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Fuel Consumption Prediction Model (FCPM) User Guide

by Greg Dogum, William Fisher, Mark Hanna, and Timothy Pohland

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This user guide is intended to familiarize new and existing users with the features and functions of the Fuel Consumption Prediction Model (FCPM). Topics covered include the vehicle database, duty cycle selection, viewing and adding fuel curves, and operating the model.

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Executive Summary

This user guide is intended to familiarize new and existing users with the features and functions of the Fuel Consumption Prediction Model (FCPM). FCPM is used to estimate military ground vehicles’ fuel consumption in support of analyses and data requests. Topics covered include the vehicle database, duty cycle selection, viewing and adding fuel curves, running the model, and topics of special interest.

1. INTRODUCTION

This user guide is intended to familiarize new and existing users with the features and functions of the Fuel Consumption Prediction Model (FCPM), Version 4.x. In Section 2, each tab in the main FCPM interface is detailed, with images and accompanying descriptions. Section 3 explains the process of viewing specific fuel consumption (SFC) curve data within the fuel model and then details the process of adding vehicle and SFC data to the model. Section 4 includes lessons learned and workarounds not included in the tab-specific write-ups to increase the user's efficiency or capabilities when using the model. Lastly, an example FCPM run is provided, which takes the reader from 1) vehicle selection to 2) duty cycle creation and then 3) model execution. The example gives a holistic view of how FCPM can be used to support data request and analysis cases.

FCPM is used to estimate military ground vehicles' fuel consumption in support of analyses and data requests. Since the mid-2000s, FCPM has been used in that context to support a multitude of Army and DoD studies. These analyses are traditionally provided to senior Army leaders in support of acquisition and sustainment-related decisions. A formal Verification, Validation, and Accreditation process was successfully completed in December 2019. The primary FCPM capabilities are as follows:

- Predicts steady-state moving/nonmoving fuel consumption on a variety of on- and off-road terrain.
- Accounts for:
    - Vehicle speeds, weights, vehicle cone index, and engine sizes.
    - Terrain grades, and soil strengths (i.e., rating cone index) and types.
    - Wheeled and tracked vehicle configurations.
- Expands on available fuel consumption test data.
- Contrasts fuel consumption characteristics of study candidates.
- Provides various formats to fulfill DoD analytical community data requests.

FCPM limitations include the following:

- Steady-state only: The calculation of power demand does not consider vehicle system inertia, acceleration, deceleration or humanistic driving factors.
- Torque converter modeled in locked mode only: FCPM cannot predict a reasonable fuel rate when a vehicle is operated with the torque convertor unlocked and at low fixed gears.
- Snow and ice conditions are not modeled, as these introduce wheel slip, which cannot be modeled in a steady-state manner.

2. FCPM USER GUIDE

2.1 Model Interface Description and Details

Figure 1 shows the Home screen when the model is opened within the Analysis/ Platforms tab. Navigating the model is performed using the tabs in the upper-left, enlarged here (Figure 2). The following sections detail the elements of each tab.

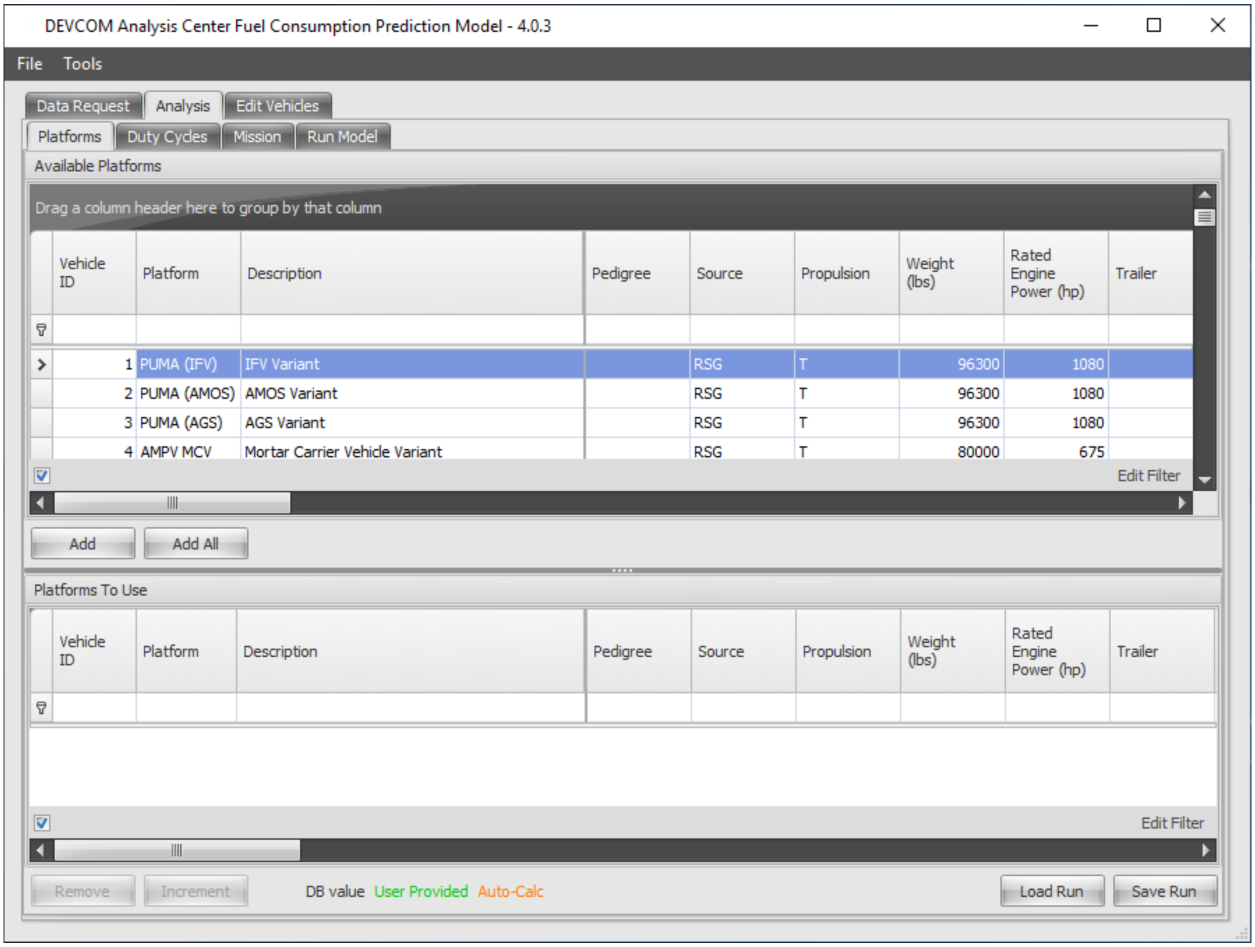

Figure 1. Analysis tab, Platform sub-tab view

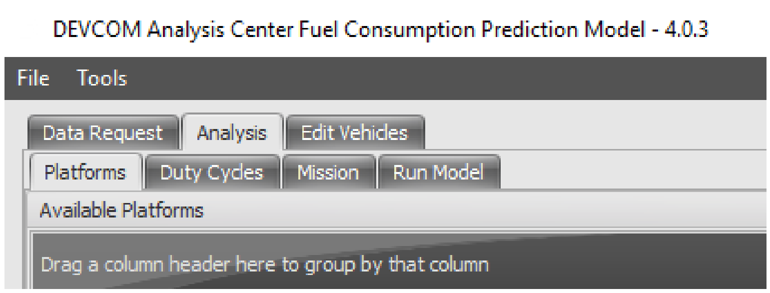

Figure 2. Zoom of model navigation

Before beginning a modeling effort, the user must choose whether they want to operate within the Data Request or Analysis mode. Generally, data requests should be worked within the Data Request tab, and all other modeling/analysis should be done in the Analysis tab. Although the modeling process flow for each is the same, there are several notable differences in the Platforms and Duty Cycle tabs for each. For example, there are Standard Mobility application programming interface (API) (STNDMob API or, simply, STNDMob) fields on the Vehicles tab and Duty Cycle tab options in the Data Request mode. Data Request and Analysis modes are discussed in detail in Sections 2.2 and 2.3, respectively.

2.2 Data Request Tab

2.2.1 Vehicles

The Vehicles tab, shown in Figure 3, is arranged as follows:

(1) Vehicle Database: The vehicle database includes most vehicles (and vehicle variants) previously modeled since the creation of the original Excel-version of FCPM in the mid-2000s. Database entries can be edited using the Edit Vehicles tab.

(2) Current Vehicles in Use: Vehicles are selected from the database **(1)** by double-clicking anywhere on the desired vehicle's row. This action copies that vehicle's row into the Platforms to Use window **(2)**. From there, individual vehicle characteristics (e.g., vehicle weight, engine horsepower, vehicle cone index, aerodynamic coefficient of drag) may be edited to suit the current analysis. Characteristics changed here do not modify these characteristics in the database, but for that run only. Instructions regarding how to change values within the Access database are found in Section 4, Adding New/Editing Existing Vehicles.

(3) Load/Save Run: These buttons either load or save vehicles in the Platforms to Use window. Clicking either button results in a pop-up window allowing the user to see details of previously saved runs (name, author, date) or to provide details of the current modeling run that you wish to save.

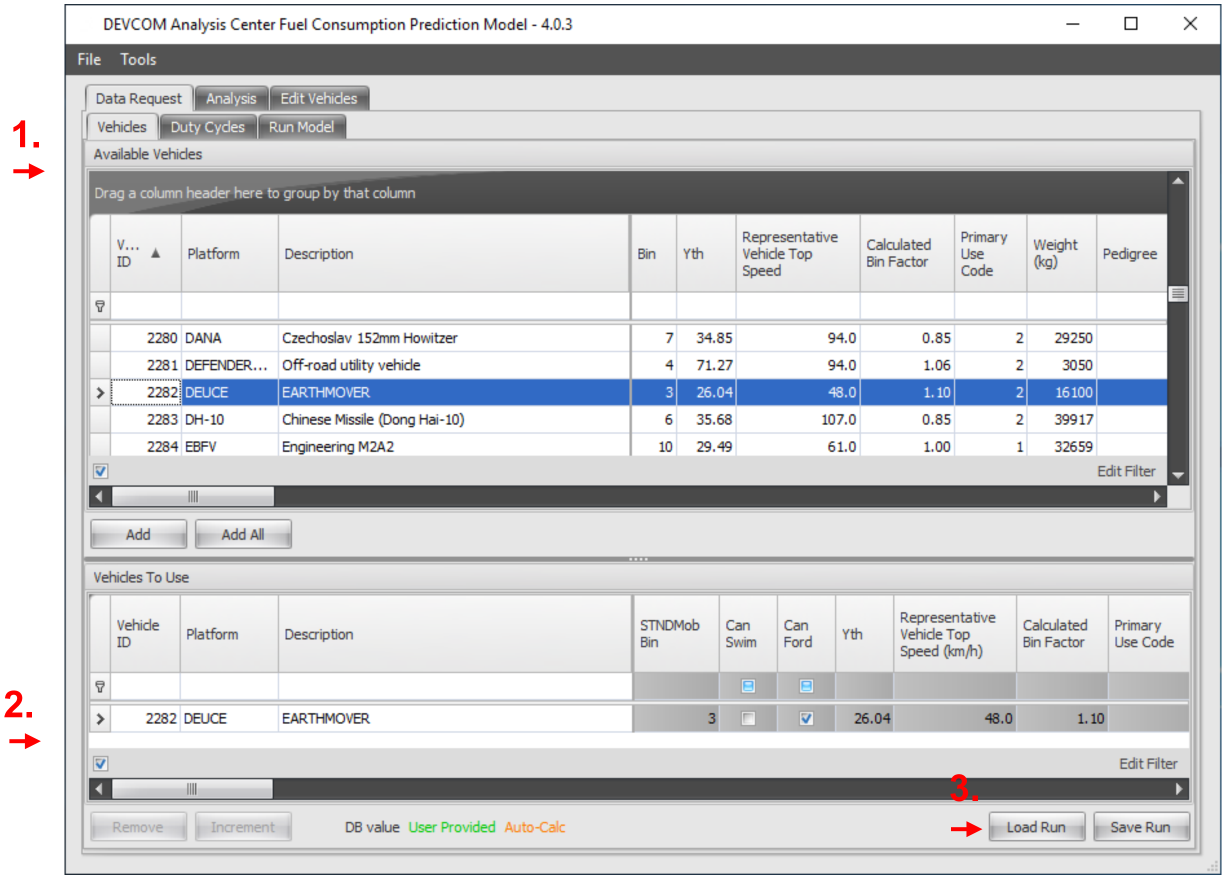

Figure 3. Vehicles tab

There are several options for navigating and filtering the vehicles within the Available Platforms window. The blank row at the top of each window acts as a search box for each column. Searches are performed in real time; as an example, if you type “M2A” in the Platform column, you will get results that include M2A2, M2A3, M2A4, and so on. Columns can be sorted alphabetically or large to small/small to large depending on the data type, and complex filters can be created by right-clicking on the column headers.

Column descriptions from left to right are shown in Table 1.

Table 1. Column descriptions

Column Name	Description
Vehicle ID	Unique vehicle identification number.
Platform	Army model number (e.g., M2A3 Bradley).
Description	Description sometimes includes add-ons, such as armor packages.
Pedigree	"OPLOGSet" denotes if vehicle characteristic data has been confirmed as accurate and used in a major data request.
Source	Source of characteristic information if available.
Propulsion	T for "tracked," W for "wheeled."
Weight (lb)	Vehicle weight; armor packages are normally included in platform or description box.
Rated Engine Power (hp)	Engine power listed by vehicle manufacturer.
Trailer	This denotes whether vehicle configuration accounts for the weight of a trailer, NOT if it can use a trailer.
Frontal Area (ft^2)	Frontal area used for air resistance calculation. Normally provided by Aberdeen Test Center.
Coefficient of Drag	A coefficient estimate based on the similar aerodynamic properties of like vehicles (e.g., size and shape); lower values indicate lower drag.
Single Pass VCI (psi)	Minimum soil strength for a vehicle to consistently complete one pass successfully, calculated from vehicle characteristics.
Tire Pressure (psi)	Specified tire pressure for wheeled vehicles, if available.
Usable Fuel Capacity (gal)	Listed fuel capacity in gallons.
No Load (Idle) Burn Rate (gal/h)	No load fuel consumption rate from test; if **not** specified, the value will be calculated based on the chosen vehicle-level SFC curve.
Fuel Type	JP-8/F-24 or DF-2 as tested; other fuel types are available.
Drivetrain Look-up	Drop-down menu to select the vehicle-level SFC curve to be used for the fuel consumption estimate.
Governed Speed (mph)	Can be added if governed speed is listed, though this is not common.
Driveline Eff. Improvement Factor	Used to increase or decrease driveline efficiency for experimental purposes.
Moving Accessory Efficiency	Commonly modeled values: 75% for standard alternator, 90% for integrated starter generator (ISG). Moving and nonmoving accessory efficiencies are traditionally modeled at the same value. FCPM allows the flexibility to model efficiencies differently if so desired.
Nonmoving Accessory Efficiency	Commonly modeled values: 75% for standard alternator, 90% for ISG. Moving and nonmoving accessory efficiencies are traditionally modeled at the same value. FCPM allows the flexibility to model efficiencies differently if so desired.
Moving Electrical Load (hp)	Mission electrical load (hp) in excess of the vehicle's innate and test equipment power loads. Moving and nonmoving electrical loads are traditionally modeled at 6.7 hp but can vary significantly given the expected mission loads for a particular vehicle and mission. FCPM allows the flexibility to model different moving and nonmoving electrical loads if so desired.
Nonmoving Electrical Load (hp)	Mission electrical load (hp) in excess of the vehicle's innate and test equipment power loads. Moving and nonmoving electrical loads are traditionally modeled at 6.7 hp but can vary significantly given the expected mission loads for a particular vehicle and mission. FCPM allows the flexibility to model different moving and nonmoving electrical loads if so desired.

Table 1. Column descriptions (continued)

Column Name	Description
Nationality	Country of origin.
Comments	Space to capture information not included elsewhere.
Original Author	Automatically populates based on user that created the vehicle.
Date Created	Automatically populates.
Last Edited By	Automatically populates.
Date Last Edited	Automatically populates.
Security Classification	All unclassified values for unclassified FCPM version; potentially some classified entries in SECRET version of FCPM.

Additional details regarding the functioning of the Standard Mobility API can be found in Fisher and Webb (2006), Baylot and Gates (2002), and Baylot et al. (2005).

The following input parameters are required to determine the maximum safe speed of a specific vehicle on defined conditions:

- Vehicle Bin
- Climate Zone
- Visibility (roads/trails)
- Visibility–Obstacle Combination (cross-country only)
- Road Type (roads, trails, or cross-country)
- Surface Condition (dry, wet, snow)
- Soil Trafficability Group Joint Simulation (STGJ)
- Vehicle Pitch (i.e., terrain slope) (%) (-40, -30, -20, -10, 0, 10, 20, 30, 40 [cross-country]; -15, -12, -8, -4, 0, 4, 8, 12, 15 [road/trails])

Tables 2 and 3 offer additional information regarding the Standard Mobility speed predictions. Table 2 addresses the STNDMob fidelity levels used within FCPM (e.g., Level 1, Fidelity 1 and Level 1, Fidelity 2). There is a STNDMob Level 2 Medium Fidelity (i.e., Level 2, Fidelity 3 and Level 2, Fidelity 4), but STNDMob Level 2 functionality is not utilized within FCPM. Table 3 identifies the number of terrain and environmental combinations, totaling 3,688,544, that STNDMob considers including terrains (cross-country, road, trails, and road/trails), environmental conditions (dry, wet, snow), climate zones, Mobility Look Up (MLU) (i.e., identifies the general characteristics of the terrain), Visibility-Obstacle combinations (VISOBS), slopes, and representative vehicle types.

Table 2. FCPM using STNDMob for maximum safe speed predictions

Fidelity		Prediction Method
Level 1 - Low	1	• Speed prediction (i.e., maximum safe operating speed given the terrain and conditions) obtained from STNDMob speed tables (i.e., look-up tables) • Speed tables based on pre-generated NRMM results • Twelve "representative" vehicles used to characterize tracked or wheeled ground vehicles • STNDMob logic is used to select a representative vehicle (see Table 5), whose mobility characteristics best match those of the "specific" vehicle of interest • Defined sets of terrain / environmental conditions • Based on the representative vehicle and terrain/environmental conditions, STNDMob extracts a speed prediction from the appropriate speed table
	2	• Speed prediction obtained by multiplying the Fidelity 1 prediction by a "bin factor" • Unique bin factor is based on the mobility characteristics of the specific vehicle of interest relative to its representative vehicle

Table 3. STNDMob speed table

Terrain	Scenario	Climate Zone	MLU	VISOBS	Slope	Vehicle	TOTAL
Cross-Country	DRY	4	187	16	9	12	1,292,544
Cross-Country	WET	4	187	16	9	12	1,292,544
Cross-Country	SNOW	3	187	16	9	12	969,408
Road/Trail	DRY	4	24	4	9	12	41,472
Road/Trail	WET	4	24	4	9	12	41,472
Road	SNOW	3	3	4	9	12	3,888
Trail	SNOW	3	21	4	9	12	27,216
							3,668,544

Table 4 and Figure 4 offer additional information about vehicle fields specifically related to data requests in FCPM.

Table 4. Vehicle field descriptions for data request

Column Name	Description
STNDMob Bin	Representative Vehicle from Standard Mobility Model (Table 5)
Can Swim	Check box if "yes" affects bin calculation
Can Ford	Check box if "yes" affects bin calculation
Yth	Standard Mob Calculation
Rep. Vehicle Top Speed (km/h)	Standard Mob Calculation
Calculated Bin Factor	Standard Mob Calculation
Primary Use Code	Vehicle Group Type: 1 – Amphibious Combat Vehicle (ACV) 2 – Truck or Other 3 – Heavy Equipment Transporter (HET)
Weight (kg)	Vehicle weight in kilograms for Standard Mob Calculation

Figure 4. Additional vehicle fields for data request

STNDMob Bin	Can Swim	Can Ford	Yth	Representative Vehicle Top Speed (km/h)	Calculated Bin Factor	Primary Use Code	Weight (kg)
4	☐	☑	60.68	94.0	0.96	2	9424
4	☐	☑	61.27	94.0	1.01	2	9285
4	☐	☑	61.31	94.0	1.01	2	9276

Table 5 provides detail on the representative vehicles for each bin.

Table 5. Representative vehicle for each bin number and description

Bin no.	Representative vehicle	Description
1	M1A1	High-Mobility Tracked
2	M270 MLRS	Medium-Mobility Tracked
3	M60 AVLB	Low-Mobility Tracked
4	M1084 MTV	High-Mobility Wheeled
5	M985 HEMTT	Medium-Mobility Wheeled
6	M917 Dump Truck	Low-Mobility Wheeled
7	M1084/M1095	High-Mobility Wheeled w/Towed Trailer
8	M985/M989	Medium-Mobility Wheeled w/Towed Trailer
9	M911/M747 HET	Low-Mobility Wheeled w/Towed Trailer
10	M113A2	Tracked Amphibious Combat Vehicle
11	LAV25	Wheeled Amphibious Combat Vehicle
12	Unmanned (ATV)	Unmanned Kawasaki Light ATV

ATV: all-terrain vehicle.

2.2.2 Duty Cycles

Within the Data Request tab, the STNDMob duty cycle options include STGJ, MLU (mobility look-up), Vis Obstacles, Visibility, Slopes, Climate Zone, and Surface Conditions (Figure 5). Most of these selections can be made by clicking to highlight (Shift- or Control-click to select multiple) desired conditions on the left window and selecting the Add >> button. Duty cycle parameters are saved or loaded using the buttons at the lower-right corner of the window.

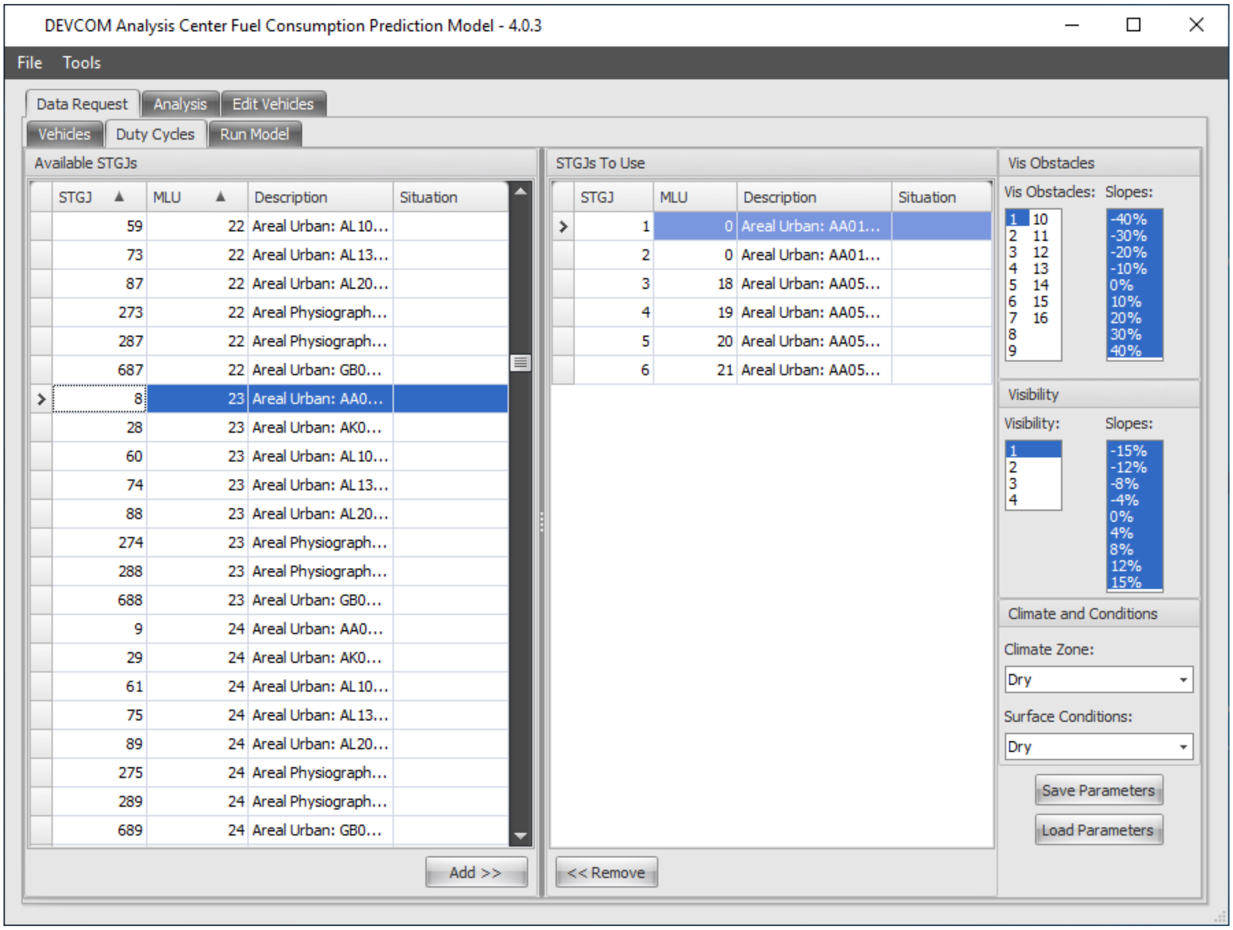

Figure 5. Duty cycle view for data request

Tables 6–9 provide detail on duty cycle fields, climate zone descriptions, visibility field descriptions, and visibility obstacle field descriptions.

Table 6. Field descriptions

Name	Description
STGJ	Surface Trafficability Group Joint Simulation System (JSIMS): a terrain code description
MLU	Mobility Look-up: gives a standard mobility max speed bin
Description	Description of STGJ code
Vis obstacles	See Table 9
Slopes	Terrain grade
Visibility	See Table 8
Climate Zone	See Table 7
Surface Conditions	Dry or wet terrain conditions

Table 7. Climate zone descriptions

Climatic zones (6)	Subclimate zones (13)
Tropical Rainy	1. Tropical Rainforest 2. Tropical Savanna
Dry	1. Steppe 2. **Desert**
Humid Mesothermal ***(e.g., subtropical regions)***	1. Mediterranean or Dry Summer Subtropical 2. **Humid Subtropical** 3. Marine West Coast
Humid Microthermal ***(e.g., temperate regions)***	1. **Humid Continental, Warm Summer** 2. Humid Continental, Cool Summer 3. Sub Arctic
Polar	1. Tundra 2. Ice Caps
Undifferentiated Highlands ***(e.g., mountainous regions)***	1. **Undifferentiated Highlands**

Terrain databases have been produced for these climatic zones.
Subclimate zones (**bold text**) were selected to represent the four major climate zones.

Table 8. Visibility field descriptions

Visibility (road/trail)	Visibility distance (ft)	Visibility distance definitions
1	300	Virtually unlimited visibility, distant spacing of vehicles, no precipitation, day-time lighting, headlights at night, no obscurants, good contrast
2	100	Somewhat limited visibility, distant spacing of vehicles, light precipitation, day-time lighting, headlights at night, obscurants or blackout w/vision enhancement devices, fair contrast
3	50	Limited visibility, close spacing of vehicles, heavy precipitation/fog, low solar/lunar illumination, heavy obscurants w/vision enhancement devices, poor contrast
4	25	Very limited visibility, close spacing of vehicles, no solar/lunar illumination, heavy obscurants and/or blackout w/no enhanced vision devices, very poor contrast

[a] Visibility only factored for roads and trails; obstacles not considered.

Table 9. Visibility obstacle field description

Visibility - obstacle combinations (i.e., VISOBS) (cross-country)	Visibility distance (ft)	Obstacle spacing (ft)	Obstacle spacing definitions
1	300	150	Uncluttered
2	100	150	
3	50	150	
4	25	150	
5	300	30	Cluttered due to urban or industrial area damage, concentration of damaged vehicles, cratering, rubble, rock outcrops, some vegetation
6	100	30	
7	50	30	
8	25	30	
9	300	25	
10	100	25	
11	50	25	
12	25	25	
13	300	20	*Severely* cluttered due to heavy urban or industrial area damage, *dense* concentration of damaged vehicles, cratering, rubble, rock outcrops, dense vegetation
14	100	20	
15	50	20	
16	25	20	

[a] Visibility and obstacles are both considered for cross-country. Refer to visibility distance definitions here in association with the obstacle spacing definitions.

2.2.3 Run Model

The Run Model tab (Figure 6) is the final step to producing modeling results. This tab walks the user through the process of selecting the final details before generating results. The tab is broken down into the following:

1. Output Format
2a. How to Handle PL [Power Limited]
3. Undefined Duty Cycle
4. Output File Destination
5. Run Model

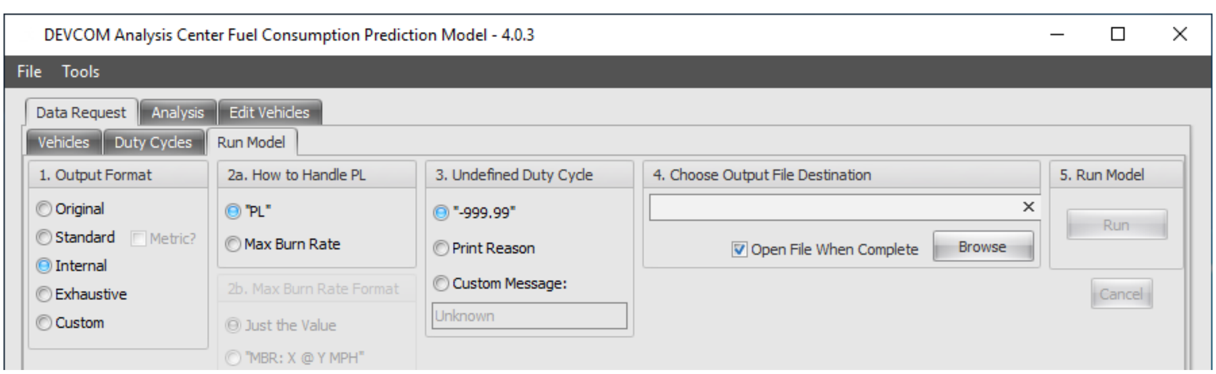

Figure 6. Data Request mode Run Model sub-tab

2.2.3.1 Output Format

This section describes the items and the differences between the various output templates that have been developed. Figure 7 shows the output format options. The Original, Standard, Internal, and Exhaustive templates, as the most frequently used, are addressed within this section. The Custom template option allows the user to specify which parameters are desired in order to build a unique output format. The Custom template option is not discussed further in this guide.

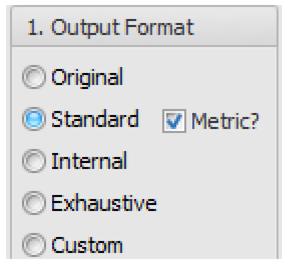

Figure 7. Screenshot of Output Format options

The Original template format, shown in Table 10, provides the user with the following output parameters for a data request run. The Standard output places vehicles of interest into columns. This file output format is suitable for a few vehicles, as each vehicle has its own dedicated speed and consumption (i.e., burn) rate columns (the values in italics).

- Climate Zone
- Condition
- Vis
- VisOb
- STGJ
- MLU
- NRMM Soil Type
- Soil Strength (RCI [rating cone index])
- Slope (%)
- Situation
- *Full Speed (m/s)*
- *Full Speed (mph)*
- *Full Speed Burn Rate (gal/h)*
- *2/3 Speed (mph)*
- *2/3 Speed Burn Rate (gal/h)*
- *1/3 Speed (mph)*
- *Idle Speed (0 mph)*
- *Idle Burn Rate (gal/h)*

Table 10. Screenshot of example Original output

Following output produced by FCPM version 4.0.2																		
										NOTIONAL VEHICLE								
										Bin: #								
										ID: #								
Climate Z	Condition	Vis	VisOb	STGJ	MLU	NRMM So	Soil Stren	Slope (%)	Situation	Full Spee	Full Spee	Full Spee	2/3 Speed	2/3 Speed	1/3 Speed	1/3 Speed	Idle Spee	Idle Burn
Dry	Dry		1	510	107	1	37	-10	Normal	18.5	41.4	11.7	27.6	7.55	13.8	4.73	0	2.18
Dry	Dry		1	510	107	1	37	0	Normal	8.8	19.7	12.92	13.1	9.61	6.6	6.18	0	2.18
Dry	Dry		1	510	107	1	37	10	Normal	5.4	12	13.13	8	9.87	4	6.36	0	2.18
Dry	Dry		2	510	107	1	37	-10	Normal	14.1	31.5	8.58	21	6.05	10.5	4.2	0	2.18
Dry	Dry		2	510	107	1	37	0	Normal	8.8	19.7	12.92	13.1	9.61	6.6	6.18	0	2.18
Dry	Dry		2	510	107	1	37	10	Normal	5.4	12	13.13	8	9.87	4	6.36	0	2.18
Dry	Dry		3	510	107	1	37	-10	Normal	9.1	20.4	5.92	13.6	4.7	6.8	3.65	0	2.18
Dry	Dry		3	510	107	1	37	0	Normal	8.8	19.7	12.92	13.1	9.61	6.6	6.18	0	2.18
Dry	Dry		3	510	107	1	37	10	Normal	5.4	12	13.13	8	9.87	4	6.36	0	2.18

The Standard template format, shown in Table 11, provides the user with the following parameters as the output (columns) of a data request run; the vehicles are all individual rows. As an additional option, these values can be provided in metric units as well.

- Vehicle
- Climate Zone
- Soil Condition
- Vis
- VisOb
- Slope (%)
- Full Speed (mph)
- Full Speed Burn Rate (gal/h)
- 2/3 Speed (mph)
- 2/3 Speed Burn Rate (gal/h)
- 1/3 Speed (mph)
- Idle Speed (mph)
- Idle Speed Burn Rate (gal/h)
- Percent Loaded
- Fuel Type
- Classification
- Propulsion
- Loaded Weight (lb)
- Power (hp)
- Fuel Capacity (gal)
- Speed Bin
- STGJ Code
- MLU
- STGJ Description

Table 11. Screenshot of example Standard output format

Following output produced by FCPM version 4.0.2																								
Vehicle	Climate Zo	Soil Condi	Vis	VisOb	Slope (Pe	Full Speec	Full Speec	2/3 Speed	2/3 Speed	1/3 Speed	1/3 Speed	Idle Speec	Idle Speec	Percent Lo	Fuel Type	Classificat	Propulsio	Loaded W	Power (hp	Fuel Capa	Speed Bin	STGJ Code	MLU	STGJ Desc
NOTIONA	Dry	Dry		1	-10	41.4	11.7	27.6	7.55	13.8	4.73	0	2.18	0	JP-8/F-24	U	T	10000	800	175	1	510	107	Areal Veg
NOTIONA	Dry	Dry		1	0	19.7	12.92	13.1	9.61	6.6	6.18	0	2.18	0	JP-8/F-24	U	T	10000	800	175	1	510	107	Areal Veg
NOTIONA	Dry	Dry		1	10	12	13.13	8	9.87	4	6.36	0	2.18	0	JP-8/F-24	U	T	10000	800	175	1	510	107	Areal Veg
NOTIONA	Dry	Dry		2	-10	31.5	8.58	21	6.05	10.5	4.2	0	2.18	0	JP-8/F-24	U	T	10000	800	175	1	510	107	Areal Veg
NOTIONA	Dry	Dry		2	0	19.7	12.92	13.1	9.61	6.6	6.18	0	2.18	0	JP-8/F-24	U	T	10000	800	175	1	510	107	Areal Veg
NOTIONA	Dry	Dry		2	10	12	13.13	8	9.87	4	6.36	0	2.18	0	JP-8/F-24	U	T	10000	800	175	1	510	107	Areal Veg
NOTIONA	Dry	Dry		3	-10	20.4	5.92	13.6	4.7	6.8	3.65	0	2.18	0	JP-8/F-24	U	T	10000	800	175	1	510	107	Areal Veg
NOTIONA	Dry	Dry		3	0	19.7	12.92	13.1	9.61	6.6	6.18	0	2.18	0	JP-8/F-24	U	T	10000	800	175	1	510	107	Areal Veg
NOTIONA	Dry	Dry		3	10	12	13.13	8	9.87	4	6.36	0	2.18	0	JP-8/F-24	U	T	10000	800	175	1	510	107	Areal Veg

"Internal" and "Exhaustive" include many additional values that are calculated during the modeling process (e.g., resistance due to slope/aerodynamic/rolling, tractive power, and total mobility power demand). These values can be used for further analysis when required. Table 12 provides a list of the output parameters for these two formats. Due to the number of columns, an example of this output format is not depicted.

Table 12 Parameter list for Internal and Exhaustive output format

Category	Internal	Exhaustive
Mobility Model	Climate Zone	Climate Zone
	Condition	Condition
	Vis	Vis
	VisOb	VisOb
	STGJ	STGJ
	MLU	MLU
	Soil Type	Soil Type
	Soil Strength (RCI)	Soil Strength (RCI)
	Slope (%)	Slope (%)
	Situation	Situation
	Speed (m/s)	Speed (m/s)
	Speed Type	Speed Type
Duty Cycle	Terrain Surface	Terrain Surface
	Speed (mph)	Speed (mph)
	Slope %	Slope %
	Soil Group	Soil Group
	Soil Strength (RCI)	Soil Strength (RCI)
	Rolling Resistance Factor	Rolling Resistance Factor
	Duty Cycle Error	Duty Cycle Error
Platform	Vehicle	Vehicle
	Current Platform	Current Platform
	Platform Configuration Description	Platform Configuration Description
	Platform Propulsion (Track/Wheel)	Platform Propulsion (Track/Wheel)
	Vehicle Weight Configuration (lb)	Vehicle Weight Configuration (lb)
	Swimming Speed (km/h)	Swimming Speed (km/h)
	Fording Speed (km/h)	Fording Speed (km/h)
	Rate Engine Power (hp)	Rate Engine Power (hp)
	Platform Frontal Area (ft^2)	Platform Frontal Area (ft^2)
	Coef. Of Drag	Coef. Of Drag
	Platform Single Pass Vehicle Cone Index (psi)	Platform Single Pass Vehicle Cone Index (psi)
	Tire Pressure PSI (if applicable)	Tire Pressure PSI (if applicable)
	Usable Fuel Capacity (gal)	Usable Fuel Capacity (gal)
	Fuel Curve	No-load Burn Rate (gal/h Idle)
	Moving ACC Eff.	Fuel Type
	Nonmoving ACC Eff.	Fuel Curve
	Moving Electrical Load (kW)	Governed Speed (mph)
	Nonmoving Electrical Load (kW)	Driveline Efficiency
	Surface Resistance Coefficient	Moving ACC Eff.
	Surface Motion Resistance (lb)	Nonmoving ACC Eff.
	Slope Resistance (lb)	Moving Electrical Load (kW)
	Aerodynamic Resistance (lb)	Nonmoving Electrical Load (kW)
	Max Tractive Power Without Accessories (hp)	Classification
	Speed (mph)	Percent Loaded

Table 12 Parameter list for Internal and Exhaustive output format (continued)

Category	Internal	Exhaustive
	Total Mobility Power Demand (hp)	Surface Resistance Coefficient
	Minimum Driveline SFC At Wheel (lb/hp-h)	Surface Motion Resistance (lb)
	Minimum Driveline SFC At Engine (lb/hp-h)	Slope Resistance (lb)
	SFC for Condition (lb/hp-h)	Aerodynamic Resistance (lb)
	Flow Rate (lb/h)	Max Tractive Power Without Accessories (hp)
	Burn Rate (gal/h)	Speed (mph)
	Fuel Economy (mpg)	Total Mobility Power Demand (hp)
Fuel Model	Range (mi)	Minimum Driveline SFC at Wheel (lb/hp-h)
	Model Output String	Minimum Driveline SFC at Engine (lb/hp-h)
		SFC for Condition (lb/hp-h)
		Flow Rate (lb/h)
		Burn Rate (gal/h)
		Fuel Economy (mpg)
		Range (mi)
		Model Output String

2.2.3.2 How to Handle PL (Power Limited)

Power limited situations arise when the desired operating condition (surface type, slope, speed, etc.) require more tractive power than the vehicle can produce. In these cases, the user has the following options for how the results will be displayed in the output:

“PL” returns the letters “PL” instead of a consumption rate, meaning that the vehicle could not meet the requested driving condition. This is often the desired format, as it indicates that the vehicle is not able to meet the demands of the requested condition.

“Max Burn Rate” returns the max theoretical consumption rate of the vehicle on that terrain condition. This approximates the vehicle traveling as fast as possible given available power, but slower than the desired speed. If this option is chosen, the user has an additional choice to display just the consumption rate or the consumption rate along with the maximum speed that the vehicle could travel on the requested terrain condition before becoming power limited. These options are shown in Figure 8.

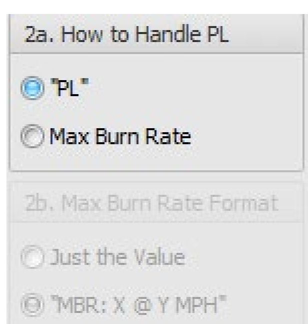

Figure 8. Screenshot of How to Handle PL options

2.2.3.3 Undefined Duty Cycle

The Run Model tab provides a way to address undefined duty cycles via the option box depicted in Figure 9. There are three scenarios that could lead to an undefined duty cycle: 1) running a swimming or fording duty cycle with an MLU of 0 (STNDMob designated this combination as a non-mobility event), 2) specifying an undefined MLU, speed, and slope combination (this occurs often when specifying a swimming or fording scenario with a nonzero slope), and 3) running the model with an unknown Unified Soil Classification System soil type. If any of the three situations occur, the option selected in the Undefined Duty Cycle area of the interface will change the Model Output String field of the output file as follows:

1. "-999.99" option will post that number.
2. "Print Reason" will write the reason for causing an undefined duty cycle (one or more of the three scenarios previously enumerated).
3. "Custom Message" allows the user to specify whatever message they wish in the output file.

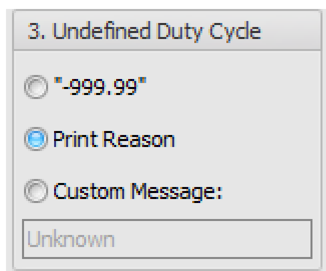

Figure 9. Screenshot of Undefined Duty Cycle

2.2.3.4 Choose Output File Destination

In this box, the user selects the output file destination on their computer and chooses if the file should open automatically when the modeling run is completed (on by default). The model will suggest a file name based on the chosen output format and date.

2.2.3.5 Run Model

When all previous choices are set, select Run Model (see Figure 6), which initiates the model and will open a spreadsheet with the results. When reviewing the results, there may be cases where the model flags a special situation. Those are typically referred to as a "no-go" scenario. This means the vehicle cannot perform under the specified condition. There are several possible reasons for a no-go: 1) the vehicle is power limited, or PL, signifying that the vehicle required more power than it has available; 2) having a rating cone index (RCI) value greater than its vehicle cone index (VCI); 3) FCPM determining the maximum safe speed for the particular MLU is 0; 4) defining a swimming/fording duty cycle for a vehicle that cannot swim/ford; and 5) an undefined duty cycle.

By default, a value of "999.99" is output for the consumption rate, enabling the customer to overlook that condition, if appropriate, for the vehicle. However, if customers wish to examine the specific reason behind a no-go event, they can choose a more detailed output.

2.3 Analysis Tab

2.3.1 Platforms

The Platforms tab, shown in Figure 10, is arranged as follows:

(1) Available Platforms (from the Vehicle Database): The vehicle database includes most vehicles and variants thereof previously modeled since the creation of the original Excel-version of FCPM in the mid-2000s. Database entries can be edited using the Edit Vehicles tab.

(2) Platforms to Use: Vehicles are selected from the database's Available Platforms **(1)** by double-clicking anywhere on the desired vehicle's row. This action copies that vehicle's row into the Platforms to Use window **(2)**. From there, individual vehicle characteristics (e.g., vehicle weight, engine horsepower, vehicle cone index, aerodynamic coefficient of drag) may be edited to suit the current analysis. Characteristics changed here are modified for that run only; they are not modified in the database. Instructions regarding how to change values within the Access database are found in the Edit Vehicles discussion (Section 4).

(3) Load Run/Save Run: These buttons either load or save vehicles in the Platforms to Use window. Clicking either button results in a pop-up window allowing the user to see details of previously saved runs (name, author, date) or to provide details of the current modeling run to be saved.

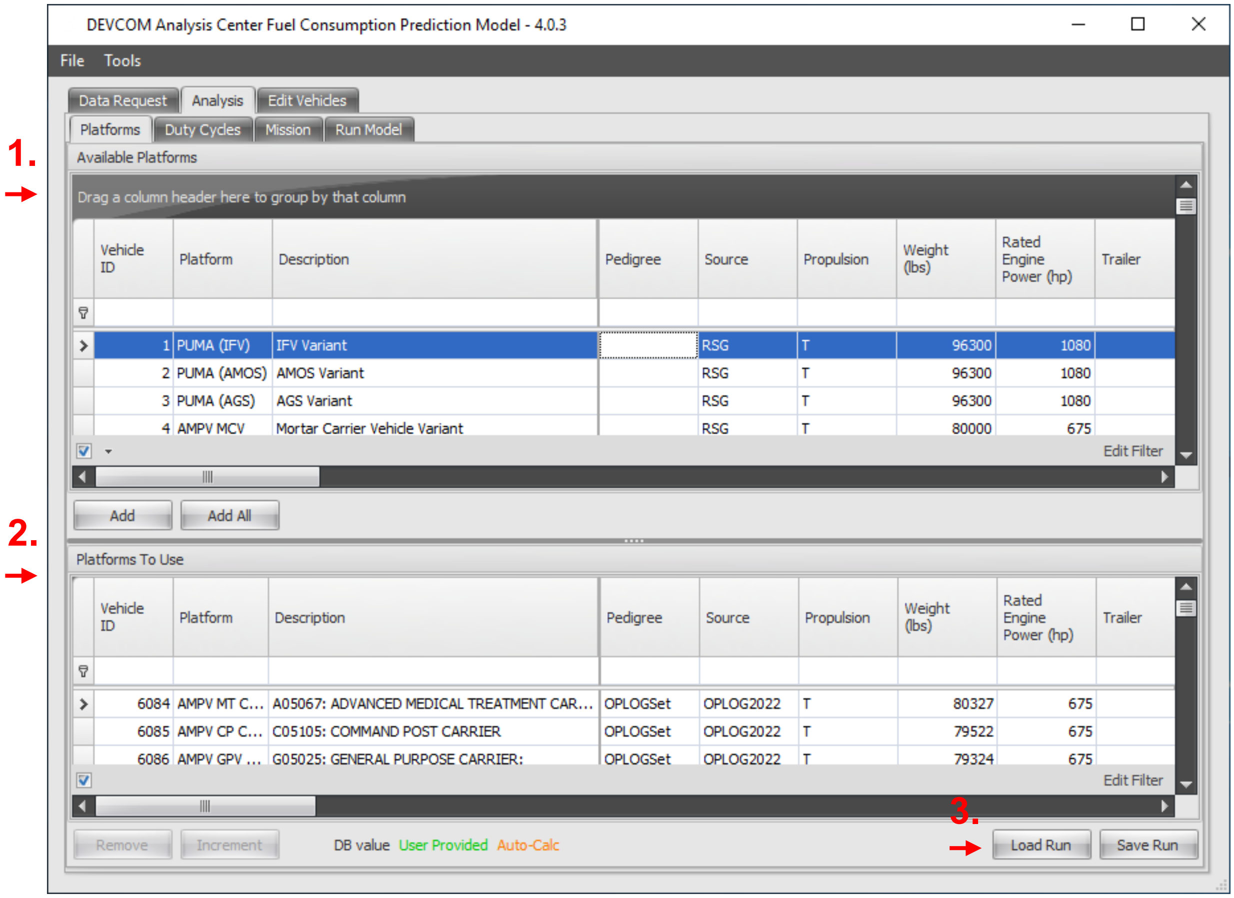

Figure 10. Platform sub-tab

There are several options for navigating and filtering the vehicles within the Available Platforms window. The blank row at the top of each window acts as a search box for each column. Searches are performed in real time; e.g., if you type “M2A” in the Platform column, you will get results that include M2A2, M2A3, M2A4, and so on. Columns can be sorted alphabetically or big/small depending on the data type, and complex filters can be created by right-clicking on the column headers. Column descriptions from left to right are as listed in Table 13:

Table 13. Column descriptions

Column Name	Description
Vehicle ID	Unique FCPM vehicle identification number
Platform	Army "model number" (e.g., M2A3 Bradley)
Description	Description sometimes includes add-on's such as armor packages
Pedigree	"OPLOGSet" denotes if vehicle characteristic data has been confirmed accurate and used in a major data request
Propulsion	T for "tracked," W for "wheeled"
Weight (lb)	Vehicle weight; (armor packages are normally included in description box)
Rated Engine Power (hp)	Engine power listed by vehicle manufacturer
Trailer	This denotes whether vehicle configuration accounts for the weight of a trailer, not if it can use a trailer
Frontal Area (ft^2)	Frontal area used for air resistance calculation. Normally provided by Aberdeen Test Center.
Coefficient of Drag	A coefficient estimate based on the similar aerodynamic properties of like vehicles (e.g., size and shape); lower values indicate lower drag
Single Pass VCI (psi)	Minimum soil strength for a vehicle to consistently complete one pass successfully, calculated from vehicle characteristics
Tire Pressure (psi)	Specified tire pressure for wheeled vehicles if available
Usable Fuel Capacity (gal)	Listed fuel capacity in gallons
No Load (Idle) Burn Rate (gal/h)	No load fuel consumption rate from test; if not specified, the value will be calculated based on the chosen vehicle-level SFC curve
Fuel Type	JP-8/F-24 or DF-2 as tested; other fuel types are available
Drivetrain Lookup	Drop-down menu to select the vehicle-level SFC curve to be used for the fuel consumption estimate
Governed Speed (mph)	Can be added if governed speed is listed, though this is not common
Driveline Efficiency Improvement Factor	Used to increase or decrease driveline efficiency for experimental purposes
Moving Generator Efficiency	Commonly modeled values: 75% for standard alternator, 90% for integrated starter generator (ISG). Moving and nonmoving accessory efficiencies are traditionally modeled at the same value. FCPM allows the flexibility to model these efficiencies differently if so desired.
Nonmoving Generator Efficiency	Commonly modeled values: 75% for standard alternator, 90% for ISG. Moving and nonmoving accessory efficiencies are traditionally modeled at the same value. FCPM allows the flexibility to model these efficiencies differently if so desired.
Moving Electrical Load (hp)	Mission electrical load (hp) in excess of the vehicle's innate and test equipment power loads. Moving and nonmoving electrical loads are traditionally modeled at 6.7 hp but can vary significantly given the expected mission loads for a particular vehicle and mission. FCPM allows the flexibility to model different moving and nonmoving electrical loads if so desired.
Nonmoving Electrical Load (hp)	Mission electrical load (hp) in excess of the vehicle's innate and test equipment power loads. Moving and nonmoving electrical loads are traditionally modeled at 6.7 hp but can vary significantly given the expected mission loads for a particular vehicle and mission. FCPM allows the flexibility to model different moving and nonmoving electrical loads if so desired.
Nationality	Country of origin

Table 13. Column descriptions (continued)

Column Name	Description
Source	Source of characteristic information if available
Comments	Space to capture information not included elsewhere
Original Author	Automatically populates based on user that created the vehicle
Date Created	Automatically populates
Last Edited By	Automatically populates
Date Last Edited	Automatically populates
Security Classification	All unclassified values for unclassified FCPM version; potentially some classified entries in SECRET version of FCPM

2.3.2 Duty Cycle Tab

The Duty Cycle tab (Figure 11) allows the user to quickly build a list of conditions to model. Conditions included are Terrain, Speed, Slope, Soil Group, RCI, and Rolling Resistance Factor.

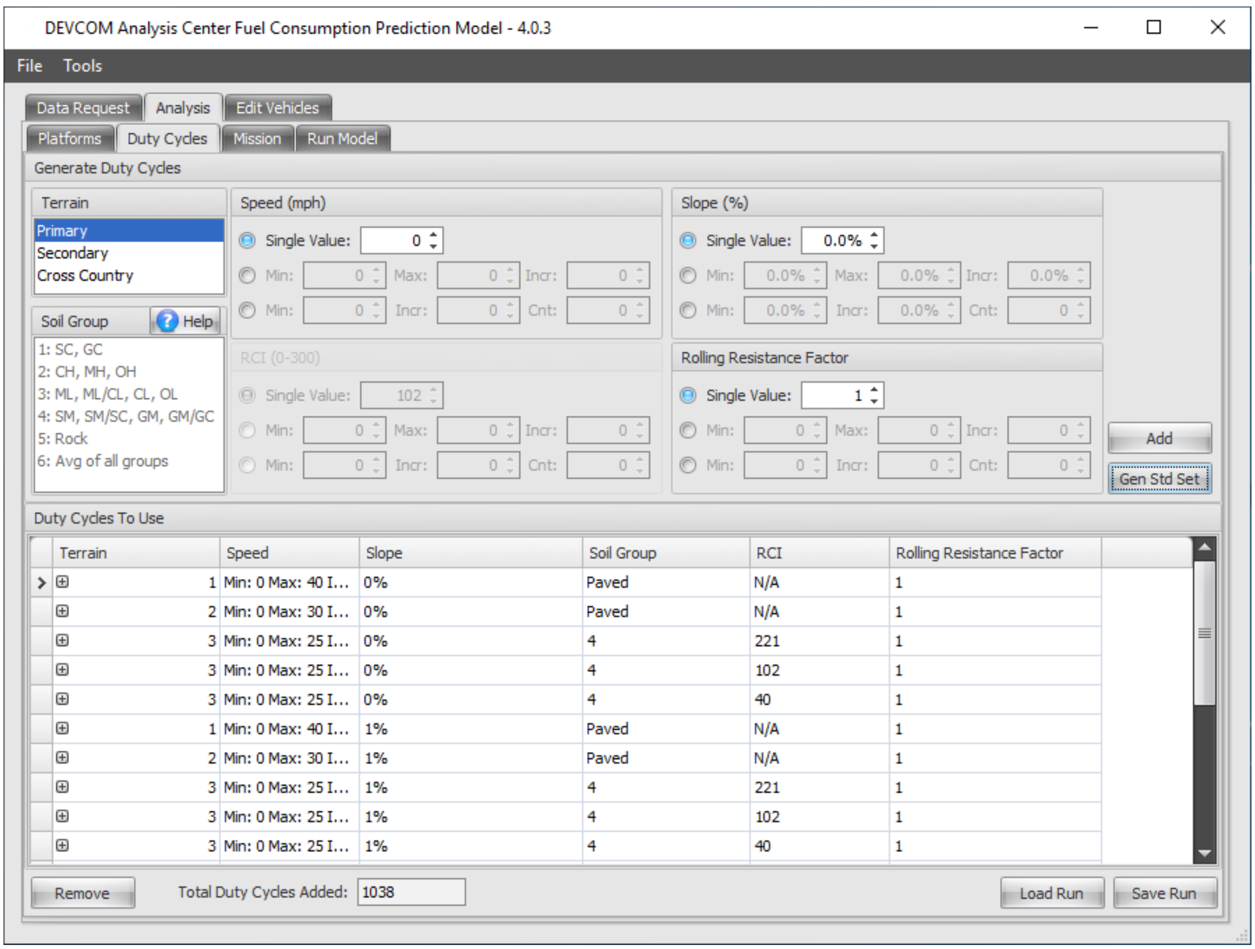

Figure 11. Analysis tab, Duty Cycle sub-tab

- ***Terrain***: Primary Road, Secondary Road, or Cross-Country.
- ***Speed***: A single speed can be specified, or a range given a min, max, and increment.
- **Slope**: A single slope (i.e., percent grade) can be specified, or a range given a min, max, and increment.
- ***Soil Group***: Only applicable for Cross-Country; Group 4 includes a mix of soil types and is used by default unless another soil group is specified.
- ***Rating Cone Index (RCI)***: A measure of soil hardness, only applicable for Cross-Country. Common values are 40 (soft), 102 (medium), and 221 (hard). A single RCI can be specified, or a range given a min, max, and increment.
- ***Rolling Resistance Factor***: Allows scaling of total rolling resistance on a percentage basis (i.e., ".9" would model a vehicle configuration at 90% of the rolling resistance of a baseline vehicle). A single rolling resistance factor can be specified, or a range given a min, max, and increment.

The Gen Std Set button generates a standard set of conditions (1038 total) covering the usual range of speeds, slopes, and RCI. This is a quick way to model all likely conditions, which can later be used with a lookup or filter to get the desired conditions.

An example process for adding a Primary Duty Cycle is as follows:

1. Select Terrain: Primary (0–40 mph, 1-mph increment)
2. Select Slope: 0%
3. Click "Add"

An example process for adding a Cross Country Duty Cycle is as follows:

1. Select Terrain: Cross-Country (1–20 mph, 1-mph increment)
2. Select Slope: 1%
3. Select Soil Group: 4
4. Select RCI: 102
5. Click "Add"

After the conditions are generated and listed in the lower window, groupings created with the "increment" function can be expanded to view the details. Duty cycles can be saved and loaded with the buttons on the bottom-right of the window.

2.3.3 Mission Tab

The Mission tab, shown in Figure 12, is arranged as follows:

(1) Mission Bank: The mission database includes the parameters that characterize a particular mission's operating profile. It essentially serves as a grouping of duty cycles for each terrain type. Each vehicle will run over the five different terrain types for the specified speeds and times. It also includes idling and auxiliary power unit (APU) usage as parameters.

(2) Platform Mission Pairings: Vehicles that were selected in the Platform tab will appear in this area automatically. However, the "Is Used" field will be initially unchecked and there will be no information (or seeded with 0's) in the bulk of the columns. Missions may be applied to a vehicle platform by first selecting one or more missions in the Mission Bank (1) and one or more vehicle platforms in the Platform Mission Pairings section (2). Clicking the Use Mission Data button in between the two areas on the left-hand side will add every combination of missions and platforms. From there, individual mission characteristics (e.g., force density and total time) may be edited to suit the current analysis.

(3) Load/Save Run: These buttons either load or save vehicles in the Platform Mission Pairings window. Selecting either button results in a pop-up window allowing the user to see details of previously saved runs (name, author, date) or to provide details of the current modeling run to be saved. This action is the same as the one on the Platform tab, so it is recommended to save runs that use the Mission tab when in the Mission tab but load when on the Platforms tab. The form that opens after clicking the Load Run button has a field called "Mission Info?", which has a checkmark for entries that include mission info (i.e., Platform Mission Pairings exist).

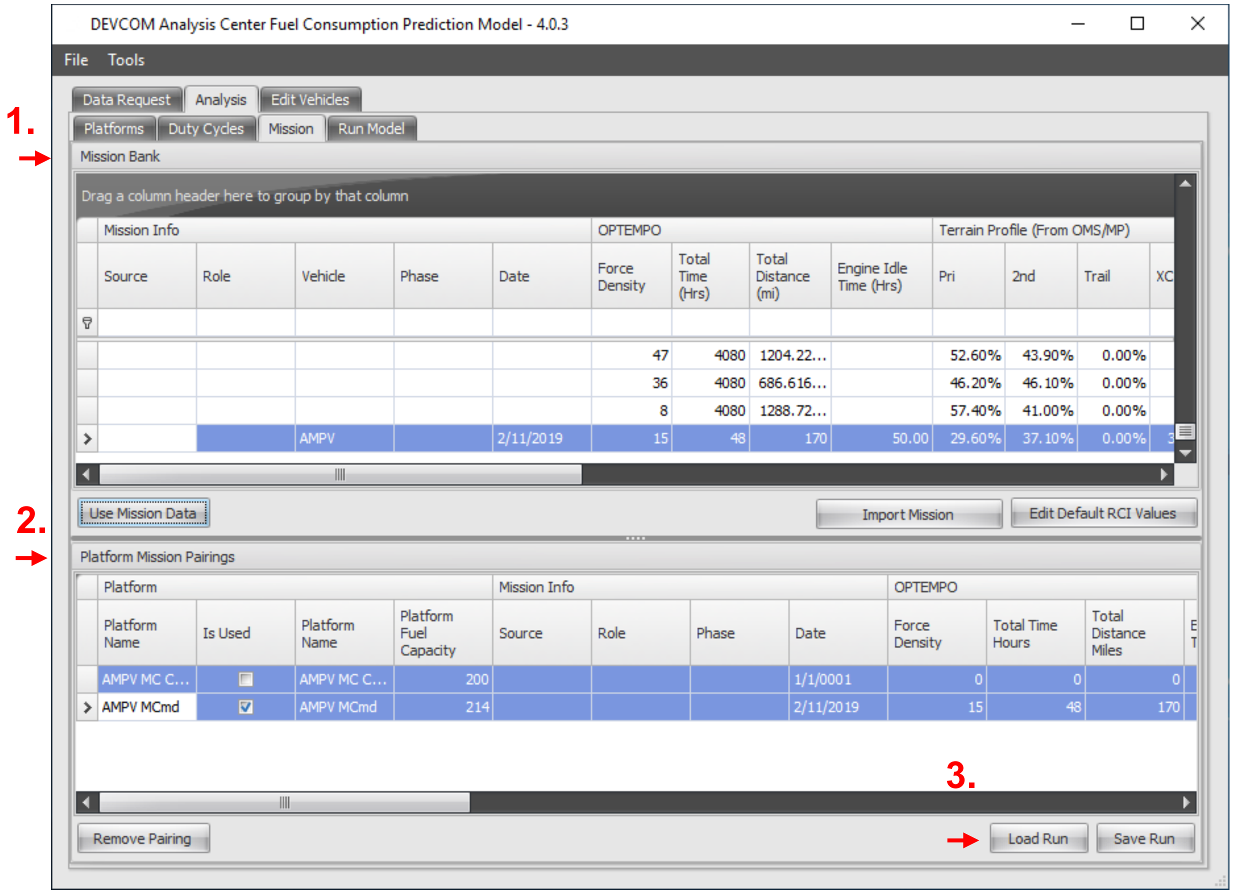

Figure 12. Mission tab graphical user interface

There are several options for navigating and filtering the vehicles within the Mission Bank. The blank row underneath the column headings acts as a search box for each column. Searches are performed in real time. Columns can be sorted alphabetically or in numerical order depending on the data type, and complex filters can be created by right-clicking the column headers and selecting the Filter Editor.

Column descriptions from left to right are listed in Table 14.

Table 14. Mission info database

Column name	Description
Source	Text field to reference where the mission profile came from.
Role	Identifies mission role (i.e., Medical Treatment or Medical Evacuation).
Vehicle	Text field to indicate which platform the mission profile was intended for.
Phase	Used to identify multiphase missions (i.e., “Seize,” “Stabilize,” “Sustain”).
Date	Date of mission creation, tied to an official document.
Force Density	The number of that particular vehicle platform performing the mission. For example, in Figure 12, 15 of each AMPV platform are being modeled.
Total Time (h)	Total mission duration in hours.
Total Distance (mi)	Total distance traveled during the mission.
Engine Idle Time (h)	Total time in hours spent idling.
Terrain Profile: Pri, 2nd, Trail, XC, Mtn	The terrain profile gives the percentage of the total distance that is spent on each of the five terrain types.
Speed (mph): Pri, 2nd, Trail, XC, Mtn	The speed columns indicate how fast the vehicle is traveling while on each of the terrain types.
Terrain Grade (% Slope): Pri, 2nd, Trail, XC, Mtn	The terrain grade columns specify the average percent slope encountered for each terrain type.
APU Burn Rate (gal/h)	If an APU is being used, this column represents its average consumption rate in gal/h. The model does **not** account for varying consumption rates based on load.
APU Time (h)	How many hours spent using an APU. The model assumes an APU only runs while the vehicle is stationary with its engine is off.
RCI Values: Hard, Medium, Soft	Allows the user to define RCI values for hard, medium, and soft surfaces. Leaving blank will have the model use the default RCI values.

If desired, there is a Remove Pairings button that will remove the mission information associated with the selected vehicle platform(s) from the Platform Mission Pairings table. If there are multiple pairings for the same vehicle platform, removing a pairing will remove the row entirely. However, this button will never remove the last row containing a particular platform. It will instead remove the mission info from the last platform row. Go back to the platform tab to completely remove all instances of a vehicle platform.

It is possible to add new mission profiles to the Mission Bank by clicking the Import Mission button. That button will open a file selection dialog to find a CSV file containing one or more sets of mission info. The CSV file may have the columns shown in Table 15 (in any order, but the column name must match). If the MissionRCISoft, MissionRCIMedium, or MissionRCIHard fields are left blank, they will use the default value stored within FCPM. The defaults can be viewed/edited by pressing the “Edit Default RCI Values” button.

Table 15. Import mission CSV structure

Column name	Description
MissionID	A unique identifier number.
MissionForceDensity	The number of that particular vehicle platform performing the mission. For example, in Figure 12, 15 of each AMPV platform are being modeled.
MissionName	Refers to source document name (i.e., SBCT OMS/MP).
MissionSource	Text field to reference where the mission profile came from.
MissionRole	Identifies mission role (i.e., medical treatment or medical evacuation).
MissionVehicleName	Indicates which platform the mission profile was intended for.
MissionPhase	Used to identify phases for multiphase missions.
MissionDate	Date of original mission document.
MissionTotalTimeHours	Total mission duration in hours.
MissionTotalMovingTime	Legacy field for older model versions. Model calculates total moving time based on total distance, terrain profile, and speeds.
MissionEngineIdleTimeHrs	Total time in hours spent idling.
MissionAPUTimeHrs	How many hours spent using an APU. The model assumes an APU only runs while the vehicle is stationary with its engine is off.
MissionPercentageOfNonMovingTimeIdling	Legacy field for older model versions. Preference is to use MissionEngineIdleTimeHrs field instead to directly insert idle times.
MissionTotalDistanceMiles	Total distance traveled during the mission.
Engine Idle Time (h)	Number of hours of planned idle time.
MissionTerrainProfilePercentagePrimary	The percentage of the total distance that is spent on a primary road.
MissionTerrainProfilePercentageSecondary	The percentage of the total distance that is spent on a secondary road.
MissionTerrainProfilePercentageTrail	The percentage of the total distance that is spent on a trail.
MissionTerrainProfilePercentageCrossCountry	The percentage of the total distance that is spent on a cross-country surface.
MissionTerrainProfilePercentageMountainous	The percentage of the total distance that is spent on a mountainous surface.
MissionSpeedMphPrimary	The speed in mph the vehicle travels while on a primary road.
MissionSpeedMphSecondary	The speed in mph the vehicle travels while on a secondary road.
MissionSpeedMphTrail	The speed in mph the vehicle travels while on a trail.
MissionSpeedMphCrossCountry	The speed in mph the vehicle travels while on a cross-country road.
MissionSpeedMphMountainous	The speed in mph the vehicle travels while on a mountainous road.
MissionTerrainGradePercentageSlopePrimary	The average percent slope encountered on primary roads.

Table 15. Import mission CSV structure (continued)

Column name	Description
MissionTerrainGradePercentageSlopeSecondary	The average percent slope encountered on secondary roads.
MissionTerrainGradePercentageSlopeTrail	The average percent slope encountered on trails.
MissionTerrainGradePercentageSlopeCrossCountry	The average percent slope encountered on cross-country.
MissionTerrainGradePercentageSlopeMountainous	The average percent slope encountered on mountainous roads.
MissionEngineOffIdleBurnRate	Legacy field for older model versions. This has been superseded by APU Burn Rate.
APU Burn Rate (gal/h)	If an APU is being used, this column represents its average consumption rate in gal/h. The model does not account for varying consumption rates based on load.
MissionRciHard	Allows the user to define RCI value for hard surfaces. If left blank, the model will use the default RCI value in the settings.
MissionRciMedium	Allows the user to define RCI value for medium surfaces. If left blank, the model will use the default RCI value in the settings.
MissionRciSoft	Allows the user to define RCI value for soft surfaces. If left blank, the model will use the default RCI value in the settings.

2.3.4 Creating an OPLOG Run

When beginning a new Operational Logistics (OPLOG) Planner run (simply referred to as OPLOG), it is advisable to use the procedure in this section as opposed to loading a previously saved run. This is because any changes that occur within the vehicles database after a run is saved will not propagate when loaded (by design). Instead, the best practice is to create a new run, thus ensuring the use of the most recent vehicle characteristics, by performing the following steps (depicted in Figure 13):

1. Add or edit any vehicles necessary for the new OPLOG dataset. The easiest way to make the changes is to utilize the Edit Vehicles tab as described in Section 4. Ensure the Pedigree column is designated as “OPLOGSet” for any new vehicles. Additionally, the platform name for the vehicle must begin with the six-character line-item number (LIN) associated with the OPLOG data call and end with the appropriate configuration— “CONUS,” “ARMORED,” “CONUS TRAILER,” or “ARMORED TRAILER.”
2. In the Analysis tab, filter the Pedigree column by typing “OPLOGSet” (not case sensitive) into the filter entry field immediately below the column name. This will show only the vehicles designated as part of the OPLOG data call. Note that even for non-OPLOG runs, the OPLOGSet is a recommended starting point as

these vehicles and their associated characteristics have received a higher degree of scrutiny.

3. Click the Add All button to bring all the OPLOG vehicles into the current run (Platforms to Use table).
4. Save the current OPLOG run.
5. Proceed directly to the “Run Model” tab. The “Duty Cycles” and “Mission” tabs are not used when performing an OPLOG run. Instead, FCPM will create four standard duty cycles with no slope: 1) 55 mph on primary roads, 2) 28.1 mph on primary roads, 3) 23.1 mph on secondary roads, and 4) 12.9 mph on cross-country roads. FCPM will also determine the idle fuel consumption rate.
6. Select the “OPLOG” output format on the “Run Model” tab. A file selection dialog will open asking for an OPLOG vehicles list (see Appendix section A.6 for a discussion on creating the vehicle list) that must be selected to continue performing an OPLOG run. If “Cancel” is selected, FCPM will revert to the previous output format selection.
7. Continue to the run the model as outlined in the following section.

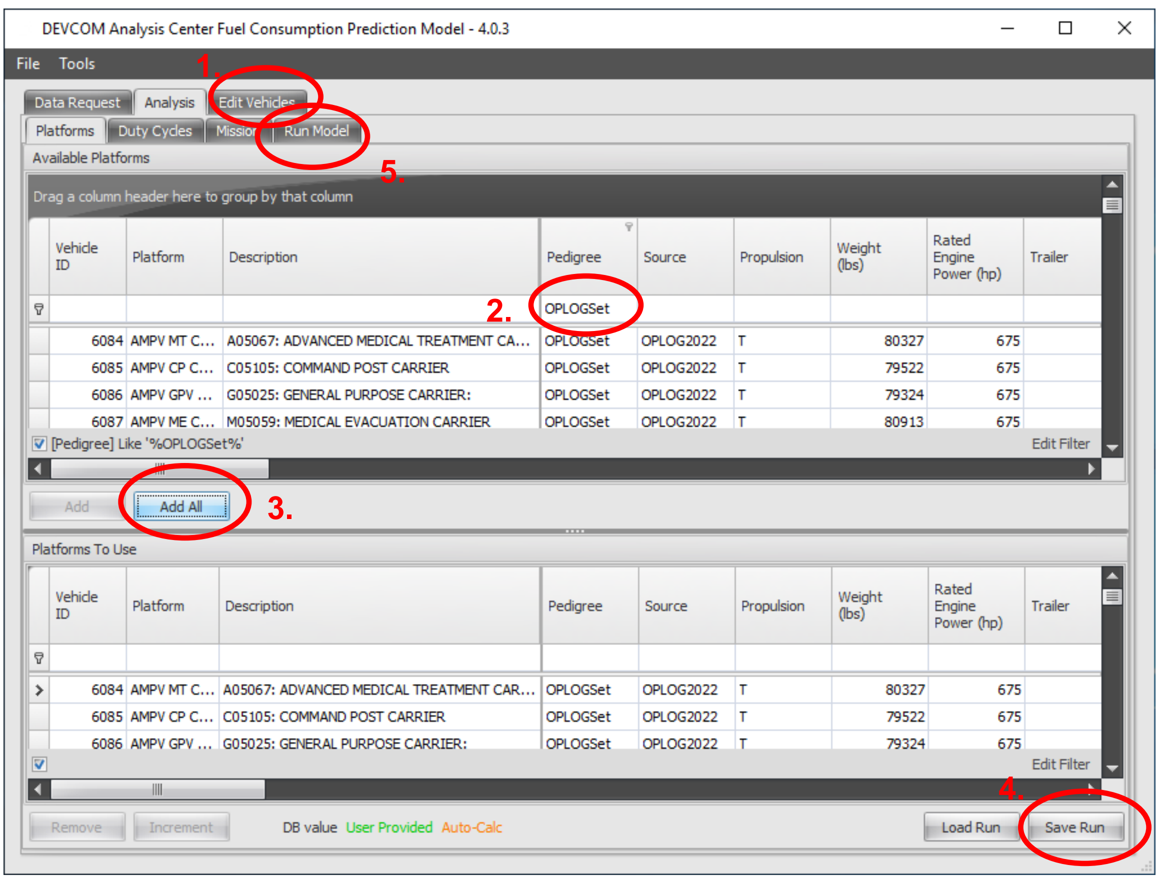

Figure 13. Starting an OPLOG run in the Analysis tab

2.3.5 Run Model

The Run Model tab (Figure 14) is the final step to producing modeling results. This tab walks the user through the process of selecting the final details before generating results. The tab is broken down into the following:

1. Output Format
2a. How to Handle PL [Power Limited]
3. Output File Destination
4. Run Model

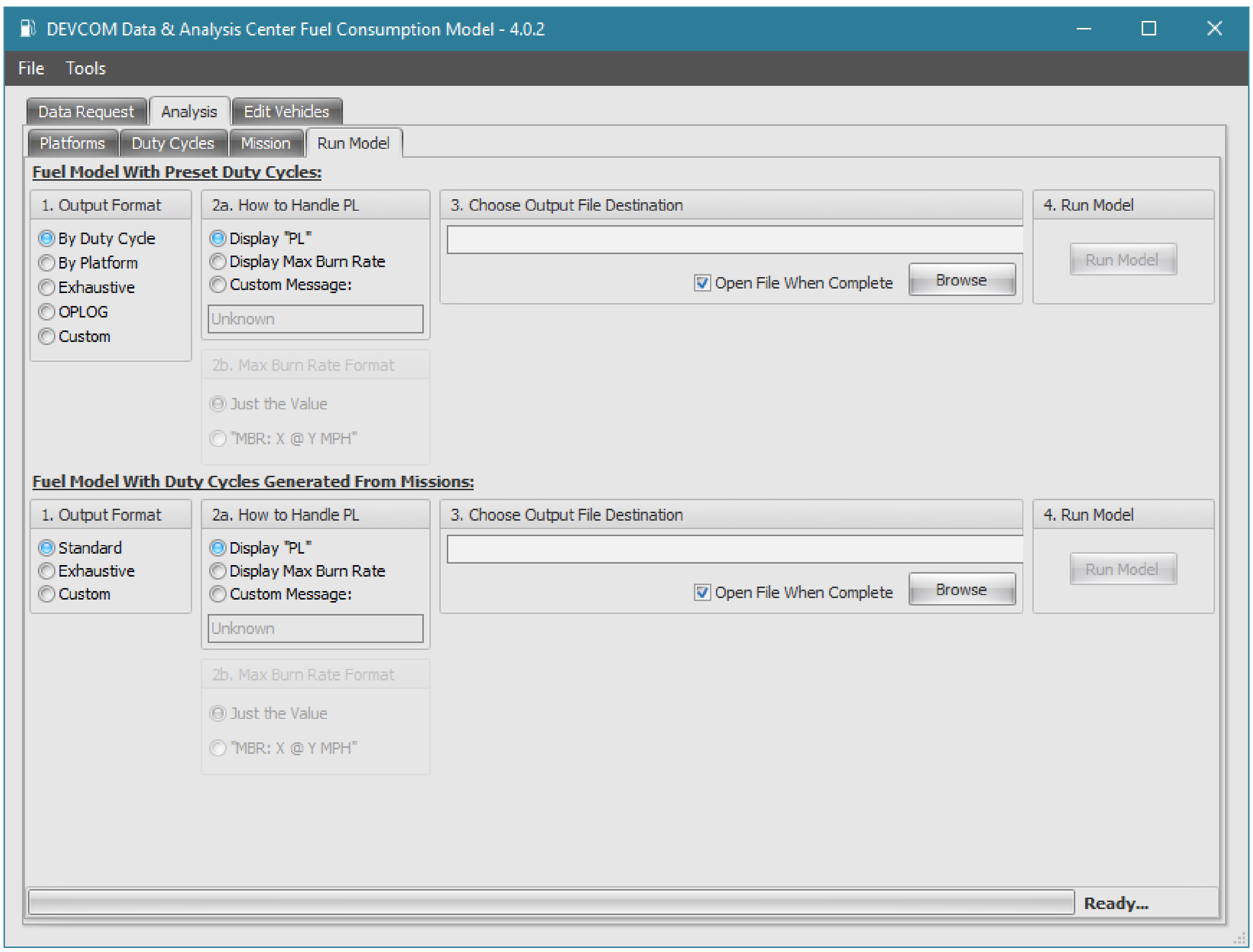

Figure 14. Analysis Run Model sub-tab

2.3.5.1 Output Format

These options allow the user to choose from a list of preset formats or specify their own. "By Duty Cycle" is organized with sets of duty cycle options in each row and vehicles being modeled in columns as shown in Table 16. This is the most commonly used format and should be used by default unless there is a need for the detail contained in the exhaustive format.

“By Platform” steps all vehicles through all duty cycle conditions one at a time. While it does provide a bit more modeling parameters in the output data, this format is cumbersome to sort through and is not used often.

“Exhaustive” builds on the “By Platform” output with a similar format but includes many values that are calculated during the modeling process. Some of these include resistance due to slope/aerodynamic/rolling, tractive power, total mobility power demand, and so on. These values can be used for further analysis when required.

“OPLOG” provides outputs in the format used for the annual OPLOG fuel data request.

“Custom” allows the user to specify which outputs are desired to build a unique format.

Table 16. Duty cycle output format

Following output produced by FCPM version 4.0.2						Vehicle ID
DEVCOM DAC Fuel Consumption Model Output (gal/h)						2379
Terrain surface	**Speed (MPH)**	**Slope %**	**Soil group**	**Soil strength (RCI)**	**Rolling resistance factor**	**KAWAATV**
1	0	0	Paved	N/A	1	0.64
1	1	0	Paved	N/A	1	0.64
1	2	0	Paved	N/A	1	0.64
1	3	0	Paved	N/A	1	0.64
1	4	0	Paved	N/A	1	0.64
1	5	0	Paved	N/A	1	0.64
1	6	0	Paved	N/A	1	0.64
1	7	0	Paved	N/A	1	0.64
1	8	0	Paved	N/A	1	0.64
1	9	0	Paved	N/A	1	0.64
1	10	0	Paved	N/A	1	0.64
1	11	0	Paved	N/A	1	0.64
1	12	0	Paved	N/A	1	0.64
1	13	0	Paved	N/A	1	0.64
1	14	0	Paved	N/A	1	0.64
1	15	0	Paved	N/A	1	0.64
1	16	0	Paved	N/A	1	0.64
1	17	0	Paved	N/A	1	0.64
1	18	0	Paved	N/A	1	0.64
1	19	0	Paved	N/A	1	0.67
1	20	0	Paved	N/A	1	0.7

2.3.5.2 How to Handle PL (Power Limited)

Power limited situations arise when the desired operating condition (surface type, slope, speed, and so on) requires more power than the vehicle can produce. In these cases, the user has a few choices for how the results should be displayed:

“Display PL” returns the letters “PL” instead of a consumption rate. This is the most accurate format, as a PL result means the vehicle could not meet the requested driving condition.

“Display Max Burn Rate” returns the max theoretical consumption rate of the vehicle on that terrain condition. This approximates the vehicle traveling as fast as possible given available power, but slower than the desired speed. If this option is chosen, the user has the choice to display only the consumption rate or the consumption rate along with the maximum speed that the vehicle could travel on the requested terrain condition before becoming power limited.

“Custom Message” allows the user to change the standard PL to something else, such as a blank space, 0, 999, or anything that conforms to the required output format.

2.3.5.3 Choose Output File Destination

In this box, the user selects the output file destination and chooses if the file should open automatically when the modeling run is completed (on by default). The model will suggest a file name based on the chosen output format and date.

2.3.5.4 Run Model

When all previous choices are set, Box 4 runs the model and will open a spreadsheet with the results. When looking through the results, there may be cases where the model flags a special situation. Those are typically referred to as a no-go scenario. This means the vehicle cannot perform under the specified condition. There are two primary reasons for a no-go: 1) the vehicle is power limited, or PL, signifying that the vehicle required more power than it has available; and 2) the vehicle has an RCI value greater than its VCI.

By default, a value of 999.99 is output for the consumption rate, enabling the customer to overlook that condition, if appropriate, for the vehicle. However, if customers wish to examine the specific reason behind a no-go event, they can choose a more detailed output.

3. VIEWING AND ADDING SFC CURVES

3.1 Viewing SFC Curves

The Fuel Curve Viewer (Figure 15) is accessed in the Tools menu → Fuel Curve Viewer. This opens a separate window containing all of the SFC curves in the database and can be used to quickly compare multiple curves or to see how smooth or rough a set of data is. The window is split into data (left) and a plot of SFC vs % max power (right). The data fields included are detailed in Table 17 and are data points that are taken from tests or calculated in the process of creating the SFC curve.

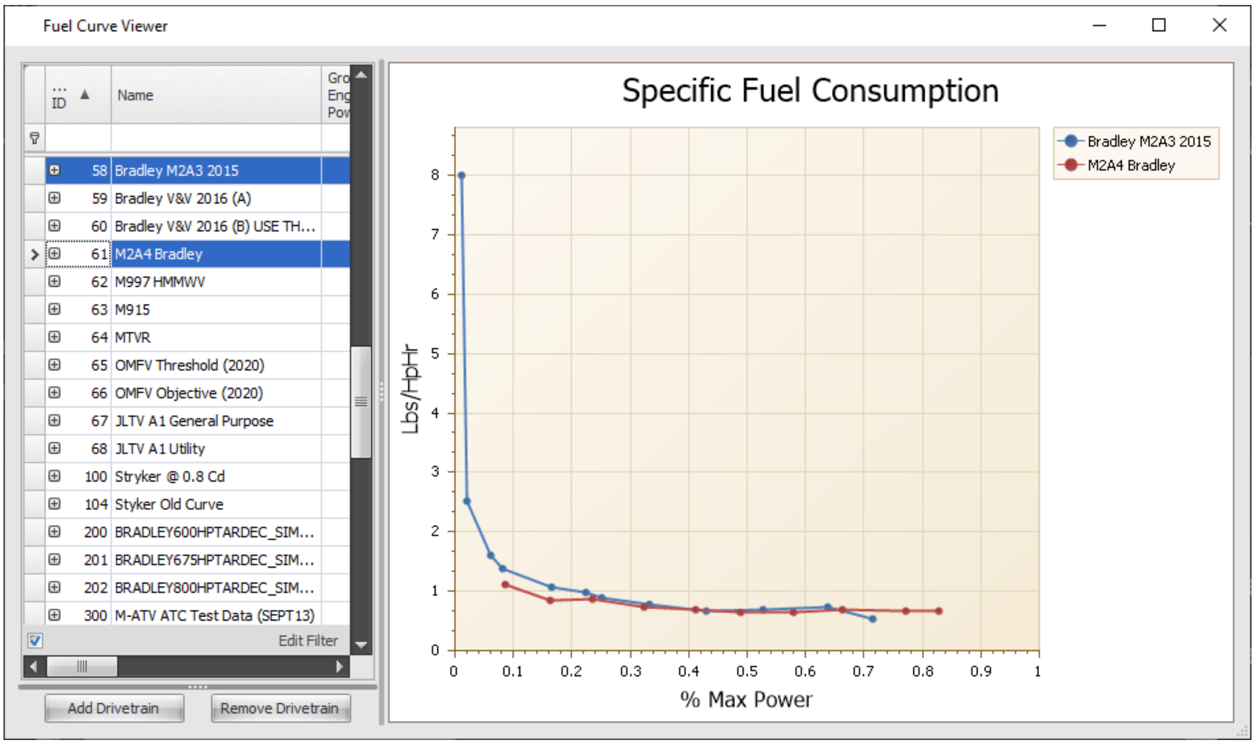

Figure 15. SFC Curve Viewer graphical user interface

The chart on the right will plot data associated with curve(s) selected on the left. Multiple curves can be viewed together by Control- or Shift-click. The chart will scale the axes to accommodate the range of data and update the legend based on the selected curves.

3.2 Adding New SFC Curves

It is possible to add new drivetrains and remove old ones to/from the FCPM using the buttons at the bottom-left of the Fuel Curve Viewer. Removing fuel curves can be done be selecting the fuel curve(s) intended to be deleted and clicking the Remove Drivetrain button. A warning message informing the user that the action cannot be undone must be accepted before any deletion occurs.

Adding a new drivetrain is done one at a time by selecting the Add Drivetrain button. Clicking that button will open a new form (Figure 16) allowing for the entry of drivetrain characteristics. The fields to be filled out are listed in Table 17.

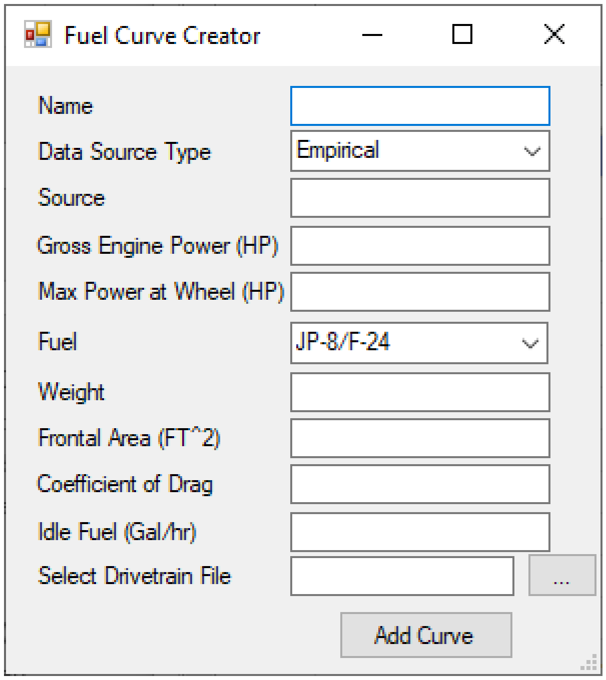

Figure 16. Fuel Curve Creator form

Table 17. Fuel Curve Creator fields

Field name	Description
Name	The name of the drivetrain entry.
Data Source Type	Drop-down allowing the drivetrain to be categorized as either “Conceptual” or “Empirical.”
Source	The name of the data source (e.g., test report).
Gross Engine Power (hp)	Engine power listed by vehicle manufacturer.
Max Power at Wheel (hp)	Maximum tractive power that makes it through the driveline to the wheels/sprocket.
Fuel	JP-8/F-24 or DF-2 as tested; other fuel types are available.
Weight (lb)	Vehicle weight
Frontal Area (ft^2)	Frontal area used for air resistance calculation. Normally provided by Aberdeen Test Center.
Coefficient of Drag	A coefficient estimate based on the similar aerodynamic properties of like vehicles (e.g., size and shape); lower values indicate lower drag.
Idle Fuel (gal/h)	No load fuel consumption rate traditionally from test.
Select Drivetrain File	Path to the CSV file that contains the individual SFC data points.

The last field, Select Drivetrain File, refers to picking a CSV file that contains two columns: PercentMaxPower and SFCLBperHPHR. The first column should be in increasing order from 0 to 1, where 0 itself is not included. As the field name suggests, this column gives percentage steps of load ranging from near zero to the max engine horsepower. The second column, specific fuel consumption, provides the associated data points for the fuel consumption rate given power produced (lb/hp-h). There must be at least two rows to make a line, but there is no maximum number of points to characterize the curve. Once all the entries are complete, clicking Add Curve will add the drivetrain entry to the Fuel Curve Viewer list and enable it to be selected from the Platforms tab. Table 18 is a properly formatted example of data ready to be added to the database.

Table 18. Drivetrain SFC data for import

PercentMaxPower	SFCLBperHPHR
0.011003972	2.616135208
0.024042308	2.394768315
0.04900265	1.366223163
0.075799059	1.1393761
0.10534957	0.958808862
0.138572215	0.824390475
0.181274622	0.747619684
0.326544821	0.793431383
0.391898647	0.816193988
0.466432811	0.82794103
0.551065346	0.870673476
0.584181931	0.87012566

4. ADDING NEW/EDITING EXISTING VEHICLES

The Edit Vehicle tab (Figure 17) allows the user to modify vehicle platform entries in the database. The Data Request and Analysis tabs pull vehicle data from this database. These changes will be persistent after closing and reopening FCPM for all users of the shared database. Therefore, it is important to be cautious when making changes in this tab.

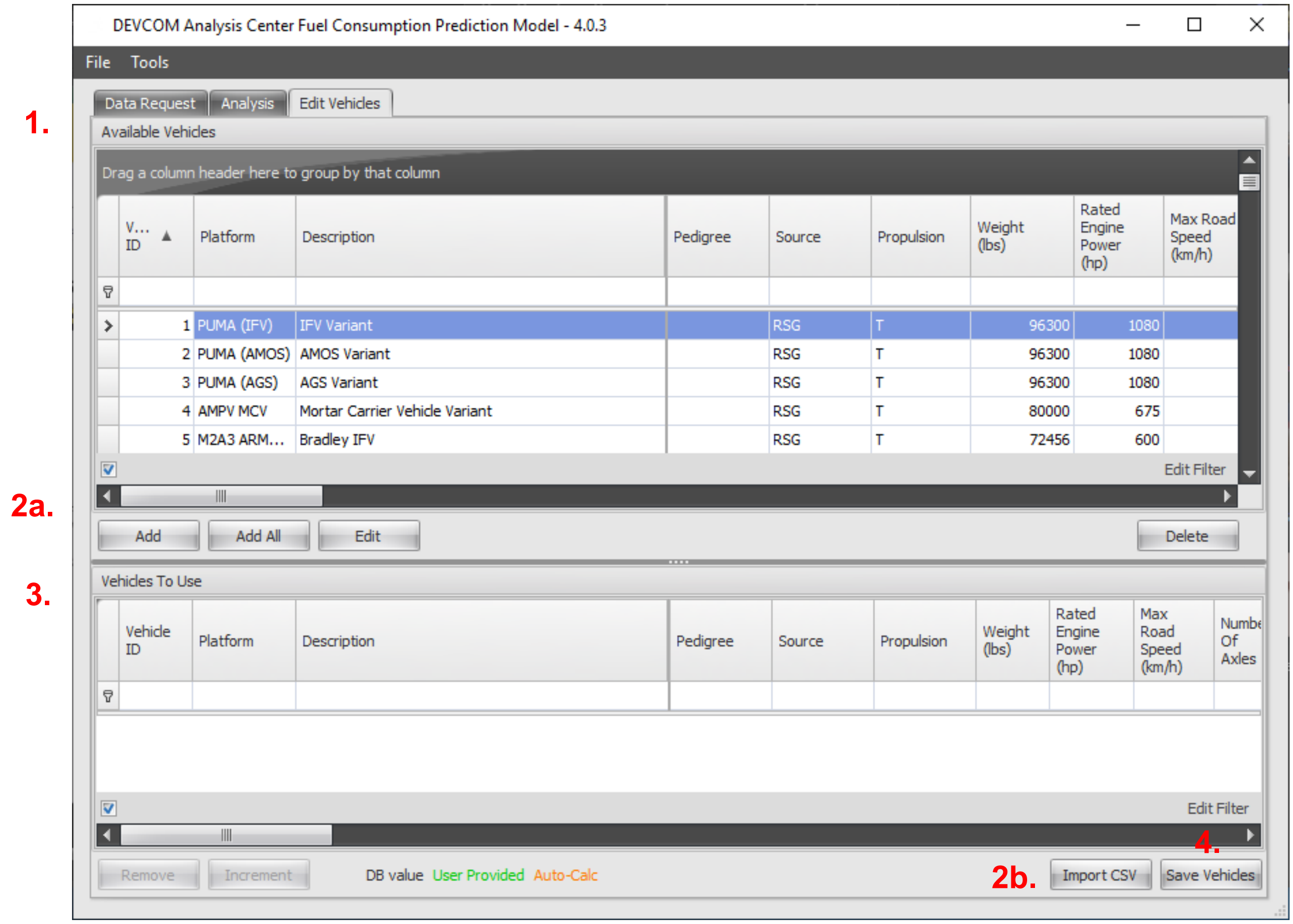

Figure 17. Edit Vehicles tab

The layout of the tab is as follows:

(1) Vehicle Database: The Vehicle Database includes most vehicles (and vehicle variants) previously modeled since the creation of the original Excel version of FCPM in the mid-2000s.

(2) There are two ways to add new vehicles to the database: **a)** cloning an existing vehicle and **b)** importing from CSV. When cloning an existing vehicle, select one or more vehicles and click the Add button or double-click anywhere in a desired vehicle's row. This will copy the vehicle information in the Vehicles To Use window **(3)** but with an updated Vehicle ID. Editing a vehicle works similarly, but the Vehicle ID will be the same and that entry will be overwritten. Importing from a CSV file will be discussed later in this section.

(3) Current Vehicles in Use: This window is the staging area for what will be written to the database. After populating this table, individual vehicle characteristics (e.g., vehicle weight, engine horsepower, vehicle cone index, aerodynamic coefficient of drag) may be edited to meet the new vehicle's specifications.

(4) Save Vehicles: Once all the vehicles to be added/edited have been properly defined, click this button to perform the write to the database action. This selection prompts a pop-up window warning the user that the action cannot be undone.

When adding a small number of vehicles, especially when creating a variant that is very similar to an existing vehicle, the process described here from within FCPM is likely the fastest and easiest method. However, when adding several unique vehicles, it may be easiest to define them in a CSV and import those vehicles from a file. To do that, click the Import CSV button. That button will open a file dialog allowing the user to select a CSV of vehicles to import. The structure of the vehicle CSV file should reflect the list in Table 19.

Table 19. Vehicle import CSV fields

Column name	Description
VehicleID	This field will auto-populate, so it can remain blank or be omitted entirely.
Platform	Army "model number" (e.g., M2A3 Bradley).
Description	Description sometimes includes add-on's such as armor packages.
Propulsion	T for "tracked," W for "wheeled."
WeightLBS	Vehicle weight.
RatedEnginePowerHP	Engine power listed by vehicle manufacturer.
MaxRoadSpeedKMH	Maximum road speed in km/h.
NumberOfAxles	Number of axles. (This variable is presently not used within the model.)
Amphibious	"Y" or "N" indicating whether or not the vehicle is amphibious.
FordingSpeedKMH	Speed at which vehicle can ford in km/h.
SwimmingSpeedKMH	Speed at which vehicle can swim in km/h. Should be set to 0 if not amphibious, but the model will ignore if flagged as amphibious.
MaxGradient	Maximum slope vehicle can climb from 0 to 100.
Trailer	This denotes whether vehicle configuration accounts for the weight of a trailer, not if it can use a trailer.
PrimaryUse	Used for data requests. If tracked, "Amphibious Combat Vehicle" or "Other." If wheeled, "Amphibious Combat Vehicle," "Heavy Equipment Transporter," or "Truck."

Table 19. Vehicle import CSV fields (continued)

Column name	Description
FrontalAreaFT2	Cross-sectional frontal area in square feet.
CoefficientOfDrag	A coefficient estimate based on the similar aerodynamic properties of like vehicles (e.g., size and shape); lower values indicate lower drag.
SinglePassVCIPSI	Minimum soil strength for a vehicle to consistently complete one pass successfully, calculated from vehicle characteristics.
TirePressurePSI	Specified tire pressure for wheeled vehicles if available.
UsableFuelCapacityGAL	Listed fuel capacity in gallons.
NoLoadBurnRateIdleGALHR	No load fuel consumption rate from test; if not specified, the value will be calculated based off of the chosen SFC curve.
FuelType	JP-8/F-24 or DF-2 as tested; other fuel types are available.
Drivetrain	Drop-down menu to select the vehicle-level SFC curve to be used for the fuel consumption estimate.
GovernedSpeedMPH	Can be added if governed speed is listed, though this is not common.
DrivelineEfficiencyImprovementFactor	Used to increase or decrease driveline efficiency for experimental purposes.
MovingAccEff	Commonly modeled values: 75% for standard alternator, 90% for Integrated Starter Generator (ISG); use decimal value.
NonmovingAccEff	Commonly modeled values: 75% for standard alternator, 90% for ISG: use decimal value.
MovingElectricalLoadHP	Required for mission electrical loads (hp); above vehicle innate and test equipment electrical loads.
NonmovingElectricalLoadHP	Required for mission electrical loads (hp); above vehicle innate and test equipment electrical loads.
PercentLoaded	[0,100] representing the percentage of weight to use in the model.
Nationality	Country of origin.
Pedigree	“OPLOGSet” denotes if vehicle characteristic data has been confirmed accurate and used in a major data request.
Source	Source of characteristic information if available.
Comments	Space to capture information not included elsewhere.
OriginalAuthor	Automatically populates based on user that created the vehicle.
DateCreated	Automatically populates.
LastEditedBy	Automatically populates.
DateLastEdited	Automatically populates.
SecurityClassification	All unclassified values for unclassified FCPM version; potentially some classified entries in SECRET version of FCPM.

5. CONCLUSION/CONCLUDING REMARKS

This user guide is intended to familiarize new and existing users with the features and functions of the FCPM. For further information, contact the DAC Operational Power and Energy Analysis Branch.

6. REFERENCES

Baylot, A., & Gates, B. (2002, November). *Procedure for categorizing ground vehicles* (ERDC/GSL TR-022-21). U.S. Army Engineer Research and Development Center.

Baylot, A., Gates, B., Green, J., Richmond, P., Goerger, N., Mason, G., Cummins, C., & Bunch, L. (2005, February). *Standard for ground vehicle mobility* (ERDC/GSL TR-05-06). U.S. Army Engineer Research and Development Center.

Fisher, W., & Webb, B. (2006, July). *Validation of the standard mobility application programming interface fidelity 1 and 2* (TR-2006-16). U.S. Army Materiel Systems Analysis Activity.

Appendix A – Fuel Consumption Prediction Model Computations: Topics of Special Interest

A.1 Methodology – Electrical Load Impact on Fuel Consumption

U.S. Army Combat Capabilities Development Command (DEVCOM) Analysis Center (DAC) and DEVCOM Ground Vehicle Systems Center engineers developed a methodology to address fuel consumption when increasing or decreasing electrical loads are applied to the vehicle. The minimum brake-specific fuel consumption (BSFC) value was selected as the basis for the estimate. Unfortunately, the BSFC map is not routinely available to the analyst due to its proprietary nature. In order to estimate the minimum BSFC, the following procedure is used:

1. Select a surrogate drivetrain to closely represent the vehicle of interest (Fuel Curve ID).
2. Find the most fuel-efficient point (i.e., minimum) from the surrogate vehicle's Fuel Curve (i.e., Vehicle-Level SFC vs. Tractive Power curve). (Vehicle SFC_{min})
3. Multiply this value by the quotient of Tractive $Power_{max}$ / brake horsepower (bhp)
4. The product is then multiplied by the quotient of Electrical Load / Electric Generator Efficiency (e.g., alternator, integrated starter generator) to estimate the fuel consumption rate necessary to satisfy the requirement.

$$\text{Fuel Consumption (lb/h)} = \text{Vehicle } SFC_{min} * \frac{\text{Tractive Power}_{max}}{bhp} * \frac{\text{Electrical Load}}{\text{Electric Generator Efficiency}}$$

Examples of parameters used for calculating the impact of electrical load on fuel consumption are shown in Table A-1.

Table A-1. Example of parameters for electrical load impact on fuel consumption

FCPM Input	Value	Notes
Vehicle	M2A2	Vehicle of interest.
Fuel Curve ID	#4	Fuel curve that best represents the M2A2.
Vehicle SFC_{min}	0.55 lb/hp-h	Minimum point of Fuel Curve #4.
Tractive $Power_{max}$	408 hp	Usually estimated from a combination of Road and Full Load test results.
bhp	600 hp	For FCPM purposes, this value traditionally reflects the engine's "rated" horsepower.
Electric Generator Efficiency	0.75	For FCPM purposes, the Electric Generator Efficiency for a moving and nonmoving vehicle may be treated independently; however, traditionally the two efficiency values are set equal.
Electric Load	10 kW = 13.4 hp	Conversion of electrical load from kilowatts to horsepower.

Fuel consumption (lb/h) to satisfy the electrical load

= Vehicle SFC_{min} x (Tractive $Power_{max}$ / bhp) x (Electric Load / Electric Generator Efficiency)

= 0.55 lb/hp-h x (408 hp / 600 hp) x (13.4 hp / 0.75)

= 6.7 lb/h

Therefore, it will take a 6.7 lb/h fuel rate to satisfy the 10-kW electrical load. That fuel rate value is added, within the Fuel Consumption Prediction Model (FCPM), to the vehicle's moving or nonmoving fuel consumption rate(s). The sum is the total fuel rate necessary to satisfy the moving/nonmoving requirement and the electrical load requirement.

For a validation discussion regarding this methodology, please reference Mastrola.[1]

A.2 Methodology – Idle Fuel Consumption Scaling Methodology: Engine Horsepower Change

A frequent analytical exercise is to quantify the impact of idle fuel consumption if the vehicle's configuration is altered relative to the tested configuration. Weight and engine horsepower changes are the two most common modified characteristics requested. A vehicle weight change does not impact the idle fuel consumption rate. Modifying the engine horsepower, however, will change the expected idle fuel consumption rate and will require scaling.

As noted, a common "what if" question is to understand the idle fuel rate impact when the engine horsepower is theoretically increased or decreased. DAC has examined measured idle fuel consumption data from many military vehicles with engine sizes ranging from 150 to 1500 hp. In doing so, a linear trend line was created to generalize the impact of increasing or decreasing engine power on the idle fuel consumption rate. The slope of the trend line is used to estimate the idle fuel consumption rate for the vehicle in question. If the engine power of interest differs from the rated engine power by 5% or less, then the idle fuel consumption rate is not scaled. If the idle fuel consumption rate is defined by the analyst within the vehicle data (i.e., analyst specifies the idle consumption rate for the vehicle of interest), then the scaling logic is not used. The logic is utilized only when the idle fuel consumption rate is sourced from the initial vehicle's fuel curve (i.e., the analyst does not specify a rate). Figure A-1 and its corresponding list are intended to assist in understanding this methodology.

[1] Mastrola, M. (2016, January). *Fuel consumption prediction model verification and validation – medium weight wheeled vehicle* (TR-2016-01). Army Materiel Systems Analysis Activity.

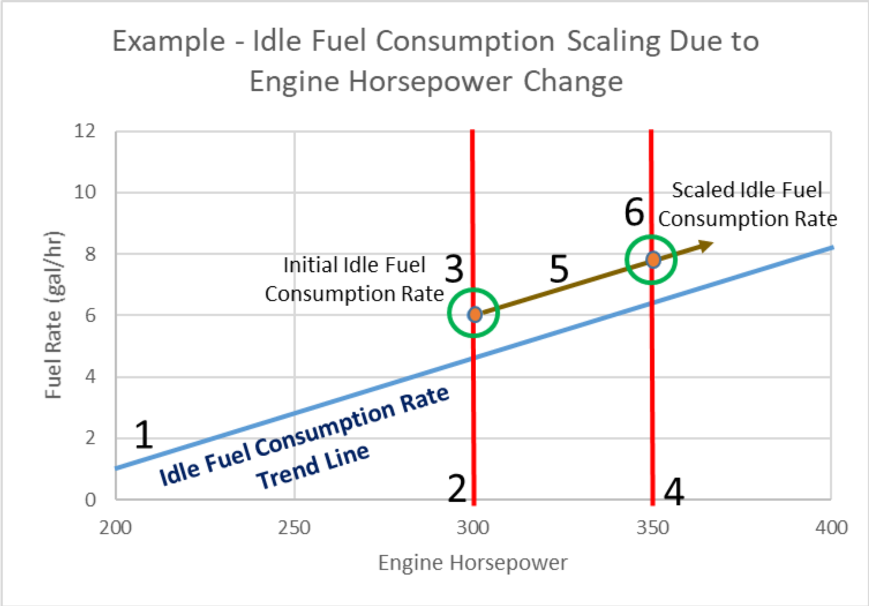

Figure A-1. Idle fuel consumption scaling due to engine horsepower change

1. **Idle Fuel Consumption Rate Trend Line.** Linear trend line (1) developed by DAC to reflect the idle fuel rate relative to engine power change. The trend line is based on many No-Load test results encompassing a wide range of engines (e.g., engine power rating from approximately 150 to 1500 hp).
2. **Base Vehicle Rated Engine Power.** Rated engine horsepower (2) (300 hp in this example) of vehicle from which the idle consumption rate was measured.
3. **Base Vehicle Idle Fuel Consumption Rate.** Idle fuel consumption rate (3) (6 gal/h in this example) that is either specified by the analyst within the vehicle data or pulled from the vehicle-level fuel consumption curve. Note that in this case, the base vehicle's idle fuel consumption rate happens to exceed the Idle Fuel Consumption Rate Trend Line.
4. **New Vehicle Rated Engine Power.** Rated engine horsepower (i.e., 350 hp) of the vehicle of interest. The idle fuel consumption rate for the base vehicle (i.e., 300 hp) will be scaled to estimate the increased idle fuel rate of the 350 hp vehicle (4).
5. **New Vehicle Idle Fuel Consumption Rate Trend Line.** New trend line (5) originating from the Base Vehicle Idle Fuel Consumption Rate (3) whose slope mirrors the slope of the of the Idle Fuel Consumption Rate Trend Line (1).
6. **New Vehicle Idle Fuel Consumption Rate.** Idle fuel consumption rate estimate to be used by the model is the intersection of the New Vehicle Idle Fuel Consumption Rate Trend Line (5) and the engine power of the new vehicle (4). This example produces an estimate of 8 gal/h (6) as the expected increase in fuel consumption from a 300- to 350-hp engine for the vehicle of interest.

If the New Vehicle Rated Engine Power (4) was within ±5% of the Base Vehicle Rated Engine Power (2), then the Base Vehicle Idle Fuel Consumption Rate (3) would be used. In the previous example, if the New Vehicle Rated Engine Power was 285–315 hp (i.e., within 5% of 350 hp), then no scaling logic would be applied.

A.3 Methodology ‑ Single Pass VCI Scaling

A frequent analytical exercise is to quantify the impact of adjusting the vehicle weight. However, the single pass vehicle cone index (VCI) is correlated with a vehicle weight so when the weight is changed, the VCI value needs to be adjusted as well. DAC has examined, measured, and calculated VCI values from many military vehicles. In doing so, DAC has created two linear trend lines to generalize the relationship between vehicle weight and VCI—one associated with tracked vehicles and one associated with wheeled vehicles. The corresponding trend line slope, for the appropriate drivetrain, is used to estimate the new single pass VCI value. The scaling effect is computed by the following equation:

$$\text{New VCI} = \text{Old VCI} + \frac{\text{New Weight} - \text{Old Weight}}{\text{Wheeled or Tracked Vehicle Trend Line Slope}}$$

Regarding VCI associated with a vehicle and trailer combination, the impact on VCI within FCPM is the same as adding the trailer and payload weight to the prime mover. As an example, Vehicle A (15,000 lb) is combined with Trailer B (5,000 lb). The VCI for this vehicle and trailer combination would be represented in FCPM as if Vehicle A weighed 20,000 lb. The User sums the vehicle, trailer, and payload weights to represent the combined configuration within FCPM. FCPM does not automatically compute this sum. This is a limitation of FCPM since the resulting VCI does not account for the additional load bearing axle(s) provided by the trailer. While the method is coarse, FCPM, through the adjustment of the prime mover’s weight, does scale the VCI to account for vehicle and trailer combinations. Addressing this limitation should be considered for future methodology development.

A.4 Idle Fuel Consumption Rate

The idle fuel rate for a vehicle of interest will originate within FCPM from one of two locations:

1. As a data element defined by the analyst within the vehicle data (i.e., analyst specifies the idle consumption rate for the vehicle of interest in either the Vehicles table in the database or in the “Vehicles/Platforms To Use” table).

2. As a data element associated with the vehicle-level fuel consumption curve (i.e., fuel curve). The value may be found directly within the associated data table located with the fuel curve or will be computed by extrapolating between points on the curve if not exactly found. NOTE: If an analyst-defined idle fuel rate value exists, located within the vehicle data, that value takes precedence over a value derived from the fuel curve.

The idle fuel consumption rates within FCPM are based on the significant amount of test data DAC has accumulated over the years. Most of these datasets will include an idle consumption rate value obtained during a standard Army test referred to as No-Load testing. The test is relatively straightforward in that the vehicle's idle fuel consumption rate is measured with no additional electrical loads taxing the engine (i.e., vehicle is stationary with no mission equipment or auxiliary electrical loads applied other than potentially test metering equipment). The exception being the engine cooling fan(s), which is traditionally locked on to allow for consistent test data to be collected. This fan may be driven mechanically or electrically.

This test is conducted at a vehicle's normal engine idle speed (RPM). If the vehicle has a tactical idle feature (i.e., increased engine RPM setting to accommodate increased electrical loads), then the fuel consumption rate(s) at the higher engine RPM may be measured as well. In some cases, an additional test is conducted, which incrementally increases the electrical load to determine the fuel rate, at normal and/or tactical idle, for each specified electrical load value.

A.5 Methodology – Surface Motion Resistance

FCPM must compute the surface resistance coefficient to ultimately determine the fuel consumption of a vehicle on a particular terrain. The way the coefficient is calculated is dependent upon the propulsion type (tracked or wheeled) and the terrain type (primary, secondary, or cross-country).

On primary roads, all tracked vehicles use a surface resistance coefficient of 0.0375. Wheeled vehicles calculate the surface resistance coefficient as a function of tire pressure as in the equation

$$\text{Surface Resistance Coefficient} = 0.007 + \frac{0.0939}{\text{Tire Pressure (PSI)}}$$

The surface resistance coefficient is calculated in a similar fashion for secondary surfaces. Tracked vehicles use a coefficient value of 0.045 and wheeled vehicles utilize the equation

$$\text{Surface Resistance Coefficient} = 0.014 + \frac{0.1878}{\text{Tire Pressure (PSI)}}$$

When performing an analysis on cross-country terrain, FCPM must use a more sophisticated equation. The coefficient for wheeled and tracked vehicles is calculated as follows:

$$\text{Surface Resistance Coefficient} = A + \frac{B}{C + RCI - VCI} + D(RCI - VCI)$$

Vehicle cone index (VCI) is a value defined in the Vehicles table and rating cone index (RCI) is defined during the Duty Cycle setup. Parameters A, B, C, and D are constant values determined by the propulsion type and soil group as defined in Table A-2:

Table A-2. Soil lookup parameters

Soil lookup					
Propulsion	**Soil group**	**A**	**B**	**C**	**D**
Tracked	1	0.052	2.3075	6.5	0
Tracked	2	0.052	2.3075	6.5	0
Tracked	3	0.052	2.3075	6.5	0
Tracked	4	0.062	2.3075	6.5	0
Tracked	5	0.052	2.3075	6.5	0
Tracked	6	0.054	2.3075	6.5	0
Wheeled	1	0.042	2.3075	6.5	–0.000025
Wheeled	2	0.042	2.3075	6.5	–0.000025
Wheeled	3	0.035	2.3075	6.5	–0.000025
Wheeled	4	0.06	2.3075	6.5	–0.000025
Wheeled	5	0.035	2.3075	6.5	–0.000025
Wheeled	6	0.0428	2.3075	6.5	–0.000025

A.6 OPLOG Vehicle List

FCPM asks for a vehicle list when selecting the OPLOG output format. The list is a .csv file beginning with a header row of the labels defined by Table A-3. FCPM uses the LIN and MODEL combination as unique identifiers of vehicles. The remaining fields are passed through to the output file. The subsequent data rows represent the vehicles targeted for the run. The list enables FCPM to output all duty cycles and configurations of the same vehicle (i.e., CONUS, ARMORED, CONUS TRAILER, ARMORED TRAILER) on one line.

Table A-3. OPLOG vehicle list headers

LIN	Line-Item Number. FCPM uses the LIN + MODEL as a unique identifier.
NOMENCLATURE	Combined Arms Support Command (CASCOM) Table of Organization and Equipment (TOE) nomenclature. The field is provided by the requestor and passed to the output file but not otherwise used by FCPM.
EC	Equipment Code. The field is provided by the requestor and passed to the output file but not otherwise used by FCPM.
FAMILY	Family of vehicle. The field is provided by the requestor and passed to the output file but not otherwise used by FCPM.
MODEL	Vehicle platform name. FCPM uses the LIN + MODEL as a unique identifier.

LIST OF ACRONYMS

ACV	Amphibious Combat Vehicle
ATV	all-terrain vehicle
bhp	brake horsepower
BSFC	brake-specific fuel consumption
DAC	DEVCOM Analysis Center
DEVCOM	U.S. Army Combat Capabilities Development Command
ERDC	Engineer Research and Development Center
FCPM	Fuel Consumption Prediction Model
hp	horsepower
h	hour
HET	heavy equipment transporter
ISG	integrated starter generator
JSIMS	Joint Simulation System
kW	kilowatt
lb	pound
MLU	mobility look-up
MPH	miles per hour
OPLOG	Operational Logistics Planner
PL	power limited
PSI	pound per square inch
RCI	rating cone index
RPM	revolutions per minute
SFC	Specific Fuel Consumption
STGJ	Soil Trafficability Groups JSIMS
STNDMob API	Standard Mobility Application Programming Interface
VCI	vehicle cone index
VISOBS	Visibility-Obstacle combinations