

Table 1. Possible assignments of state, local, and regional responsibilities.

Candidate Element Classifications	Planning	Implementa-tion	Enforce-ment
Traffic operation im-provement	Regional, local, state	State, local	State, local
Improve transit and high-occupancy vehicles treatment and service	Regional, local	Regional, local	State, local
Pedestrian and bicycle movement	Regional, local	State, local	State, local
Parking management	Regional, local	Local	Local
Vehicle inspection and maintenance	Regional, state	State	State
Transportation pricing	Regional, state	State, local	State, local
Control of emissions at source (mechanical control)	Regional	State, local	State, local

In the Washington metropolitan area, a local-state-regional partnership approach has been proposed. It builds on the experience and cooperative working relations developed under the general COG umbrella.

Under this approach, the TPB would have primary responsibility for planning and scheduling transportation control measures. The AQPC would have primary responsibility for measures to reduce nonmobile sources of air pollution. The primary responsibility of the Board of Directors (BOD) of COG will be to ensure that the planning efforts of TPB and AQPC can be integrated into a revised plan that will meet national standards. The goal of this joint cooperative effort is a comprehensive 5-year program of implementable measures designed to achieve air quality standards for the region by the end of 1982.

Two principles were followed in drafting the proposed organizational framework and planning process necessary to comply with the act.

1. The existing planning structure of COG (its committees of local and state government representatives) was used to avoid duplication of effort or the creation of a separate agency or planning process.

2. While building on the existing decision-making structure in COG, participation in the process would not diminish the special transportation planning authority in the TPB or the policy role of the AQPC.

The proposed general planning sequence and responsibilities for carrying out the necessary planning effort are given below.

Planning Sequence	Responsible Authority
Predict future growth patterns	BOD
Predict future transportation demand	TPB
Predict future air quality levels	AQPC
Review existing land use measures	BOD
Review existing transportation measures	TPB
Review existing nonmobile measures	AQPC
Identify potential of locally implemented land use measures	BOD
Identify potential transportation measures	TPB
Identify potential nonmobile measures	AQPC
Determine air quality benefits of all measures	AQPC
Determine feasibility of locally implemented land use measures	BOD
Determine feasibility of transportation measures	TPB
Determine feasibility of nonmobile sources	AQPC
Integrate the coordinated planning efforts of TPB and AQPC into a revised TCP meeting national standards	BOD

Table 1 identifies possible assignments of local, state, and regional responsibilities for various candidate element classifications.

Considerable negotiating efforts still lie before us, but we believe that the cooperative organizational principles proposed, including the involvement and active participation of all responsible local, state, and regional agencies in the planning process, will enable us to meet the requirements of the Clean Air Act Amendments of 1977 and to develop a realistic and implementable program of measures designed to achieve air quality standards for the region in a timely and acceptable manner.

Development of a Method to Relate 8-Hour Trip Generation to Emissions Characteristics

Lonnie E. Haefner, J. Lee Hutchins, Donald E. Lang, Robert W. Meyer, and Bigan Yarjani, Department of Civil Engineering, Washington University, St. Louis

The objective of this paper is to demonstrate the development and integration of an efficient method for computing 8-h periods of trip generation and their resulting carbon monoxide, nitrogen oxide, and hydrocarbon emissions, by employing current emissions-dispersion models in conjunction with a direct assignment algorithm and appropriate regression analysis. After appropriate determination of land use stimuli and functional highway class, volumes are forecast using the direct assignment approach and input into the emissions model computations.

Subsequently, calibration of a regression-of-emissions versus trip-generation input yields the capability to forecast a series of emissions consequences versus land use.

Transportation planners are becoming increasingly concerned about the planning tools available for small to

medium-sized cities (50 000 to 250 000 population). The analytic modeling and associated computer packages developed to date are only cost-effective for larger urban areas. Another issue that has compounded this problem is the Clean Air Act of 1970, which as amended forces air quality criteria into the transportation and land use planning process. Further, the current models for assessment of air quality are also more useful for larger urban areas.

In light of the above, the objective of this research endeavor is to demonstrate the development and integration of an efficient method for computing 8-h periods of trip generation and their resulting carbon monoxide (CO), nitrous oxide (NO_x), and hydrocarbon (HC) emissions by employing current emissions models (1) in conjunction with a direct assignment algorithm and appropriate regression analysis (2). After appropriate determination of land use stimuli and functional highway class, volumes are forecast using the direct assignment approach and input into the emissions model computations. Subsequently, calibration of a regression-of-emissions versus trip-generation input is made, which yields the capability of forecasting a series of emissions consequences of specific land use patterns and highway network components.

Concern in the early 1960s about planning tools for small to medium-sized urban areas indicated development of a gap between needs and capabilities. Computer packages, such as the urban transportation plan (UTP) program package, were only cost-effective for larger urban areas that have large areawide networks and transportation systems. More recent activity, such as the incorporation of air quality criteria (3) in the planning process have aggravated this gap through the use of assessment models directed to larger urban areas.

The direct assignment technique was first developed by Schneider (4) in the early 1960s to mitigate many of the above disadvantages as well as to fulfill needs for detailed local information. The capability was sought to relate specific land use or development impacts to adjoining street segment volumes, thus yielding the capability to analyze specific network links or modifications.

For the application of the direct assignment technique, certain critical parameters must be defined or quantified. (SI units are not given for the variables of this model inasmuch as its operation requires that the variables be in U.S. customary units.) Trip end density refers to a measure of the specific area attractiveness, expressed in terms of trip ends per acre. Roadway spacing refers to the mean distance between various parallel links of functionally equivalent roadway segments, such as expressway, arterial, and local. Finally, a value for the mean trip length must be developed to reflect travel behavior in the region under study. The output of the direct assignment is the 24-h average daily traffic (ADT) for the specific link in question (5).

Direct assignment can be viewed as a generalized form of a gravity model, which has been typically expressed as

$$T_{ij} = V_i F_{ij} V_j / I_j \quad (1)$$

where

- T_{ij} = trips between points i and j ,
- V_i = trip origins at i ,
- F_{ij} = separation function between i and j ,
- V_j = trip destinations at j , and
- I_j = accessibility function.

The approach of direct assignment is to substitute for

the term V_j some measure of land development at j , the notation R_j . Now the above equation becomes

$$T_{ij} = V_i F_{ij} R_j / I_j \quad (2)$$

where

$$R_j = \text{measure of land development at } j \quad (6).$$

For the purposes of direct assignment, a trip is defined as that portion (complete or partial) of the travel trajectory lying on the minimum cost path. This path can be typically represented by an exponential decay function with input parameters, such as travel time and travel cost. As seen from the above equation, an increase in trip volumes will result from increases in accessibility and land development (7).

Generally, for any given link in a network, direct assignment of traffic volumes is a four-step procedure. Initially, domain boundaries for the specific link in question are defined, as well as the associated minimum path trees. The domain boundary represents the set of indifference points that can be reached equally well by traveling the link either northbound or southbound.

The north prime domain (n') is a subset of points of the north domain for which the minimum path of northbound necessitates the use of the link under study. By a similar definition, the south prime domain (s') is presented.

Next, the minimum path trees are also defined for other links crossing the domain boundary. The minimum path trees for the link in question are then partitioned into two sets. One set consists of minimum path trees that are not part of the minimum path trees for any competing link and are designated as the prime domains. The other is the entire nonpartitioned set of minimum path trees.

Finally, the traffic volume on the link under study is calculated from the equation

$$Q = (I_n I'_n + I_s I'_s) / (I_n + I_s) \quad (3)$$

where

- Q = traffic volume,
- I_n = north domain integral,
- I_s = south domain integral,
- I'_n = north prime domain integral, and
- I'_s = south prime domain integral.

These domain integrals have the following interpretation. For each of the respective domain regions, I is defined as the accessibility of a point that generates trip density (V) modified by the appropriate land development (R). Notationally,

$$I_i = \sum_j R_j F_{ij} \quad (4)$$

where

- I_i = domain integral for point i ,
- R_j = measure of land development at point j , and
- F_{ij} = separation function between i and j .

In practice, such prime domain-minimum time paths and the associated travel costs are used in conjunction with trip end density, trip length, and measures of roadway spacing to generate a book of direct assignment tables (8). Previous analysis and applications (9, 10) indicated a reasonable fit of predicted to actual link volumes. Limitations do exist for this assignment technique. Direct assignment is not formulated to

consider the travel demand process for the individual tripmaker. However, the technique has proved reliable in the estimation of traffic volumes under the previously described study design and parameters.

After some period of study, the Kansas Air Pollution Package (KAPP) (11) was chosen as suitable for the uses anticipated in this project. KAPP is an integrated package of an emissions model and a diffusion model. Although the emissions model is generically the same as the SAPOLLUT model (12) (i.e., based on average speed), it possesses several advantages. Of primary importance, it is oriented toward current emission estimates and uses actual roadway count information. It is simple to modify vehicle age distributions in the model for both trucks and automobiles to be more specific to a particular local area. KAPP is a comprehensive package, well documented, containing excellent report and graphics capabilities. Finally, it has an efficient input format, which allows ease of estimation of emissions on arbitrary roadway segments. This latter characteristic renders it especially attractive for site-specific studies, where the analyst is continually varying certain parameters of the site and observing the results.

OVERVIEW OF MODELING APPROACH

The modeling process developed in this research study uses available land use and roadway information inputs for an arbitrarily compact study area and attempts to translate these into meaningful estimates of traffic volumes and emissions. The theoretical foundation of this process includes empirical trip generation information and direct traffic assignment computational entities. The end result has several significant advantages over existing traffic and emissions estimating procedures: (a) the process requires data that can be obtained easily and inexpensively for a small area, and (b) the overhead of running an emissions model for an entire network to observe the results in a small area is not required. This latter result is important from the point of view of both the land use developer and the local public agency charged with making zoning decisions that affect air quality. By employing such a modeling approach, the developer is not required to make costly, detailed site plans in order to estimate the air quality impact, only to discover that the development would violate air quality standards.

Submodels

The first submodel uses land use and roadway information to predict roadway traffic volume estimates for a given geographic area. It will be referred to as the Stage I model. The first input to the model is land use information, which takes the form of the number of acres of specific types of land in the geographic area of interest. For the Peoria case study sites, the land use acreages by ten categories for the transportation analysis zones (TAZ) were used.

The next set of inputs are the roadway network characteristics. These include average spacing (in miles) between local streets, arterial streets, and expressways. The input information is used in a group of regression equations to predict the output of the Stage I model. The output is predicted 24-h roadway volume stratified by functional class of roadway (local, arterial, or expressway). The direct assignment process is incorporated in this model via the regression equations. Direct assignment is used to provide the predicted volumes, by functional class, to be used as dependent variables in the calibration process.

The Stage II model makes the next logical step in the modeling process, using the same land use and roadway spacing inputs employed in the Stage I model. It is used to predict emissions of CO, NO_x, and HC for small geographic areas. The Stage II model results in a series of regression equations; however, the equations now predict total emissions of CO, NO_x, and HC for the geographic area under consideration. An important component of the calibration of the Stage II model is the emissions estimation process used to derive dependent variables for the Stage II model calibration procedure. The process has several inputs. The first set is the predicted roadway volumes by functional class output from the Stage I model direct assignment process for a particular geographic area's roadway links. The other set of inputs is average speed information on each link in the geographic area. This information was obtained from the Federal Highway Administration (FHWA) link data cards supplied by Illinois Department of Transportation. Additional link information such as link distance and node numbers are used as appropriate identification characteristics of the links under study.

All of the above information is used by the KAPP emission model to predict emissions of CO, NO_x, and HC for a particular geographic area. The Stage I model is used to predict roadway volumes, and the Stage II model is used to predict area emissions given such volumes. Both use the same land use and roadway spacing information and yield valuable information on land use and roadway network behavior and land use-mobile source emissions.

Case Study City

Peoria is a medium-sized city in west-central Illinois with a metropolitan area population of 127 000. Peoria has just completed an urban transportation planning study in conjunction with the Illinois Department of Transportation. Recently Peoria has been the site of an air pollution monitoring program by the Illinois Environmental Protection Agency (13).

Peoria has seen pressures in recent years for outward urban growth similar to that in other cities within the 50 000 to 250 000 population size. Concurrent with this outward migration, a freeway system is emerging within the urban area. Finally, the socioeconomic breakdown of the population of the Peoria area is similar in nature to that of other small to medium-sized cities of Illinois, thus allowing for comparison with other areas within the state.

STAGE I MODEL CALIBRATION PROCEDURE

The calibration procedure for the Stage I model was composed of several steps, as indicated in Figure 1. The first task involved the selection of a representative sample of traffic analysis zones to be used as observations. A sample of 30 zones was selected randomly and included several from the Peoria central business district (CBD), some from Peoria city, Peoria County, and some from Tazewell County, including East Peoria. The next step in the procedure was to stratify the selected zones. Stratification was done on the basis of zone sites (in acres) because the smaller, more urban zones would likely have different network behavior than the larger suburban and semirural zones. This line of reasoning was proven to be appropriate: Results indicated that the statistical fit with two stratifications was roughly twice as good as when all zones are in the same sample. The size limit for the zone was set at 50 acres; 16 zones fell in the less than 50-acre class and 14 zones fell in the over 50-acre class.

The next major step in the process was to estimate end density for vehicle trips for the zones in the sample. The land use and site-specific trip generation rates derived from selected Illinois small to medium-sized cities were adjusted slightly for the Peoria area and were used with the various land-use acreages in each zone to estimate the vehicle trip ends generated. These estimated vehicle trip ends were then divided by the

total acreage in each zone to yield the vehicle trip end density for each zone.

The above end densities for vehicle trips were then used to estimate roadway volumes via the direct assignment technique. The other parameters needed for each zone were the average spacing between local streets, arterial streets, and expressways, and the mean trip length.

Using the Peoria 1970 network, individual roadway links were assigned to each of the zones. The mean trip length of 6 miles was used for the direct assignment process (4, p. 74). Given the three spacing parameters, the trip end density, and the mean trip length for each zone, a direct assignment was carried out for each zone, which yielded estimates of daily local, arterial, and expressway volumes. In general, the direct assignment volumes tended to be quite close for arterials, somewhat low for local streets, and somewhat high for expressways compared to the indicated daily volumes on the link records.

The predicted volumes for each functional class in each zone were then used in a multivariate linear regression procedure. The volumes were treated as dependent variables, and the acres of land by type and the roadway spacing by class were treated as independent variables. Hence, one regression model was run for each functional class for each of the two-zone size stratifications, resulting in a total of six regressions. A summary of the regression statistics for the six models is shown below.

Dependent Variable	F-Ratio	R ²
Local street volume		
Small zones (A)	15.86	0.977
Large zones (B)	8.38	0.978
Arterial street volume		
Small zones (C)	9.78	0.964
Large zones (D)	6.22	0.971
Expressway volume		
Small zones (E)	7.75	0.955
Large zones (F)	20.61	0.991

The variables for each model were the same, and the coefficients for each, the intercept term, and the standard errors of estimate are depicted in Table 1. The percentage of total variance explained by the models is very high, 95.5 to 99.1, but the confidence intervals for several of the parameter coefficients include zero. One possible explanation for this might be the relatively large number of variables in the models. It can be shown that the percentage of variance explained increases, in general, as more variables are added. Further analysis indicated that satisfactory fits could be obtained with about half as many variables.

Figure 1. Stage I model calibration.

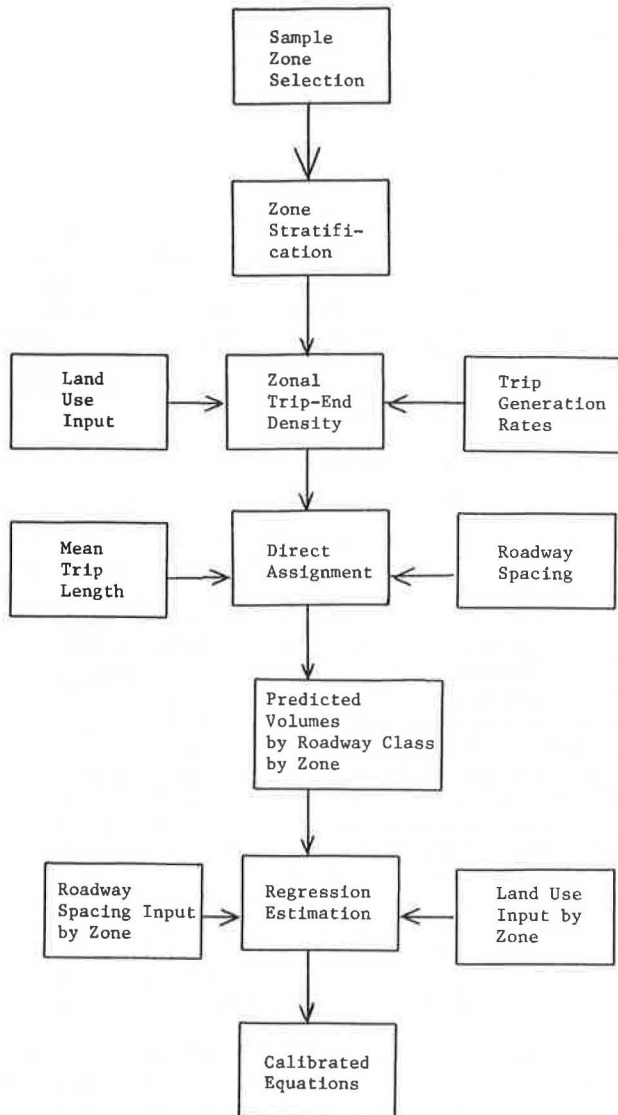


Table 1. Variable coefficients and standard errors for Stage I model.

Variable	Coefficients ^a						Standard Error					
	A	B	C	D	E	F	A	B	C	D	E	F
Intercept	1388	208	10 399	2 345	455 507	117 306	497	378	5 880	2892	208 339	38 531
Automobile parking	-555	-95	-4 381	-298	-128 842	-4 919	253	20	2 996	156	106 171	2 084
Residential	-55	-3	-404	-30	-13 200	-652	25	2	300	17	10 617	226
Institutional	8	-4	-828	1	-13 521	328	286	10	3 386	78	119 957	1 047
Office	583	38	6 424	194	172 601	15 154	212	41	2 513	311	89 019	4 138
Commercial	976	145	9 649	1 059	264 693	23 999	206	63	2 435	479	86 280	6 386
Warehouse	-54	-74	1 447	-306	21 232	-27 252	557	105	6 593	805	233 568	10 725
Industrial	-7292	-17	-75 884	-78	-2 013 873	3 408	3236	62	38 278	471	1 356 142	6 278
Transportation-utility	-58	-9	-567	-91	-11 072	-1 223	41	4	489	29	17 328	383
Open	-280	2	-3 187	6	-91 783	67	187	0.36	2 210	3	78 292	37
Recreational	-69	-6	-826	-6	-27 423	-719	112	12	1 321	92	46 789	1 220
Arterial spacing	-1507	1588	-10 520	13 124	-852 057	22 762	1365	945	16 151	7224	572 207	96 253

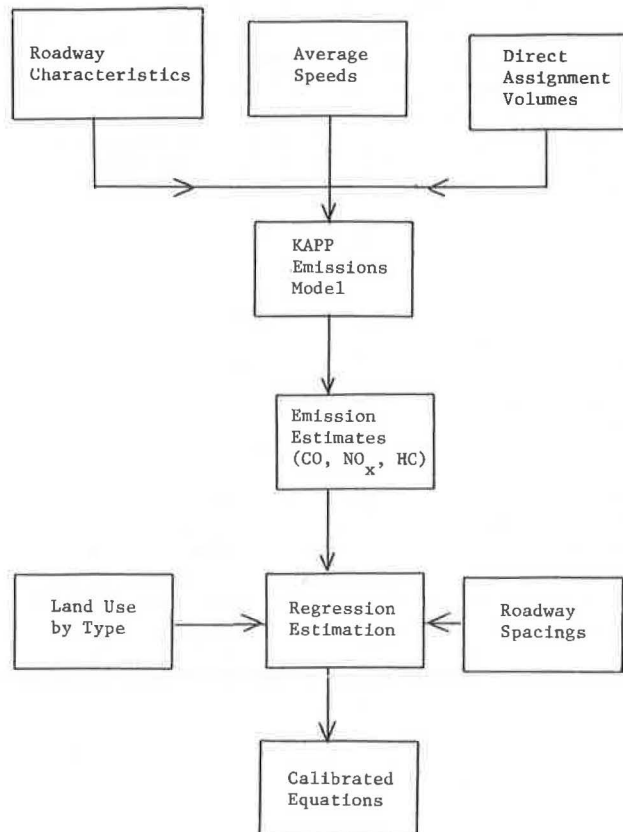
^aDependent variables are identified in text table 1.

STAGE II MODEL CALIBRATION PROCEDURE

The calibration procedure used for the Stage II model was quite simple in comparison to that for the Stage I model. The procedure is depicted in Figure 2, using the same sample set of zones and the same stratification from the Stage I model. The appropriate link distances and link average speeds for those links within each of the 30 zones were used from the Peoria 1970 network. The volumes used for the emissions estimation were those derived from the direct assignment process.

At this point, the KAPP emissions model was employed to yield estimates of the emissions of CO, NO_x, and HC. These emission estimates were made using 1976 as the calendar year, no correction for cold start operation, and a vehicle mix compiled from registration data for the Peoria area.

Figure 2. Stage II model calibration procedure.



The emissions estimates were the dependent variables and the roadway spacings and land use by type for each zone were the independent variables when a regression model was run for each pollutant. The land use information and the roadway spacing information were the same as those used by the Stage I model calibration procedure. The regression statistics are displayed below.

Dependent Variable	F-Ratio	R ²
CO		
Small zones (A)	8.88	0.96
Large zones (B)	0.53	0.74
NO _x		
Small zones (C)	8.14	0.95
Large zones (D)	0.46	0.71
HC		
Small zones (E)	8.96	0.96
Large zones (F)	0.52	0.74

The variable coefficients and standard errors are shown in Table 2. In general, the percent of variance explained is high, ranging from 71 to 96. As with the Stage I model, the standard errors on the estimates of the variable coefficients are somewhat high. Additional analysis on this data indicated that models with fewer land use variables could produce R²'s in the vicinity of 0.70, an acceptable level.

SELECTED SITE ANALYSIS

This section illustrates the use of the Stage I and Stage II models on four selected sites in the Peoria area. The sites include one in the Peoria CBD, one elsewhere in the city of Peoria, one in Peoria County, and one in Tazewell County. In each case, the land use and roadway spacing inputs will be presented as well as the volume estimates from the Stage I model and emission estimates from the Stage II model. In addition, the hourly and 8-h maximum emission estimates will be presented. All results are shown in Table 3.

The first area to be examined is in the Peoria CBD and corresponds to traffic analysis zone 3 of the Peoria Area Transportation Study (PATS). It is bounded by Washington, Main, Adams, and Fulton streets. The land is predominantly used in this zone for commercial and office space. The daily local street volume estimated (2382 vehicles) was somewhat low compared to actual counts, but the arterial volume (21 667 vehicles/d) was within 5 percent of actual counts. The Stage II model estimated 55.03 kg of CO, 4.52 kg of NO_x, and 5.01 kg of HC.

The second area considered for analysis was one selected elsewhere in the city of Peoria. It corresponds to traffic analysis zone 63 and is located on the south side of Peoria in the vicinity of Lincoln and Jefferson

Table 2. Variable coefficients and standard errors for Stage II model.

Variable	Coefficients ^a						Standard Error					
	A	B	C	D	E	F	A	B	C	D	E	F
Intercept	-28.43	175	-3.77	23	2.7	17.3	94	502	7.8	59	8.4	48.2
Automobile parking	4.23	-3.64	-0.97	-0.9	0.16	-0.41	48	27	3.97	3.2	4.3	2.6
Residential	-2.43	1.32	-0.21	0.07	-0.22	0.11	4.8	2.95	0.39	0.34	0.43	0.28
Institutional	-16.76	1.27	-1.60	-0.38	-1.52	0.04	54	13	4.49	1.61	4.88	1.31
Office	-0.13	-21	0.07	-1.9	-0.04	-1.93	40	54	3.33	6.3	3.62	5.2
Commercial	10.6	45	2.03	0.75	1.11	3.67	39	83	3.23	9.8	3.51	8
Warehouse	7.61	-23	2.25	3.2	0.54	-1.39	105	139	8.74	16.5	9.51	13.4
Industrial	-1450.0	-3.2	-122	0.46	-132	-0.19	614	81.9	50	9.6	55	7.9
Transportation-utility	-16	2.8	-1.52	0.36	-1.52	0.27	7.8	5	0.64	0.59	0.70	0.48
Open	61	-0.06	4.37	0	5.51	0	35	0.49	2.93	0.05	3.18	0.04
Recreational	59	-3.3	4.31	-0.77	5.36	-0.37	21	15.9	1.75	1.88	1.90	1.52
Arterial spacing	569	-72	51	-11	52.29	-7.37	259	1256	21	148	23.29	120

^aDependent variables are identified in text table 2.

Table 3. Example site analysis.

Item	Zone 3	Zone 63	Zone 198	Zone 242
Land use, acres				
Automobile parking	0.8	0.0	0.0	8.0
Residential	0.0	36.8	57.4	176.0
Institutional	0.1	6.2	0.0	10.0
Office	0.1	0.0	0.0	7.0
Commercial	1.5	4.2	0.0	3.0
Warehouse	0.0	2.1	2.0	4.0
Industrial	0.0	0.0	8.5	22.0
Transportation-utility	0.0	0.0	65.3	159
Open	0.3	1.0	1161.2	2222.0
Recreational	0.0	0.0	70.1	87.1
Total	2.8	50.2	1364.6	2698
Roadway spacing, miles				
Local	0.1	0.1	0.5	0.5
Arterial	0.2	0.4	1.0	0.6
Stage I predicted volumes, vehicles/d				
Local	2 382	528	650	1535
Arterial	21 667	5050	12 869	1954
State II predicted emissions/d, kg				
CO	55.03	155.33	20.63	85.12
NO _x	4.52	13.33	2.28	8.08
HC	5.01	14.20	1.94	7.86
8-h maximum CO, kg	30.82	86.98	11.54	47.66

avenues. Table 3 shows that land use mix for the zone is predominately residential in nature. The Stage I model estimates of roadway volumes are 528 vehicles/d on local streets and 5050 vehicles/d for arterials. Again, as with zone 3, the local street volumes are somewhat low and the predicted arterial volumes are within 5 percent of the observed. The Stage II model estimated 155.33 kg of CO, 13.33 kg of NO_x, and 14.20 kg of HC.

A third geographic area used for analysis purposes was located in eastern Peoria County. It corresponded to zone 198 and is located between IL-8 and the town of Norwood. The area can be characterized as predominantly open space with some residential, some recreational, and a small amount of industrial land. As shown in Table 3, the Stage I model estimated daily volumes of 650 vehicles for local streets and 12 869 vehicles for arterials. The local street volume predicted exceeds the observed by about 400 vehicles/d. There were no arterial roads in this zone. The low volumes are offset by the roadway links, which tend to be rather long in a zone of this size and geographic character. The Stage II model predicted 20.63 kg of CO, 2.28 kg of NO_x, and 1.94 kg of HC.

The final example zone analyzed was located in Tazewell County and corresponds to zone 242. It is located on either side of IL-116, northeast of the McClugage Bridge in extreme north Tazewell County. Like the previous area, it is dominated by open space and residential acreage. As shown, the Stage I model predicted daily volumes for local streets at 1535 vehicles and for arterials at 1954 vehicles. No local streets in the zone were coded for the network. The observed arterial volumes were significantly higher than the predicted. This may be because the major arterial through the area is a major state route and hence carries traffic not destined for the zone itself. The Stage II model predicted emissions of 85.12 kg of CO, 8.08 kg of NO_x, and 7.86 kg of HC.

NETWORK SENSITIVITY

The volume and emission results of the Stage I and Stage II models are daily estimates for typical weekday operation. Using the hourly and 8-h maximum travel distribution information developed, emission estimates can be developed for any given hour of the day or for an 8-h maximum period. Examples of the 8-h maximum CO

emissions for the four test sites are also shown in Table 3.

An appropriate issue in dealing with the results of the above models is their sensitivity to land use and network changes. The capability obviously exists to change the land use mix in an area to correspond to some proposed development. Consider zone 198 again: If a 5-acre shopping facility and additional 20 acres of residential land were planned for development, the Stage I model would indicate that local street volume would go from 650 vehicles to 1350 vehicles/d and daily arterial volumes would go from 12 869 vehicles to 17 564 vehicles/d. The Stage II model would indicate an increase of CO from 20.63 to 123.0 kg, NO_x from 2.28 to 4.61 kg, and HC from 1.94 kg to 10.19 kg. Thus, use of the equations and their coefficients yields a simple and straightforward procedure for estimating the emissions impacts of land use changes. The travel distributions discussed earlier may then be used to compute new hourly and 8-h maximum emissions estimates.

CONCLUSIONS

It is important to categorically summarize the major research achievements emanating from the work developed in this study.

1. The development and calibration of a simple regression equation format to directly forecast mobile source emissions from a land use and its adjacent supply of highway travel facilities. Such equations, given that they are logical and meaningful, represent a major breakthrough in the mobile source emissions and air quality state of the art.

2. Development, calibration, and employment of a functional battery of models for transportation demand forecasting, and emissions computation in a small to medium-sized urban area. These models are simple and direct, can be operated manually or by computer, and make use of simple and available land use inventory and traffic count data from the urban area.

Some significant users of the above research results include:

1. The urban or regional planner who must contemplate travel and air quality shifts resulting from modifications in land use or travel facilities; and
2. The land use developer confronted with meeting air quality, zoning, parking, and traffic standards, when modifying land uses at an assembled site for capital-intensive or profit-oriented reasons. By specifying the proposed land use development, its gross acreage, net square footage of use, and adjacent highway facilities, the resulting traffic and emissions may be forecast and modified with respect to standards, without initially resorting to intensive and costly preliminary engineering or site planning and architectural analysis.

In any research endeavor, the initial effort yields shortcomings in data collection for the study design and reveals opportunities for improvement in subsequent research and modeling thrusts. The following shortcomings were noted during the conduct of this research:

1. As in any regression-oriented research, concern should be registered about the sample size. Although the city size was appropriate to small and medium-sized urban area modeling, the UTP zonation resulted in a reasonably small random sample (30 zones). The im-

part of this on the statistical validity of representation of the sample, except in judging it to exist as a heuristically representative sample for a community of such size, is simply not known.

2. Related to the above, the calibration is specific to Peoria. Its true transferability to other communities of the same size seems logical but is not guaranteed to be statistically justifiable without larger sampling of zones in other cities of a like size and character, comprising a statistical and descriptively appropriate sample of the universe of cities of this size and character in the United States.

3. An induced and ever-present problem in urban transportation planning is the zonal size and its effect on variance. The zones in Peoria vary widely in size, as typical of all UTP conventional modeling efforts. The problems of zonal variance have been well noted in the literature and will not be repeated here (15). Suffice it to say, the variance and the representation of zonal land use and zonal variety of functional classes of highways is overlaid on the statistical representation problems alluded to in 1 and 2 above.

FURTHER RESEARCH

In light of the above achievements, potential users, and shortcomings of the present research, several needs and opportunities for future research emerge, including:

1. Generalization of the model by employment of a larger random sample dealing with zones from a bigger statistical universe, possibly all U.S. or Midwestern communities of the same size range, yielding a set of statistically generalized and transferable regression equations.

2. An appropriate and significant extension of the present effort through the development of a complete regional land use simulation model that randomly developed land use plats or subregions and regenerated the entire land use plan according to a series of alternative growth and environmental policies and recorded the traffic and emissions consequences. To the extent possible, transfer and impact functions for other consequences (noise, regional value added, and change in tax base) could be developed and calibrated, and a comprehensive public works-environmental consequences taxonomy model could be pursued.

In summary, the research effort has constructively

synthesized direct traffic assignment forecasting methods with emissions computation capabilities and demonstrated an efficient approach to calculate emissions consequences of land use-highway travel supply combinations. In so doing it has yielded a significant achievement in the mobile source emissions state of the art and revealed opportunities for further advancements in subsequent research endeavors.

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