Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

User's Guide

CT-EMFAC Version 4.0

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1. INTRODUCTION

CT-EMFAC is a California-specific project-level analysis tool for modeling emissions of criteria pollutants, Mobile Source Air Toxics (MSATs), and carbon dioxide from on-road vehicles. It was originally developed by U.C. Davis under the U.C. Davis-Caltrans Air Quality Project (Wu et al., 2007). A previous version of CT-EMFAC (version 2.6, dated May 29, 2008) had a graphical user interface (GUI) developed in Visual Basic .NET and manipulated emissions data (originally populated from the EMFAC2007 model) in a Microsoft Access database. Users were required to provide input parameters and select options through the GUI (see **Figure 1-1**); the model queried emissions information from the Access database, performed data calculations, and generated .txt output files with emission factors and total emissions. A limitation of the previous CT-EMFAC version was the lack of a batch-mode run function. It could therefore be time consuming for users to specify inputs for multiple project scenarios and roadway segments; it also added workload for users to compile multiple output files and aggregate emissions information for comparison across multiple scenarios.

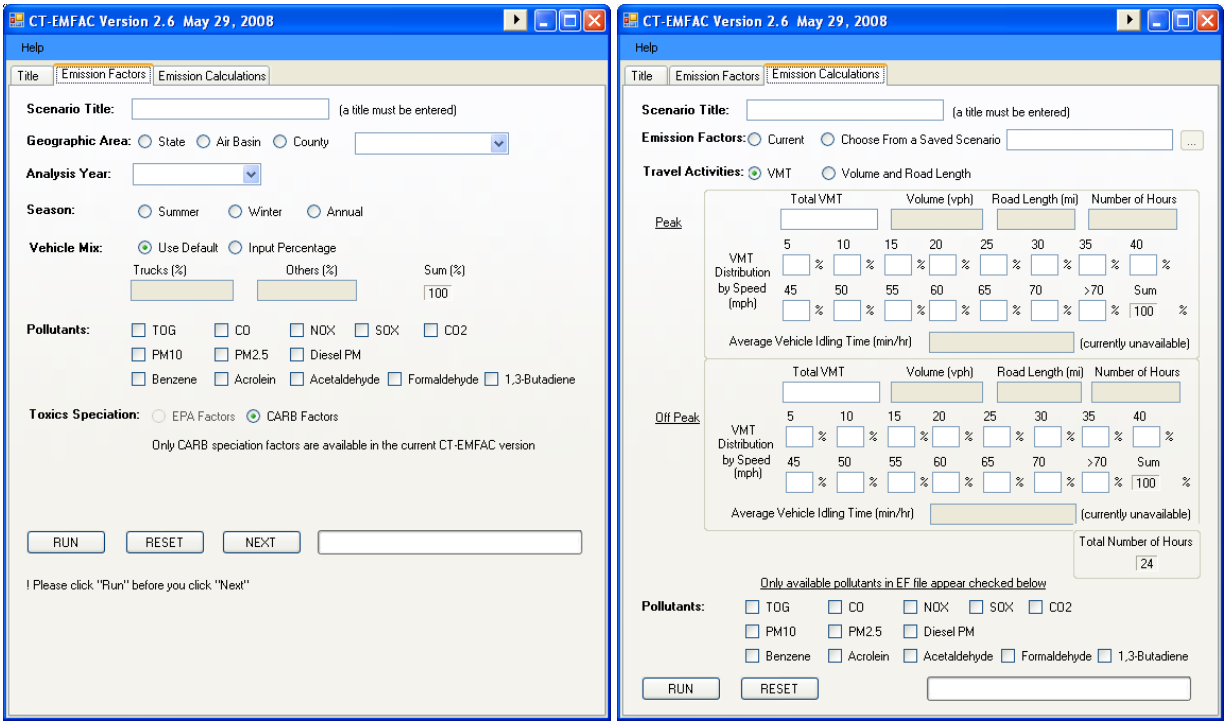
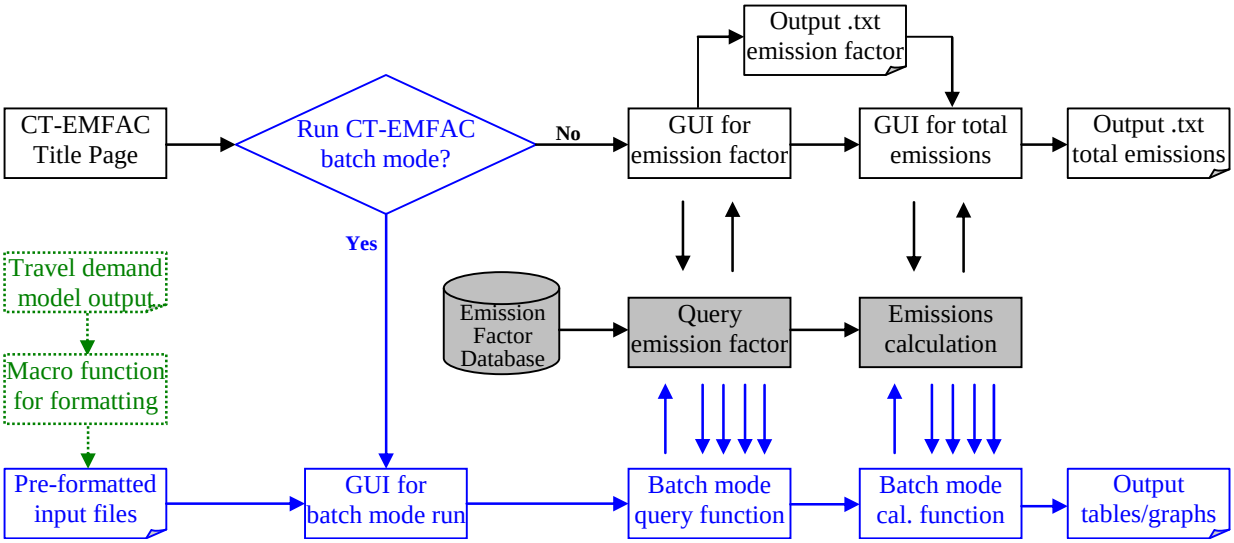


Figure 1-1. GUI of previous CT-EMFAC model (v2.6).

With permission from U.C. Davis, Sonoma Technology, Inc. (STI) worked with the San Diego Association of Governments (SANDAG) and Caltrans District 11 to develop a new version of the CT-EMFAC tool. The new version enables users to electronically load pre-formatted input data files derived from regional traffic model outputs. The revised CT-EMFAC (version 4.0, discussed in this document) accepts a spreadsheet input file with multiple worksheets and processes them in a batch-mode model run. In addition, CT-EMFAC

v4.0 also has the ability to organize the emissions output data in tabular and graphic pre-formatted files to facilitate comparisons among scenarios.

This document illustrates new features and functions in CT-EMFAC v4.0 and provides instructions for using the model batch mode. As shown in a flowchart illustrating CT-EMFAC v4.0 (**Figure 1-2**), features from the prior version of CT-EMFAC, including the original GUI and the *Emission Factors* and *Emission Calculations* tabs, remain functional as a manual mode option in this new version. In the manual mode tabs, users are still allowed to specify input parameters and obtain composite emission factors and total emissions (in output files) associated with a single run scenario. The main changes in CT-EMFAC v4.0 include (1) an additional batch-mode GUI tab with input/output routines; (2) batch-mode functions to perform both emission factors lookup and total emissions calculations in one model run; and (3) output functions to generate pre-formatted summary tables and graphics in spreadsheet files.



Black: Original CT-EMFAC model functions (version 2.6, May 29, 2008; developed by U.C. Davis)
Blue: New model functions developed for CT-EMFAC (v4.0; developed by STI)
Green: External data and functions for preparing CT-EMFAC input files (developed by Caltrans District 11)

Figure 1-2. Flowchart of the revised CT-EMFAC model.

2. GETTING STARTED WITH CT-EMFAC V4.0

2.1 What's Included in the CT-EMFAC v4.0 Package

The CT-EMFAC v4.0 package includes two file folders, one executable model file (CT-EMFAC.exe), three read-only program files (About.rtf, Bytescout.Spreadsheet.dll, and CT-EMFAC Output Template.xls), a .pdf file (CT-EMFAC-v4.0-User-Guide.pdf, this document), and a "readme" file (readme.txt). The "Database" folder includes an Access database file (CT-EMFAC.mdb) pre-populated based on the EMFAC2007 model data. The "Input-Output" folder holds four .xls spreadsheets that include an input template (CT-EMFAC

Input Template.xls), an example input file (CT-EMFAC Input Example.xls) and two example output files for a batch-mode run (CT-EMFAC Output Example.xls and CT-EMFAC Output Example-EF only.xls). The executable CT-EMFAC.exe file is used to start the GUI. The three read-only program files are used by the model's GUI and output functions. Users should not change them (e.g., name, location, or content). Users should use the input template (or the input example file) to create their own input spreadsheet for a batch-mode run in the model (the template ensures that each input file has a consistent input format). As a default, the output files will be saved in the "Input-Output" folder (.ef and .ec text files for manual mode; .xls spreadsheet files for batch mode). Users may specify alternate file locations while using the tool.

2.2 Overview of CT-EMFAC v4.0 GUI

The CT-EMFAC v4.0 GUI has four main tabs: *Title*, *About*, *Manual Mode*, and *Batch Mode*. The *Title* tab includes authorship information; the *About* tab presents a brief introduction of the CT-EMFAC model and its release history (see **Figure 2-1**). The *Manual Mode* tab supports two sub-tabs, *Emission Factors* and *Emission Calculations* (see **Figure 2-2**), which have the same functions as those in previous CT-EMFAC versions (they load user's input specifications through the GUI and generate composite emission factors and total emissions in output .txt files). For details of how to use the CT-EMFAC manual mode, please refer to documentation for the previous CT-EMFAC model versions (Wu et al., 2007)[1]. The *Batch Mode* tab provides new features that allow users to load an input spreadsheet with information for multiple scenarios and multiple roadway segments associated with a project alternative, and to output a pre-formatted spreadsheet with emission factors and emissions.

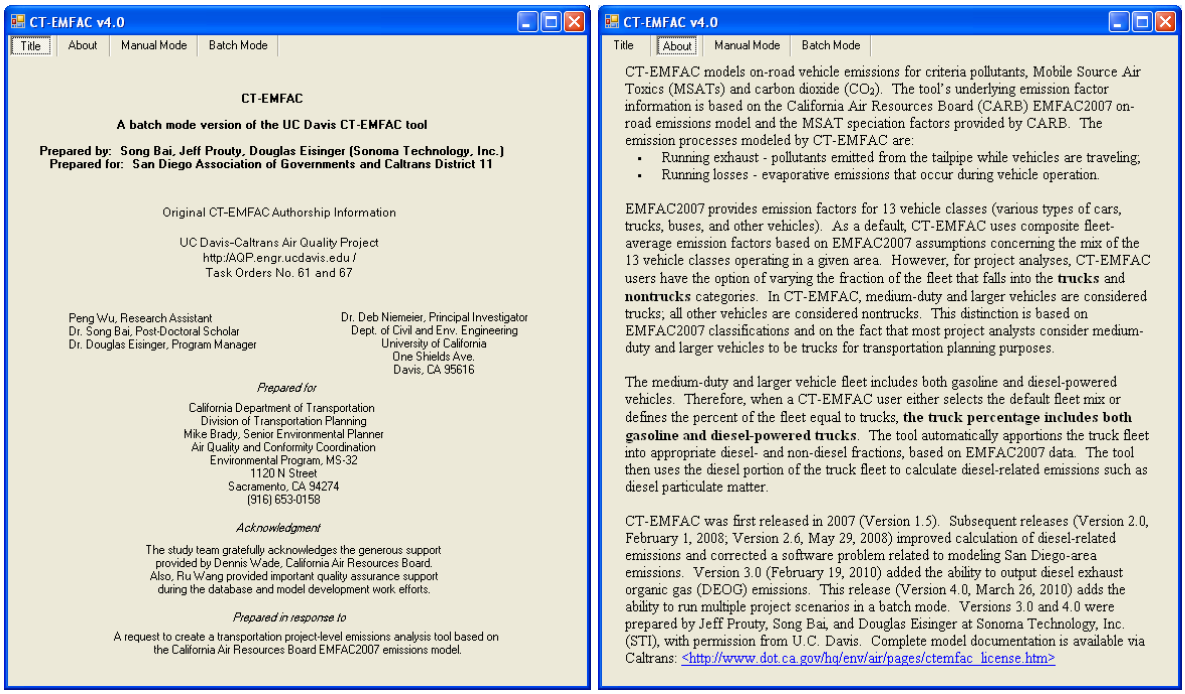


Figure 2-1. *Title* and *About* tabs in CT-EMFAC v4.0.

[1] Available from: http://www.dot.ca.gov/hq/env/air/software/camfetc/CTEMFAC-12-07-Final-Documentation.pdf.

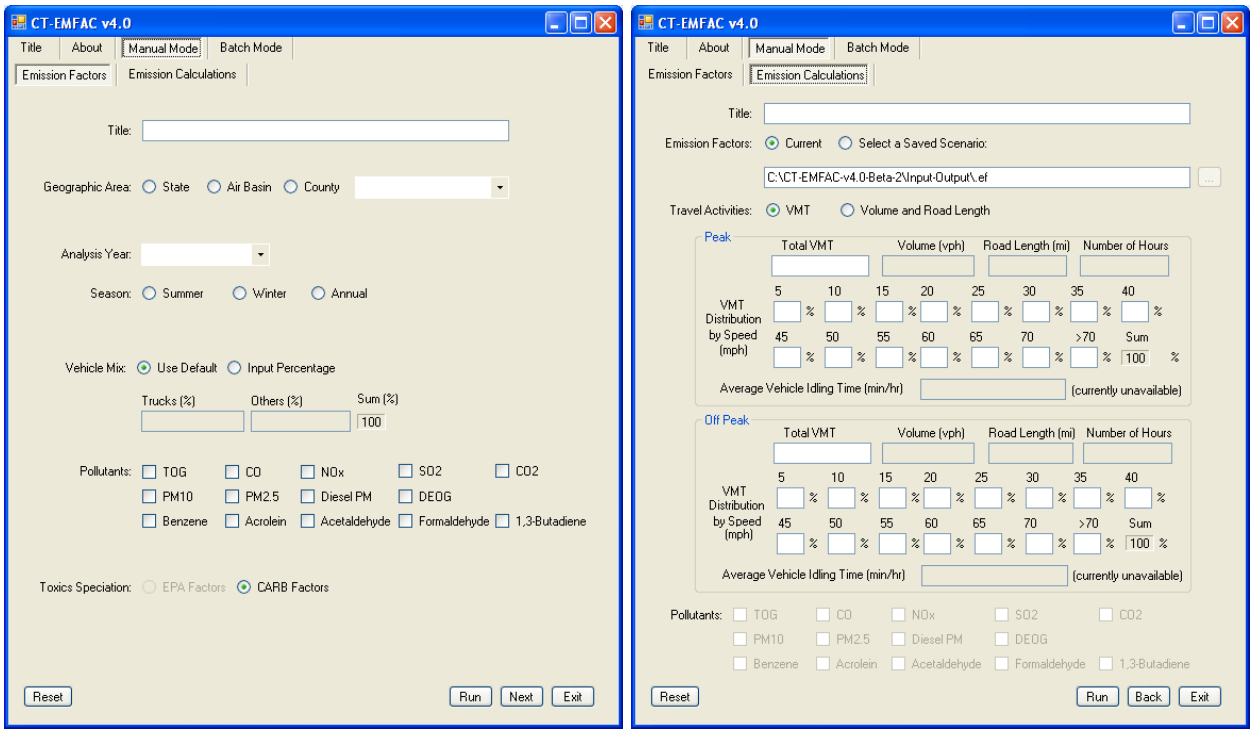


Figure 2-2. *Manual Mode* tabs in CT-EMFAC v4.0.

2.3 Overview of CT-EMFAC v4.0 Batch Mode

As shown in **Figure 2-3**, the *Batch Mode* tab in the GUI allows users to (1) select pollutants to be analyzed in the pollutant check-box list; (2) browse and load an input .xls spreadsheet file; (3) specify an output .xls spreadsheet file name and location; (4) select all or any number of the scenarios for a project alternative to be analyzed in a batch-mode run; (5) quality check and review input data (title, vehicle miles traveled [VMT] by speed distribution, area, analysis year, and fleet mix); and (6) initiate the batch-mode run to generate emission factors and total emissions results for all selected scenarios.

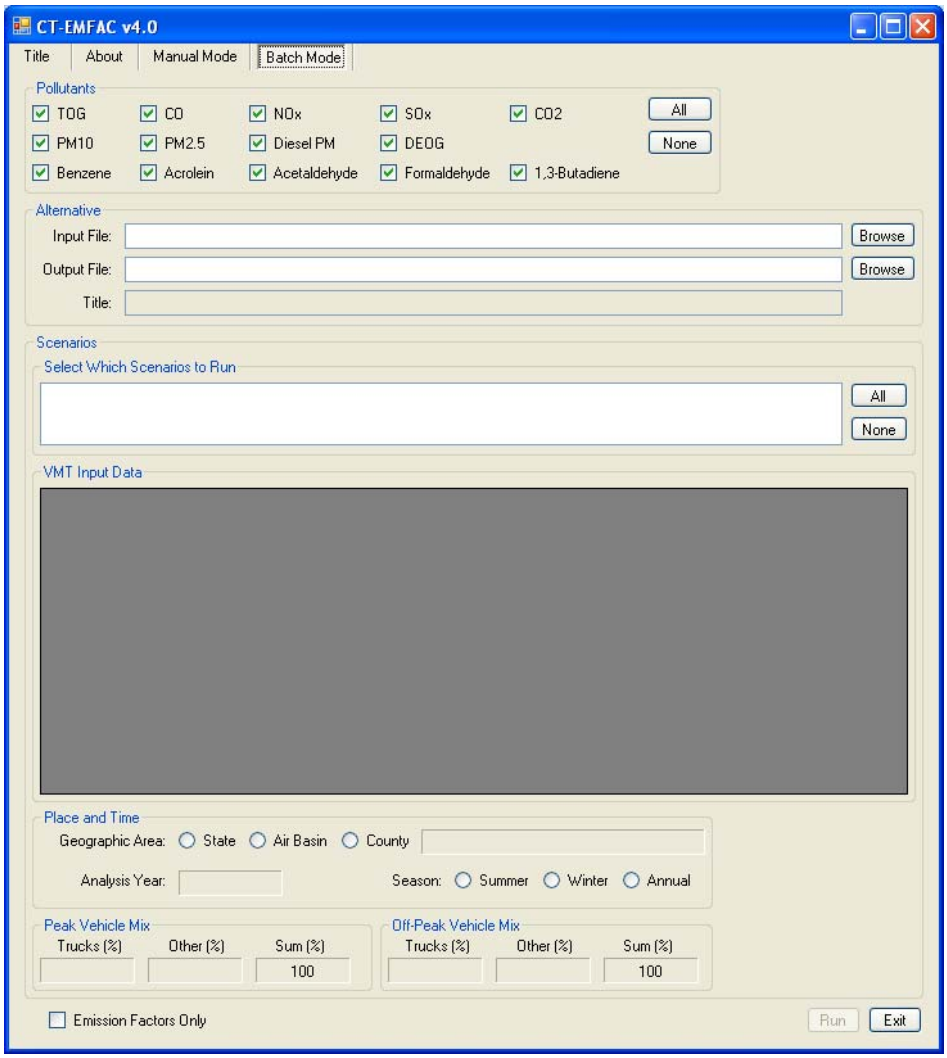


Figure 2-3. *Batch Mode* tab in CT-EMFAC v4.0.

3. USING CT-EMFAC V4.0 BATCH MODE

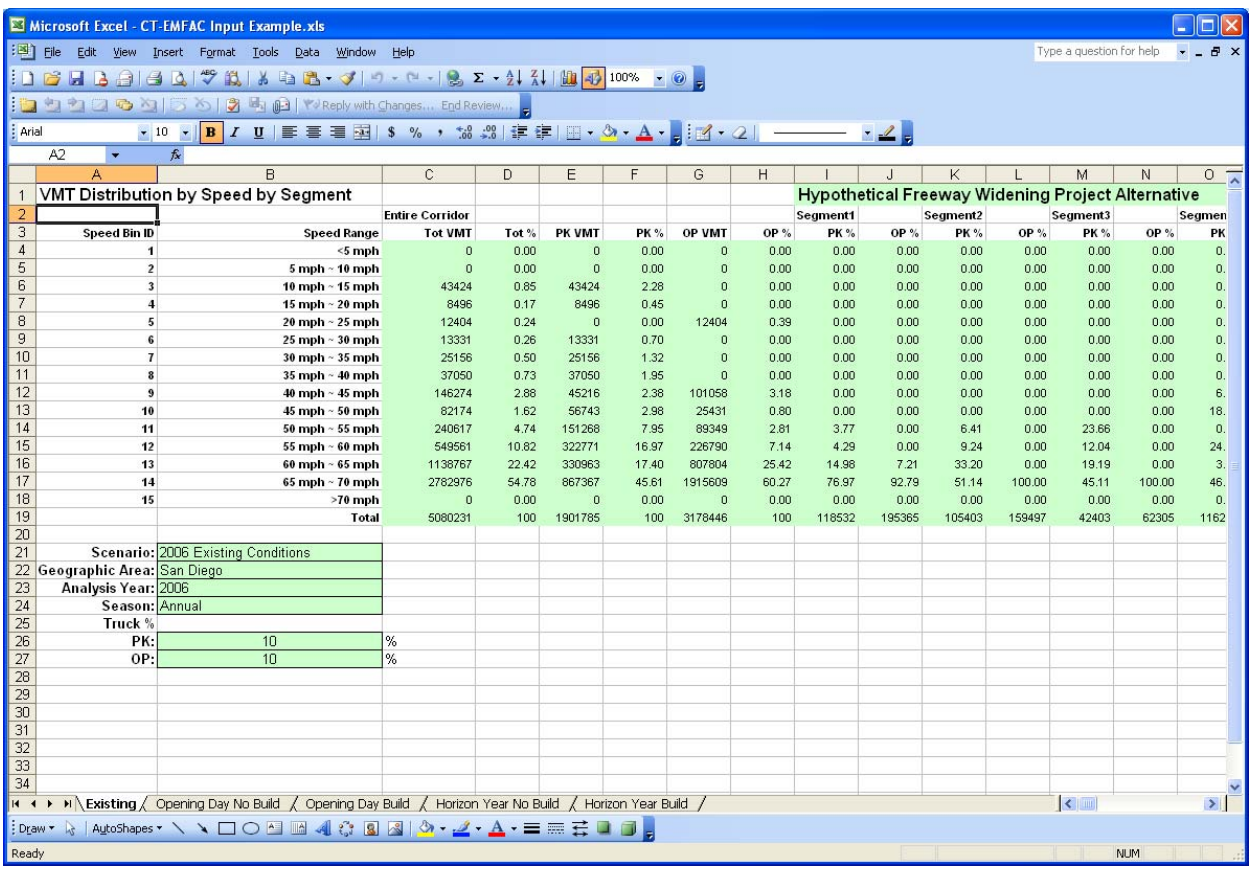
To run the CT-EMFAC v4.0 batch mode for a given project alternative, users need to create an input spreadsheet using a pre-formatted file supplied with the tool. Users load the input spreadsheet via the *Batch Mode* tab in the GUI and can quality-check input data and generate an output spreadsheet with emission factors and total project emissions. The following sections provide step-by-step instructions for users to complete a batch-mode run in CT-EMFAC.

3.1 Creating a Batch-Mode Input File

A pre-formatted input spreadsheet template is provided in the CT-EMFAC v4.0 software package; the template should be used to create project inputs for a batch-mode run. This input spreadsheet file is an Excel workbook with five worksheets, each of which is associated with a particular scenario of a project alternative. The input worksheet is designed to accept roadway

segment travel data as well as other basic input parameters for emissions calculation. The five worksheets, each organized in the same format, include *Existing*, *Opening Day No Build*, *Opening Day Build*, *Horizon Year No Build*, and *Horizon Year Build*.

A sample input worksheet (for an *Existing* scenario) is shown in **Figure 3-1**. Specifically, a scenario identified in a worksheet includes two sections: the top section in the worksheet illustrates the project alternative title and roadway segment-level travel data (VMT by speed distributions for peak and off-peak periods, respectively), which is based on post-processed travel demand modeling data. The bottom section includes basic input parameters: title of the scenario, geographic area, analysis year, season, and vehicle mix (i.e., truck percentage for peak and off-peak periods). The input template has embedded drop-down lists (for geographic area, analysis year, and season) that allow users to quickly specify input information.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	VMT Distribution by Speed by Segment								Hypothetical Freeway Widening Project Alternative						
2			Entire Corridor						Segment1		Segment2		Segment3		Segmen
3	Speed Bin ID	Speed Range	Tot VMT	Tot %	PK VMT	PK %	OP VMT	OP %	PK %	OP %	PK %	OP %	PK %	OP %	PK
4	1	<5 mph	0	0.00	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
5	2	5 mph ~ 10 mph	0	0.00	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
6	3	10 mph ~ 15 mph	43424	0.85	43424	2.28	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
7	4	15 mph ~ 20 mph	8496	0.17	8496	0.45	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
8	5	20 mph ~ 25 mph	12404	0.24	0	0.00	12404	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.
9	6	25 mph ~ 30 mph	13331	0.26	13331	0.70	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
10	7	30 mph ~ 35 mph	25156	0.50	25156	1.32	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
11	8	35 mph ~ 40 mph	37050	0.73	37050	1.95	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
12	9	40 mph ~ 45 mph	146274	2.88	45216	2.38	101058	3.18	0.00	0.00	0.00	0.00	0.00	0.00	6.
13	10	45 mph ~ 50 mph	82174	1.62	56743	2.98	25431	0.80	0.00	0.00	0.00	0.00	0.00	0.00	18.
14	11	50 mph ~ 55 mph	240617	4.74	151268	7.95	89349	2.81	3.77	0.00	6.41	0.00	23.66	0.00	0.
15	12	55 mph ~ 60 mph	549561	10.82	322771	16.97	226790	7.14	4.29	0.00	9.24	0.00	12.04	0.00	24.
16	13	60 mph ~ 65 mph	1138767	22.42	330963	17.40	807804	25.42	14.98	7.21	33.20	0.00	19.19	0.00	3.
17	14	65 mph ~ 70 mph	2782976	54.78	867367	45.61	1915609	60.27	76.97	92.79	51.14	100.00	45.11	100.00	46.
18	15	>70 mph	0	0.00	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
19		Total	5080231	100	1901785	100	3178446	100	118532	195365	105403	159497	42403	62305	1162
20															
21	Scenario:	2006 Existing Conditions													
22	Geographic Area:	San Diego													
23	Analysis Year:	2006													
24	Season:	Annual													
25	Truck %														
26	PK:	10	%												
27	OP:	10	%												

Figure 3-1. Sample input worksheet for a CT-EMFAC v4.0 batch-mode run.

3.2 Using the Batch Mode User Interface

Once the input file is prepared, users need to use the *Batch Mode* tab and follow six steps (see **Figure 3-2**) to complete a batch-mode run in CT-EMFAC v4.0.

Step 1: Select pollutants to be analyzed from the "Pollutants" check-box list. Users can select "All" or "None" buttons, or use check boxes to select specific pollutant names to include in a batch-mode run. Once the pollutants are selected through the GUI, each batch-mode run will provide emission estimates for the same set of selected pollutants for all five scenarios associated with a project alternative.

Step 2: Browse and load the input spreadsheet file in the "Input File" text box. Once the file is loaded, the GUI will display input information including the title of the studied project alternative, available scenarios, VMT by speed distribution data, and other basic input parameters. If users modify the existing loaded input spreadsheet file, they can save the file, reload the changed input file by using either the "Browse" function and opening it again, or by placing the mouse cursor in the "Input File" text box with the file name and pressing the "Enter" key.

Step 3: Browse or manually type an output file name in the "Output File" text box. As a default, the output spreadsheet file will be saved in the "Input-Output" sub-folder in the CT-EMFAC program folder. Users can either browse for an existing spreadsheet file, or type a file name and press the "Enter" key to create a new output file (the full file path will appear in the text box). Users should note that to complete a batch-mode run, the output spreadsheet must be closed.

Step 4: Check and/or highlight available scenarios in the "Scenarios" box. After the input spreadsheet (for a specific project alternative) is loaded, the GUI will automatically display five scenarios in a list (the "Select Which Scenarios to Run" box). Users can select "All" or "None" buttons, or use the check box before each scenario title to select specific scenarios to include in a batch-mode run. By clicking the scenario title in the list or using arrow keys, users can highlight a scenario and view its input information displayed in the GUI.

Step 5: Quality-check input data for the selected scenario. The data shown in the "VMT Input Data" box is used in CT-EMFAC to calculate total emissions for each roadway segment. If desired, users can visually check these data before running the tool (e.g., they can check the total VMT by segment and the percent distribution by speed bin). Users can also check the basic input parameters for "Place and Time", "Peak Vehicle Mix", and "Off-Peak Vehicle Mix" in the *Batch Mode* tab display for the selected project alternative. The input information displayed is read-only; users need to make changes in the input spreadsheet file and reload updated input information.

Step 6: Specify output option and initiate the batch-mode run. The CT-EMFAC v4.0 batch mode can generate both emission factors and total emissions for the selected scenarios. If users select "Emission Factors Only", the output spreadsheet will include only composite running exhaust and running loss emission factors. Clicking the "Run" button will start the batch-mode run; a progress bar and a pop-up message will inform users about the progress and completion of a batch run. Users can click the "Exit" button to close the program at any time (not during a run).

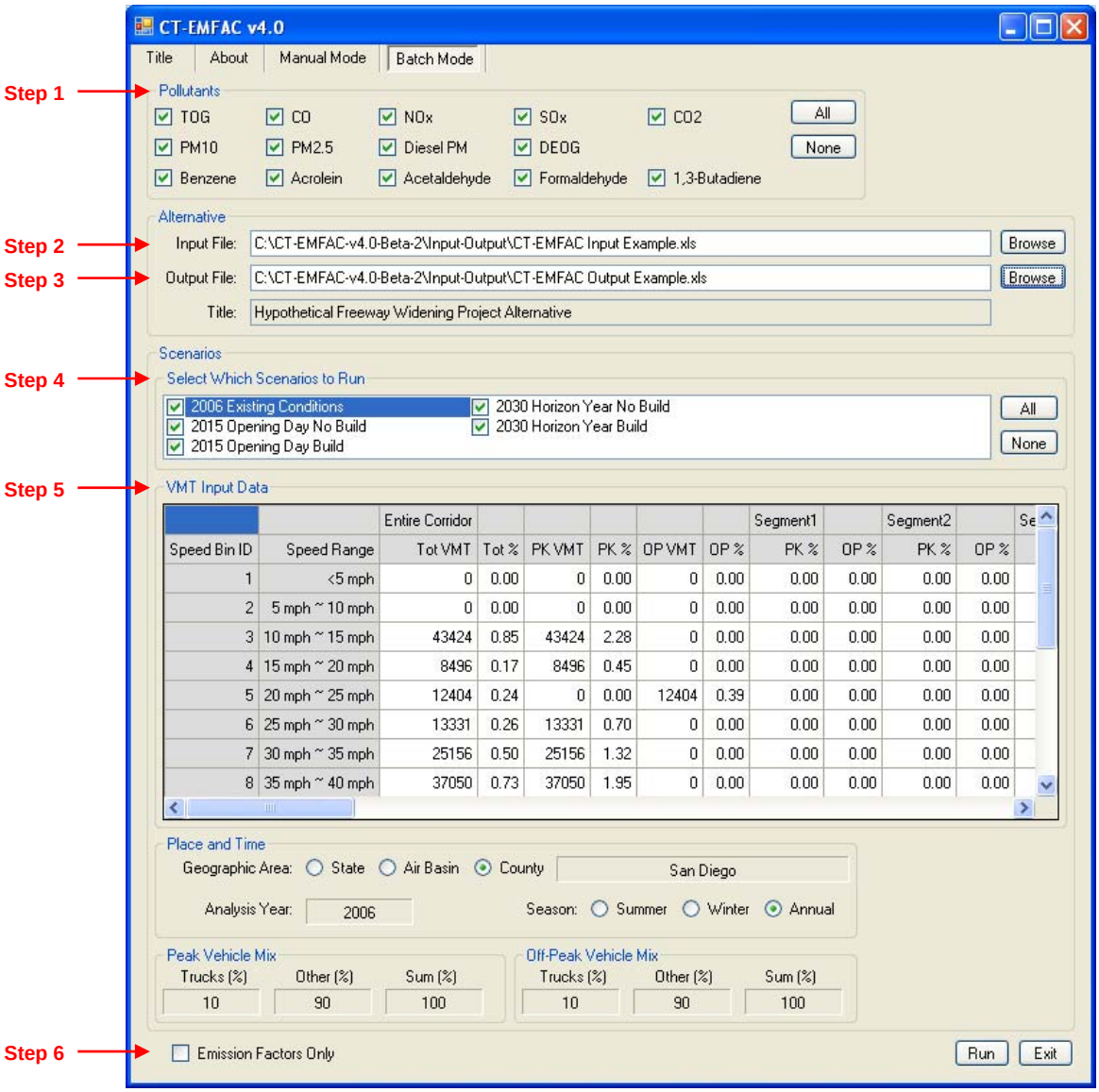
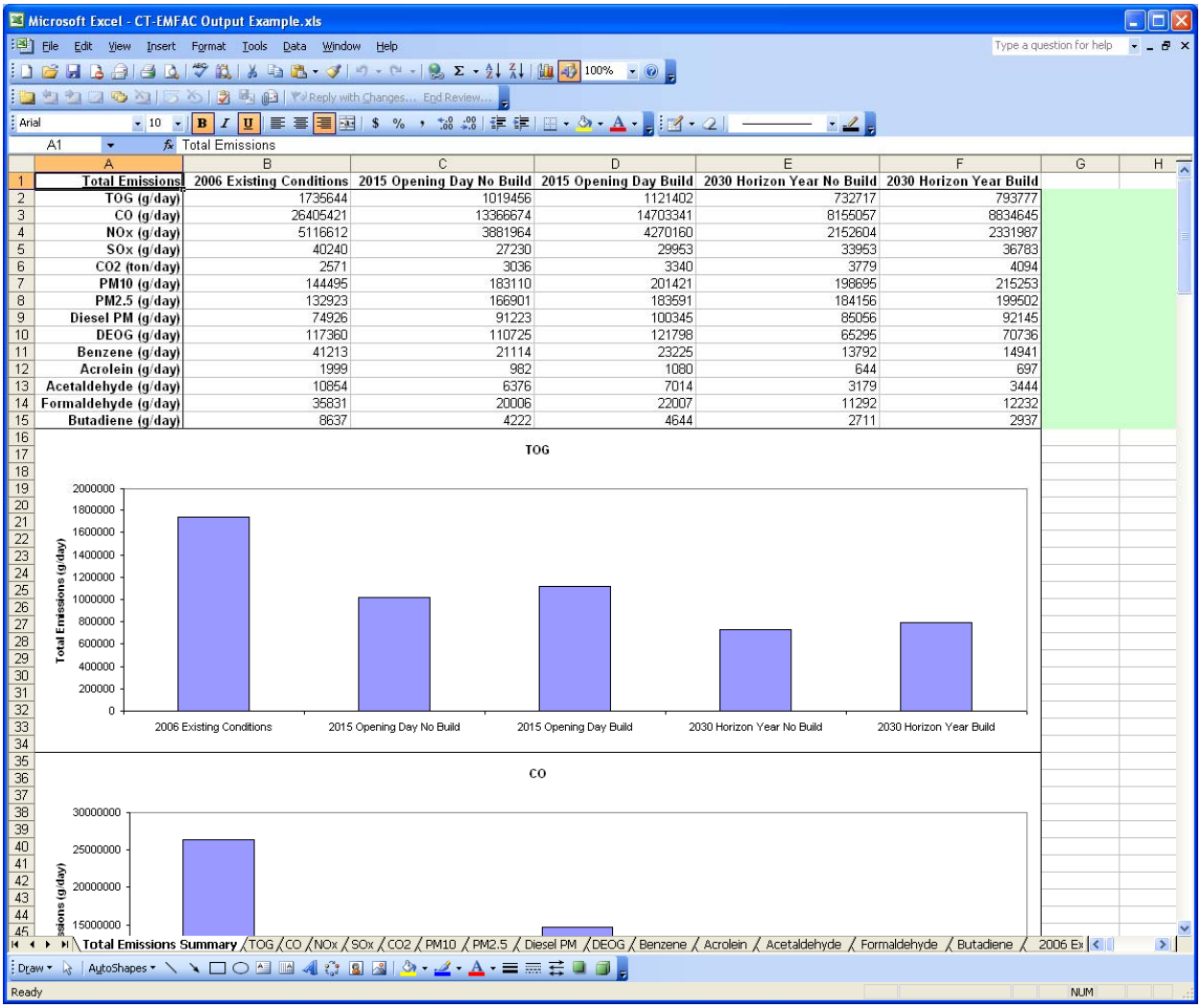


Figure 3-2. Sample CT-EMFAC v4.0 batch mode GUI with input data loaded.

3.3 Retrieving a Batch-Mode Output File

The batch-mode run results are saved in a Microsoft Excel workbook with multiple worksheets. The first worksheet includes a summary table of total emissions by pollutant for each of the five scenarios of a project alternative. Pollutant-specific bar charts for total emissions based on the summary table are also provided to facilitate comparisons among the five scenarios (see **Figure 3-3**).

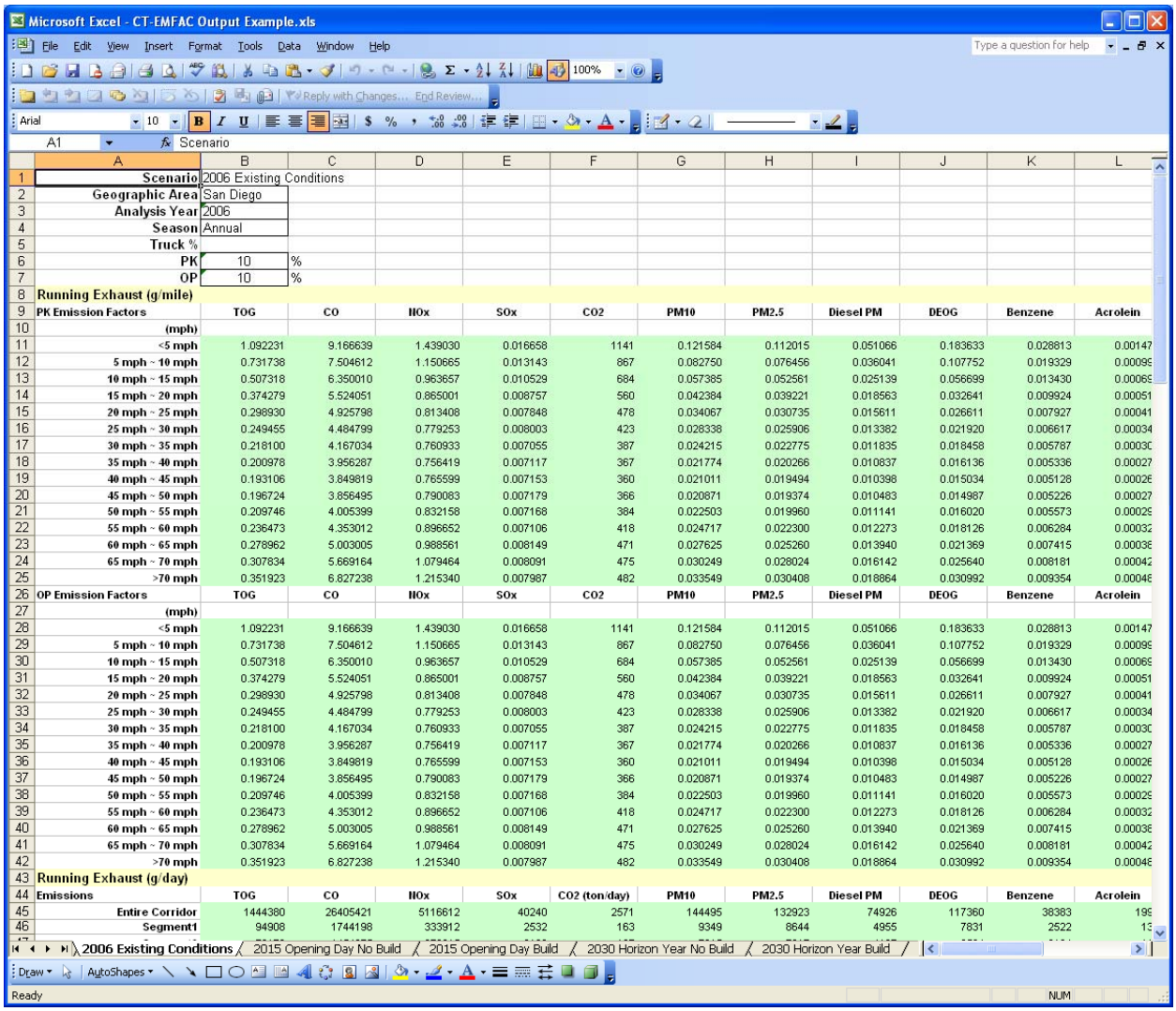


Total Emissions	2006 Existing Conditions	2015 Opening Day No Build	2015 Opening Day Build	2030 Horizon Year No Build	2030 Horizon Year Build
TOG (g/day)	1735644	1019456	1121402	732717	793777
CO (g/day)	26405421	13366674	14703341	8155057	8834645
NOx (g/day)	5116612	3881964	4270160	2152604	2331987
SOx (g/day)	40240	27230	29953	33953	36783
CO2 (ton/day)	2571	3036	3340	3779	4094
PM10 (g/day)	144495	183110	201421	198695	215253
PM2.5 (g/day)	132923	166901	183591	184156	199502
Diesel PM (g/day)	74926	91223	100345	85056	92145
DEOG (g/day)	117360	110725	121798	65295	70736
Benzene (g/day)	41213	21114	23225	13792	14941
Acrolein (g/day)	1999	982	1080	644	697
Acetaldehyde (g/day)	10854	6376	7014	3179	3444
Formaldehyde (g/day)	35831	20006	22007	11292	12232
Butadiene (g/day)	8637	4222	4644	2711	2937

Figure 3-3. Sample CT-EMFAC v4.0 batch-mode output summary with graphs.

The next several worksheets, each corresponding to one of the five scenarios, include composite emission factors (grams per mile for running exhaust emission and grams per minute for running loss emission, for peak and off-peak periods) and segment level emissions (see **Figure 3-4** for sample outputs). If users generate only emission factors (by checking "Emission Factors Only" in the GUI), the output file will include only the scenario output worksheets with emission factors results.

The rest of the worksheets in the output file, each for a specific pollutant selected for the batch-mode run, include line graphs and data for roadway segment emissions by scenario (see **Figure 3-5** for sample outputs).

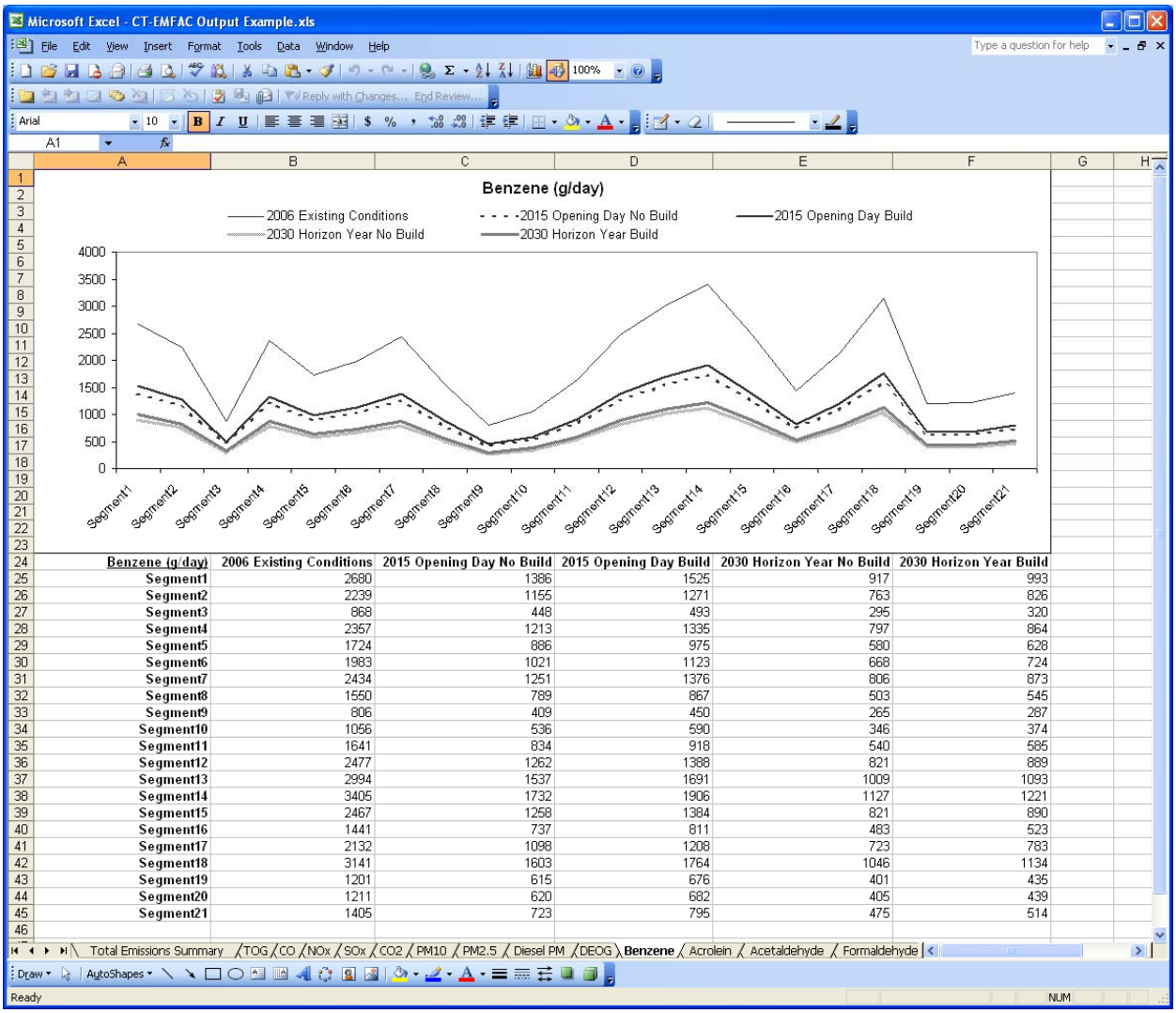


Microsoft Excel - CT-EMFAC Output Example.xls

	A	B	C	D	E	F	G	H	I	J	K	L
1	Scenario	2006 Existing Conditions										
2	Geographic Area	San Diego										
3	Analysis Year	2006										
4	Season	Annual										
5	Truck %											
6	PK	10	%									
7	OP	10	%									
8	Running Exhaust (g/mile)											
9	PK Emission Factors	TOG	CO	NOx	SOx	CO2	PM10	PM2.5	Diesel PM	DEOG	Benzene	Acrolein
10	(mph)											
11	<5 mph	1.092231	9.166639	1.439030	0.016658	1141	0.121584	0.112015	0.051066	0.183633	0.028813	0.00147
12	5 mph ~ 10 mph	0.731738	7.504612	1.150665	0.013143	867	0.082750	0.076456	0.036041	0.107752	0.019329	0.00095
13	10 mph ~ 15 mph	0.507318	6.350010	0.963657	0.010529	684	0.057385	0.052561	0.025139	0.056699	0.013430	0.00069
14	15 mph ~ 20 mph	0.374279	5.524051	0.865001	0.008757	560	0.042384	0.039221	0.018563	0.032641	0.009924	0.00051
15	20 mph ~ 25 mph	0.298930	4.925798	0.813408	0.007848	478	0.034067	0.030735	0.015611	0.026611	0.007927	0.00041
16	25 mph ~ 30 mph	0.249455	4.484799	0.779253	0.008003	423	0.028338	0.025906	0.013382	0.021920	0.006617	0.00034
17	30 mph ~ 35 mph	0.218100	4.167034	0.760933	0.007055	387	0.024215	0.022775	0.011835	0.018458	0.005787	0.00030
18	35 mph ~ 40 mph	0.200978	3.956287	0.756419	0.007117	367	0.021774	0.020266	0.010837	0.016136	0.005336	0.00027
19	40 mph ~ 45 mph	0.193106	3.849819	0.765599	0.007153	360	0.021011	0.019494	0.010398	0.015034	0.005128	0.00026
20	45 mph ~ 50 mph	0.196724	3.856495	0.790083	0.007179	366	0.020871	0.019374	0.010483	0.014987	0.005226	0.00027
21	50 mph ~ 55 mph	0.209746	4.005399	0.832158	0.007168	384	0.022503	0.019960	0.011141	0.016020	0.005573	0.00029
22	55 mph ~ 60 mph	0.236473	4.353012	0.896652	0.007106	418	0.024717	0.022300	0.012273	0.018126	0.006284	0.00032
23	60 mph ~ 65 mph	0.278962	5.003005	0.988561	0.008149	471	0.027625	0.025260	0.013940	0.021369	0.007415	0.00038
24	65 mph ~ 70 mph	0.307834	5.669164	1.079464	0.008091	475	0.030249	0.028024	0.016142	0.025640	0.008181	0.00042
25	>70 mph	0.351923	6.827238	1.215340	0.007987	482	0.033549	0.030408	0.018864	0.030992	0.009354	0.00046
26	OP Emission Factors	TOG	CO	NOx	SOx	CO2	PM10	PM2.5	Diesel PM	DEOG	Benzene	Acrolein
27	(mph)											
28	<5 mph	1.092231	9.166639	1.439030	0.016658	1141	0.121584	0.112015	0.051066	0.183633	0.028813	0.00147
29	5 mph ~ 10 mph	0.731738	7.504612	1.150665	0.013143	867	0.082750	0.076456	0.036041	0.107752	0.019329	0.00095
30	10 mph ~ 15 mph	0.507318	6.350010	0.963657	0.010529	684	0.057385	0.052561	0.025139	0.056699	0.013430	0.00069
31	15 mph ~ 20 mph	0.374279	5.524051	0.865001	0.008757	560	0.042384	0.039221	0.018563	0.032641	0.009924	0.00051
32	20 mph ~ 25 mph	0.298930	4.925798	0.813408	0.007848	478	0.034067	0.030735	0.015611	0.026611	0.007927	0.00041
33	25 mph ~ 30 mph	0.249455	4.484799	0.779253	0.008003	423	0.028338	0.025906	0.013382	0.021920	0.006617	0.00034
34	30 mph ~ 35 mph	0.218100	4.167034	0.760933	0.007055	387	0.024215	0.022775	0.011835	0.018458	0.005787	0.00030
35	35 mph ~ 40 mph	0.200978	3.956287	0.756419	0.007117	367	0.021774	0.020266	0.010837	0.016136	0.005336	0.00027
36	40 mph ~ 45 mph	0.193106	3.849819	0.765599	0.007153	360	0.021011	0.019494	0.010398	0.015034	0.005128	0.00026
37	45 mph ~ 50 mph	0.196724	3.856495	0.790083	0.007179	366	0.020871	0.019374	0.010483	0.014987	0.005226	0.00027
38	50 mph ~ 55 mph	0.209746	4.005399	0.832158	0.007168	384	0.022503	0.019960	0.011141	0.016020	0.005573	0.00029
39	55 mph ~ 60 mph	0.236473	4.353012	0.896652	0.007106	418	0.024717	0.022300	0.012273	0.018126	0.006284	0.00032
40	60 mph ~ 65 mph	0.278962	5.003005	0.988561	0.008149	471	0.027625	0.025260	0.013940	0.021369	0.007415	0.00038
41	65 mph ~ 70 mph	0.307834	5.669164	1.079464	0.008091	475	0.030249	0.028024	0.016142	0.025640	0.008181	0.00042
42	>70 mph	0.351923	6.827238	1.215340	0.007987	482	0.033549	0.030408	0.018864	0.030992	0.009354	0.00046
43	Running Exhaust (g/day)											
44	Emissions	TOG	CO	NOx	SOx	CO2 (ton/day)	PM10	PM2.5	Diesel PM	DEOG	Benzene	Acrolein
45	Entire Corridor	1444380	26405421	5116612	40240	2571	144495	132923	74926	117360	38383	199
46	Segment1	94908	1744198	333912	2532	163	9349	8644	4955	7831	2522	13

2006 Existing Conditions / 2015 Opening Day No Build / 2015 Opening Day Build / 2030 Horizon Year No Build / 2030 Horizon Year Build

Figure 3-4. Sample CT-EMFAC v4.0 batch-mode output for a scenario.



Benzene (g/day)	2006 Existing Conditions	2015 Opening Day No Build	2015 Opening Day Build	2030 Horizon Year No Build	2030 Horizon Year Build
Segment1	2680	1386	1525	917	993
Segment2	2239	1155	1271	763	826
Segment3	868	448	493	295	320
Segment4	2357	1213	1335	797	864
Segment5	1724	886	975	580	628
Segment6	1983	1021	1123	668	724
Segment7	2434	1251	1376	806	873
Segment8	1550	789	867	503	545
Segment9	806	409	450	265	287
Segment10	1056	536	590	346	374
Segment11	1641	834	918	540	585
Segment12	2477	1262	1388	821	889
Segment13	2994	1537	1691	1009	1093
Segment14	3405	1732	1906	1127	1221
Segment15	2467	1258	1384	821	890
Segment16	1441	737	811	483	523
Segment17	2132	1098	1208	723	783
Segment18	3141	1603	1764	1046	1134
Segment19	1201	615	676	401	435
Segment20	1211	620	682	405	439
Segment21	1405	723	795	475	514

Figure 3-5. Sample CT-EMFAC v4.0 batch-mode output for a pollutant.

4. REFERENCE

Wu P., Bai S., Eisinger D., and Niemeier D. (2007) CT-EMFAC: a computer model to estimate transportation project emissions. Prepared for the California Department of Transportation, Division of Transportation Planning, Sacramento, CA, by the UC Davis-Caltrans Air Quality Project, Davis, CA, Task Orders No. 61 and 67, December 10.