PART 3

Air Quality

Impact of Preaggregation of Highway Network Travel Data on Accuracy of MOBILE4-Based Emissions

W. THOMAS WALKER

Preliminary Environmental Protection Agency guidance for the generation of mobile source emissions inventories indicates that a link-level computation based on simulated network volumes is preferred in urban areas. However, because of the size and complexity of some link-level emissions computations, a streamlined postprocessor based on 5-km grid aggregates of network vehicle miles traveled (VMT) and speed may also be useful to facilitate sensitivity testing and refinement of the MOBILE4 parameters used to generate an emissions inventory and to plan for emissions reductions. The results are presented of a series of accuracy checks made to ensure that the preaggregation of network VMT and speed does not introduce significant errors or biases into the resulting emissions estimates. These comparisons also shed some light on network aggregation errors that result from generating gridded emissions from Highway Performance Monitoring System VMT and speed data on other nonnetwork sources. The results clearly show that a postprocessor methodology is adequate to calculate emissions when the VMT and speed inputs are stratified by highway functional class. This does not mean that traffic simulation networks are not needed for preparing emissions inventories and planning for emissions reductions. When available, travel simulations are the most consistent and cost-effective way to estimate current and forecasted VMT and speed. However, for a given network assignment, using the postprocessor can expedite and streamline the calculation of emissions with little loss of accuracy or consistency.

In support of air quality planning activities required by the Clean Air Act Amendments of 1990, the Delaware Valley Regional Planning Commission (DVRPC) has been asked to prepare an inventory of mobile source emissions of three pollutants—volatile organic compounds (hydrocarbons), carbon monoxide, and oxides of nitrogen—for the Philadelphia ozone nonattainment area. This inventory will be prepared for a 5-k grid system that covers DVRPC's Pennsylvania and New Jersey counties, as well as Cumberland and Salem counties in New Jersey, Kent and New Castle counties in Delaware, and Cecil County, Maryland (see Figure 1).

It is anticipated that developing the emissions inventory will require the use of alternative emissions scenarios using different combinations of MOBILE4 parameters and seasonal travel factors. MOBILE4 parameters incorporate factors such as control device tampering rates, vehicle type and age distributions, inspection and maintenance programs, vehicle refueling practices, ambient temperatures, cold start percentages, and fuel volatility into the emissions calculation. Taken together, these factors have a great impact on the quantity of emissions produced.

Each of the four states in the Philadelphia nonattainment area is likely to use a different set of emissions factors consistent with their air quality programs. Calibrating the urban airshed model will require the reestimation of mobile source emissions inputs that reflect the conditions that occurred on the day of the episode being modeled. Sensitivity analyses will also be useful for preliminary testing and evaluation of emissions reduction strategies.

Figure 2 presents an overview of the proposed emissions inventory process. Inputs are shown in dashed boxes, and outputs are specified in solid-lines boxes. This process contains two emissions calculators shown in the heavy-lined boxes. The base case processor obtains simulated vehicle miles trav-

FIGURE 1 Philadelphia ozone nonattainment area.

Delaware Valley Regional Planning Commission, The Bourse Building, 21 South Fifth Street, Philadelphia, Pa. 19106.

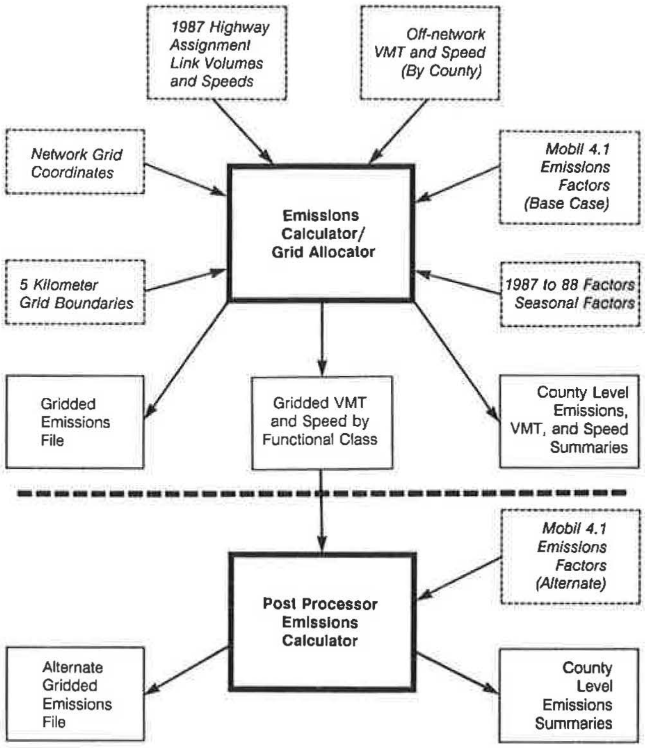

FIGURE 2 MOBILE source emissions inventory process.

eled (VMT) and speed data from a computerized highway network, calculates link-level emissions that reflect the base case set of seasonal and MOBILE4 emissions factors, and then allocates the emissions, VMT, and highway speed to each 5-km grid traversed by the link. This allocation is based on the proportion of the link distance within that grid. VMT that occurs on local streets not included in the regional network will be separately allocated to grids from county-level control totals.

Preliminary guidance from the Environmental Protection Agency (EPA) for the generation of mobile source emissions inventories indicates that a link-level computation based on simulated network volumes is preferred in urban areas (*1*). However, the participating state air quality agencies have requested that streamlined computational procedures also be developed to allow them a hands-on capability to fine-tune the MOBILE4 parameters that are used to generate the emissions inventories for the portions of the air quality region under their jurisdictions. For this reason, the postprocessor is included in the inventory process to recalculate grid-level emissions that reflect alternative sets of emissions factors.

The postprocessor emissions calculator is a simple matrix manipulator that considers MOBILE4 emissions factors by speed range and two highway demand matrices aggregated from link-level data by the base processor. These matrices, one containing VMT and the other average speed, are cross-classified by grid and highway functional class (freeway, arterial, and local/collector). Emissions for a given grid are calculated by multiplying the VMT for each functional class by the emissions factor appropriate for the average speed of that roadway class. Both base and postprocessors produce state- and county-level VMT, speed, and emissions summaries to assist in controlling and interpreting the inventory process.

A postprocessor is required to expedite the development of emissions scenarios because of the large size and diverse nature of the highway travel inputs to the base case processor. Ultimately, this calculation will use data from three highway networks containing about 60,000 links, Highway Performance Monitoring System (HPMS) data for three rural counties, and off-network VMT grid allocations for 14 counties. Although it is shown as a single box, the base case processor involves a number of separate computer programs, some of which must be run on a mainframe computer. Although the computation time and disk storage requirements for the link-level computation are not large for a modern mainframe (about 5 min on an IBM 4361 and 5,000 K of disk storage), the postprocessor reduces this time to about 8 sec and data storage to about 200 K and, more important, allows the downloading of both data and computation to a microcomputer for distribution to state and local air quality agencies.

However, using the postprocessor for this requires that a series of accuracy checks be performed to ensure that the preaggregation of VMT and speed from individual highway links to 5-km grids does not introduce significant errors or biases into the resulting emissions estimates. If speeds on individual links vary widely within a given grid, the nonlinearity of emission factors with respect to speed could cause significant differences. This paper presents the results of a series of accuracy checks that compared network-generated emissions with corresponding results from the postprocessor program. These accuracy comparisons will also shed some light on network aggregation errors that result from generating gridded emissions estimates from HPMS VMT and speed data and other nonnetwork sources. However, one should remember that gridded VMT based on HPMS data will also contain significant statistical errors because of the crude methods used to allocate county totals to grids and the small sample of highway links that are counted as part of this FHWA program.

DVRPC'S REGIONAL TRAVEL SIMULATION

The travel simulation models in use at DVRPC follow the traditional steps of trip generation, trip distribution, modal split, and travel assignment (minimum path, equilibrium capacity restraint for highway). They use computer programs included in the federally sponsored Urban Transportation Planning System (UTPS). The 1987 travel simulation, used as a basis for this analysis, was prepared from traffic zone–level socioeconomic trip generation inputs (households, automobile ownership, employed residents, and employment by place of work) extrapolated from the 1980 census and highway and public transit networks updated to include all facilities opened to traffic in 1987. This 1987 travel simulation is documented in detail in a commission report (*2*). Of particular interest to this exercise is the highway network and simulated traffic volumes and the method used to convert link-level simulated volume/capacity ratio into average operating speed. The 1987 simulated highway volumes were validated with traffic counts using FHWA screenline methods.

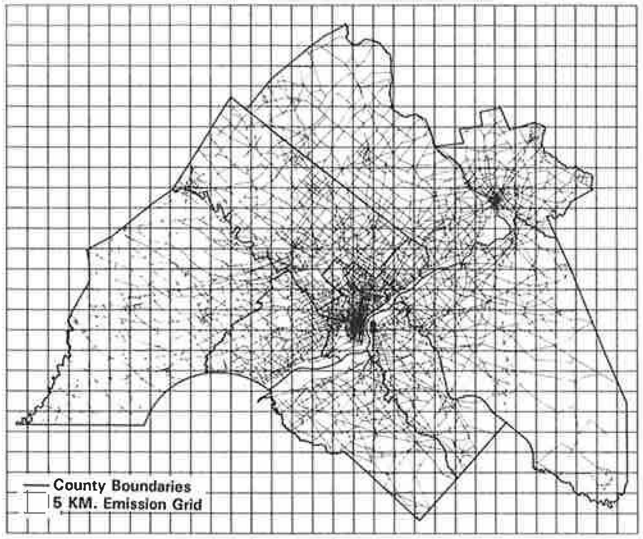

FIGURE 3 DVPRC 1987 highway simulation network.

Figure 3 displays a regional plot of the links included in the 1987 highway network with the 5-km grid system to be used for airshed modeling superimposed. The highway network covers only the DVRPC region shown in crosshatch in Figure 1. This network is very large, covering the 3,580-mi^2 DVRPC region at an average density of about 110 network arcs per 5-km grid.

Overall, the network (see Table 1) contains 1,449 traffic centroids, more than 12,500 nodes, 22,500 two-way links and 2,211 one-way links, which generate 47,227 network arcs for purposes of minimum path building and highway assignment (a two-way link generates two arcs; a one-way link, one arc).

TABLE 1 1987 Highway Simulation Network Statistics

Area Covered	3,846.8 Square Miles
Traffic Centroids	1,449
Nodes	12,533 (including centroids)
Two-way Link Cards	22,508 (including centroid connectors)
One-way Link Cards	2,211
Network Arcs	47,227
Average Arcs/Grid	109.6

Highway Route Miles

Functional Class	Computerized Network	Total Open to Traffic	% in Network
Freeway	739	739	100.0
Arterial	4,348	4,348	100.0
Collector/Local	1,580	14,464	10.9
TOTAL	6,667	19,551	34.1%

This network contains some 6,667 centerline-mi of roadway, which constitutes virtually all freeways and arterial facilities but only 11 percent of the local roads. These local facilities are mostly minor streets within local communities, industrial parks, and residential subdivisions. Local roads usually carry small traffic volumes and, in total, are thought to contribute about 12 percent to regional VMT, despite making up about two-thirds of the region's roadway mileage (*3*)

Emission factors calculated by MOBILE4 vary with vehicle operating speed to a very significant degree. For this reason, the amount and distribution of the mobile source pollutants are influenced by the accuracy and sensitivity of the method used to convert network measures of highway congestion into operating speed. Highway travel time studies conducted by the commission have shown that the so-called FHWA restraining curve has a severe tendency to underestimate operating speeds in the Delaware Valley region (by as much as 50 percent). This speed function is intended to facilitate the simulation of accurate link volumes (via capacity restraint) more than to produce realistic operating speeds. The use of this function to estimate simulated operating speeds would result in severely overestimated emissions. The FHWA restraining curve is given by

$$T = T_0[1.0 + 0.15(V/C)^4]$$

where

T = adjusted link travel time,
T_0 = unloaded link travel time,
V = assigned volume,
C = capacity of the link, and
maximum V/C = 4.0.

For this analysis, a complex but more accurate set of curves was used to estimate simulated operating speeds. These curves were taken from a report prepared by Creighton, Hamburg, Inc., for FHWA (*4*). A separate set of curves was used for freeways and arterials. The freeway curves relate peak-hour link operating speed to the link speed limit, capacity, and peak-hour simulated vehicular volume. The arterial curves relate peak-hour link speed to the speed limit, capacity, traffic signal density (per mile), a free-flow speed, and the peak-hour simulated link volume. The freeway curve required no modification for use in the DVRPC region. The arterial curve, however, required the addition of a minimum speed of 8 to 10 mph (depending on area type) to the Creighton, Hamburg formulation to adequately replicate DVRPC's travel time survey data. The revised curves are determined by the following equations:

Modified Creighton, Hamburg surface arterial equations:

$$S(w_s,n) = \frac{3{,}600}{\left(\frac{3{,}600}{w_s}\right) + 12.5n}$$

$$f(n) = -0.336n^3 + 3.905n^2 - 16.116n \qquad \text{if } n < 5.5$$

$$f(n) = 0.69n - 39.14 \qquad \text{if } n \geq 5.5$$

For $d_s \leq 0.8\ c_s$

$$a = S(w_s,n) + d_s f(n)$$

For $1.4c_s > d_s > 0.8c_s$

$$m = \frac{S(w_s,n) + 0.8c_s f(n) - S_m}{-0.6}$$

$$b = 2.333S(w_s,n) + 1.867c_s f(n) - 1.333S_m$$

$$a = \frac{md_s}{c_s} + b$$

For $d_s \geq 1.4c_s$

$$a = S_m$$

where

a = average surface arterial speed (mph),
d_s = surface arterial volume per lane (vehicle/sec),
n = number of signals per mile,
w_s = surface arterial speed limit (mph),
c_s = surface arterial capacity per lane (vehicle/sec),
$S(w_s,n)$ = free-flow speed for a given speed limit and given number of signals per mile,
$f(n)$ = rate of speed change with volume, and
S_m = minimum speed (mph).

Modified Creighton, Hamburg freeway equations:

$$K_2 = \ln\left(\frac{3,600}{K_1 S_c} - \frac{3,600}{K_1 w_f}\right)$$

For $c_f > d_f$

$$S = \frac{3,600}{K_1 \exp\left(\frac{K_2 d_f}{c_f}\right) + \frac{3,600}{w_f}}$$

For $c_f < d_f$

$$S = \frac{3,600}{K_1 \exp\left[K_2\left(\frac{d_f}{c_f}\right)^{1/2}\right] + \frac{3,600}{w_f}}$$

where

S = average freeway speed (mph),
w_f = speed limit on freeways (mph),
c_f = freeway capacity per lane (vehicle/hr),
d_f = freeway volume per lane (vehicle/hr),
K_1 = 0.4,
K_2 = intermediate value, and
S_c = speed at capacity.

Peak-hour link volumes were estimated from simulated daily volumes through the use of a peak-hour percentage (by functional class and area type) taken from traffic counts collected within the region. Speed limits, signal densities, and free-flow speeds were input as a table lookup by functional class and area type. DVRPC travel time surveys have found that daily speeds are on average about 10 percent higher than peak-hour speeds. Recent travel time surveys seem to indicate that the modified Creighton, Hamburg curves given may underestimate actual speeds by about five percent, because drivers have become more acclimated to operating their vehicles under congested conditions (*5*). For this reason the speeds output by the curves were increased by up to five percent (subject to the minimum speed and speed limit) in the emissions computations that will be described.

Table 2 presents regional travel and average speed statistics for the 1987 travel simulation and for a test run that assumed an across-the-board 50 percent increase in vehicular travel. On an average day, about 72,590,800 VMT occur on the highways included in the 1987 simulation network. This travel volume consumes about 58 percent of the theoretical daily capacity of the roadways, which results in 3,393,800 vehicle-hr for an overall average speed of 21.4 mph. A 50 percent increase in the traffic volume/capacity ratio reduces the average speed by about 25 percent to 16.1 mph. Although this VMT growth is arbitrary—some suburban and rural areas are likely to grow faster and urban areas to grow slower in a long-range horizon—it is interesting to see the effect of this increase and corresponding speed reduction on regional emissions. But first we must document the emission factor scenarios that will be used to test the postprocessor calculation method.

TABLE 2 Effect of 50 Percent Across-the-Board Increase in Highway Traffic on Regional Average Vehicle Speed

	1987 Traffic Estimates	50% Traffic Increase	% Difference
Vehicle Miles of Travel (000's)	72,590.8	108,885.9	50.0
Vehicle Hours of Travel (000's)	3,393.8	6767.2	99.4
Average Speed (mph)	21.4	16.1	- 24.8

MOBILE4 EMISSION FACTOR SCENARIOS

Emission factors produced by the MOBILE4 computer program vary significantly depending on the settings of various policy and climatic options that are included to tailor the output to seasonal conditions and to state and local emissions control programs (*6*). Therefore, a thorough testing of the postprocessor methodology requires that a series of emissions factor scenarios be tested. This will ensure that findings apply to all MOBILE4 outputs that may be generated during the development of emissions reduction strategies. Generally, a base scenario reflective of summer conditions in the Delaware Valley was specified, and from this base selected MOBILE4 options were tested one at a time. Although the MOBILE4.0 model used herein is now superseded by MOBILE4.1, the range of variation in emission factors generated by the extreme parameter settings in these sensitivity tests far exceeds the differences between MOBILE4.0 and MOBILE4.1 in practical applications. Therefore, the conclusions reached in this analysis will still be valid for MOBILE4.1 and future versions of this emissions model.

Base Case Conditions

The base case is a generalization reflective of 1989–1990 summer emission factors in the Delaware Valley region. It is not possible to have one set of base factors for the entire air quality region, because inspection procedures, Stage II recovery systems, and so forth vary between the four constituent states. However, for testing purposes, we assume that the base and in-use Reid vapor pressure (RVP) of gasoline sold in this low-altitude region was 11.5 psi (although it was reduced to 9.0 during 1990) and that daily temperatures varied from 70 to 94°F. In addition, a computerized, decentralized inspection and maintenance program based on an ideal emissions test was assumed to be in effect for all vehicle types except heavy truck. This program was assumed to begin in 1984 with a 6 percent waver rate and a 93 percent compliance rate. Refueling emissions were assumed to be uncontrolled and the default (EPA-supplied) VMT accumulations by vehicle type and age were used.

Alternative Emissions Scenarios

Nine emissions scenarios were tested that cover the significant policy and climatic parameters of MOBILE4. The first two scenarios substituted RVPs of 15.2 and 7.0 for the 11.5 assumed under the base case. These are the maximum and minimum RVP values allowed in MOBILE4.0. The winter temperature scenario substituted a daily range of 20 to 45°F (VMT was held constant for this exercise, although on average, winter VMTs are thought to be about 5 percent lower than summer). The high-altitude scenario increased the altitude from 500 to 5,500 ft. The fifth scenario eliminated the inspection and maintenance program, and Scenario 6 substituted an antitampering program for inspection and maintenance. The heavy-truck scenario increased the combined heavy gas and diesel truck percentage from the EPA default of 4.9 percent to 25 percent. Twenty-five percent trucks is thought to be representative of the maximum value found on specific general-purpose public highways. The final scenario uses factors that reflect the emissions control devices that are anticipated to be installed in vehicles in calendar year 2020.

Table 3 displays the mean values and standard deviations of the MOBILE4 emission factors that resulted from this series of scenarios. Despite the significant reductions in emissions brought about by the catalytic converter and other vehicle-mounted pollution control devices, carbon monoxide (CO) is still the principal pollutant produced by vehicular travel. MOBILE4.0 factors at the average speed (21 mph) for CO range from 3 to 5 times the values for volatile hydrocarbons (HC), which in most cases are significantly higher than the factors for nitric oxides (NO_x). The large standard deviations with respect to vehicle speed associated with CO emissions factors indicate that the quantity of this pollutant produced varies significantly with speed, with larger factors generally being produced at low speeds, and with much smaller factors at higher speeds. HC emissions factors also vary with speed, but to a lesser degree, and NO_x factors have the least variation with vehicle operating speed and follow a U-shaped curve.

Changes in gasoline vapor pressure mainly affect HC emissions (by up to 70 percent), although CO emissions are also

TABLE 3 Sensitivity of MOBILE4.0 Emissions Factors to Selected Scenario Options

	<-- CO -->		<-- HC -->		<-- NOX -->	
Emissions Scenario	GM/Mile @ 21 mph[1]	Mean/Std Deviation[2]	GM/Mile @ 21 mph[1]	Mean/Std Deviation[2]	GM/Mile @ 21 mph[1]	Mean/Std Deviation[2]
Base Case[3]	24.8	28.6/27.4	5.5	5.8/2.2	2.1	2.2/0.3
RVP 15.2	27.3	31.4/29.9	9.5	9.8/2.3	2.1	2.2/0.3
RVP 7.0	20.7	24.1/23.3	2.9	3.2/2.0	2.1	2.2/0.3
Winter Temperature[4]	28.5	32.5/30.8	2.5	3.0/3.0	2.6	2.7/0.3
High Altitude	33.9	38.3/33.6	6.7	7.1/2.3	2.0	2.1/0.3
No Inspection & Maintenance	31.7	36.9/35.7	5.9	6.3/2.6	2.2	2.3/0.3
Substitute Anti-tampering Only	28.8	33.5/32.4	5.5	5.9/2.3	2.2	2.3/0.3
25% Heavy Truck[5]	26.4	30.1/26.9	5.3	5.6/2.1	4.7	5.0/0.8
Calendar Year 2020	14.4	13.1/ 7.7	3.4	3.6/1.2	1.3	1.3/0.3

[1]The mean simulated traffic speed from the 1987 network assignment was 21.4 mph.

[2]Mean and standard deviation over 53 emission factors calculated by whole mile per hour increment from 3 to 55 mph.

[3]Base case includes an RVP of 11.5 PSI, summer temperature (70-94° F), default vehicle mix (4.9% heavy truck), 1990 Calendar Year, and low altitude.

[4]20°-45° F.

[5]7.5% heavy duty gas truck and 17.5% heavy duty Diesel truck.

affected. Winter temperatures increase CO emissions by some 15 percent and NO_x by 24 percent but reduce HC emissions by more than 50 percent. The high-altitude option causes large increases in CO (37 percent) and HC emissions (22 percent) but reduces NO_x emissions slightly.

Inspection and maintenance programs tend to reduce all pollutants, with the biggest effect on CO (28 percent) and the smallest on NO_x (5 percent). The emissions improvement brought about by antitampering programs appears to be limited to CO and NO_x emissions (16 and 5 percent, respectively). A high concentration of heavy trucks more than doubles average NO_x emissions (123 percent) but tends to slightly reduce HC emissions (by 4 percent) and to increase CO emissions by just over 6 percent.

By 2020, great reductions in vehicle emissions rates are anticipated. CO emissions factors are to be cut by another 42 percent, and HC and NO_x emissions each by 38 percent. Significantly, the standard deviation with respect to speed is also to be reduced dramatically; therefore, much of this pollution relief will occur even if increased highway congestion significantly reduces prevailing highway vehicle operating speed over time.

As of this writing, EPA is still developing refinements to MOBILE4. However, taken together, the given emissions scenarios are adequate for postprocessor testing because they effectively cover the range of factors likely to be produced by MOBILE4 (and its successors) during emissions inventory development and in planning for air pollution reductions by state and local air quality planners.

POSTPROCESSOR VERSUS LINK-LEVEL EMISSIONS ESTIMATES

The postprocessor recalculated 5-km grid-level emissions based on gridded VMT and average speed stratified by highway functional class (freeway, arterial, and local/collector). These grid-level VMT and speed data were tabulated by the base processor from network link volumes and speeds. Off-network VMT is not included in either emissions calculation in order to focus the analysis on link volume/speed aggregation phenomenon. The inclusion of off-network VMT would reduce postprocessor errors because this VMT surcharge is allocated from county control totals and is therefore a constant by grid for both the link-level and postprocessor emissions calculators.

Base Case Scenarios

Table 4 shows that the errors in emissions attributable to postprocessor aggregation are minimal. Regional totals produced by the postprocessor are within 0.5 percent of the link-level–based estimates for all three pollutants. At the grid level, the percentage root mean squared (*RMS*) errors are less than 3 percent; the coefficient of determination (R^2) between emission estimates is essentially 1.0 (i.e., perfect colinearity). Theil tests indicate that almost all mean squared differences are attributable to scatter (UC) and that only minimal differences result from systematic variation in mean (UM) or standard deviation (US) (7).

TABLE 4 Stratified Postprocessor Error Statistics Under Base Case Emissions Scenario

	– CO –	– HC –	– NOX –
Regional Total Emissions (Tons/Day)			
Post-Processor	1722.6	392.7	159.1
Link Level	1716.4	392.7	159.6
% Difference	0.4	-	- 0.3
Grid Level Emissions Error Statistics			
RMS Error (KG)	110.71	8.22	6.89
% RMS Error	2.78	0.90	1.86
Coef. of Determination (R^2)	0.9999	1.0000	0.9998
Theil Tests			
UM	0.02	0.00	0.03
US	0.00	0.02	0.05
UC	0.98	0.97	0.92

These errors are insignificant for emissions reduction planning and are far less than the expected errors in the underlying emission factors or link-level VMT and speed estimates. Fundamentally, because of continuity of development patterns and connectivity in the highway system, the situation rarely occurs when one freeway or arterial in a 5-km grid is uncongested with high operating speeds while another of the same functional class in the same grid has low speeds resulting from severe congestion. Prevailing traffic conditions tend to apply to all highways of a given functional class within a grid.

Grid-level speed differences do occur by functional class, however, because of differences in access policies from abutting land uses and other design criteria. Freeways generally have higher speeds than arterials, which in turn generally operate at higher speeds than local streets. Table 5 compares link-level emissions with those produced by an alternative postprocessor that omitted the stratification by functional class. The omission of speed differences by functional class significantly increased the postprocessor errors in emissions. This is particularly true for NO_x, which is now underestimated by 2.3 percent at the regional level and has grid-level percentage *RMS* errors in excess of 5 percent. There are now significant Theil components for errors in mean and standard deviation. CO is also significantly affected by the loss of the functional class stratification, but to a somewhat lesser degree. HC is relatively unaffected by the simplification to the postprocessor.

TABLE 5 Postprocessor Error Statistics Without Disaggregation by Highway Functional Class

Regional Total Emissions (Tons/Day)

	— CO —	— HC —	— NOX —
Post-Processor	1728.0	392.8	155.8
Link Level	1716.4	392.7	159.6
% Difference	0.7	-	- 2.3

Grid Level Emissions Error Statistics

	— CO —	— HC —	— NOX —
RMS Error (KG)	172.00	11.28	- 19.98
% RMS Error	4.32	1.24	- 5.40
Coef. of Determination (R^2)	0.9994	0.9996	0.9995

Theil Tests

	— CO —	— HC —	— NOX —
UM	0.03	0.01	0.18
US	0.11	0.01	0.20
UC	0.86	0.98	0.62

TABLE 6 Effect of 50 Percent Increase in VMT on Postprocessor Errors

Base Case Regional Total Emissions (Tons/Day)

	— CO —	— HC —	— NOX —
Post-Processor	3365.8	650.7	247.5
Link Level	3351.7	650.2	247.7
% Difference	0.4	-	- 0.1

Base Case Grid Level Emissions Error Statistics

	— CO —	— HC —	— NOX —
RMS Error (KG)	259.19	20.44	7.33
% RMS Error	3.33	1.36	1.28
Coef. of Determination (R^2)	0.9996	0.9999	0.9999

Percent Growth From 1987 VMT Estimate

Emissions Scenario	— CO —	— HC —	— NOX —
Base Case	95.3%	65.6%	55.2%
Year 2020	-5.9%	3.4%	-7.1%

This result is somewhat surprising given the small standard deviation with respect to speed in the NO_x emission factors (Table 3). But one should remember that it is emission factor differences in the prevailing range of highway operating speeds (15 to 35 mph), not overall variation, that count. CO emission factors do have a large standard deviation with respect to speed, but this variation largely results from geometric increases as speeds decrease below 8 or 10 mph. Very few roadways in the region operate at speeds this low.

To test the applicability of the stratified postprocessor in congested roadway conditions that may occur in a long-range forecast, all simulated link volumes were increased by 50 percent and the speed and emissions calculations reexecuted. Table 6 compares the postprocessor output (functional class stratified) with the corresponding link-level emissions estimates. Generally, the errors both at the regional and grid levels have increased only slightly over those reported in Table 4 for 1987 highway data. The stratified postprocessor methodology appears to remain applicable when analyzing long-range forecasts.

However, the effect of the reduced speeds under the 50 percent VMT increase on regional emissions is also of considerable interest. For the base case scenario, a 50 percent increase in travel increases regional CO emissions by 95.3 percent, HC emissions by 65.6 percent, and NO_x emissions by 55.2 percent. Although the 50 percent increase in travel is arbitrary for a long-range growth estimate, it is not out of line with the rapid traffic growth rates that occurred in the Delaware Valley region during the 1980s.

Given increasing funding restraints on highway construction dollars, it is most unlikely that highway capacity can be increased by anything approaching 50 percent even in the long run. Improvements in vehicular emissions control technology must be relied on to prevent these geometric increases in vehicular pollution. Regional emissions totals calculated from the year 2020 scenario emissions factors (also in Table 6) indicate that anticipated additional vehicle emissions controls are just about adequate to handle this 50 percent increase in VMT. Despite traffic growth, CO and NO_x emissions decline by 5.9 percent and 7.1 percent, respectively, whereas HC emissions increase by 3.4 percent. The national pollution control program improvements in emissions control technology included in MOBILE4.0 appear to be able to absorb about a 50 percent increase in travel in calendar year 2020 without significant increases in mobile source emissions even if fuel volatility is not reduced.

Alternative Emissions Factor Scenarios

None of the emissions factor scenarios produced significant errors in emissions totals. Only the year 2020 scenario pro-

TABLE 7 Differences in Regional Emissions Totals (ton/day) by MOBILE4.0 Scenario Option

	<— CO —>			<— HC —>			<— NOX —>		
Scenario	Post Proc.	Link	% Diff.	Post Proc.	Link	% Diff.	Post Proc.	Link	% Diff.
Base Case	1,722.6	1,716.4	0.4	392.7	392.7	-	159.1	159.6	- 0.3
RVP 15.2	1,895.7	1,887.7	0.4	683.7	683.8	-	159.1	159.6	- 0.3
RVP 7.0	1,443.3	1,439.7	0.3	207.1	207.0	-	159.1	159.6	- 0.3
Winter Temp.	1,970.1	1,960.4	0.5	175.2	175.3	0.1	194.8	195.4	- 0.3
High Altitude	2,358.3	2,374.6	- 0.3	482.0	481.9	-	150.3	150.7	- 0.3
No Insp. & Maint.	2,209.6	2,203.3	0.3	426.0	426.0	-	162.3	162.8	- 0.3
Substitute Anti-tamp.	2,006.4	2,000.8	0.3	398.8	398.8	-	160.4	160.9	- 0.3
25% Heavy Truck	1,859.8	1,851.0	0.5	380.8	379.9	0.2	355.7	357.5	- 0.5
Calendar Year 2020	920.7	891.8	3.2	248.7	248.7	-	92.1	91.3	- 0.9

TABLE 8 Grid-Level Emissions Errors by MOBILE4.0 Scenario Option

	<— CO —>			<— HC —>			<— NOX —>		
Scenario	RMS Error (kg.)	% RMS Error	R^2	RMS Error (kg.)	% RMS Error	% R^2	RMS Error (kg.)	% RMS Error	R^2
Base Case	110.71	2.78	0.9999	8.22	0.90	1.0000	6.89	1.86	0.9998
RVP 15.2	122.45	2.80	0.9997	8.66	0.55	1.0000	6.86	1.85	0.9998
RVP 7.0	92.51	2.77	0.9997	7.49	1.56	0.9999	6.95	1.88	0.9998
Winter Temperature	128.66	2.83	0.9997	11.27	2.77	0.9997	8.13	1.79	0.9998
High Altitude	141.95	2.61	0.9998	8.97	0.80	1.0000	6.52	1.87	0.9998
No Insp. & Maint.	142.30	2.78	0.9997	9.87	1.00	1.0000	6.96	1.84	0.9998
Substitute Anti-tamp.	129.35	2.79	0.9997	8.73	0.94	1.0000	6.96	1.87	0.9998
25% Heavy Truck	121.27	2.82	0.9997	9.44	1.07	1.0000	23.98	2.89	0.9996
Calendar Year 2020	149.19	7.21	0.9996	4.41	0.77	1.0000	4.72	2.23	0.9999

duced errors noticeably larger than the base case, and this was limited to CO—3.2 percent regional overestimate with 7.21 percent *RMS* error by grid (see Tables 7 and 8). Otherwise, both regional and grid-level error statistics presented are without exception comparable to those from the base case scenario. Regional totals differ by 1 percent or less, and grid-level *RMS* errors, by 3 percent or less.

CONCLUSIONS

Clearly, postprocessor methodology is adequate to test all emissions factor reduction strategies that can be generated by MOBILE4. When the postprocessor VMT and speed inputs are stratified by functional class, the magnitude of error in emissions estimates as a result of link and speed aggregation, even at the grid level, is very small. However, aggregation errors increased substantially when the functional class strata were removed.

This does not mean that traffic simulation networks are not needed for preparing emissions inventories and planning for emissions reduction. Travel simulations are the most accurate and cost-effective way to estimate gridded VMT and speed. HPMS data bases contain far too few observations to be statistically reliable at the grid level. Even when supplemental traffic counts are available, the process of calculating VMT and allocating it to grids can be extremely tedious and labor-intensive. Generalized lookup tables of link volumes must still be used for most roadways because it is not feasible to take a current traffic count on each of the many thousands of highway links that exist in an urban area. Travel simulation models produce volumes for all links in the network in a systematic way. Current simulated volumes are subject to screenline validation with traffic counts. Simulated forecasted volumes quantify the impact of projected land use changes and new highway facilities in a consistent fashion.

However, for a given network assignment, using the postprocessor can expedite and streamline the calculation of emissions with little loss of accuracy or consistency. This capability is very useful when conducting sensitivity tests that are needed for refining and customizing the MOBILE4 parameters and options to be used for inventory development and for testing possible emissions reduction strategies.

REFERENCES

1. *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources.* Office of Air Quality Planning and Standards, Environmental Protection Agency, Research Triangle Park, N.C., Dec. 1988.
2. *1987 Travel Simulation for the Delaware Valley Region.* Delaware Valley Regional Planning Commission, Philadelphia, Pa., May 1988.
3. *Conformity of the Regional Transportation Plan and Program.* Delaware Valley Regional Planning Commission, Philadelphia, Pa., Sept. 1991.
4. Creighton, Hamburg, Inc. *Freeway-Surface Arterial VMT Splitter.* FHWA, U.S. Department of Transportation, 1971, pp. 22–24.
5. *1971–73 to 1986 Highway Travel Time and Speed Comparisons in the New Jersey Portion of the DVRPC Region.* Transportation Planning Data Bulletin 9, Delaware Valley Regional Planning Commission, Philadelphia, Pa., Sept. 1987.
6. *Users Guide to MOBILE4.* Office of Air and Radiation, Environmental Protection Agency, Ann Harbor, Mich., Feb. 1989.
7. H. Theil. *Applied Economic Forecasting.* Rand McNally, Chicago, Ill., 1966, pp. 29–36.

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