$) in the inbound (peak-flow) lanes and M' is the number of outbound lanes. Therefore,

$$M'F_o' = qMF_o \tag{18}$$

and

$$M'V_o'(70 - V_o') = qMV_o(70 - V_o) \tag{19}$$

For $M' = M$ (which is assumed throughout the following analysis),

$$V_o' = 35\{1 + \sqrt{1 - [4qV_o(70 - V_o)/4900]}\} \tag{20}$$

Because it is assumed that neither the total number nor the total density of outbound automobiles is altered by the diversion of inbound automobile drivers to buses,

$$N_I' = N_o'$$

$$(M - 1)(70 - V_I') = M(70 - V_o') \tag{21}$$

from which

$$V_I' = 70 - \phi(70 - V_o') \tag{22}$$

In Figure 5, a schematic diagram of the assumed traffic density before and after reservation of an exclusive counterflow bus lane indicates an assumed 20 percent diversion for a four-lane highway with a normal directional split of 60-40. Figure 5 shows that the reservation of one of the two outbound lanes as an exclusive bus lane results in a doubling of the lane density on the remaining outbound lane.

Appropriate values for CO emission rates, before and after implementation of the exclusive counterflow bus lanes, are determined from Equations 3, 9, 15, 19, and 21, as follows:

$$\begin{aligned} \bar{E}_I &= \bar{N}_I \times \bar{V}_I \times e \times \bar{f}_I \\ &= k \times N_o \times \bar{V}_I \times e \times \bar{f}_I \\ &= (k \times E_o \times \bar{V}_I \times \bar{f}_I)/V_o f_o \end{aligned} \tag{23}$$

$$\begin{aligned} E_o' &= N_o' \times V_o' \times e \times f_o' \\ &= q \times N_o \times V_o \times e \times f_o' \\ &= (q \times E_o \times f_o')/f_o \end{aligned} \tag{24}$$

Figure 6. Minimum percentage diversion versus number of inbound lanes for counterflow HC emissions.

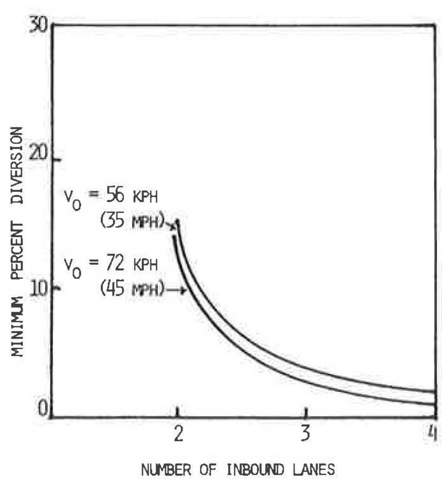


Table 2. Percentage diversion required to effect emissions reduction for in-lane exclusive bus lanes.

	Required Diversion (%)					
	CO			HC		
V_o (km/h)	Two Lanes	Three Lanes	Four Lanes	Two Lanes	Three Lanes	Four Lanes
56	10	9	8	30	18	13
64	8	4	2	27	15	10
72	5	0	0	21	11	8
80	0	0	0	15	6	4

Note: 1 km = 0.62 mile.

and

$$\begin{aligned} E_I' &= N_I' \times V_I' \times e \times f_I' \\ &= N_o' \times V_I' \times e \times f_I' \\ &= (q \times E_o \times V_I' \times f_I')/V_o' f_o \end{aligned} \tag{25}$$

Thus, the effectiveness of counterflow exclusive bus lanes in reducing CO emissions is determined by the following ratio:

$$(\bar{E}_I + E_I')/(E_o + E_o') = [(k\bar{V}_I\bar{f}_I/V_o) + (qV_I' f_I'/V_o')]/(f_o + qf_o') \tag{26}$$

Equations for total HC emissions, before and after reservation of the exclusive counterflow bus lane, are derived from Equations 4, 12, 15, and 21 on the continuing assumption that the reservoirs of peak-period inbound automobiles (P_o, $\bar{P}_I$) are proportional to the corresponding densities,

$$\bar{P}_I/P_o = \bar{N}_I/N_o = k \tag{27}$$

and the straightforward assumption that the ratio of the total number of outbound automobiles to the initial number of inbound automobiles is equivalent to the ratio of the corresponding initial flows,

$$P_o'/P_o = F_o'/F_o = q \tag{28}$$

Therefore,

$$\begin{aligned} \bar{H}_I &= \bar{P}_I \times L \times h \times \bar{g}_I \\ &= k \times P_o \times L \times h \times \bar{g}_I \\ &= kH_o\bar{g}_I/g_o \end{aligned} \tag{29}$$

$$\begin{aligned} H_o' &= P_o' \times L \times h \times g_o' \\ &= q \times P_o \times L \times h \times g_o' \\ &= qH_o g_o'/g_o \end{aligned} \tag{30}$$

and

$$\begin{aligned} H_I' &= P_I' \times L \times h \times g_I' \\ &= q \times P_o \times L \times h \times g_I' \\ &= qH_o g_I'/g_o \end{aligned} \tag{31}$$

Emission-reducing effectiveness for HC is subsequently determined by the ratio

$$(\bar{H}_I + H_I')/(H_o + H_o') = (k\bar{g}_I + qg_I')/(g_o + qg_o') \tag{32}$$

Figure 6 shows the variation of the minimum percentage diversion with the number of inbound lanes for reduction of HC emissions for a counterflow configuration in which the normal directional split is 55-45. The figure shows that a reduction in HC emissions requires a minimum diversion of 15 percent for a four-lane highway with a pre-bus-lane speed of 56 km/h (35 mph) and diversions of 4 and 2 percent respectively for six- and eight-lane highways.

RESULTS

In-Lane Configuration

The percentage of diversion from automobiles to transit required to effect a reduction in pollutant emissions for in-lane exclusive bus lanes, as determined by Equations 7, 11, and 14, is given in Table 2 for various initial-

Table 3. Percentage diversion required to effect emissions reduction for counterflow exclusive bus lanes.

		Required Diversion (%)					
		CO			HC		
Directional Split	V_o (km/h)	Two Lanes	Three Lanes	Four Lanes	Two Lanes	Three Lanes	Four Lanes
50-50	56	5	5	4	>35	>35	22
	64	20	4	2	>35	35	18
	72	4	0	0	>35	18	10
	80	0	0	0	34	9	5
55-45	56	0	0	0	15	4	2
	64	0	0	0	18	4	3
	72	0	0	0	14	4	0
	80	0	0	0	9	0	0
60-40	56	0	0	0	3	2	0
	64	0	0	0	3	0	0
	72	0	0	0	3	0	0
	80	0	0	0	2	0	0

Note: 1 km = 0.62 mile.

Table 4. Minimum percentage diversion required to achieve significant reductions of CO and HC emissions.

	Required Diversion (%)											
	In-Lane			50-50 Counterflow			55-45 Counterflow			60-40 Counterflow		
Volume/Capacity Ratio	Two Lanes	Three Lanes	Four Lanes	Two Lanes	Three Lanes	Four Lanes	Two Lanes	Three Lanes	Four Lanes	Two Lanes	Three Lanes	Four Lanes
Carbon monoxide												
1.00	22	20	14	40	40	40	0	0	0	0	0	0
0.98	9	7	5	40	40	40	0	0	0	0	0	0
0.90	9	0	1	40	40	40	0	0	0	0	0	0
0.80			0			40			0			0
0.75		0			40			0			0	
0.70	0			40			0			0		
Hydrocarbons												
1.00	40	24	18	—[a]	—[a]	—[a]	—[a]	10	5	6	2	0
0.98	34	20	14	—[a]	—[a]	—[a]	—[a]	20	7	7	0	0
0.90	25	16	11	—[a]	—[a]	—[a]	—[a]	10	0	10	0	0
0.80			6			40			0			0
0.75		10			40			10			0	
0.70	20			—[a]			40			10		

[a] Impossible to achieve significant emission reductions at less than 50 percent diversion from automobiles.

speed values. The data show that, for highways with an average initial speed ≥56 km/h, HC reductions require diversions that vary from 15 to 30 percent for two inbound lanes and from 4 to 13 percent for four inbound lanes. CO reductions can be achieved for highways in which the average initial speeds exceed 72 km/h (45 mph) for two inbound lanes or 64 km/h (40 mph) for three or more inbound lanes.

Counterflow Lane Configuration

The percentage diversion required to effect a reduction in pollutant emissions for counterflow exclusive bus lanes, as determined by Equations 16, 20, 22, 26, and 32, is given in Table 3 for various values of average initial speed and directional split. The data show the following:

1. For highways with a 50-50 directional split, reductions in hydrocarbon emissions require a diversion from the automobile mode greater than 33 percent for half of the cases examined and an average diversion of 10 percent for the remaining cases.
2. For a highway with a directional split of 55-45, reductions in CO emissions will occur for all cases. HC reductions require diversions of 4 to 18 percent on four- or six-lane highways where the speed before the exclusive bus lane is less than 80 km/h (50 mph).
3. For a highway with a directional split of 60-40, emission reductions will occur for all cases except for four-lane highways, where reductions in HC emissions require a modest diversion from automobiles to transit.

Table 4 gives the minimum diversion percentages required, for various configurations and directional splits, if CO and HC emissions are to be significantly reduced (by more than half the diversion percentage).

CONCLUSIONS

Reductions in CO emissions can be achieved by means of in-lane exclusive bus lanes where average traffic speeds exceed 72 km/h (45 mph) and by means of counterflow lanes where directional splits equal or exceed 55-45. Reductions in HC emissions can be achieved by means of counterflow lanes if the directional split exceeds 55-45 and the percentage of people diverted from automobiles exceeds 5 percent.

ACKNOWLEDGMENTS

I thank Nancy Goldman of the University of Pennsylvania, a work-study student in the EPA regional office, and Steven Powers of EPA for their assistance in performing the calculations and preparing the figures for this report. The views expressed in this paper are mine and are not necessarily endorsed by the U.S. Environmental Protection Agency.

REFERENCES

1. Highway Capacity Manual. HRB, Special Rept. 87, 1965.
2. Compilation of Air Pollution Emission Factors. U.S. Environmental Protection Agency, Rept. AP-42, 2nd Ed., Supplement 5, Dec. 1975.

Publication of this paper sponsored by Committee on Transportation and Air Quality.

Abridgment

Line Source Emissions Modeling

Lonnie E. Haefner, D. E. Lang, R. W. Meyer, J. L. Hutchins, and Bigan Yarjani, Civil Engineering Department, Washington University

The objective of this paper is to describe the development of the line source sorting model NETSEN II and its use in conjunction with the automobile exhaust emissions modal analysis model of the U.S. Environmental Protection Agency (EPA) (1). Speed-profile analogies from the Regional Air Pollution Study of the St. Louis air quality control region (AQCR), developed for use in the modal emissions model, are used.

MODAL EMISSIONS MODEL

The automobile exhaust emissions modal analysis model developed by the Calspan Corporation for EPA was designed to calculate the amounts of hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) emitted by individual automobiles or groups of automobiles stratified by age and geographic location (1). Emission rates were deduced from surveillance tests performed on a test fleet of 170 automobiles in six American cities at varying altitudes. Emissions were output for any given second-by-second driving sequence within a speed range of 0 and 96.8 km/h (0 and 60 mph). The model developers recognized that the emissions response of an automobile depends on the speed profile experienced by its occupants as they travel from origin to destination. The developers also recognized that different light-duty vehicles have separate emissions responses for the same speed, acceleration, and deceleration profiles. The model does not treat meteorological or transport processes. It specifically details the distribution of emissions along a user-defined highway link and computes the total CO, HC, and NO_x contributions to the atmosphere from the highway source.

The inputs into the EPA modal emissions model include both traffic and emissions data. The traffic inputs are representative second-by-second speed profiles on the defined line sources, the number of automobiles assignable to the particular speed profiles on the defined line sources, their age distribution by model year, and the relative altitude at which they are operated. The emission parameters include emission-rate coefficients that are specific to speed profiles and are either user supplied or produced by default in the computer program itself. Because of cost and time, unless the user has a vehicle fleet and dynamometer testing equipment, the default emission-rate coefficients should be used. The emission-rate coefficients supplied by the model do not include the effects of cold starts, which generate a sizable portion of automobile emissions. No deterioration factors are applied, but they are indirectly incorporated in that the vehicle fleet used in the surveillance program reflected age and maintenance effects.

The modal emissions model estimates actual CO and HC emissions within 13 percent but only predicts NO_x within 80 percent. Because the model was developed for a single vehicle fleet, its ability to reproduce emissions from additional vehicle fleets was also tested. The model replicated performance to within 30 percent. Although this error seems significant, the input data from the model's own original vehicle fleet could not be replicated any better a second time. Both microscale and mesoscale emission-analysis methods have this drawback.

The modal emissions model is capable of operating at a truly microscale level. It allows for highly specific analysis of the emissions effects of traffic congestion. In using the model for this purpose, however, the user must define the established regional highway network—a major undertaking for a region the size of St. Louis. In addition, second-by-second speed-profile data and localized data on the emission response of vehicles must be collected either in the field or by development of a systematic scheme of speed-profile analogies for line sources.

DESCRIPTION OF NETSEN II MODEL

The network sensitivity model NETSEN II is an updated version of NETSEN, which was designed in an EPA study (2). The updated version has additional variables and subroutines and the ability to test for the following roadway characteristics in defining a line source: average daily traffic, five types of special topography, four types of capacity alterations, eight types of sensitive land uses, five types of activity centers, five types of progressive movement, channelization, functional classification, link distance, peak speed differences, truck and bus volumes, and volume/capacity (V/C) ratio.

Definition of a Line Source

The definition of a line source hinges on the capability of analyzing the highway network and its traffic and design attributes at varying levels of detail, and that capability depends on the availability of data and the level of spatial refinement sought by the user for input into pollution models such as the modal emissions model. Thus, if adequate data are available, the user has a range of capabilities, from developing a very refined set of descriptors—termed ultimate line sources—to developing a very unrefined set of descriptors—termed gross line sources. The following basic definition of a line source was used in the development of the NETSEN II program: "A line source is the smallest segment of inventoried roadway depictable with a given specific set of attributes for the roadway" (2).