SAPOLLUT: ESTIMATING THE AIR QUALITY IMPACT OF VEHICULAR EMISSIONS RESULTING FROM A TRAFFIC ASSIGNMENT

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Special area pollution (SAPOLLUT) is the noise and air quality analysis portion of special area analysis (SAA) developed by the U.S. Department of Transportation. SAA is an attempt to encourage the consideration of social and environmental factors in the planning of transportation systems for urban areas by providing the analytical tools to address some of the social and environmental issues. SAA was initially included as a mandatory item of the 1974 National Transportation Study for all urban areas greater than 500,000 population. Participation in the SAA portion of the study was later made voluntary.

The purpose of the air quality analysis section of SAA is to present a methodology to quantitatively estimate the daily atmospheric loading of the highway-related pollutants (carbon monoxide, hydrocarbons, and nitrogen oxides) resulting from the daily travel on an urban street and highway system. This analysis is pertinent due to the requirements of the Clean Air Act Amendments of 1970 and the Federal-Aid Highway Act of 1970. Consequently, SAPOLLUT is being used in many areas for transportation system alternatives evaluation and transportation and air quality consistency determinations.

Approximately 50 copies of the program software have been distributed by the Urban Planning Division of the Federal Highway Administration to state transportation and highway departments, local urban transportation planning agencies, air quality planning agencies, consultants, and universities. SAPOLLUT was initially distributed in late 1973. Many comments on the program were received and, as a result, a new version of the program was developed. Major changes to the program have been made that improve its operating efficiency, add flexibility to the input requirements, and increase the output options. I will discuss these changes later, but first I will describe the basic SAPOLLUT methodology, program operation, data requirements, and output.

SAPOLLUT METHODOLOGY AND PROGRAM OPERATION

SAPOLLUT is an emission program; that is, the measure of the air quality impact is in kilograms of pollutants. The total amount of pollutants may be, at the user's option, stratified by hour of day, area type, functional classification, and pollution district.

A standard Federal Highway Administration (FHWA) historical record and default values supplied internally in the program (or user-specified values) are used to stratify the volume on each link in the network (except controid connectors) by a battery of factors according to the functional classification and area type of the link. The vehicle miles of travel (VMT) is also factored for 3 vehicle types and by model year for each type. The model year of interest and the previous 13 model years are used.

For the required emission factors, the program enters an internal table of carbon monoxide, hydrocarbons, and nitrogen oxide exhaust emission factors, deterioration factors, speed adjustment factors, and hydrocarbon evaporative emission factors. These 126 factors (3 pollutants × 3 vehicle types × 14 model years) are multiplied by

the factored link VMT to give the hourly carbon monoxide, hydrocarbon, and nitrogen oxide emissions on each link for each hour. The new version of SAPOLLUT does not actually go through each of these steps for each link; it combines the tables where possible prior to network processing to optimize the link processing. This has resulted in a substantial decrease in CPU time required over the original SAPOLLUT.

The program will also estimate exhaust emissions from intrazonal travel if the necessary data are input. These are the percentage of the total travel in a zone not represented on the network and an arbitrary speed for this local travel.

A more detailed discussion of the SAPOLLUT methodology is given in another report (11).

DATA REQUIREMENTS AND OUTPUT

A loaded historical record is all that is necessary to use SAPOLLUT. Each link of the network must have coded average daily traffic (ADT); length; area designation (CBD, central city, suburbs); functional classification (freeway, arterial); and capacity or speed table stratified by hour, functional classification, and area type. As mentioned earlier, SAPOLLUT contains default tables that are used to factor the ADT into hourly, directional, and vehicular volumes. These tables are also used to determine the link speed and emission factors. The tables used in SAPOLLUT are

1. Hourly distribution of ADT,
2. Hourly distribution of directional split,
3. Hourly truck factors,
4. Speed versus volume to capacity ratio,
5. Distribution of age of vehicles,
6. Exhaust emission factors (CO, HC, NO_x),
7. Evaporative hydrocarbon factors,
8. Emission deterioration factors, and
9. Emission adjustment due to speed.

These tables were derived from national studies, and the tables for computing the emission factors are taken from the EPA publication (12); various reports (1, 2, 3, 4, 5, 6, 7, 8) are the sources of information for these tables. A draft report by the SAE Task Force on Emission Projection Techniques was also a source.

I would like to emphasize that the software has been designed to allow for easy user input of location-specific data whenever possible. We strongly encourage using local data when they are available. The user also has the option to redefine the location of the variables on the input historical record. This option is useful when a standard FHWA format historical record is not used.

The output of SAPOLLUT is a series of tables that give the amount of hydrocarbons, carbon monoxide, and nitrogen oxide (in kilograms) emitted by hour, or a range of hours, for a specific area type and functional classification. The vehicle miles of travel for each hour is also given along with the ratios of grams of pollutant per vehicle mile and grams of pollutant per passenger mile (Figure 1). The amount of pollutants in specific "pollution districts" may also be computed and output on a daily basis for freeways and arterials only.

EXPERIENCE WITH SAPOLLUT

Many people have shown a great deal of interest in SAPOLLUT, and, as a result, we were able to get some good feedback on its use. It soon became obvious where the strengths and weaknesses in the program were.

Since SAPOLLUT interfaces directly with the Federal Highway Administration's urban transportation planning computer programs, it was the obvious choice as the next step in evaluating the air quality impact of the transportation system. This interfacing,

Figure 1. SAPOLLUT output.

AREA=1 CBD
FUNC=1 FREEWAY

HOUR	VEHICLE MILES	KILOGRAMS OF AIR POLLUTANT (1)=CO	(2)=NO	(3)=HC	POLLUTANT (GRAMS/VEH-MILE) (1)=CO	(2)=NO	(3)=HC	POLLUTANT (GRAMS/PASS-MILE) (1)=CO	(2)=NO	(3)=HC
0	255	1.066	1.797	0.232	4.183	7.052	0.910	2.092	3.526	0.455
1	173	0.927	1.636	0.191	5.456	10.630	1.124	2.728	5.315	0.562
2	85	0.524	1.392	0.107	6.169	16.388	1.260	3.085	8.194	0.630
3	85	0.450	1.334	0.096	5.298	15.705	1.130	2.649	7.853	0.565
4	170	1.292	2.763	0.252	7.605	16.263	1.483	3.802	8.132	0.742
5	340	2.122	2.295	0.423	6.245	9.668	1.236	3.123	4.834	0.618
6	934	7.191	4.353	1.241	7.696	4.659	1.328	3.848	2.329	0.664
7	1,444	14.394	4.253	2.225	9.968	2.943	1.541	4.984	1.472	0.770
8	1,189	12.432	3.942	1.942	10.454	3.348	1.633	5.227	1.674	0.816
9	765	6.335	3.146	1.115	8.352	4.118	1.464	4.176	2.059	0.732
10	680	4.978	2.876	0.916	7.327	4.232	1.348	3.663	2.116	0.674
11	765	5.628	3.177	1.054	7.628	4.156	1.379	3.812	2.078	0.689
12	765	5.631	3.123	1.026	7.366	4.085	1.342	3.683	2.043	0.671
13	765	5.784	3.129	1.047	7.566	4.093	1.370	3.783	2.046	0.685
14	934	7.469	3.338	1.321	8.203	3.572	1.414	4.102	1.786	0.707
15	1,274	12.688	4.060	2.011	10.115	3.186	1.578	5.057	1.593	0.789
16	1,614	16.131	4.369	2.461	9.976	2.706	1.525	4.988	1.353	0.762
17	1,359	11.116	3.335	1.901	8.179	2.454	1.325	4.089	1.227	0.663
18	849	4.876	2.618	1.029	5.360	3.082	1.094	2.930	1.541	0.547
19	680	3.122	2.293	0.641	4.594	3.360	0.943	2.297	1.680	0.472
20	595	2.562	2.218	0.549	4.309	3.730	0.908	2.154	1.865	0.454
21	510	2.427	2.061	0.499	4.762	4.042	0.979	2.381	2.021	0.490
22	425	1.548	2.135	0.346	3.645	5.027	0.815	1.822	2.513	0.407
23	340	1.285	1.737	0.295	3.782	5.112	0.839	1.891	2.556	0.419
TOT	16,989	132.697	89.567	22.702	7.811	4.036	1.336	3.905	2.018	0.668

Figure 2. Example of SAPLSM link report.

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ANODE	BNODE	HOUR	GRAMS OF POLLUTANTS CO	NOX	HC	LINK KM.	DAILY VEH KM.	DAILY VOLUME
31	32	0-23	8587	5893	1623	0.22	1386	6300
32	33	0-23	14034	7376	2449	0.21	1869	8900
33	79	0-23	14833	5691	2578	0.24	2184	9100
33	34	0-23	12349	6222	2128	0.15	1590	10600
33	80	0-23	9354	4027	1526	0.10	1060	10600
34	108	0-23	5156	1569	757	0.17	442	2600
34	35	0-23	33290	15476	5568	0.34	4012	11800
35	48	0-23	56896	12333	7991	0.30	5070	16900
35	36	0-23	29497	11161	4527	0.16	2896	18100
35	49	0-23	13010	9696	2442	0.17	2142	12600
36	37	0-23	32957	6566	4489	0.16	2720	17000
37	95	0-23	7774	1479	1046	0.14	616	4400
37	38	0-23	33669	6777	4606	0.17	2805	16500
37	94	0-23	4902	1973	781	0.15	525	3500
38	101	0-23	19660	3992	2697	0.11	1650	15000
40	101	0-23	7187	2887	1140	0.05	755	15100
41	42	0-23	18825	8015	3040	0.15	2070	13800
41	71	0-23	4194	2818	784	0.09	666	7400
42	43	0-23	15405	5584	2379	0.11	1518	13800
43	107	0-23	11051	2016	1474	0.25	850	3400
46	78	0-23	2175	1127	429	0.52	416	800
46	47	0-23	12813	5832	2402	0.44	2200	5000
47	61	0-23	13307	4419	2186	0.16	1728	10800
47	48	0-23	21899	4355	2984	0.11	1804	16400

without any data adjustments, we believe is one of its strongest attributes. SAPOLLUT also recognizes the different transportation and air quality factors that must be accounted for in any transportation-air quality analysis. Vehicle type, vehicle age, facility type, area type, speed, and VMT are all addressed in computing the amount of pollutants emitted.

Some of the major drawbacks in SAPOLLUT centered around its extensive computation time and its rigorous requirements for the input data. We also received several comments on its inability to diffuse pollutants.

THE NEW SAPOLLUT

SAPOLLUT was originally developed as a user-oriented program. The data needed to run the program were in general easily obtainable, and the user had many options on the degree of refinement of the analysis. Several shortcomings of the program had to be corrected, however, to make it truly user oriented.

The computation time was by far the biggest problem. Several agencies had to shut down the program after it ran for a couple of hours, wasting several hundreds of dollars. The new version of SAPOLLUT has corrected this problem by first summing the emission tables for each vehicle type and pollutant type prior to link processing. This technique has resulted in a substantial savings of CPU time. With data from the Puget Sound area, I obtained an 89 percent reduction in CPU time between the old and new versions (23 versus 2.5 min).

Most of the factors used in SAPOLLUT are a function of the area type and functional classification of the link. Consequently, both bits of information are needed to process each link. This has presented a problem for some users since the area type and functional classification were not coded for each link. This meant that they had to go back and code this information on each link card, a tedious task. The new program still requires functional classification and area type information for each link, but the user now has greater flexibility in specifying links of certain functional classification or area type or both to be processed. A fourth area type has also been added.

Another major modification to SAPOLLUT has been the addition of a SELECT option. This allows the user to select only certain hours or ranges of hours or portions of the network or all of these for processing. The original program did not allow for more than one range of hours or for certain links to be specified. This option greatly enhances the versatility of SAPOLLUT for use in either peak-hour analyses or route analyses.

SAPOLLUT now has the capability to "window in" on a rectangular area. The user just has to specify the x and y coordinates of the corners.

As mentioned earlier, SAPOLLUT is an emission program. It does not diffuse and consequently its output cannot be directly related to a concentration standard. The APRAC-1A urban diffusion model computer program has been modified to accept the output of the SAPOLLUT program. This will enable users of the SAPOLLUT-APRACMOD package to compute emissions for hydrocarbons, carbon monoxide, and nitrogen oxide and to get concentrations of carbon monoxide. Another major concern of many users was the output format of SAPOLLUT. A spatial stratification by link, zone, or grid or all of these was requested. We too felt a need for this type of output, and consequently a new post processor program was developed.

SAPLSM

SAPLSM, the SAPOLLUT post processor program, summarizes the link emissions by link, zone (districts), and grid. The program reports also contain the link distance and VMT information. The user has complete flexibility in specifying the grid system and range of hours. Examples of the reports are given in Figures 2, 3, and 4. The original output of SAPOLLUT has been kept in the SAPOLLUT program. SAPLSM merely reads an output file from SAPOLLUT and outputs it in the user-specified form.

Figure 3. Example of SAPLSM grid report.

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GRID	HOURS	GRAMS OF POLLUTANTS CO	NOX	HC	LINK KM.	DAILY VEH KM.
1	0-23	13797	4232	2034	0	1218
2	0-23	21981	6633	3224	0	1848
6	0-23	865	459	149	1	114
7	0-23	53191	17559	7969	1	4850
8	0-23	64557	34067	11192	1	8514
9	0-23	22647	10768	3821	0	2812
12	0-23	91821	44691	15503	1	11283
13	0-23	73908	35007	12662	1	10013
14	0-23	87762	35852	13994	2	9827
17	0-23	107636	30195	16369	2	11746
18	0-23	219038	65582	32704	2	21956
19	0-23	117070	42785	18193	2	12692
22	0-23	7736	3814	1500	1	1438
23	0-23	14053	6473	2647	1	2440
25	0-23	0	0	0	0	0
TOTAL WITHIN THE DEFINED SYSTEM --						
	0-23	896061	338118	141959	16	100751
TOTAL OUTSIDE THE DEFINED SYSTEM --						
	0-23	135	83	23	0	20
TOTAL OF THE WHOLE SYSTEM--						
	0-23	896196	338201	141982	16	100771

Figure 4. Example of SAPLSM district report.

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DIST	HOURS	GRAMS OF POLLUTANTS CO	NOX	HC	LINK KM.	DAILY VEH KM.
1	0-23	132858	68736	22872	3	17522
2	0-23	111176	47838	18094	2	12848
3	0-23	88960	44132	15200	2	11458
4	0-23	119182	49796	19272	2	13216
5	0-23	58534	27300	9500	1	6778
6	0-23	51916	13942	7844	1	5564
7	0-23	147414	30610	20432	1	12966
8	0-23	124412	35026	19136	3	14114
9	0-23	62666	22002	10564	1	8802
TOTAL WITHIN THE DEFINED SYSTEM --						
	0-23	896196	338201	141982	16	100771
TOTAL OUTSIDE THE DEFINED SYSTEM --						
	0-23	0	0	0	0	0
TOTAL OF THE WHOLE SYSTEM--						
	0-23	896196	338201	141982	16	100771

The decision to develop a new program for this task was based on economy of operation. Only one run of SAPOLLUT is now needed. The user has the option either to input the results into APRACMOD or to summarize them by using SAPLSM. The user may at a later time get a different summary or rerun APRACMOD without having to run SAPOLLUT again.

COLD STARTS

One of the major objectives in developing a new version of SAPOLLUT was to incorporate a method of calculating emissions due to cold starts. Cold-start emissions are

a function of the number of trips made and not the length of the trip as are hot-running emissions. This presented us with somewhat of a problem in developing a methodology that accounts for both types of emissions and uses the transportation data that are generally available.

We opted to relate the land use of the traffic analysis zone to the hourly trip origins in that zone. A cold-start emission rate (in grams/trip) can then be applied to this volume. A hot-running emission rate (in grams/mile) can be applied to the interzonal volumes.

This was accomplished by developing a series of tables that relate land use to an hourly factor of trip origins. This hourly factor is further stratified by the parking duration. This information was developed by analyzing several sets of internal trip report cards. The parking systems analysis (10) procedure was used for this analysis.

The cold-start emission rates were computed by applying the cold-start ratio developed by Cirillo and Wolsko (9) to the emission factors of Publication AP-42 (8). The hot-running emission rates were also developed in a similar manner as described by Cirillo and Wolsko. The cold-start analysis in SAPOLLUT only applies to light-duty vehicles and carbon monoxide and hydrocarbons. The default emission tables are taken directly from Publication AP-42 and consequently the user has to revise them to strictly hot-running emissions if the COLDSTART option is used.

Nine land use categories are used in this analysis: residential, commercial, offices, industrial, agricultural, public utilities, institutional, recreational, and undeveloped. A land use classification must be coded for each centroid connector. As with all default tables in SAPOLLUT, it is strongly recommended that locally developed data be used whenever possible.

SUMMARY

SAPOLLUT is an effective tool to estimate the air quality impact of a highway system. The easily obtainable input data and extensive user options have made SAPOLLUT applicable to most systemwide transportation-air quality analyses.

Extensive modifications to SAPOLLUT have improved its operating efficiency, added flexibility to its input requirements, and increased the analysis options. A post processor program, SAPLSM, was developed to summarize the emissions by either link, zone (district), or grid. The APRAC-1A urban diffusion model computer program has been modified to accept the output of SAPOLLUT.

These modifications were developed with the help of the many SAPOLLUT users, and we hope to have their continued support in the future.

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