Excel-Based Program for Project Level MOVES Modeling

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ABSTRACT

'Project scale' is the finest level of modeling in MOVES. However, it requires considerable amount of both time and resources to prepare the requisite run specification files, create the input databases, run the model, and post-process the results. This is especially challenging for applications outside of the U.S. where required information can be scarce. An automated excel-based program was developed to perform pre- and post-processing steps involved in a project level MOVES run combining the USEPA conversion tools and other resources. The program serves as a one-stop solution for a project level MOVES run that can calculate emission rates for each hour of a day in a single session for projects involving roadways, transit facilities, and hoteling activities. The program can save as much as 80% of the workload required if relying solely on manual file preparation using the MOVES GUI.

The program prepares runspec files by pre-selecting common options specific to the project scale. It uses climate normal data, registration distribution, and population distribution to populate database tables, or it can draw the information from the MOVES default database where available. Generally, it uses average speed by link but uses MOVES default operating mode distributions adjusted for idling for intersection approach links. Options are also provided to adjust average speeds based on level of congestion. The second-by-second drive schedule and operating mode distribution options have yet to be implemented. For some applications, users are required to tweak some tables manually to fit project-specific requirements.

INTRODUCTION

'Project scale' is the finest level of modeling in MOVES. It allows the simulation of highways and arterial roads as a series of roadway links. It can also calculate emissions from transit facilities using off-network links that may include start, extended idle, and/or running emissions (FHWA, 2012). Users are required to perform the following basic steps for each project-level model run:

- Create a run specification file (runspec) using the MOVES graphical user interface (GUI);
- Populate database tables with information such as link properties, age distribution, meteorology, fuel properties, etc. in a series of spreadsheets;
- Create an input database from the project specific database tables;
- Run the MOVES model; and,
- Post-process the MOVES outputs to obtain suitable emission rates.

Although users can setup a project-level model using the MOVES GUI, it allows users to setup only one combination of county, year, month, and hour at a time. Thus, users may need to setup multiple model runs to simulate a project. For example, a typical PM hot spot analysis requires at least sixteen (16) model runs (EPA, 2013).

Although the runspec file generated in one setup can be accessed and updated several times using the MOVES GUI, other tasks such as updating database tables, creating an input database, and post-processing MOVES outputs still takes a considerable amount of time. Users may also use default MOVES database tables for the U.S. specific applications. However, these options are not readily available for international applications (e.g., in Canada). For custom applications outside the U.S., users must prepare all of the project details manually.

Post-processing MOVES outputs also takes a substantial amount of time, especially when dealing with multiple model runs. The USEPA has provided some post-processing scripts. However, users are required to run these scripts multiple times for each project-level run. Dealing with project-level runs also requires some basic to intermediate level knowledge of relational databases and MYSQL.

An automated excel-based program (MOVES Utility Tool) was developed to perform pre- and post-processing steps involved in a project level MOVES run that utilizes some of the USEPA conversion tools and other available resources. The program serves as a one-stop solution for a project level MOVES run. It can produce emission rates for each hour of a day in a single session for projects involving roadways, transit facilities, and extended idling activities. It can handle both U.S. and international project-level MOVES runs. The primary advantage of this tool over the MOVES GUI is the time it saves a user. Other advantages include:

- It can handle both MOVES2010b and the latest MOVES2014 versions of the model;
- It can prepare multiple runspec files at a time by pre-selecting common options;
- It can utilize user-defined or MOVES default information to populate database tables;
- It requires minimal knowledge of relational databases and MySQL;
- It creates batch files required to run multiple project-level models; and,
- It automatically post-processes MOVES output to generate suitable emission rates.

The purpose of this paper is to describe available features and technical details of the MOVES Utility Tool. It also provides instructions on how to use the tool and details the required user inputs.

STRUCTURE OF MOVES UTILITY TOOL

The MOVES Utility tool is a Microsoft Excel spreadsheet consisting of multiple worksheets and twenty one (21) visual basic for applications (VBA) macros. Although the tool contains multiple worksheets, most of them are hidden from end users. Users see only a single worksheet named "Input Information" where they provide information related to a project. The worksheet has been designed in a way that users only see information pertaining to their project.

Conceptually, the tool requires the same information as that required by the MOVES GUI. However, users are generally required to provide fewer details about a project since the tool pre-selects some of the inputs. In addition to these common user inputs, the tool requires some user-defined information to populate tables required to generate MOVES input databases. User inputs within the worksheet are divided into several sub-sections. **Table 1** presents the list of sub-sections in the "Input Information" worksheet. Detailed descriptions of each sub-section are provided in later sections.

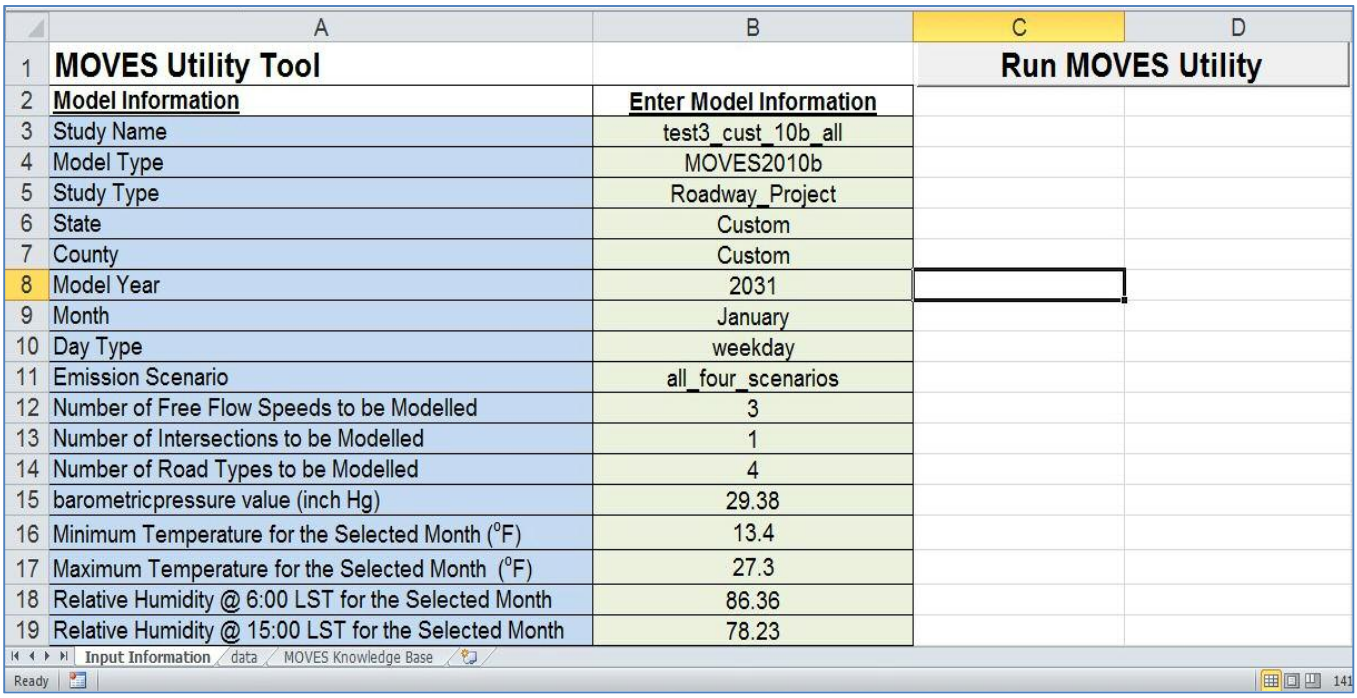
Table 1: Description of sub-sections in "Input Information" worksheet.

Section Name	Description
Model Information	General project related information.
Questionnaire	Users are required to answers these questions to customize the worksheet.
Pollutant Type Selection	Users select pollutant types.
Fuel Type Selection	Users select fuel types.
Vehicle Type Selection	Users select vehicle types.
Road Type Selection	Users select road types.
Free Flow Speed Selection	Users select free flow speeds.
Intersection Link Selection	Users define intersection links.
Other Information Section	Users can provide custom registration distribution, source type hour fractions, soak time distribution, etc.

Model Information

This is where users define the project. This information is required to customize the worksheet so that users only see information pertaining to their project. A screenshot of the section is presented in **Figure 1**. Individual model information within this section is described in **Table 2**.

Figure 1: Screenshot of model information section of the MOVES utility tool.



	A	B	C	D
1	**MOVES Utility Tool**		**Run MOVES Utility**	
2	**Model Information**	**Enter Model Information**		
3	Study Name	test3_cust_10b_all		
4	Model Type	MOVES2010b		
5	Study Type	Roadway_Project		
6	State	Custom		
7	County	Custom		
8	Model Year	2031		
9	Month	January		
10	Day Type	weekday		
11	Emission Scenario	all_four_scenarios		
12	Number of Free Flow Speeds to be Modelled	3		
13	Number of Intersections to be Modelled	1		
14	Number of Road Types to be Modelled	4		
15	barometricpressure value (inch Hg)	29.38		
16	Minimum Temperature for the Selected Month (^{o}F)	13.4		
17	Maximum Temperature for the Selected Month (^{o}F)	27.3		
18	Relative Humidity @ 6:00 LST for the Selected Month	86.36		
19	Relative Humidity @ 15:00 LST for the Selected Month	78.23		

Input Information | data | MOVES Knowledge Base

Ready

Table 2: Description of model information section.

Information Type	Description
Study Name	A 20-Character space for the study name.
Model Type	Users can select either MOVES2010b or MOVES2014.
Study Type	Users must select one of the three options: “Roadway_Project”, “Transit_Facility”, or “Extended_Idle_Emission”.
State	Users can select any state from the list or can select “Custom” for international applications (e.g., Canada).
County	Users can either select a county from the list or “Custom” for international applications.
Model Year	Users can select any model year from 2001-2050.
Month	Users can select one of the twelve months.
Day Type	Users can either select weekdays or weekend.
Emission Scenarios	This area provides options for different emission scenarios. Users can select either any hour of a day, all hours of a day, four different times of a day as per hotspot analysis guidelines, or simply one of the four pre-defined times as per hotspot analysis guidelines.
Number of Free Flow Speeds	Users must choose the number of free flow speeds to be modeled.
Number of Intersections to be Modelled	Users can select up to ten (10) intersections in a single session. See the technical discussion section for additional details.
Number of Road Types to be Modelled	Users can select up to four (4) road types. For transit facilities and extended idling emissions the tool automatically selects the offnetwork road type.
Barometric Pressure Value (inch Hg)	This is required for “Custom Domain” only.

Information Type	Description
Minimum and Maximum Temperature for the Selected Month (^{o}F)	Users can provide climate normal minimum and maximum average temperatures for the selected month. This is only required for custom domain to create the zoneMonthHour table. For any state-county combination, the tool generates this information from the MOVES default database and no user-input is required. The tool uses the USEPA conversion tool internally to generate hourly temperatures from the climate normal minimum and maximum temperatures.
Relative Humidity @ 6:00 and 15:00 LST for the Selected Month	Users can provide climate normal relative humidity data for 6:00 and 15:00 hours at local standard time (LST) for custom domains. The tool uses the base temperature used by the EPA temperature converter to generate hourly relative humidity from 6:00 and 15:00 LST relative humidity data, depending on the inverse relationship between temperature and relative humidity. Users are advised to use these values with caution. These values can be replaced manually.

Questionnaire

Users are required to answer questions related to vehicle registration, age distribution, and vehicle population so that appropriate ranges can be defined. **Table 3** provides a description of these questions.

Table 3: Description of the questionnaire section.

Question	Description
How do you like to provide vehicle population data?	The tool provides the following options to determine source type hour fractions. • MOVES source use types • Default MOBILE6.2c • Custom MOBILE6.2 Vehicle Categories (either 8, 12, 16, or 28 MOBILE6.2 type vehicle categories can be selected) Users are not required to provide any data when the default MOBILE6.2c option is selected. The tool calculates vehicle population based on MOBILE6.2c vehicle count (MvCount) and registration distribution. The tool uses same source type hour fractions for all hours of a day. If users wish to use different fractions for different hours they either can run the tool for each hour separately or manually change the source type hour fractions within the spreadsheets generated by the tool. Since the output of the post-processing tool is in terms of either MOVES source use types or FHWA vehicle classes, users can also use the vehicle population fractions afterward to calculate weighted average emission rates for the entire fleet.
How Do You Like to Calculate Age Distribution?	Several options are provided to calculate age distribution. Users can select the MOVES default, MOBILE6.2c default, or custom registration distribution options. When users select the custom registration distribution option, the tool ‘un-hides’ a range where these values can be provided.

Question	Description
	The tool uses the EPA conversion tool internally to convert user-provided MOBILE6.2 type registration distribution to MOVES type age distribution. The custom registration distribution option is only available for MOBILE6.2 vehicle types. Similar option for MOVES source use types is planned for future versions of the tool.
Which Gasoline Fuel Properties Would You Like to Use?	This question is specific to Canada only. It asks users to select pre-defined fuel properties. The available options are "Atlantic", "Ontario/Quebec", "West", and "Canada". The fuel properties are pre-compiled from Environment Canada's Benzene in Gasoline Regulation, Annual Report 2009 (EC 2011). This option is only available for the custom domain option, and is hidden from the users if any state/county combination is selected. Users can manually override these values within the spreadsheets populated by the tool.
How Do You Like to Define Soak Distribution for Each Hour?	Users are required to answer this question only when they are modeling a "Transit_Facility" for multiple scenarios. Users can select either "Same Soak Time for Each Hour" or "Different Soak Time for Each Hour".

Pollutant Selection Panel

Screenshots of the Pollutant Selection Panel are presented in **Figures 2 and 3**. Some of the common primary pollutants are pre-selected. However, users can change this selection at any time. The tool automatically selects the corresponding process types. Users can also select additional air toxics, PAHs, metals, and dioxin and furans. Additionally, the tool automatically selects all corresponding chained pollutants. The section of the pollutant selection panel presented in **Figure 3** is only viewable if users request these pollutants.

Figure 2: Screenshot of pollutant selection section of the MOVES utility tool (primary pollutants).

Pollutant Selection Panel	Select Pollutants
1,3-Butadiene	yes
Acetaldehyde	yes
Acrolein	yes
Atmospheric CO2	yes
Benzene	yes
CO2 Equivalent	yes
Carbon Monoxide (CO)	yes
Formaldehyde	yes
Oxides of Nitrogen (NOx)	yes
Primary Exhaust PM10 - Total	yes
Primary Exhaust PM2.5 - Total	yes
Sulfur Dioxide (SO2)	yes
Would You Like to Include Additional Air Toxics?	yes
Select Polycyclic Aromatic Hydrocarbon (PAH)?	all
Would You Like to Include Any Metals?	yes
How Do You Like to Include Dioxins and Furans?	all

Figure 3: Screenshot of pollutant selection section of the MOVES utility tool (additional pollutants).

Additional Air Toxics:	Select Pollutants
2,2,4-Trimethylpentane	yes
Ethyl Benzene	yes
Hexane	yes
Propionaldehyde	yes
Styrene	yes
Toluene	yes
Xylene	yes
Metals	**Select Pollutants**
Mercury Elemental Gaseous	yes
Mercury Divalent Gaseous	yes
Mercury Particulate	yes
Arsenic Compounds	yes
Chromium 3+	yes
Chromium 6+	yes
Manganese Compounds	yes
Nickel Compounds	yes

Fuel Type Selection

A screenshot of the fuel type selection section is presented in **Figure 4**. Users can select any or all of diesel, gasoline, and compressed natural (Gas) fuels for both versions of MOVES and can select ethanol (E85) in the case of MOVES2014. The tool generates an error message if no fuel types are selected and bars users from running the tool. For any state/county combination, the tool uses information from MOVES default database. Users who wish to change these default fuel properties can do so manually in a subsequent step.

The E85 fuel is, by default, hidden. The tool provides a user-prompt allowing users to choose whether to include E85 fuel. If they choose not to include E85 fuel the tool automatically uses only gasoline for flexible fuel vehicles (FFVs). Users can also provide the fraction of E85 fuel for FFVs when modeling a custom domain. If users do not select all fuel types, the tool automatically generates an AVFT spreadsheet by adjusting the default values. The tool also updates runspec and XML importer files automatically to include the AVFT table.

Vehicle Type Selection

A screenshot of the vehicle type selection section is also presented in **Figure 4**. All MOVES source use types are pre-selected. Users can change this setting at any time. The tool generates an error message and bars users from running the tool if no vehicle type is selected. The tool automatically selects appropriate fuel types for the selected vehicles; no user input is required.

Figure 4: Screenshot of fuel and vehicle type selection sections of the MOVES utility tool.

Fuel Type Selection	Select Fuel Type
Gasoline	yes
Diesel Fuel	yes
Compressed Natural Gas (CNG)	yes
Vehicle Type Selection	**Select Vehicle Type**
Combination Long-haul Truck	yes
Combination Short-haul Truck	yes
Intercity Bus	yes
Light Commercial Truck	yes
Motor Home	yes
Motorcycle	yes
Passenger Car	yes
Passenger Truck	yes
Refuse Truck	yes
School Bus	yes
Single Unit Long-haul Truck	yes
Single Unit Short-haul Truck	yes
Transit Bus	yes

Road Type Selection

Figure 5 presents the road type selection section of the input worksheet. The number of rows available for road type selection depends on the user's answer to the "Number of Road Types to be Modeled" question. Repeating the same road type multiple times is not permitted. The offnetwork road type is automatically selected when transit facility or extended idle emission options are selected.

Figure 5: Screenshot of road type and free flow speeds selection sections of the MOVES utility tool.

Road Types	Select Road Type	
1	Urban Restricted Access	
2	Urban Unrestricted Access	
3	Rural Restricted Access	
4	Rural Unrestricted Access	
Free Flow Speeds	**Enter Free Flow Speed (km/hr)**	**Enter Grade (-5 to +5)**
1	0	0
2	2	0
3	10	0
4	15	0
5	20	0
6	25	0
7	27	0
8	35	0
9	40	0
10	50	0
11	70	0

Free Flow Speed Selection

Figure 5 also presents the free flow speeds selection section of the input worksheet. As mentioned earlier, a maximum of fifteen free flow speeds can be modelled for each scenario. All speeds

are in kilometers per hour in the current version (more options are planned for future versions of the tool). The tool automatically assumes the appropriate speeds for all road types selected.

Intersection Link Information

A maximum of ten (10) intersections can be defined in a single session for each hour to be modeled. The tool automatically generates appropriate ranges within the worksheet for the selected hours. This allows users to define different speed and signal data for different times of a day. If the information is the same for each hour users can simply copy the information from one hour to another.

For an intersection approach link users need to provide percent of idle time at each direction (northbound, southbound, westbound, and eastbound) of a four-way intersection. For a three-way intersection, the user can simply enter a zero idle time and the tool will recognize it as being nonexistent (for that given direction). The tool also requires average grade for approach links.

The tool uses this information to access the MOVES default database and generate operating mode distribution tables adjusted and normalized for idle time in an intersection. This approach is similar to the tool provided by the EPA to operating mode distribution for an approach link. However, the entire process is automated and is performed by directly accessing the MOVES default database, instead of relying on hundreds of operating mode distribution files as required by the EPA tool. The approach link section of the input worksheet is presented in **Table 4** Error! Reference source not found. for a three-way intersection and four different scenarios.

Table 4: Intersection approach link setup (presented for one intersection and four scenarios).

Intersection Name	Idle Time (%)				Average Speed (km/h)				Average Grade			
	NB	WB	SB	EB	NB	WB	SB	EB	NB	WB	SB	EB
Emission Scenario: am												
Intersection01	0.51	0.5	0	0.51	40	50	0	50	0	0	0	0
Emission Scenario: pm												
Intersection01	0.51	0.5	0	0.51	40	50	0	50	0	0	0	0
Emission Scenario: midday												
Intersection01	0.51	0.5	0	0.51	40	50	0	50	0	0	0	0
Emission Scenario: overnight												
Intersection01	0.51	0.5	0	0.51	40	50	0	50	0	0	0	0

Notes:

1. NB = Northbound; SB = Southbound; WB = Westbound; and EB = Eastbound.
2. An idle time of "0" means southbound approach link does not exist (three-way intersection).

Users are required to provide cruise speed, average grade, and v/c ratios for a departure link. The tool calculates departure link speed based on the cruise speed, red time fraction, and v/c ratios. If v/c ratios are not available the tool uses free flow cruise speed. The tool uses an adjusted average speed approach for departure link as specified in the PM hot spot analysis guidance document (EPA 2013).

The tool first calculates congested speed based on the updated BPR curve for arterial roads (Skabardonis and Dowling, 1997) and assumes a uniform arrival rate for the intersection. Thus, red time fraction has been used as the fraction of vehicles that accelerate from idling until they reach the congested cruise speed. The rest of the vehicles are assumed to be arriving during the green time (i.e., those vehicles will pass the intersection uninterrupted). Finally, the tool calculates a weighted average speed based on the fractions of interrupted and uninterrupted flows and congested speed. Users can

change the speeds calculated by the tool in the link spreadsheet generated by the tool. The departure link section of the input worksheet is presented in **Table 5**.

Table 5: Intersection departure link setup (presented for one intersection and four scenarios).

Intersection Name	Free Flow Speed (km/h)				Volume to Capacity Ratio				Average Grade			
	NB	WB	SB	EB	NB	WB	SB	EB	NB	WB	SB	EB
Emission Scenario: am												
Intersection01	0	40	50	60	0	0	0	0	0	0	0	0
Emission Scenario: pm												
Intersection01	0	40	50	60	0	0	0	0	0	0	0	0
Emission Scenario: midday												
Intersection01	0	40	50	60	0	0	0	0	0	0	0	0
Emission Scenario: overnight												
Intersection01	0	40	50	60	0	0	0	0	0	0	0	0

Notes:

1. NB = Northbound; SB = Southbound; WB = Westbound; and EB = Eastbound.
2. Free flow speed of "0" km/h means northbound departure link does not exist (three-way road).

Other Information Section

Some of the sections are hidden from users in the default view and are only available when requested. These sections serve as placeholders for custom user-defined information. **Table 6** provides a list of items that are hidden in the normal view.

Table 6: Sections for custom user-defined information.

Information Type	Description
Soak Time Distribution	Available for transit facility only
Custom Population Fractions	Users can provide custom vehicle population data in terms of MOBILE6.2 vehicle type or MOVES source use types
Custom Registration Distribution	Users can provide custom registration distribution for MOBILE6.2 vehicle types
Additional Pollutant Types	Users can select additional pollutants, such as metals, air toxics, dioxin and furans

RUNNING MOVES UTILITY TOOL

The tool uses several excel-based VBA procedures arranged in thirteen (13) modules. These VBA modules and a user form are linked to a single button at the top right hand corner of the "Input Information" worksheet. Users click on the "Run MOVES Utility" button after completing the sections of "Input Information" worksheet. A series of events take place after the click. First, the tool checks for errors within the user-completed input worksheet. A list of errors checked by the tool is presented in **Table 7**. Each of these errors generates an error message and bars the tool from running. Users must fix these errors before being able to run the tool.

Table 7: Description of errors checked by the MOVES utility tool.

Error Type	Description
General Blank Cells Check	The tool looks for blank cells where users are supposed to select or provide some information.
Air Toxics Empty Check	If the user selects air toxics but does not specify them, this error is raised.
Metals Empty Check	If the user selects metals but does not specify them, this error is raised.
Population Fractions Check	If the user selects custom vehicle population but does not provide population fractions within the specified range, this error is raised.
Custom Registration Distribution Check	If the user selects custom registration distribution but does not provide the data, this error is raised.
Free Flow Speed Check	This error is raised when users do not provide the correct number of speed types. For example, this error is raised when users select 15 free flow speeds to be modeled but provides only 10 free flow speeds.
Road Type Check	This error is raised when the user does not select the correct number of road types.
Pollutant Type Check	An error is raised when no pollutant is selected.
Source Use type Check	An error is raised when no source use type is selected.
Soak Time Check	An error is raised when the sum of all soak times does not add up to 1 for each hour.
Road Type Check for Intersection Links	An error is raised when an unrestricted road type is not selected but intersection links are defined.
MOVES Version Check	An error is raised when correct MOVES installation folder is not selected using the file dialogue box.
Empty Folder Check	The tool checks for any folders from previous model runs to avoid accidentally overwriting previous runs / folders.
Other Error Checks	Additional error checks are built in to the VBA modules themselves.

When users run the tool after fixing the errors, if any, a file dialogue box appears where users must select the MOVES installation folder (see **Figure 6**). The user must select a file location and click "Ok" to proceed. In the case of MOVES2014, a prompt will appear before the file dialogue box whereby the user is required to confirm E85 fuel selection.

Next, a user form prompting the user to select different post-aggregation levels is displayed. **Figure 7** depicts the available post-aggregation levels. Options 1 and 2 are pre-selected by default. Option 2 converts MOVES source use types into corresponding SCC classes. This option is only available for MOVES2010b. A similar option has not yet been implemented for MOVES2014 but is planned for future versions.

Figure 6: A screenshot of file dialogue box to choose MOVES installation folder.

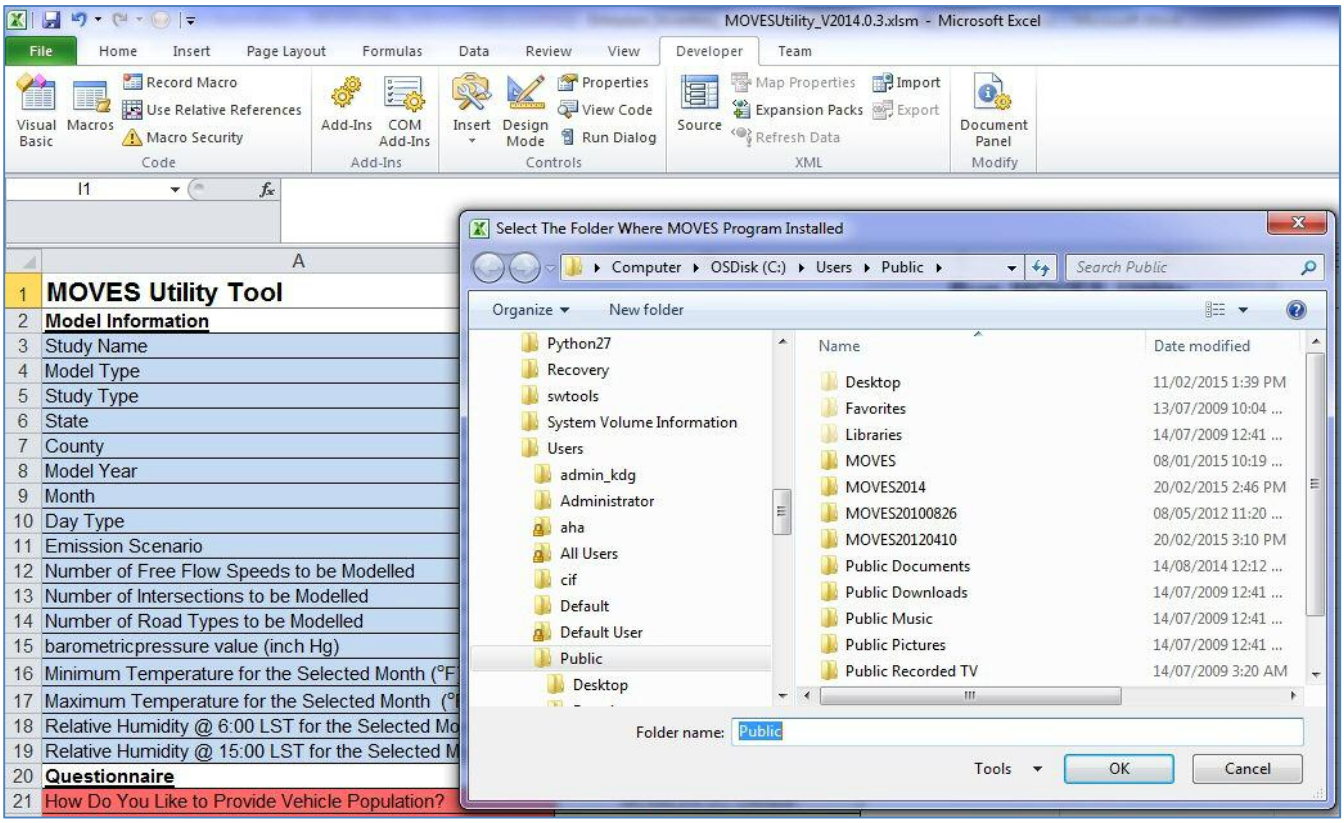
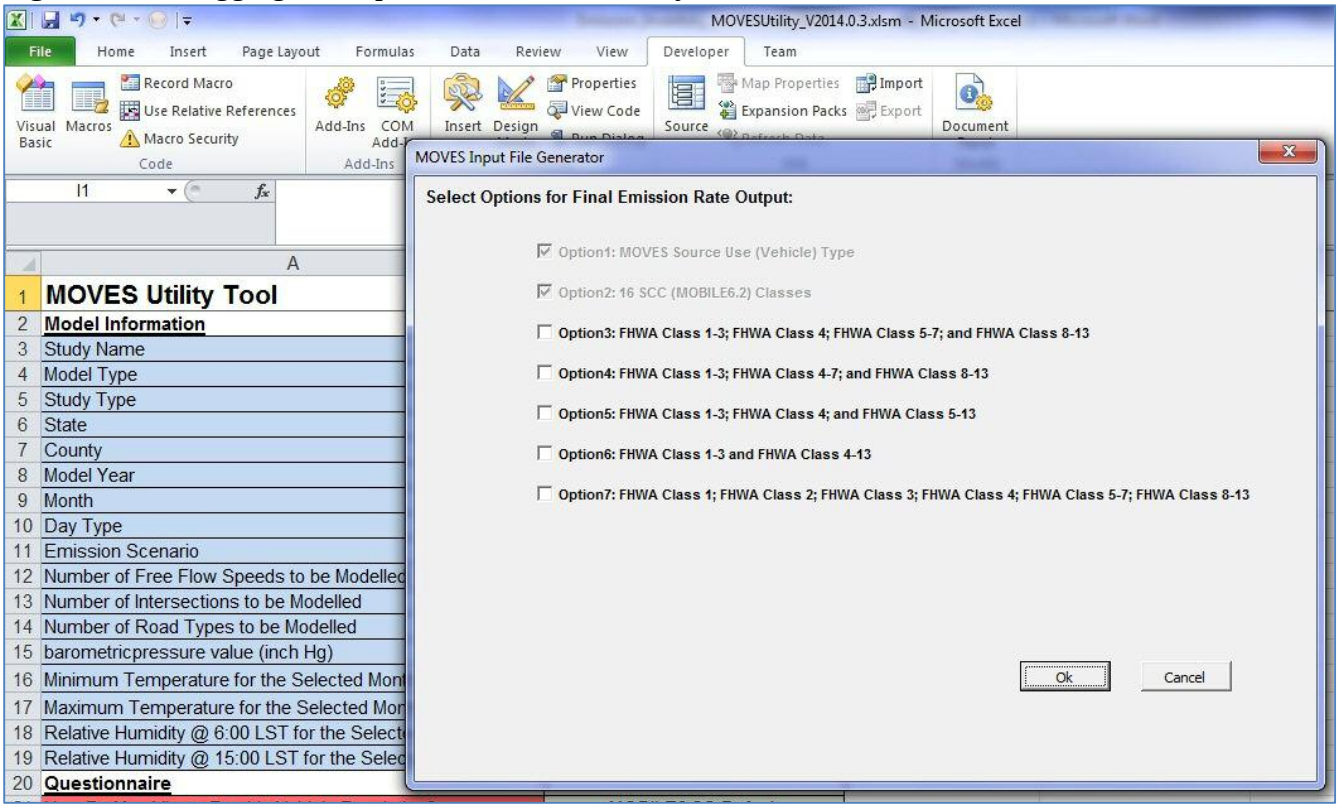


Figure 7: Post-aggregation options in MOVES utility tool.



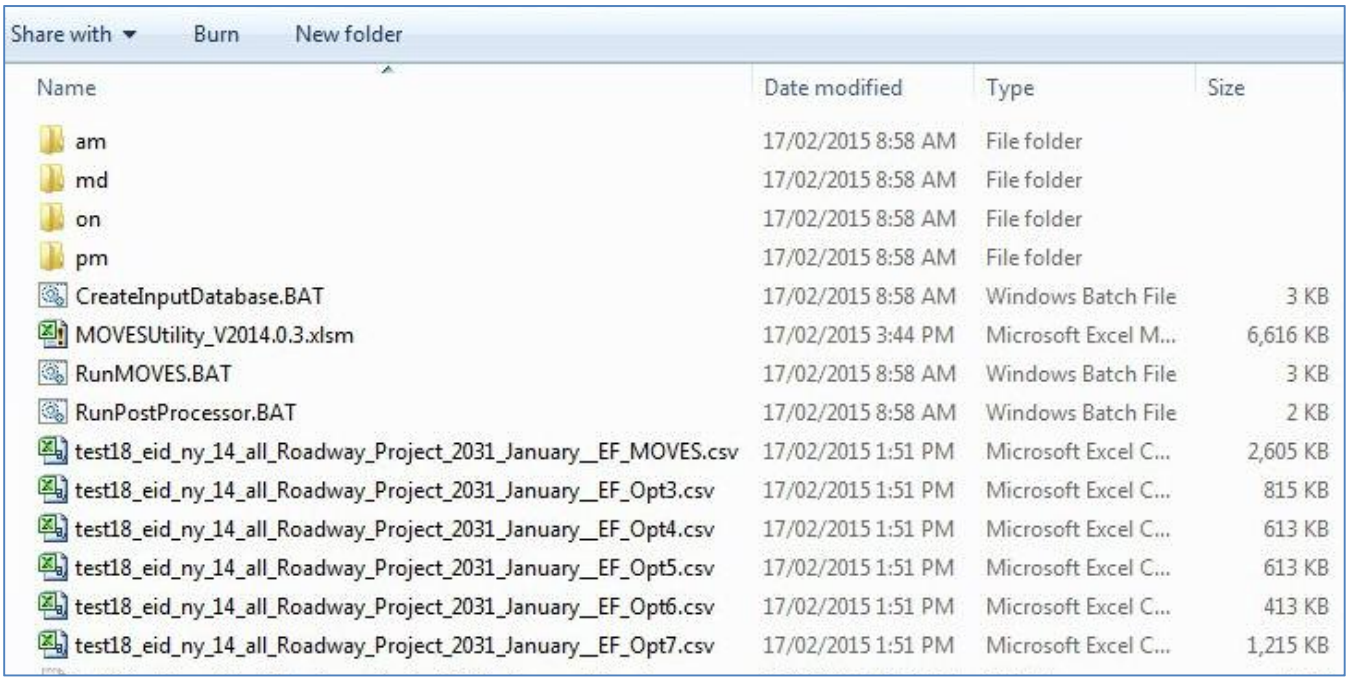
The other post-aggregation options (Options 3 to 7) generate emission rates for different combinations of FHWA vehicle classes. Sometimes vehicle population fractions are only available for a group of FHWA vehicle classes. The post-aggregation options automatically distribute the MOVES vehicle classes to appropriate FHWA group of vehicles. **Table 8** describes how the tool apportions MOVES source use types into different FHWA groups.

Table 8: MOVES source use types to FHWA vehicle class conversion.

Fhwa Class ID	FHWA Classes	MOVES Source Use Types
1	Motorcycles	11–Motorcycle
2	Passenger Cars	21–Passenger Car
3	Other 2-axle/ 4- tire Vehicles	31–Passenger Truck; and, 32–Light Commercial Truck
4	Buses	41–Inter-city Bus; 42–Transit Bus; and, 43–School Bus
5-7	Single-unit Trucks	51–Refuse Truck; 52–Single-unit Short Haul; 53–Single-unit Long Haul; and, 54–Motor Home
8–13	Combination Trucks	61–Combination Short Haul; and, 62–Combination Long Haul

After selecting the post-aggregation levels and clicking “Ok”, the tool produces one sub-folder for each selected hour (scenario) within the parent folder where the tool is located. The tool generates database tables for the input database, a runspec file, an xml importer file and a post-processing script within each of the scenario folders. In addition to this, the tool also creates three batch files within the parent folder. Screenshots of the session run files are presented in **Figure 8** and **9**. The CreateInputDatabase.BAT batch file creates the input database for each scenario using the spreadsheets and xml importer files. The RunMOVES.BAT batch file runs MOVES for the selected hours. The RunPostProcessor.BAT batch file produces emission rates required for a CAL3QHCR model run.

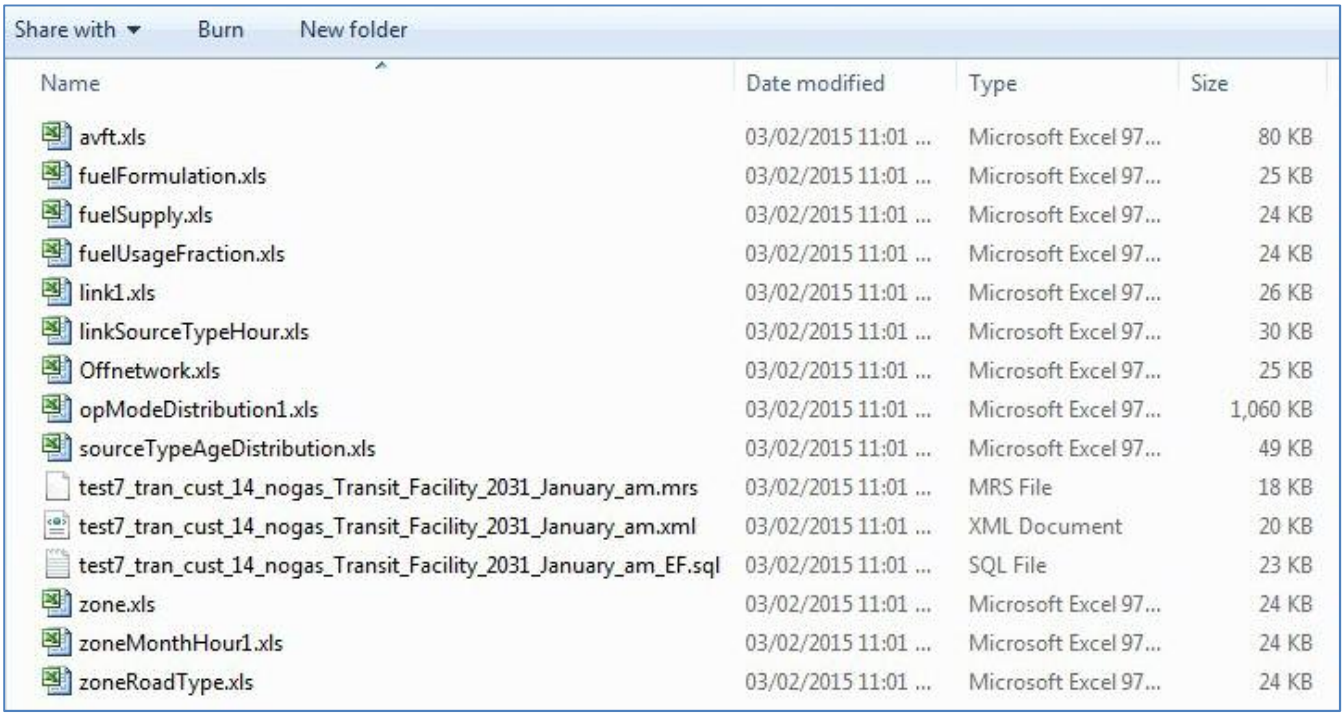
Figure 8: A screenshot of session run files created by MOVES utility tool.



Share with ▾ Burn New folder

Name	Date modified	Type	Size
am	17/02/2015 8:58 AM	File folder	
md	17/02/2015 8:58 AM	File folder	
on	17/02/2015 8:58 AM	File folder	
pm	17/02/2015 8:58 AM	File folder	
CreateInputDatabase.BAT	17/02/2015 8:58 AM	Windows Batch File	3 KB
MOVESUtility_V2014.0.3.xlsm	17/02/2015 3:44 PM	Microsoft Excel M...	6,616 KB
RunMOVES.BAT	17/02/2015 8:58 AM	Windows Batch File	3 KB
RunPostProcessor.BAT	17/02/2015 8:58 AM	Windows Batch File	2 KB
test18_eid_ny_14_all_Roadway_Project_2031_January__EF_MOVES.csv	17/02/2015 1:51 PM	Microsoft Excel C...	2,605 KB
test18_eid_ny_14_all_Roadway_Project_2031_January__EF_Opt3.csv	17/02/2015 1:51 PM	Microsoft Excel C...	815 KB
test18_eid_ny_14_all_Roadway_Project_2031_January__EF_Opt4.csv	17/02/2015 1:51 PM	Microsoft Excel C...	613 KB
test18_eid_ny_14_all_Roadway_Project_2031_January__EF_Opt5.csv	17/02/2015 1:51 PM	Microsoft Excel C...	613 KB
test18_eid_ny_14_all_Roadway_Project_2031_January__EF_Opt6.csv	17/02/2015 1:51 PM	Microsoft Excel C...	413 KB
test18_eid_ny_14_all_Roadway_Project_2031_January__EF_Opt7.csv	17/02/2015 1:51 PM	Microsoft Excel C...	1,215 KB

Figure 9: A screenshot of files created by MOVES utility tool within the scenario folder.



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Name	Date modified	Type	Size
avft.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	80 KB
fuelFormulation.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	25 KB
fuelSupply.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	24 KB
fuelUsageFraction.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	24 KB
link1.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	26 KB
linkSourceTypeHour.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	30 KB
Offnetwork.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	25 KB
opModeDistribution1.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	1,060 KB
sourceTypeAgeDistribution.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	49 KB
test7_tran_cust_14_nogas_Transit_Facility_2031_January_am.mrs	03/02/2015 11:01 ...	MRS File	18 KB
test7_tran_cust_14_nogas_Transit_Facility_2031_January_am.xml	03/02/2015 11:01 ...	XML Document	20 KB
test7_tran_cust_14_nogas_Transit_Facility_2031_January_am_EF.sql	03/02/2015 11:01 ...	SQL File	23 KB
zone.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	24 KB
zoneMonthHour1.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	24 KB
zoneRoadType.xls	03/02/2015 11:01 ...	Microsoft Excel 97...	24 KB

TECHNICAL DISCUSSION

The MOVES Utility tool uses the USEPA conversion tools, MOVES JAVA codes translated into VBA, and other VBA procedures to combine the steps required for a complete project level MOVES run into a single platform. All project specific spreadsheets, runspec files, XML importer files, batch files, and post-processing scripts are generated using VBA macros that rely on information provided by the user in an easy to use Excel Spreadsheet. Each task is assigned to a macro while a VBA program calls the individual macros and creates the necessary files for a complete MOVES run. These tasks are divided into the following three groups for ease of discussion:

- MOVES runspec and XML importer file preparation;
- Spreadsheets for input database; and,
- Batch files preparation.

MOVES Runspec and XML Importer File Preparation

The tool relies on user-defined information along with some internally pre-selected options to generate a runspec file. An excel macro generates this file as a text file with a file extension of "*.mrc". The tool adjusts the runspec file for different versions of MOVES and for different user selections. The runspec file generated by the tool can be directly accessed via the MOVES GUI if desired. The XML importer file is required to generate the input databases from the database tables written into excel spreadsheets. A macro similar to the one for the runspec file is used to generate the XML importer file. The XML importer file is accessed by the "CreateInputDatabase.BAT" batch file to generate the requisite input databases.

Spreadsheets for Input Databases

In MOVES, users are required to provide project specific information such as link properties, source type hour, age distribution, meteorology, fuel properties, road types, operating mode, etc. These tables are generally prepared in a series of excel spreadsheets and then converted into a MOVES input database. This is probably the most time consuming part of any project-level MOVES run. Manual file preparation takes a considerable amount of time and can be prone to human error. Therefore, these tasks have been automated in the MOVES utility tool. Some manual editing may still be required; however, users can use these tables as templates for their project. Each spreadsheet is generated by a VBA macro. Functional details of each macro are provided below.

Link Spreadsheet

The macro assigned to populate the link spreadsheet works in three stages. First, it populates information for any offnetwork link. It assumes the traffic volume to be one and the link length and link average speed to be zero for an offnetwork link.

Next, it populates information for free-flow speeds selected by the user. For free-flow links, traffic volume and link lengths are set to '1' (except in the case of idling link for which the link length is set to zero). Since the final outputs are generated as emission rates, actual traffic volumes and link lengths are not required. However, users wishing to enter actual traffic parameters can do so manually.

Finally, the macro then populates the information for intersection approach and departure links. Average speeds for approach and departure links are calculated using the method described previously. This process is repeated for each unrestricted road type and selected hour. Although not a requirement, users can manually change or adjust any parameters in the populated spreadsheet, except link IDs and

road type IDs as these are pre-requisite for other database tables. Users who wish to change link IDs and road type IDs must update other database tables that uses link IDs and road type IDs.

Link Source Types

The link source type hour fractions spreadsheet contains the fractions of the link traffic volume, which is driven by each source type. This spreadsheet is populated in two ways. Firstly, the macro uses user-defined fractions when provided. If user-defined data are provided for MOBIL6.2 vehicle types, they are converted to MOVES source use types using the EPA converter. If users select the MOBILE6.2c default option, the macro uses the default MOBILE6.2 vehicle counts along with user-defined or default registration distribution data to map them to MOVES source use types.

Secondly, the macro pulls information directly from the input worksheet when users provide hour fraction for MOVES source use types. The EPA has provided a conversion tool for 28, 16, 12, or 8 MOBILE6.2 vehicle types. Due to the similarity of these conversion tools, they are combined into a single conversion platform.

Fuel Properties

The tool populates fuel supply, fuel formulation, and, in the case of MOVES2014, fuel usage fraction spreadsheets using three separate macros. The tool pulls the requisite information from the MOVES default database for any state/county combination. The tool also uses pre-selected values to populate fuel properties for any custom domain application in Canada. Users outside of the U.S. and Canada need to change the fuel properties manually in the populated spreadsheets.

Age Distribution

The tool populates age distribution based on user-selected options. If users select the MOVES default, the MOVES default age distributions are used for the selected source use types. When the MOBILE6.2c default is selected, default MOBILE6.2c registration distributions are mapped to MOVES age distributions for the corresponding source use types using the EPA conversion tool. The tool can also incorporate custom registration distributions into the conversion process.

Canada-specific registration distributions are provided within the available options. These registration distributions are based on the “Canadian Vehicle Survey Report, 2009” (Statistics Canada, 2009). These distributions are initially converted to corresponding MOBILE6.2 vehicle classes and then converted to MOVES source use types. Any missing data are replaced by default MOBILE6.2c data. More recent data are now available for Canada, but they not been incorporated into the tool yet. In the interim, using the MOBILE6.2c or MOVES default age distribution is recommended.

ZoneMonthHour

The tool uses information from the MOVES default database to populate the zoneMonthHour spreadsheet for any state/county combination. It uses user-supplied temperatures and relative humidity information for any custom domain. The user-supplied temperatures and relative humidity are converted to appropriate hourly values using the procedure described in **Table 2**.

Zone, ZoneRoadType, and SCCRoadTypeDistribution

These spreadsheets are required for the custom domain option only. The tool automatically generates these spreadsheets based on the user-supplied information and selected road types. The tool generates these spreadsheets considering a single custom zone. Users can change the tables manually if working with multiple zones.

The startAllocFactor, idleAllocFactor and SHPAllocFactor parameters in the Zone table are set to one according to the requirement. The tool automatically selects the road types from the input information worksheet to the ZoneRoadType table. The SCCRoadTypeDistribution spreadsheet is generated using generalized assumptions about road type distribution. **Table 9** presents the assumptions used for road type distribution. Users are recommended to verify their road distribution and adjust the values manually as required.

Table 9: Road type distribution assumptions for SCCRoadTypeDistribution table.

Road Type	SCCRoadTypeDistribution
Rural Restricted Access	Rural Interstate = 1, and others = 0
Rural Unrestricted Access	Rural Major Arterial = 1, and others = 0
Urban Restricted Access	Urban Interstate = 1, and others = 0
Urban Unrestricted Access	Urban major Arterial = 1, and others = 0
Offnetwork	Offnetwork = 1

Operating Mode Distribution

The tool generates the operating mode distribution spreadsheet in three stages. If transit facility is selected the tool populates the operating mode distribution for the offnetwork link first. It assigns appropriate fractions to OpMode IDs 101 to 108 according to the user-supplied information. This procedure is repeated for all applicable pollutant-process combinations and source use types.

In the case of extended idle emissions, the tool assigns a value of one OpMode ID 200 in case of MOVES2010b, and apportions the default fractions between OpMode IDs 200 and 201 in case of MOVES2014.

For intersection approach links the tool accesses the default MOVES database and calculates the operating mode distribution, updates the idle fractions according to the user-supplied information, normalizes the updated distribution, and populates the operating mode distribution spreadsheet with the final distribution.

Offnetwork

The tool populates this spreadsheet when transit facility or extended idle emission is selected. It sets the start fraction to one for start emissions modelled by transit facility option. The process is repeated for each source use type. The tool sets the extended idle emission fraction to one when modeling extended idling emission. The spreadsheet populates extended idle emissions for combination long haul trucks only.

AVFT

The tool automatically populates this spreadsheet when users do not want to model all fuel types. The tool adjusts the default fuel-engine fractions by setting unselected fuel fractions to zero, and then renormalizing the distribution. The tool internally determines the requirement of an AVFT file. However, users who wish to change the default AVFT parameters can do so manually within the populated spreadsheet.

Batch Files Preparation

As discussed previously the tool generates three batch files as described in the following sections.

Batch File to Create Input Databases

After running the tool, users are required to double click the "CreateInputDatabase.BAT" file. This will create input databases for each scenario using the database tables written into a series of spreadsheets and an xml importer file. The batch file uses the MOVES command line interface.

Although not a requirement, users are recommended to review the input databases generated by this batch file. Users can access the database using MySQL Query Browser or Workbench (may require elevated access level depending on local security settings).

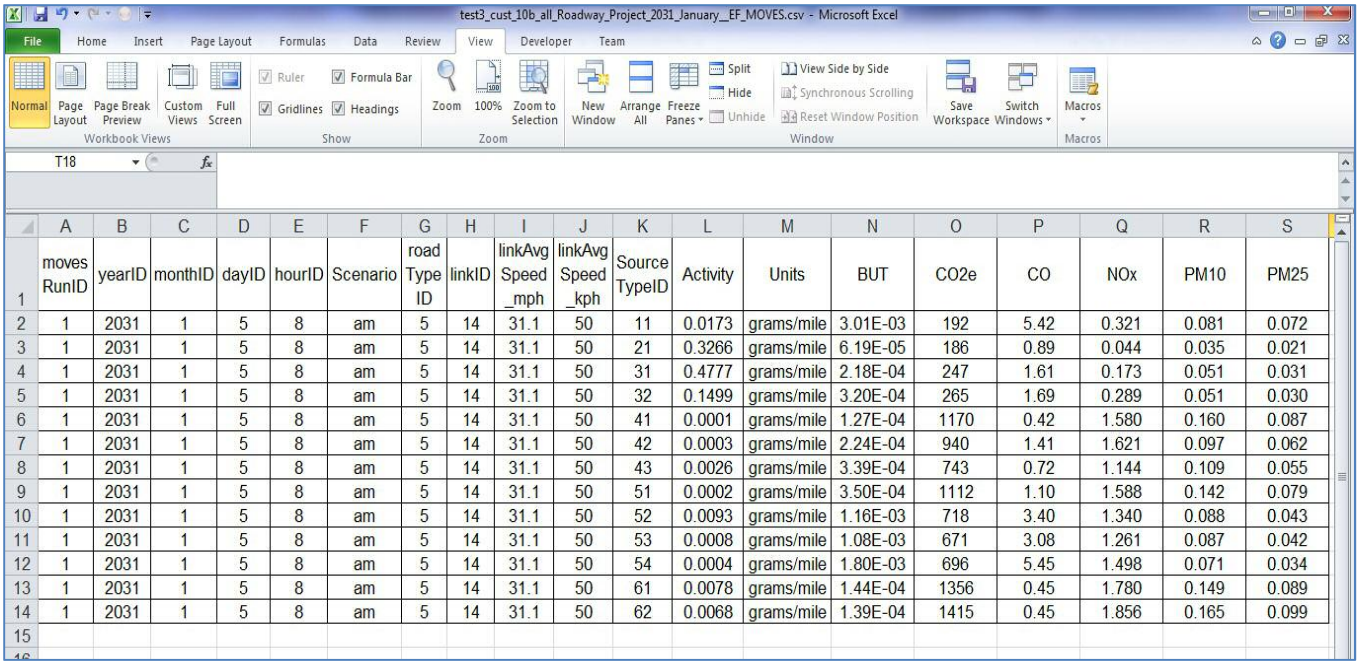
Batch File to Run MOVES

After generating the input databases, users can run the second batch file that runs MOVES for the selected hours (scenarios). The batch file uses a command line interface to run MOVES. Since the batch file uses the same MOVES command line interface used by MOVES GUI, the tool has no effect on the run time. In addition, the batch file cannot track the progress of the run. If users are interested to see the run progress, they can use MOVES GUI to run the model, instead of the command line interface.

Batch File to Post-Process MOVES Output

The third and final batch file "RunPostProcessor.BAT" produces emission rates for a CAL3QHCR model. This batch file runs a MySQL script generated by the tool to produce the emission rates based on user-selected output options. By default, this script produces emission rates for all selected hours, road types, and pollutants in a single comma delimited file (CSV) for all MOVES source use types. It can also aggregate emissions into several FHWA groups as outlined previously. The post-processing scripts generated by the tool also contain the appropriate code to combine brakewear and tirewear emissions into total PM emissions. A screenshot of a sample output is presented in **Figure 10** for a subset of pollutants.

Figure 10: A screenshot of output file produced by the post-processing batch file.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	moves RunID	yearID	monthID	dayID	hourID	Scenario	road Type ID	linkID	linkAvg Speed _mph	linkAvg Speed _kph	Source TypeID	Activity	Units	BUT	CO2e	CO	NOx	PM10	PM25
2	1	2031	1	5	8	am	5	14	31.1	50	11	0.0173	grams/mile	3.01E-03	192	5.42	0.321	0.081	0.072
3	1	2031	1	5	8	am	5	14	31.1	50	21	0.3266	grams/mile	6.19E-05	186	0.89	0.044	0.035	0.021
4	1	2031	1	5	8	am	5	14	31.1	50	31	0.4777	grams/mile	2.18E-04	247	1.61	0.173	0.051	0.031
5	1	2031	1	5	8	am	5	14	31.1	50	32	0.1499	grams/mile	3.20E-04	265	1.69	0.289	0.051	0.030
6	1	2031	1	5	8	am	5	14	31.1	50	41	0.0001	grams/mile	1.27E-04	1170	0.42	1.580	0.160	0.087
7	1	2031	1	5	8	am	5	14	31.1	50	42	0.0003	grams/mile	2.24E-04	940	1.41	1.621	0.097	0.062
8	1	2031	1	5	8	am	5	14	31.1	50	43	0.0026	grams/mile	3.39E-04	743	0.72	1.144	0.109	0.055
9	1	2031	1	5	8	am	5	14	31.1	50	51	0.0002	grams/mile	3.50E-04	1112	1.10	1.588	0.142	0.079
10	1	2031	1	5	8	am	5	14	31.1	50	52	0.0093	grams/mile	1.16E-03	718	3.40	1.340	0.088	0.043
11	1	2031	1	5	8	am	5	14	31.1	50	53	0.0008	grams/mile	1.08E-03	671	3.08	1.261	0.087	0.042
12	1	2031	1	5	8	am	5	14	31.1	50	54	0.0004	grams/mile	1.80E-03	696	5.45	1.498	0.071	0.034
13	1	2031	1	5	8	am	5	14	31.1	50	61	0.0078	grams/mile	1.44E-04	1356	0.45	1.780	0.149	0.089
14	1	2031	1	5	8	am	5	14	31.1	50	62	0.0068	grams/mile	1.39E-04	1415	0.45	1.856	0.165	0.099
15																			

USER EXPERIENCES

The MOVES utility tool has initially been written for Ontario-specific roadway air quality assessment projects. Since then the tool has been used extensively to generate emission rates for a variety of applications including CAL3QHCR and AERMOD (with some additional post-processing). It has also been used to generate datasets for start emissions from transit facilities and parking lots. The tool has been used in several Canadian and the US locations for such applications.

File preparation time has been reduced greatly by using the tool. The tool generally takes fewer person-hours to generate emission rates than using MOBILE6.2 when using default information (not including run times).

LIMITATIONS

Although the tool succeeds at simplifying the pre- and post-aggregation effort it has some shortcomings inherent in its dependence on VBA within a Microsoft Excel spreadsheet.

The tool is currently unable to handle multiple zones automatically, although this can be manually included within the populated database tables. In case of a multiple zone applications, the tool can still be used to generate template tables and batch files.

Generally, the uses average speed by link but uses MOVES default operating mode distributions adjusted for idling for intersection approach links. Options are also provided to adjust average speeds based on level of congestion. The second-by-second drive schedule and operating mode distribution options have yet to be implemented.

In some cases, users are required to update the database tables to meet project-specific requirements. This is especially true for any international application outside of the US and Canada.

The tool can handle project scale only. A similar tool has been created for MOVES county scale but the two are not integrated into one interface.

FUTURE WORK

Several enhancements and new features are planned for future versions. Since the original intent was to use the tool internally, any improvements to the tool are need-based. Some of the features planned for future versions are listed below:

- User-define second-by-second drive cycle and operating mode distribution.
- Enhanced relative humidity calculator for custom domain.
- Multiple zone input.
- Improved hour-by-hour free flow speed algorithm.
- Addition of multiple speed calculation options for approach and departure links.
- Addition of ‘County’ scale.

CONCLUSIONS

The MOVES utility tool is an effective tool for performing pre- and post-processing steps involved in project-level MOVES runs. The program serves as a one-stop solution for a project level MOVES run that can calculate emission rates for each hour of a day in a single session for projects involving roadways, transit facilities, and extended idling activities. File preparation time is greatly reduced using the tool.

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KEY WORDS

MOVES
Project Scale
Operating Mode
Automated Model Setup
Automated Pre- and Post-Processing