Vehicle Operating Cost Toolkit
User Manual

The Center for Transportation Research
at the University of Texas at Austin

Texas Department of Transportation

September, 2011

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Project Title

Estimating Texas Motor Vehicle Operating Costs, TXDOT 0-5974

Project Sponsor
Texas Department of Transportation

Performing Agency
Center for Transportation Research (CTR)
The University of Texas at Austin

Project Engineer
Dr. Ronald Matthew, University of Texas at Austin

Research Supervisor
Robert Harrison, Deputy Director, CTR

Research Team
Dan Seedah - Toolkit and GUI Development
Murat Ates - Drive Cycles and Engine Models
Kyung Jin Kim - Transmission Models
Garrett Anderson - Hydraulic Hybrid Models
James Vaughn - Differential Models
Dimitrios Dardalis - Engine Models
Dr. Hao Lijun – Light Duty and Heavy Duty Hybrid Model

User Manual and Debugging
Joshua Muckelston, CTR USIT '11 Intern

Project Directors
Dr. Duncan Stewart (RTI)
Don Lewis (retired)

Project Advisors (TXDOT)
Janie Temple, Jackie Ploch, Jo Woten, Paul Campbell, Peggy Thurin

Logo Design
Ashley Williams, CTR

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GETTING STARTED GUIDE

The Center for Transportation Research (CTR) / Texas Department of Transportation (TXDOT) Vehicle Operating Cost Toolkit (CT-Vcost) is user-friendly and robust software that provides operating cost estimates for specific representative vehicles or vehicle fleets. The toolkit default data is based on verified secondary vehicle cost data and certified vehicle databases such as the Environmental Protection Agency's (EPA) Fuel Economy database and Annual Certification Test Results database. The toolkit also allows users to change key variable parameters so that cost calculations are specific to any particular situation, and can be updated as the economic or technological landscape changes. Sample cost categories included in the CT-Vcost toolkit include depreciation, financing, insurance, maintenance costs, fuel cost, driver costs, road use fees (e.g. tolls) and other fixed costs such as vehicle registration. It also comes packaged with sophisticated fuel economy prediction models for heavy duty, light duty and hybrid vehicles. The fuel prediction models, developed using both experimental and survey data, have the ability to measure fuel consumption for default or custom drive cycles specified by users. Output from the fuel prediction models can be used in with the toolkit to perform different types of analyses as described later in this manual. In summary, the CT-Vcost toolkit was designed to be intuitive and flexible enough for simulating different scenarios and situations.

System Requirements

CT-Vcost was developed using Visual C# .NET Studio and is compatible with all Microsoft Windows versions which have Microsoft® .NET Framework 4.0 installed. The minimum system requirements for CT-Vcost are:

1) 1 GHZ Pentium 3 (or equivalent) and 512 MB RAM
2) 1 GB Free Hard Drive Space
3) Microsoft® .NET framework 4[1]

[1] Microsoft .NET Framework 4 is packaged with the CT-Vcost setup and will be installed automatically if the framework is not already installed on the system. It is also available for download at Microsoft.com

Installation

Run the ***VcostSetup.exe*** file, as shown in Figure 2, and follow the instructions on the screen.

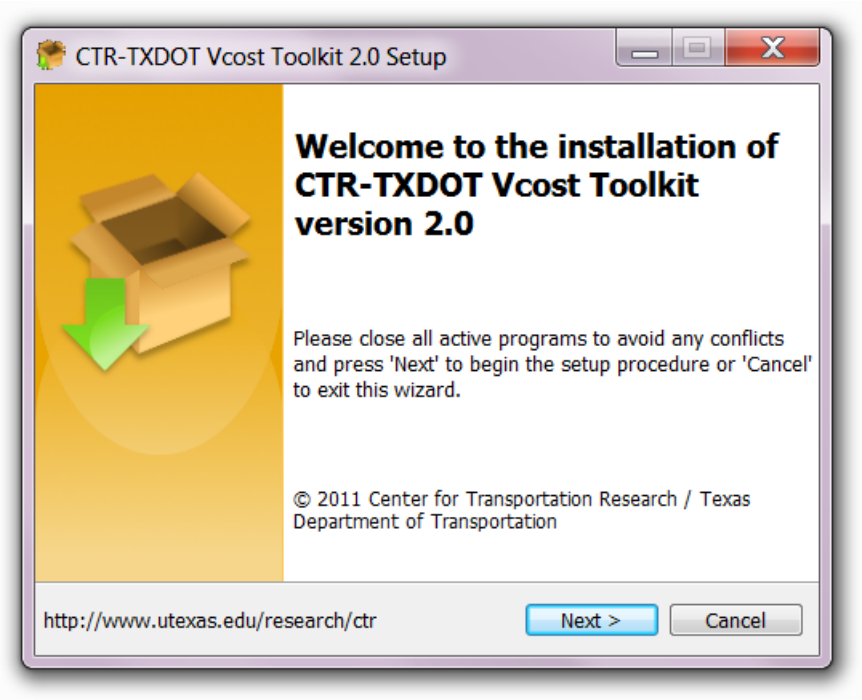


Figure 1a: Running *VcostSetup.exe*

After installing CT-Vcost, run the CT-Vcost executable (***Vcost.exe***) either from the Windows® *Start Menu* or the CT-Vcost folder. Figure 1b is a screen shot of CT-Vcost start screen.

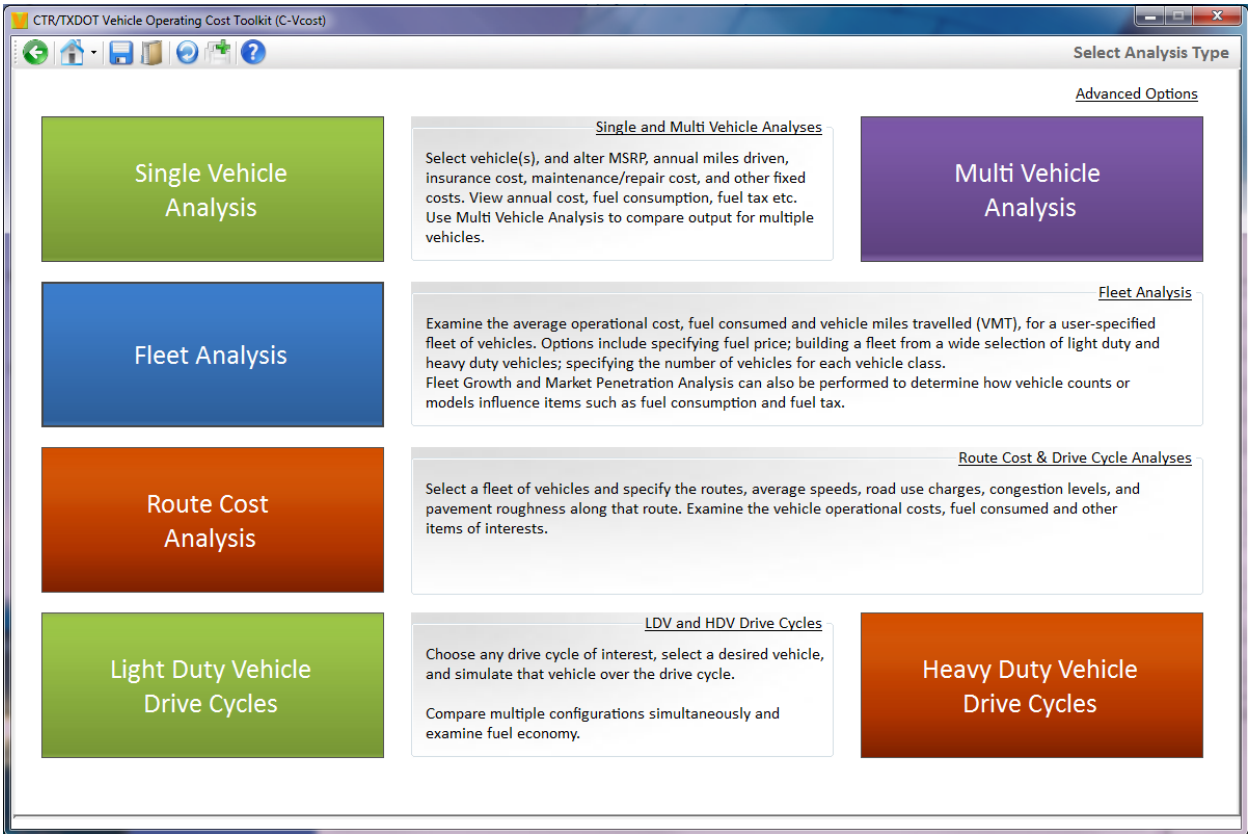


Figure 1b: CT-Vcost Start Screen

Advanced Option for V*ehicle Fuel Economy Models*

In order to be able to build and run the fuel economy prediction models using the ***Vehicle Fuel Economy Models***[2]***,*** users must install the MATLAB® Compiler Runtime (MCR) libraries, a standalone set of shared libraries that enable the execution of MATLAB® files on computers without an installed version of MATLAB®. The *VcostSetup.exe* comes packaged with MCR and users have the option of installing the MCR package during setup. The MCR libraries can be installed at a later time when users choose to use the Vehicle Fuel Economy Models. Figure 2 shows the installer for the Matlab MCR libraries (MCRInstaller.ex) which can be found in the *VehicleFuelEconomyModel* folder.

[2] The model names are as follows: **UTFEM_HDV.exe** for heavy duty vehicles, **UT FEM_LDV.exe** for light duty vehicles. Further details on these models can be found in the Final Report of this study.

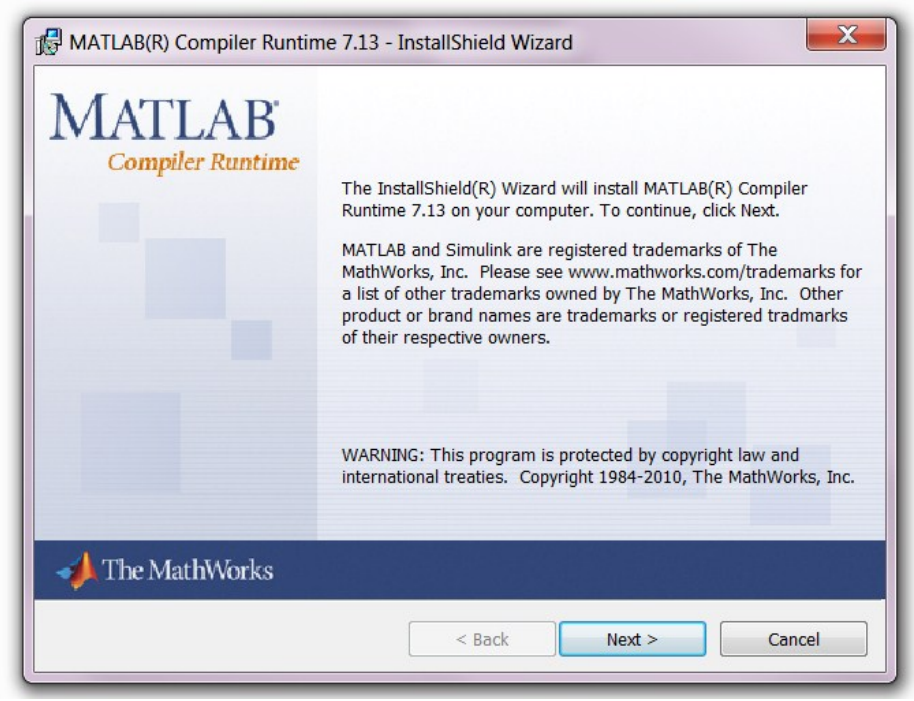


Figure 2: MATLAB® Compiler Runtime (MCR) Installer

Default Data vs. User Data

Default CT-Vcost data is stored in the ***DefaultData*** folder and user generated data is stored in the ***UserData*** folder. The two separate folders enable users to easily distinguish between default data prepackaged with CT-Vcost and data generated by others.

Default data is stored in four Extensible Markup Language (XML) files:

I. *DefaultVehicles.xml* : This database file stores specific default vehicle data such as vehicle make, model, class, city miles per gallon (mpg), highway mpg, manufacturer's suggested retail price (MSRP), axle ratio, ….. Each vehicle is assigned a unique ID starting with the prefix *veh*. For example the first vehicle is referenced by the unique ID *veh001*. CT-Vcost uses this ID for data storage, cost calculations and user interactions via the Graphical User Interface (GUI). The unique ID property also enables vehicles to retain their unique identities and data values when dealing with multiple vehicles, vehicle classes, and vehicle fleets. If the vehicle is missing a certain data requirement, e.g. MSRP, the data value is represented as -1 in the database, and the vehicle class average value is used in the calculations.

II. *DefaultParameters.xml***:** This file stores default parameter values for various vehicle classes. Default parameter values stored by vehicle class include average annual miles traveled, annual insurance cost, annual percentage rate[3] (APR), finance term (in years), average first year depreciation, subsequent year depreciation, and other fixed costs such as vehicle registration. Further details on how the default values are obtained can be found in the Final Report of this study.

III. *DefaultValues.xml:* This file stores miscellaneous default data used in various aspects of the toolkit. Examples of information stored in this file include:

[3] Annual percentage rate (APR) describe the interest rate for a whole year (annualized) as applied on a vehicle loan.

- Default scenario values such as 2011 Texas average fuel price and fuel tax values, analysis period, combined fuel economy weights, fuel price and tax projections, and the time value of money.
- Default light duty and heavy duty utilization ratios
- Default fleet size value of a 100 vehicles.
- Default speed constraint values for congested, moderate and highway conditions.

For further notes on the different modules that use the above listed data, please refer to their specific sections: **Scenario Module**, **Vehicle Utilization Module**, **Fleet Vehicle Composition,** and the **Route Builder** modules**.** The Final Report of this study also provides information on how these default values were obtained.

IV. *DefaultMaintenance.xml:* This file stores default maintenance cost data by vehicle class and by individual vehicles when available. The database stores the following parameters: vehicle name/class, vehicle make, vehicle model, begin year and end year[4], maintenance item description, frequency of work performed, and cost associated with the item

Cost data for light duty vehicles was collected from RepairPal.com® and TXDOT's Fleet Maintenance Database. For additional information on vehicle maintenance data and calculations, please refer to **Vehicle Maintenance Module** section of this manual and the Final Report of this study.

[4] This parameter is used for maintenance schemes that are similar for vehicle models of different years.

Tool Strip Shortcuts

The icons shown in Figure 3 are located at the top left hand corner of the CT-Vcost toolkit. These icons serve as shortcuts to various functions of the model.

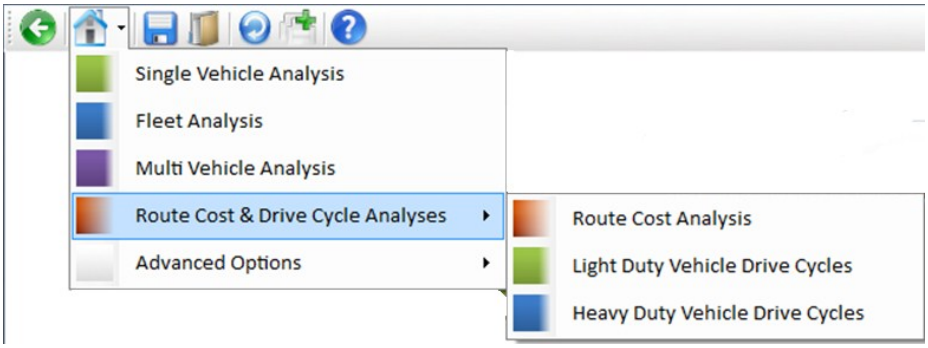


Figure 3: CT-Vcost Tool Strip Shortcuts

The ***Previous*** icon, as the name signifies, returns the user to the most recently visited page.

The ***Home*** icon provides shortcut links to all the different analysis types available in CT-Vcost as illustrated in Figure 3.

The ***Save File*** icon enables users to save the entire application at its current state. Simply click the Save File icon and this will open a new window. Select the folder in which to save the analysis and designate the file's name for future reference. Click the save button to save. CT-Vcost then saves every user input into the file format ***.vcost***.

The ***Open File*** icon enables users to open and load an already saved CT-Vcost document. Click on the icon above and this will open a window with a list files having the ***.vcost*** extension. To open a file, select on the file name and click the Open button. A dialog box showing the modules updated will be displayed (see Figure 4)

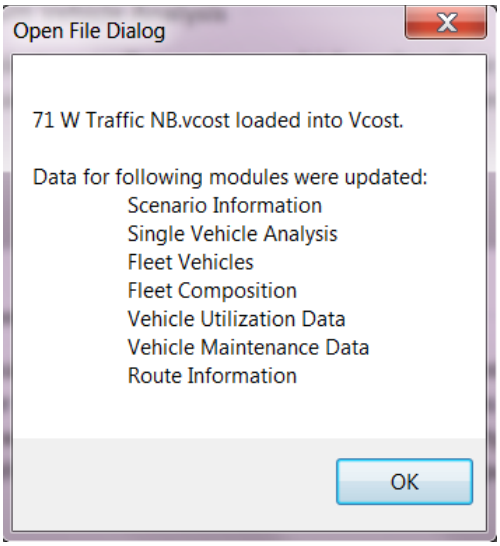


Figure 4: Example of a loaded CT-Vcost Document

The ***Restart*** icon restarts the application and the ***Start New*** icon enables users to create another instance of the application.

Getting Help

Click on the ***Help*** button to view this user manual. Also look for the *"Quick Reference Guide"* boxes which provide simple explanations on what users can do on a certain page. See the example shown in Figure 5.

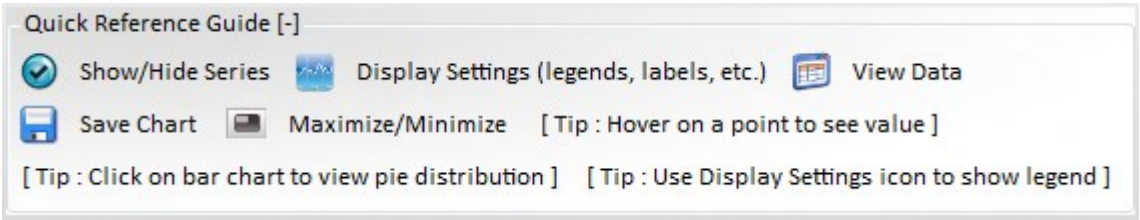


Figure 5: Output Page Quick Reference Guide

SHARED MODULES

Shared modules are modules utilized by more than one analysis type. They are accessible to users when performing certain types of analysis. The shared modules in CT-Vcost are the Scenario Module, the Vehicle Utilization Module, and the Vehicle Maintenance Module.

Scenario Module

The Scenario Module enables users to input general parameters which influence vehicle operating costs but are not specific to any given vehicle (see Figure 6). All the parameters have default values however users can modify these values based on their specific needs. Parameters that can be altered include:

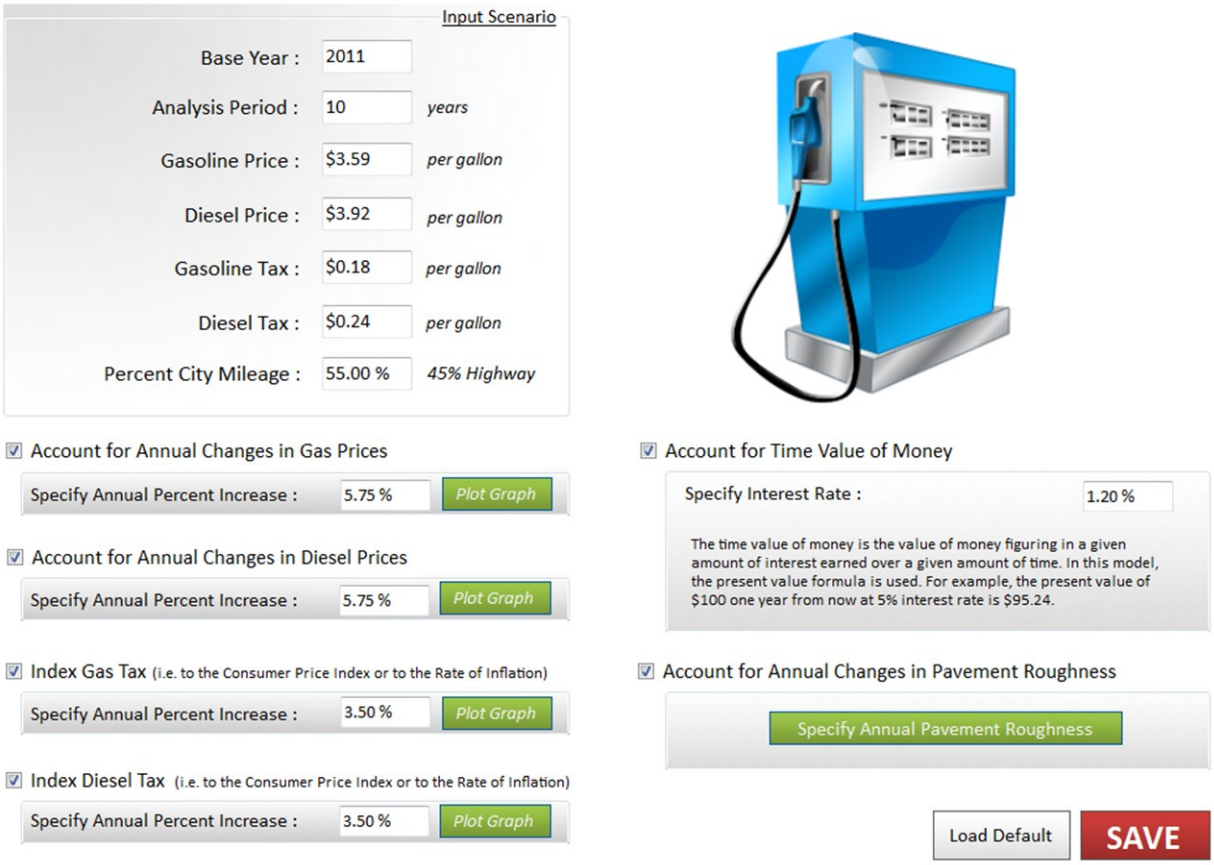


Figure 6: Scenario Module

Base Year: This sets the year from which analyses are to be performed. This value is mainly used by the Fleet Analysis module when accounting for different vehicle ages.

Analysis Period: This value sets the number of years involved in a particular analysis. Projections and calculations are made using this value.

Gasoline Price: The user specifies the base gasoline fuel price. Using the **Account for Annual Changes in Gas Prices** option, users can specify the a percent change in gasoline prices over the analysis period.

Diesel Price: Similar to the Gasoline Price input, users can specify the base diesel fuel price, and using the **Account for Annual Changes in Diesel Prices** option, users can input the percent change in diesel prices over the analysis period.

Gasoline Tax and Diesel Tax: Users can specify the current tax rate on a gallon of gasoline or diesel fuel. The **Index Gas Tax** and **Index Diesel Tax** options are used for projections based on a user specified annual percentage increase.

Percent City Mileage: This is used in calculating the combined fuel economy of vehicles. Combined fuel economy is used in determining fuel consumption when performing Single, Multi-Vehicle and Fleet Analyses.

Account for Time Value of Money: This option enables users to capture any changes in the value of money over the analysis period. It uses the Present Value formula

$$FV = PV \times (1 + i)^n$$

where Present Value (PV) is the value at time 0, Future Value (FV) is the value at time n, i is the interest rate at which the amount will be compounded each period, and n is the number of years. For further details on how Future Value calculations are incorporated in CT-Vcost, see Final Report of this study.

Account for Annual Changes in Pavement Roughness: This option utilizes fuel consumption percentage increases due to the effect of pavement roughness as reported by Zaabar and Chatti (2010), using the calibrated Highway Development and Management Software (HDM-4)[5]. When this option is selected, the *Specify Annual Pavement Roughness* button is displayed and users can click on it to access the Pavement Roughness Module (see section on the Pavement Roughness Module for further details).

[5] Imen Zaabar and Karim Chatti, 2010, Calibration of HDM-4 models for Estimating the Effect of Pavement Roughness on Fuel Consumptions for US Conditions, *Transportation Research Record: Journal of the Transportation Research Board. No. 2155,* Washington D.C., 2010, pp. 105-116.

Vehicle Utilization Module

As vehicle's age, they tend to be driven less than newer vehicles. The Vehicle Utilization Module was developed to capture this change in vehicle use over time. Default data correlating vehicle utilization with age is taken from the Transportation Energy Data Book (U.S. DOE, 2009). The Final Report of this study contains detailed information on the data used.

Users however have the option of changing the utilization curve. To alter a vehicle utilization curve, click on either the Utilization Curve button or link (available when performing an analysis) and the **Utilization Curve Generator** will pop up (see Figure 7). Utilization is represented as a ratio of the specified *Base Annual Mileage*. The ratios can be edited in the *Utilization Factor* column. To view how changes compare with default utilization values, click on the *Plot Graph* button.

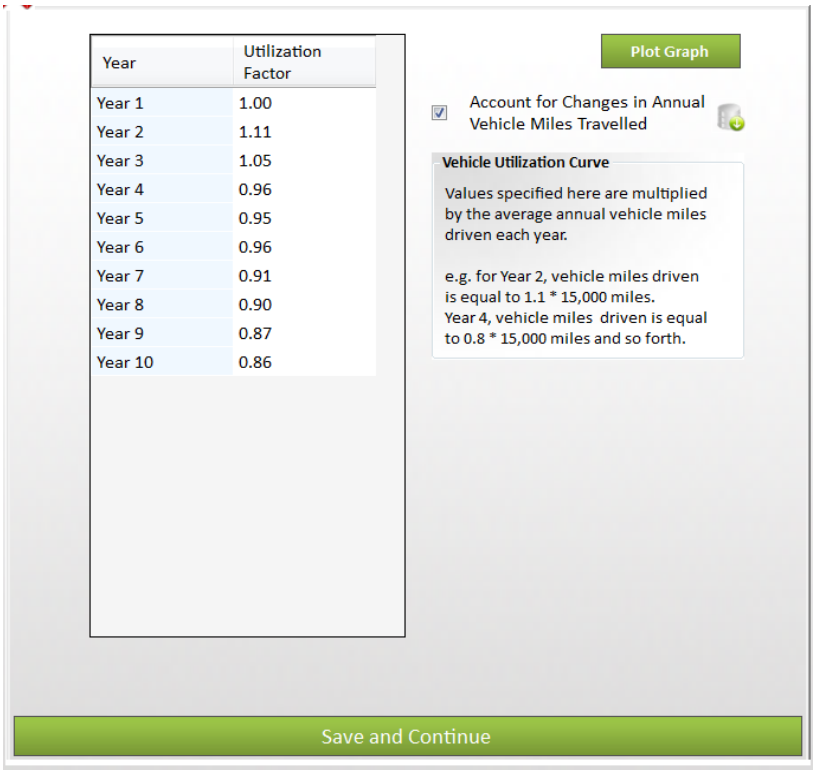


Figure 7: Utilization Curve Generator

If users decide not to account for changes in utilization with vehicle age, the *Account for Changes in Annual Vehicle Miles Traveled* check box should be unchecked.

Users can also load default data after any edits by clicking on the *Load Data*  button.

Vehicle Maintenance Module

The Vehicle Maintenance Module seeks to simulate the actual maintenance activities of a vehicle. Vehicle data from RepairPal.com and TXDOT's fleet database are used as default values. The module can be accessed via the *Edit Maintenance* button or link. Once accessed, the module displays the *Annual Maintenance Cost* of the vehicle through each year of the analysis period (see Figure 8). The *Average Annual Maintenance Cost* and *Average Per Mile Maintenance Cost* are also calculated and displayed. Annual repair cost can be graphed by clicking on the *Plot Graph* button.

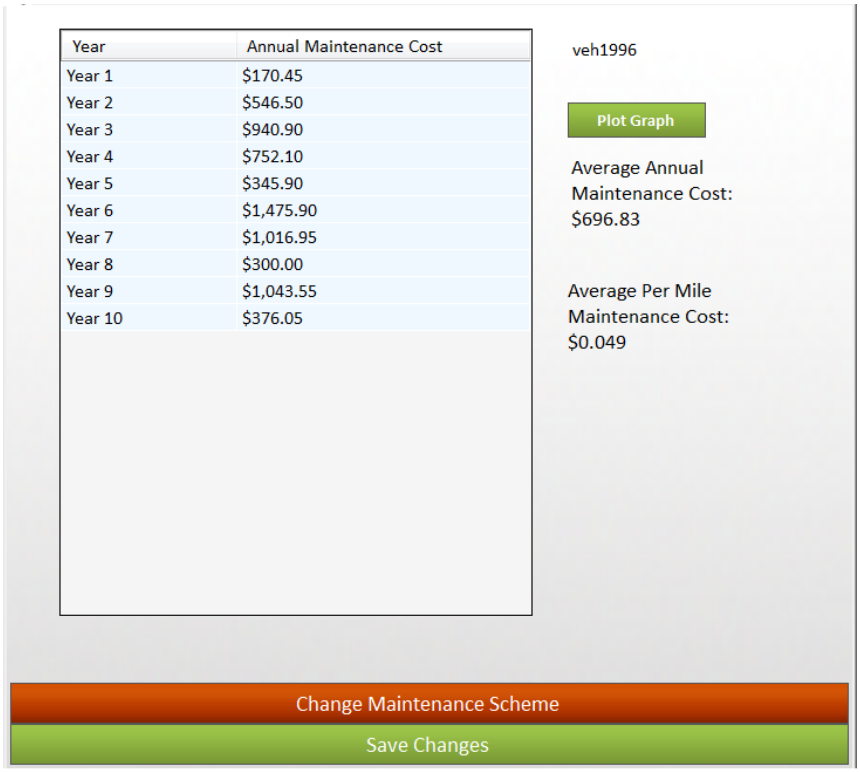
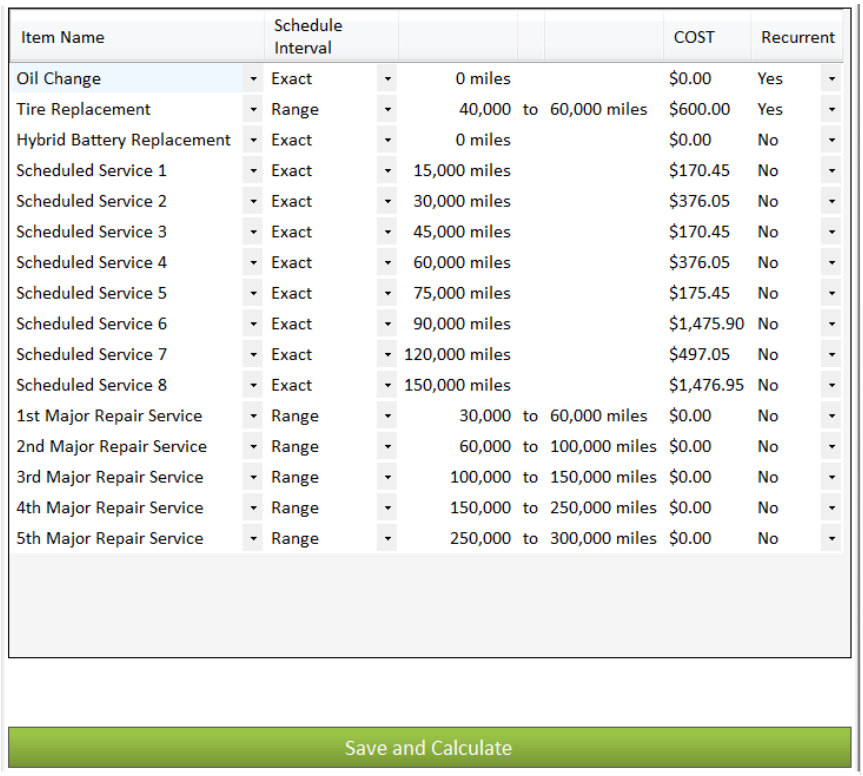


Figure 8: Vehicle Maintenance Module – Annual Maintenance Cost Display

If a user chooses to alter the maintenance scheme of the vehicle, the *Change Maintenance Scheme* button is clicked, and this opens up the vehicle's maintenance scheme page (see Figure 9). Users have a variety of options to specify a maintenance activity of a vehicle. Using the *Item Name* column, a maintenance activity can be described and set to either *Exact* or *Range* (in the *Schedule Interval* column) to determine if the activity occurs at a

fixed mileage or within a certain mile range. Example, oil change usually occurs between 3,750 miles but tire replacement varies between 40,000 to 80,000 miles depending on the type being purchased.



Item Name	Schedule Interval				COST	Recurrent
Oil Change	Exact	0 miles			$0.00	Yes
Tire Replacement	Range	40,000	to	60,000 miles	$600.00	Yes
Hybrid Battery Replacement	Exact	0 miles			$0.00	No
Scheduled Service 1	Exact	15,000 miles			$170.45	No
Scheduled Service 2	Exact	30,000 miles			$376.05	No
Scheduled Service 3	Exact	45,000 miles			$170.45	No
Scheduled Service 4	Exact	60,000 miles			$376.05	No
Scheduled Service 5	Exact	75,000 miles			$175.45	No
Scheduled Service 6	Exact	90,000 miles			$1,475.90	No
Scheduled Service 7	Exact	120,000 miles			$497.05	No
Scheduled Service 8	Exact	150,000 miles			$1,476.95	No
1st Major Repair Service	Range	30,000	to	60,000 miles	$0.00	No
2nd Major Repair Service	Range	60,000	to	100,000 miles	$0.00	No
3rd Major Repair Service	Range	100,000	to	150,000 miles	$0.00	No
4th Major Repair Service	Range	150,000	to	250,000 miles	$0.00	No
5th Major Repair Service	Range	250,000	to	300,000 miles	$0.00	No

Save and Calculate

Figure 9: Vehicle Maintenance Module – Maintenance Scheme

The difference between the two calculations is that with *Exact* interval, the repair cost is included in the cost calculation at the exact time the vehicle reaches the specified mileage. However, with the *Range* interval, repair cost is distributed between the start and end mileage range. For example, if the tires needs to be replaced somewhere between 40,000 and 60,000 miles as shown in Figure 10, once the accumulated mileage falls within that range, the tire replacement cost is included in the vehicle's repair cost for that year.

If the repair occurs over multiple years within that range, the repair cost is divided by the number of occurrences and evenly distributed over the years of occurrence (see Figure 11).

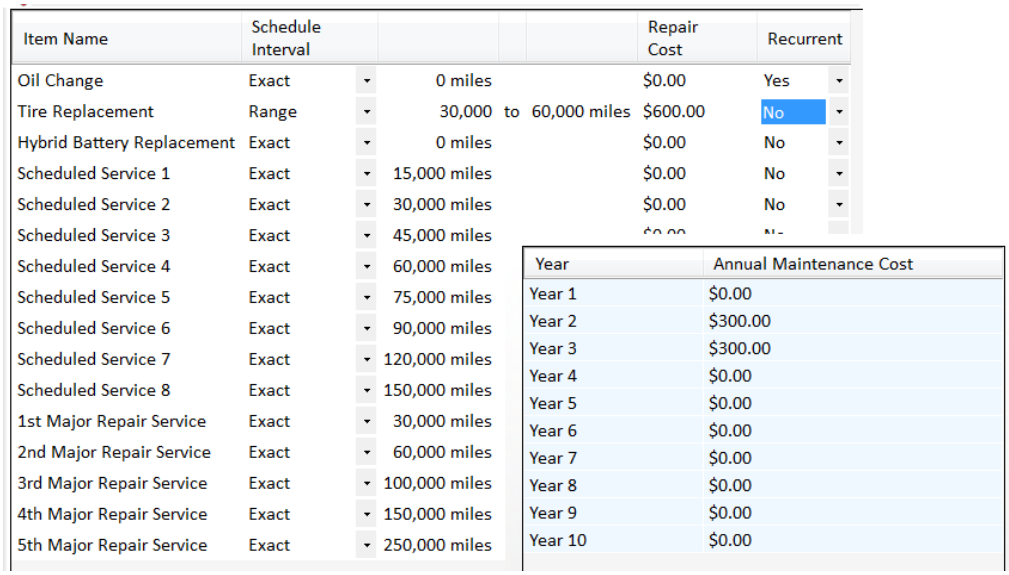
NOTE: Ranges should be used only if the range is greater than the **base annual mileage** (e.g. 15,000 miles).

In addition, a repair may be set to be recurrent (select *Yes)* which means that at the specified schedule interval, the repair item will occur again. Using the tire replacement repair as an example, tire repair cost will be calculated again when the vehicle mileage reaches between 80,000 to 120,000 mile range (see Figure 10).

Item Name	Schedule Interval				Repair Cost	Recurrent
Oil Change	Exact	0 miles			$0.00	Yes
Tire Replacement	Range	40,000	to	60,000 miles	$600.00	Yes
Hybrid Battery Replacement	Exact	0 miles			$0.00	No
Scheduled Service 1	Exact	15,000 miles			$0.00	No
Scheduled Service 2	Exact	30,000 miles			$0.00	No
Scheduled Service 3	Exact	45,000 miles			$0.00	No
Scheduled Service 4	Exact	60,000 miles				
Scheduled Service 5	Exact	75,000 miles				
Scheduled Service 6	Exact	90,000 miles				
Scheduled Service 7	Exact	120,000 miles				
Scheduled Service 8	Exact	150,000 miles				
1st Major Repair Service	Exact	30,000 miles				
2nd Major Repair Service	Exact	60,000 miles				
3rd Major Repair Service	Exact	100,000 miles				
4th Major Repair Service	Exact	150,000 miles				
5th Major Repair Service	Exact	250,000 miles				

Year	Annual Maintenance Cost
Year 1	$0.00
Year 2	$0.00
Year 3	$600.00
Year 4	$0.00
Year 5	$0.00
Year 6	$0.00
Year 7	$600.00
Year 8	$0.00
Year 9	$0.00
Year 10	$0.00

Figure 10: Tire Replacement between 40,000 and 60,000 miles
Recurrent turned On and corresponding Annual Maintenance Cost



Item Name	Schedule Interval				Repair Cost	Recurrent
Oil Change	Exact	0 miles			$0.00	Yes
Tire Replacement	Range	30,000	to	60,000 miles	$600.00	No
Hybrid Battery Replacement	Exact	0 miles			$0.00	No
Scheduled Service 1	Exact	15,000 miles			$0.00	No
Scheduled Service 2	Exact	30,000 miles			$0.00	No
Scheduled Service 3	Exact	45,000 miles				
Scheduled Service 4	Exact	60,000 miles				
Scheduled Service 5	Exact	75,000 miles				
Scheduled Service 6	Exact	90,000 miles				
Scheduled Service 7	Exact	120,000 miles				
Scheduled Service 8	Exact	150,000 miles				
1st Major Repair Service	Exact	30,000 miles				
2nd Major Repair Service	Exact	60,000 miles				
3rd Major Repair Service	Exact	100,000 miles				
4th Major Repair Service	Exact	150,000 miles				
5th Major Repair Service	Exact	250,000 miles				

Year	Annual Maintenance Cost
Year 1	$0.00
Year 2	$300.00
Year 3	$300.00
Year 4	$0.00
Year 5	$0.00
Year 6	$0.00
Year 7	$0.00
Year 8	$0.00
Year 9	$0.00
Year 10	$0.00

Figure 11: Tire Replacement between 30,000 and 60,000 miles with *Recurrent* turned Off and corresponding Annual Maintenance Cost

Pavement Roughness Module

Studies have shown that pavement conditions have an effect on a vehicle's fuel consumption. In 2010, Zaabar and Chatti published a paper on the fuel consumption of five different vehicle classes under different operating, weather, and pavement conditions using a calibrated version of the HDM-4 model. The vehicle classes utilized in the study include a medium sized passenger car, a SUV, a van, a light truck and an articulated truck. CT-Vcost integrates the results of the HDM-4 calibration study into the toolkit by enabling users to specify an annual pavement condition rating for each year of the analysis period (see Figure 12).

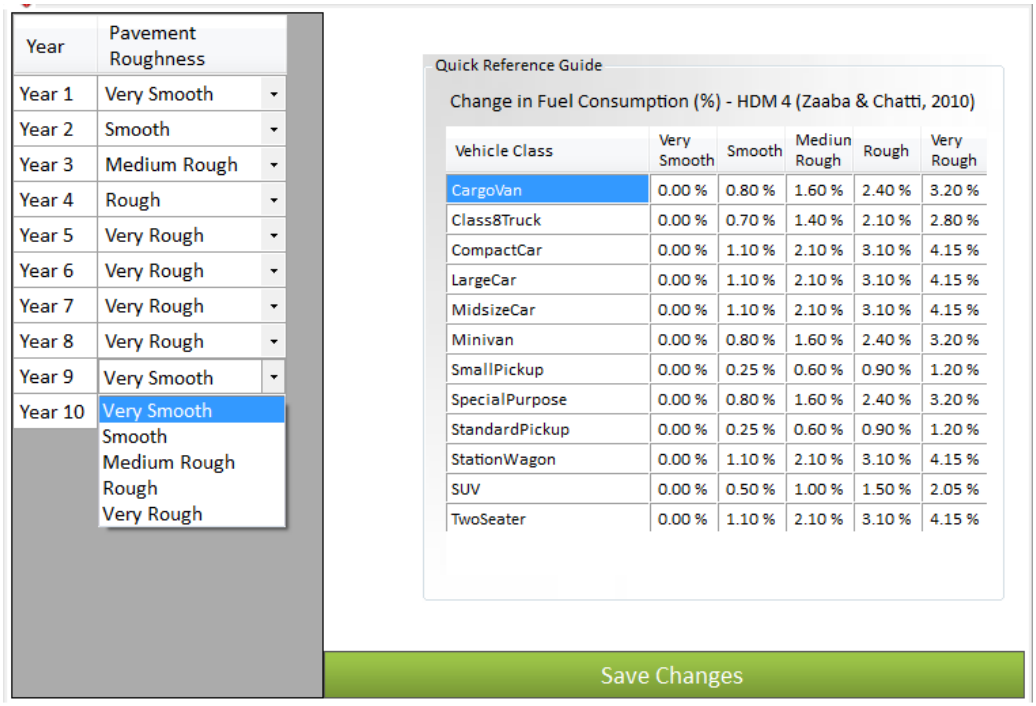


Figure 12: Pavement Roughness Module

The five available pavement roughness options available to users are listed in Table 1. Depending on the option selected by the user, CT-Vcost multiplies the percentage change in fuel consumption (by vehicle class) by the vehicle's fuel consumption in that year (see Figure 12). This results in slightly higher fuel consumption values for smooth to very rough pavement conditions.

Table 1: Pavement Roughness Descriptions and their Corresponding International Roughness Index (IRI) Score

Description	**Corresponding IRI (inches per mile)**
Very Smooth	1-59
Smooth	60-95
Medium Rough	96-130
Rough	131-169
Very Rough	170-950

PERFORMING ANALYSIS

CT-Vcost integrates all the models (or modules developed in the CTR/TXDOT Vehicle Operation Cost study. The toolkit enables users to perform various types of analysis as summarized below:

Single Vehicle Analysis module: This module enables users to select a single vehicle, and alter parameters such as vehicle value, annual mileage driven, insurance rates, maintenance cost and schedules and other fixed costs.

Multi-Vehicle Analysis module: This module is similar to the single vehicle analysis module in that users can alter vehicle parameters similar to that of the Single Vehicle Analysis module. In addition, users are allowed to select two or more vehicles to make cost comparisons. Output such as total operating cost, fuel consumption and others can be analyzed for multiple vehicle simultaneously.

Fleet Analysis module: This module builds on the single vehicle and multi-vehicle analysis by enabling users to perform analysis involving a fleet of vehicles. Users can build fleets from a wide selection of light duty and heavy duty vehicles and specify their compositions and parameters.

Growth Rate and Market Penetration module: This module which forms part of the Fleet Analysis module enables planners to examine how various vehicle types (such as hybrids and pure electric vehicles) and fleet growth rates may influence fuel tax revenues, fuel consumption and carbon emissions over a projected time period.

Route Cost Analysis module: This module enables users to simulate the cost of moving a vehicle or a fleet of vehicles via a certain routes. Multiple route length and characteristics such as speed, congestion level, driver costs etc. can be defined by the user and the vehicle operating cost via each route is calculated and presented for comparison.

Light Duty Vehicle Drive Cycles module: This module integrates the Light Duty Fuel Economy model (developed as part of this study) into CT-Vcost. The module enables users to choose a drive cycle of interest, select a desired vehicle, and simulate that vehicle over the drive cycle. In addition, users are able to compare multiple vehicles and drive cycle configurations simultaneously and examine the vehicle's fuel economy over a selected section or range of the entire drive cycle.

Heavy Duty Vehicle Drive Cycles module: Similar to its light duty counterpart, the Heavy Duty Vehicle (HDV) Drive Cycles module integrates the Heavy Duty Fuel Economy model (also developed as part of this study) into CT-Vcost. The module comes with fifty four default drive cycles involving three engine types, three roadway conditions, three vehicle weights and two drivers. In addition, users can build custom HDV drive cycles by varying the vehicle weights. Multiple drive cycles can be compared simultaneously and a vehicle's fuel economy for a selected drive cycle range can also be examined by the section or range of the entire drive cycle.

Depending on the analysis type selected by the user, CT-Vcost generates outputs in various formats such as bar graphs, line graphs and pie charts. Output data can also be exported as a comma-separated value file (CSV) which can be utilized for other analysis types using spreadsheet software like Microsoft Excel. The following sections detail each of the analysis types described above with sample output screens.

Single Vehicle Analysis

The Single Vehicle Analysis module is the simplest of the CT-Vcost applications. It enables users to select a particular vehicle and alter parameters such as vehicle price (MSRP), average annual mileage driven, insurance premium, interest rate (APR), down payment, finance term, first year depreciation, subsequent years depreciation, fixed annual costs, and maintenance costs (see Figure 13). Additional vehicle information is displayed on the right hand corner of the screen (see Figure 13). This information is used in other aspects of CT-Vcost such as the Light Duty Drive Cycle analysis.

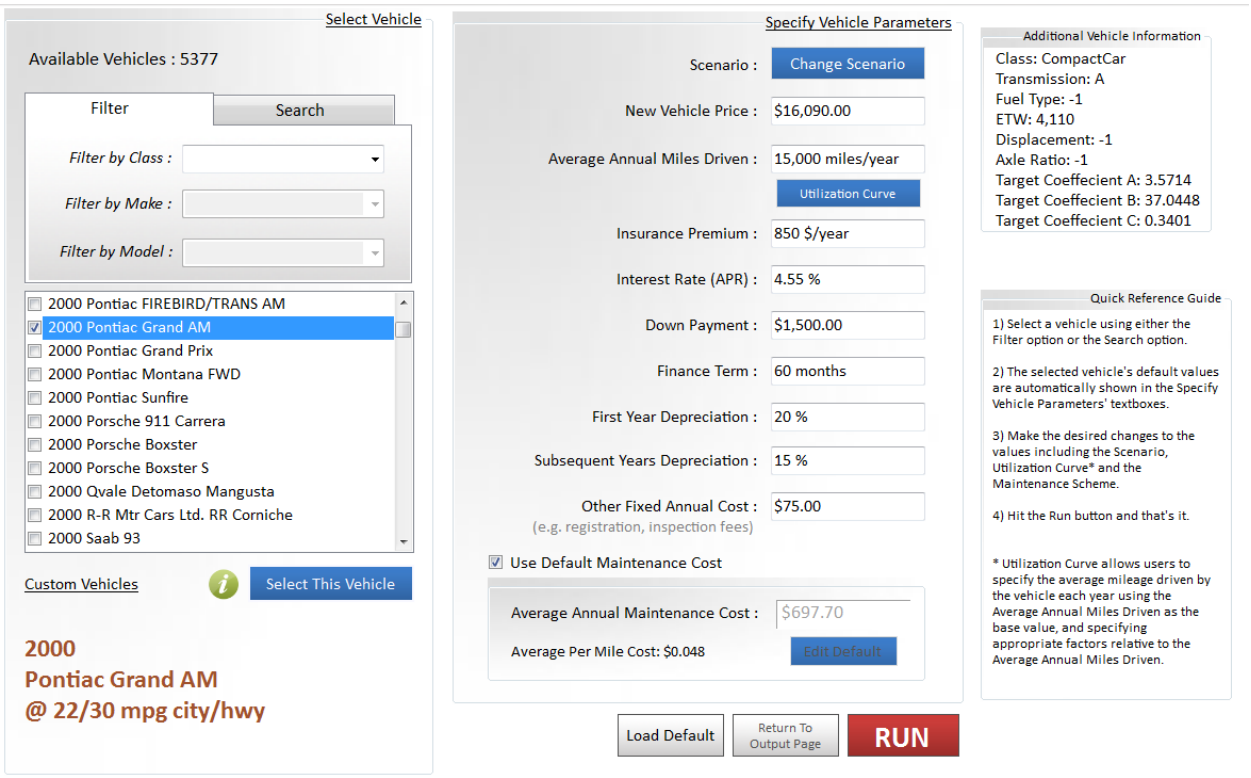


Figure 13: Single Vehicle Analysis Example

Selecting a Vehicle

The CT-Vcost database enables users to select from more than 5000 default vehicles. Vehicles can be selected either by using the **Filter** or **Search** options.

1. **Filter**: This option allows users to navigate to a specific vehicle using characteristics such as vehicle class, vehicle make, and vehicle model.

a. Begin by clicking the arrow to the right of the **Filter by Class** drop down. Select a vehicle class from the drop down menu. Once a class is selected from the drop down menu, the large window with the vehicle list will immediately display only the vehicles in the selected class will be shown (see Figure 14).
b. Use **Filter by Make** and **Filter by Model** drop downs to decrease the number of available options in the check list box.

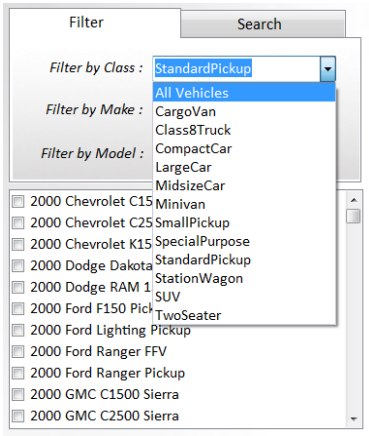


Figure 14: Filter Option Showing Available Vehicle Classes

2. **Search:** It may be quicker to select a vehicle using the **Search** option. Simply select the search tab and enter a vehicle make, model, or year into the *search* bar, as shown in Figure 15 (Pontiac 2000). Once a search description is entered into the text box, CT-Vcost will generate all vehicle names in the window below the *search* bar that match the search description.

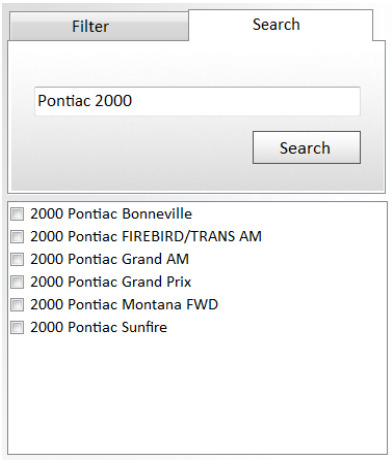


Figure 15: Search Option Showing Available Vehicle Models

3. When the desired vehicle is found in the list, click on the check box to the left of the vehicle name to *check* it.
4. A quick view of the selected vehicle's information can be accessed by clicking the  icon.
5. Once the desired vehicle is checked, click on the Select This Vehicle button to generate all of its default information. Custom vehicles can also be created if desired by clicking on the **Custom Vehicles** link (see the Creating Custom Vehicle section for more information).

Specifying Vehicle Parameters

Vehicle parameters that can be altered by users include:

New Vehicle Price: The default new vehicle price is based on the selected vehicles MSRP or an average of the vehicle's class if the MSRP is not available.

Average Annual Miles Driven: This value will vary based on the driver. The 15,000 miles/year default value is used as an average for Texan drivers, while the national average may be closer to 12,000 miles/year. Click on the *Utilization Curve* Utilization Curve button to access the Vehicle Utilization Module and define the vehicle's annual utilization as the vehicle ages.

Insurance: This is a variable cost depending on the vehicle type, age, and insurance company. However a default value of $877[6] per year is used.

Interest Rate (APR): (Annual Percentage Rate) According to HSH® Associates, the average auto loan interest rates for Dallas and Houston in March 2011 were 5.42% and 5.27% respectively[7]. CT-Vcost uses the Dallas value as a default for passenger vehicles and light trucks.

Down Payment: The average 10% given is an estimate of the down payment most consumers pay when purchasing a vehicle.

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[6] Estimate is taken from the 2007 National Association of Insurance Commissioners report and adjusted for annual inflation over this time period of 2.09%. http://www.compuquotes.com/average-costs-of-insurance.html

[7] HSH® Associates, Financial Publishers, http://www.hsh.com/autosample.html retrieved July 24, 2011.

Finance term: Deals with the period of time agreed upon to complete payment of loan. A 60 month loan agreement is used as the default value.

First Year Depreciation: Represents the immediate decline in value of a vehicle once it is labeled as "used". A default value of 20% is provided for the first year of a new LDV, and 15% for an HDV.

Subsequent Years Depreciation: Represents an annual decline in the vehicle's re-sale value. A default value of 15% is provided and users can alter this value.

Other Fixed Annual Cost: These costs include annual registration and inspection fees. CT-Vcost is calibrated for Texas conditions by default; therefore, fixed cost is the sum of the annual registration fee of $64.25[8] and the annual vehicle inspection fee is $28.75[9] for passenger vehicles and light trucks. For heavy trucks a default value of $2,300 is used.

Maintenance Cost: A detailed default maintenance schedule is given for each vehicle. If you wish to alter the maintenance cost, uncheck the box next to *Use Default Maintenance Cost* and click the *Edit Default button* (see the Vehicle Maintenance Module to view instructions on editing maintenance cost).

Running the Single Vehicle Analysis

Once the selected vehicle's specifications are complete click the **Run** button 

on the bottom of the scree which takes you to the **Output Screen.**

[8] Travis County Passenger Vehicles and Light Trucks ($50.75 registration + $13.50 local fees) beginning August 2011, http://www.traviscountytax.org/goVehiclesRegistration.do
[9] Travis and Williamson County Emission Fees (OOBDII/TSI)
http://www.txdps.state.tx.us/vi/misc/faq/insp_faq.htm

Output Screen

Navigating the output screen is very important. All cost values will be represented as annual costs, and this can be altered by checking the **Show Annual Per Mile Cost** box. This feature changes the cost values from annual totals, to cost per mile values based on the total miles predicted annually.

Users can view the output values in the form of graphs and charts (see Figure 16). The easiest way to become familiar with the legends above each graph is to look over the *Quick Reference Guide*.

Clicking the button returns the user to the most recently visited analysis page and the Modify Scenario button MODIFY SCENARIO takes the user to the **Scenario Module**. The Re-Run button RE-RUN, as the name implies, reruns the analysis after changes have been made in the **Scenario Module**.

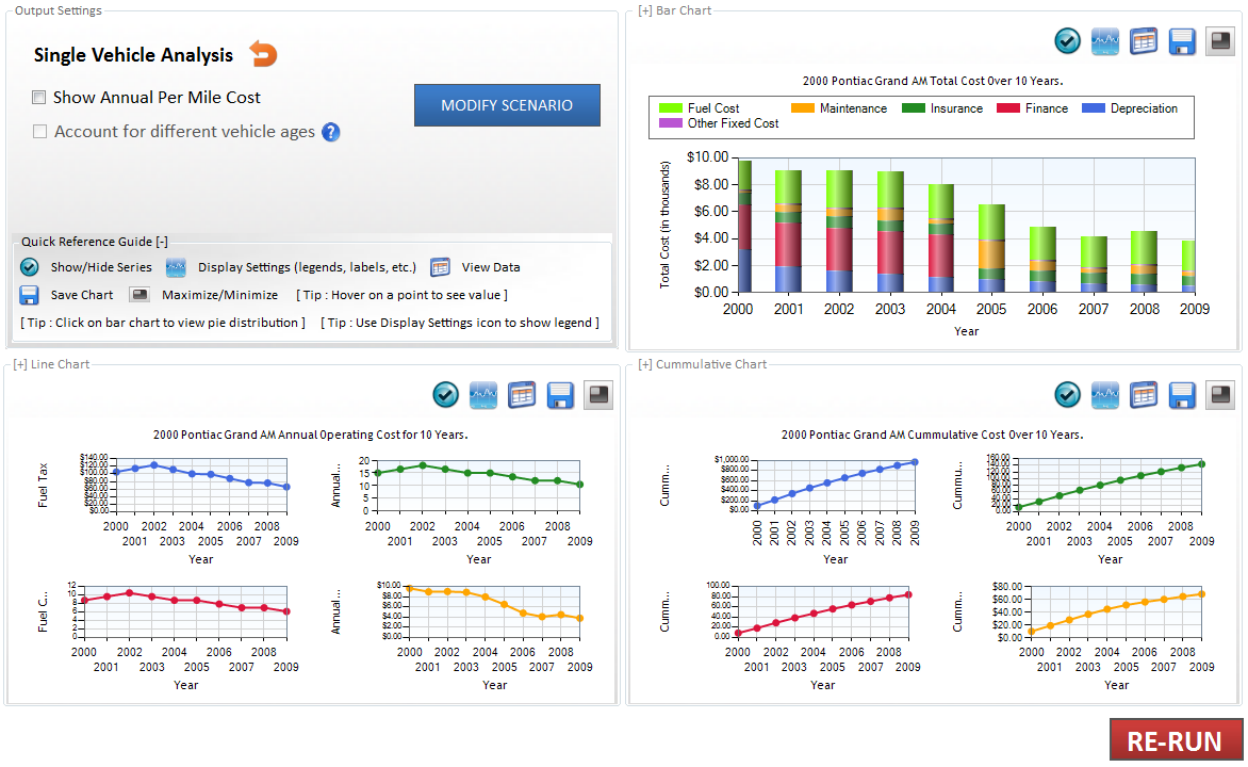

Figure 16: Single Vehicle Analysis Output Screen

Bar Chart

Single Vehicle Analysis: The bar chart shows a breakdown of total annual cost of selected vehicle for the specified analysis period. This cost is broken into the following categories: Fuel Cost, Maintenance, Insurance, Finance, Depreciation, and Other Fixed Costs. When a bar is clicked, the data is represented as a pie chart as illustrated in Figure 17.

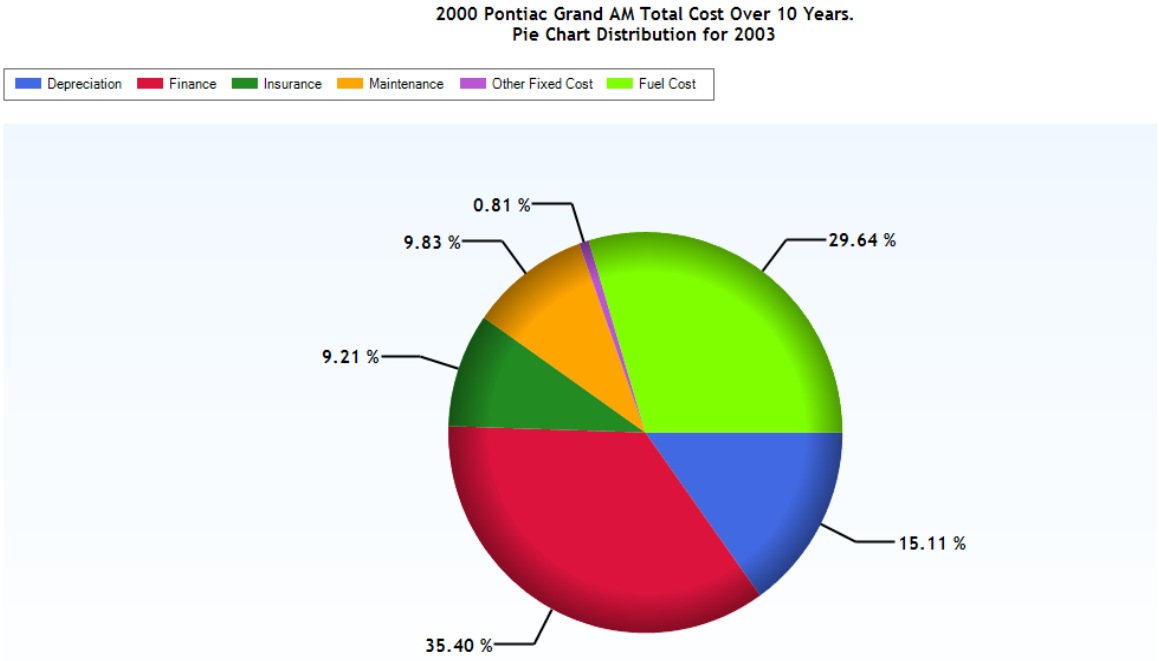

Figure 17: Pie Chart Showing Percent Distribution of Cost Categories

Multi-Vehicle Analysis: The Multi Vehicle outputs are similar to the Single Vehicle outputs, except that more than one vehicle is analyzed and multiple vehicle outputs can be compared simultaneously. Also, bar chart values are not broken down by item (e.g. depreciation, fuel, etc) but rather summed up as the total for each year in the analysis period. Navigation is based mostly on the icons described in the Quick Reference Guide.

Fleet Analysis: Bars representing the total annual cost for all of the vehicles in the selected fleet are shown, by category. When a bar is clicked, the data is represented as a pie chart as illustrated in Figure 17.

Line Chart

Single Vehicle Analysis: Operating cost are separated into annual Fuel Tax, Annual Miles, Fuel Consumed, and Annual Operating Cost (see Figure 18).

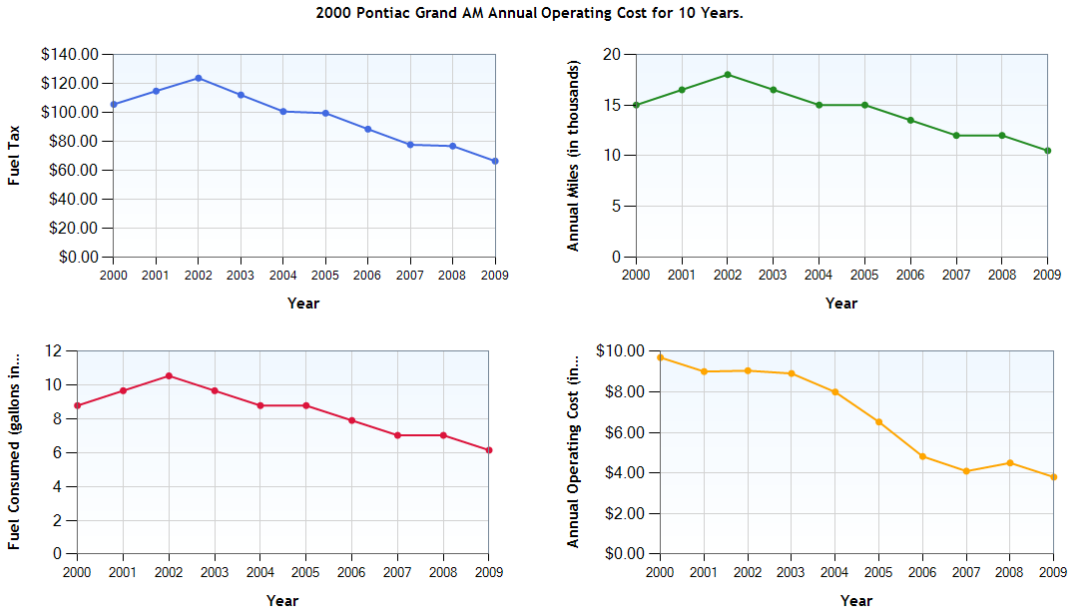

Figure 18: Line Charts showing Fuel Tax, Annual Miles Driven, Fuel Consumed and Annual Operating Cost (with their respective units)

Multi-Vehicle Analysis: Line charts in multi-vehicle analysis include Fuel Tax, Annual Miles Driven, Fuel Consumed, and Annual Operating Cost.

Fleet Analysis: Line charts represent the operating costs for the vehicle fleet and are similar to that of the Single Vehicle Analysis line chart.

Cumulative Chart

Single Vehicle Analysis: The cumulative charts show Cumulative Fuel Tax, Cumulative Annual Miles Driven, Cumulative Fuel Consumed and Cumulative Operating Cost (see Figure 19).

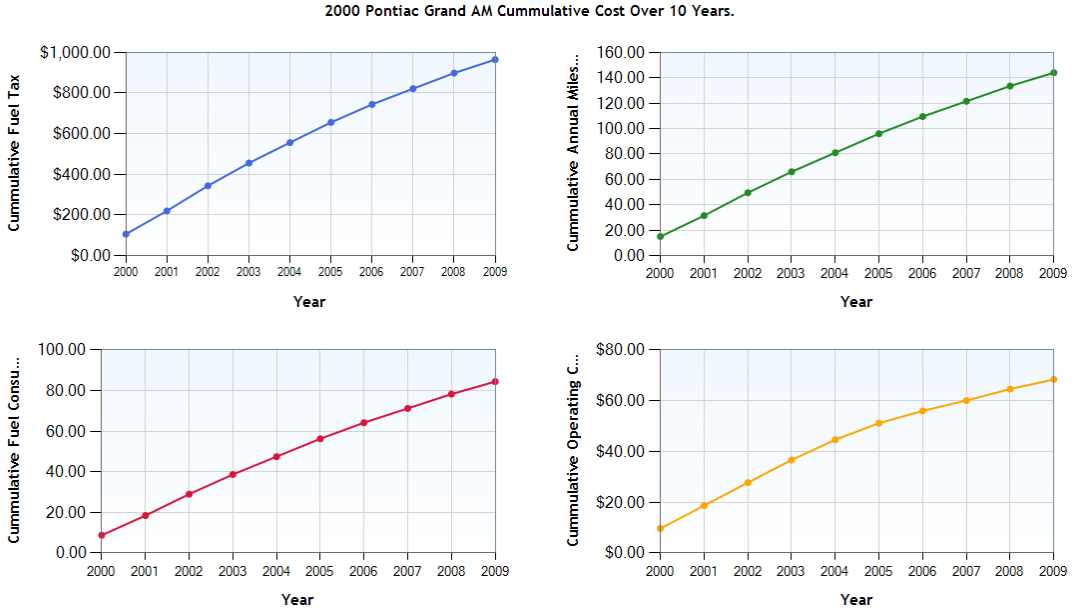

Figure 19: Cumulative Chart showing Cumulative Fuel Tax, Cumulative Annual Miles Driven, Cumulative Fuel Consumed and Cumulative Operating Cost

Multi-Vehicle Analysis: Cumulative costs for each selected vehicle are shown similar to that of the Single Vehicle Analysis output.

Fleet Analysis: Cumulative costs for fleet vehicles are shown and is similar to that of the Single Vehicle Analysis Cumulative Chart.

Show/Hide Series: As illustrated in Figure 20, the *Show/Hide Series* property allows users to either turn on or off a data series for a particular graph. Clicking on the button shows the box *Show Series On/Off* box and users can check or uncheck the series that needs to be turned on or off.

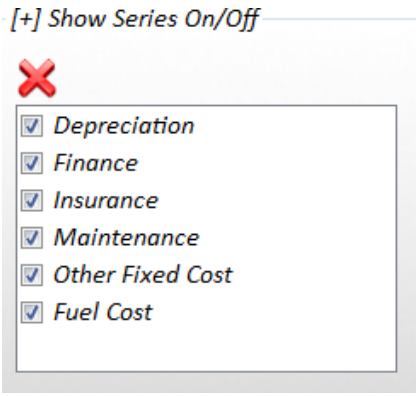

Figure 20: Show Series On/Off Box

Display Settings: As illustrated in Figure 21, the *Display Settings* property allows users to change the charts features such as legend location, chart types, label locations, marker styles, axis characteristics, and 3D charts. Using the *Show MaxMinAvg* option, users can view the maximum, minimum and average values of each series on the chart.

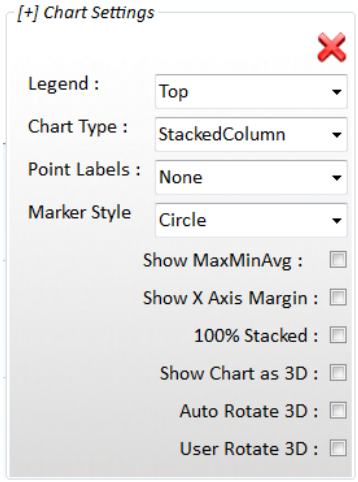

Figure 21: Chart Settings Box

View Data  : As illustrated in Figure 22, the *View Data* property displays the chart data in the form of a table, rather than a graph. The data can be exported to a CSV file when the user clicks the save button.

[+] Chart Data Grid

Year	Depreciation	Finance	Insurance	Maintenance	Other Fixed Cost	Fuel Cost
2000	$3,218.00	$3,268.00	$850.00	$178.24	$75.00	$2,103.52
2001	$1,907.91	$3,229.25	$839.92	$532.09	$74.11	$2,417.90
2002	$1,602.49	$3,190.96	$829.96	$592.32	$73.23	$2,756.30
2003	$1,345.96	$3,153.12	$820.12	$875.53	$72.36	$2,640.21
2004	$1,130.50	$3,115.73	$810.40	$355.12	$71.51	$2,508.10
2005	$949.53	$0.00	$800.79	$2,075.09	$70.66	$2,620.87
2006	$797.53	$0.00	$791.29	$693.85	$69.82	$2,464.83
2007	$669.86	$0.00	$781.91	$282.06	$68.99	$2,289.47
2008	$562.63	$0.00	$772.64	$703.73	$68.17	$2,392.41
2009	$472.57	$0.00	$763.47	$309.88	$67.37	$2,187.47

Figure 22: Chart Data Table

Save Chart  : The *Save Chart* enables users to save the graph in any specified folder in a PNG format which can then be used in documents or presentations.

Maximize/Minimize Chart  : This property enables users to expand the view of the chart. Clicking it again brings the chart back to the default minimized version.

Multi-Vehicle Analysis

Multi-Vehicle Analysis enables users to select up to five or more vehicles, alter their characteristics much like Single Vehicle Analysis, and compare their operating cost outputs.

Selecting a Vehicle

1. Vehicles are selected using the **Filter** and **Search** functions similar to that of the Single Vehicle Analysis.
2. Parameters are edited in a similar fashion as the Single Vehicle Analysis, except for the **Edit Curve** and the **Average Annual Maintenance Cost** inputs. Users can edit a vehicle's utilization curve and average annual maintenance cost values by click on their respective links (see Figure 23).

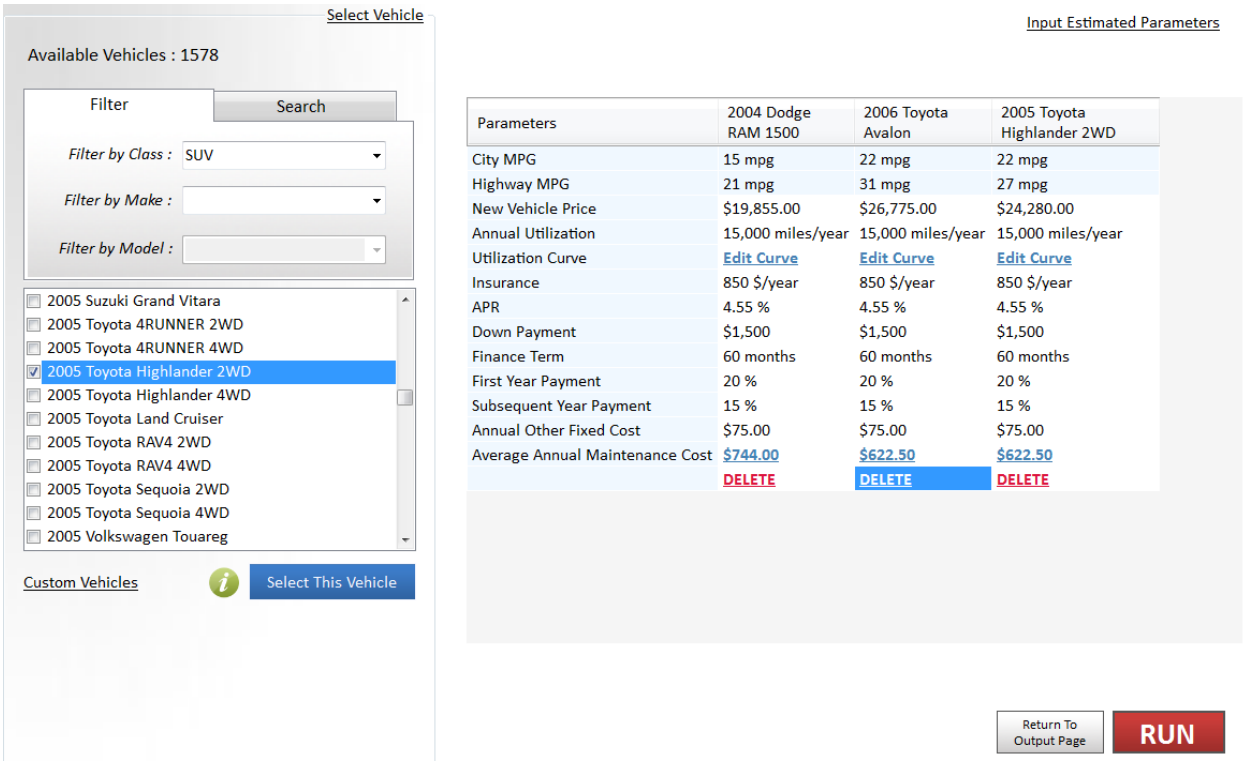

Figure 23: Multi-Vehicle Analysis

3. To delete a selected vehicle, simply click the red **Delete** link.

4. Once vehicles have been selected, click the **RUN** button to enter the Output Screen.

Multi-Vehicle Analysis Output Screen

The Multi-Vehicle outputs are similar to the Single Vehicle outputs, except that more than one vehicle is analyzed and multiple vehicle outputs can be compared simultaneously. Also, bar chart values are not broken down by item (e.g. depreciation, fuel, etc) but rather summed up as the total for each year in the analysis period (see Figure 24). Navigation is based mostly on the icons described in the Quick Reference Guide.

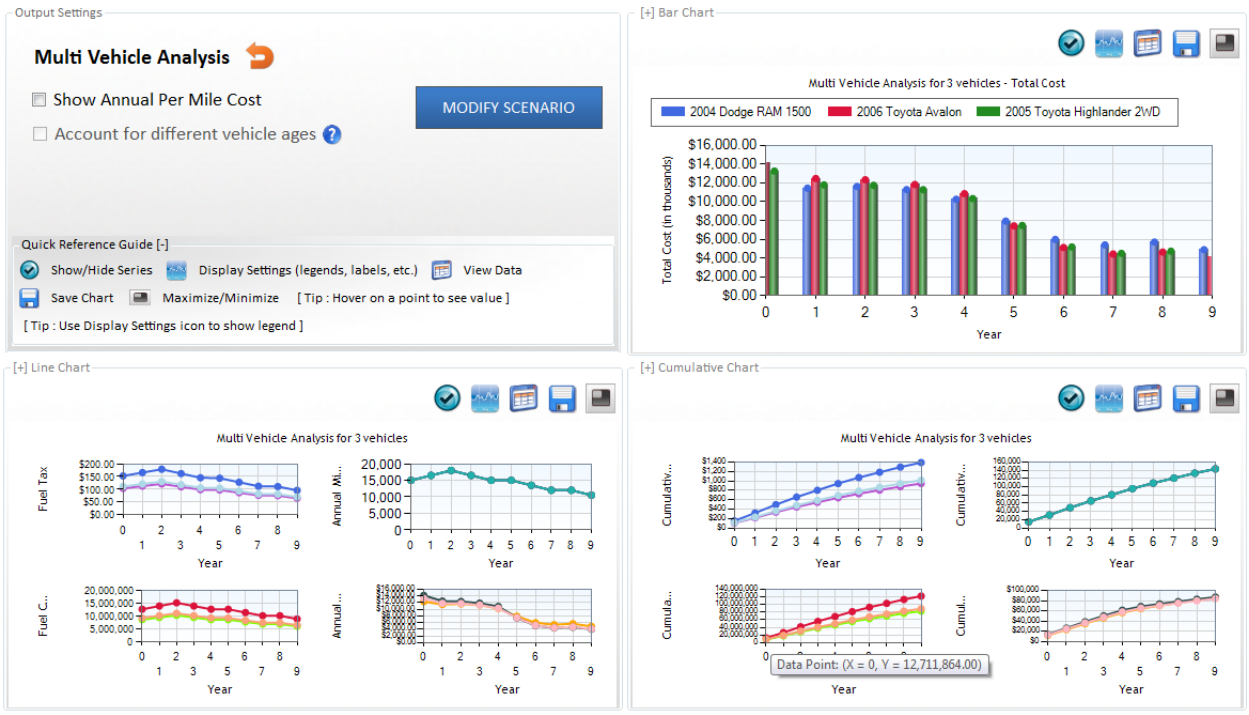

Figure 24: Multi-Vehicle Analysis Output Screen

Fleet Analysis

The Fleet Analysis module enables users to examine the average operating cost for a fleet of vehicles. Users can build a fleet of vehicles from a wide selection of light and heavy duty vehicles, specify the number of vehicles for each class (or model), and modify vehicle parameters similar to that of Single Vehicle and Multi-Vehicle Analysis. The Fleet Analysis window has five main sub-modules which can be accessed via their respective buttons, and a data summary sheet which summaries information from each sub-module (see Figure 25).

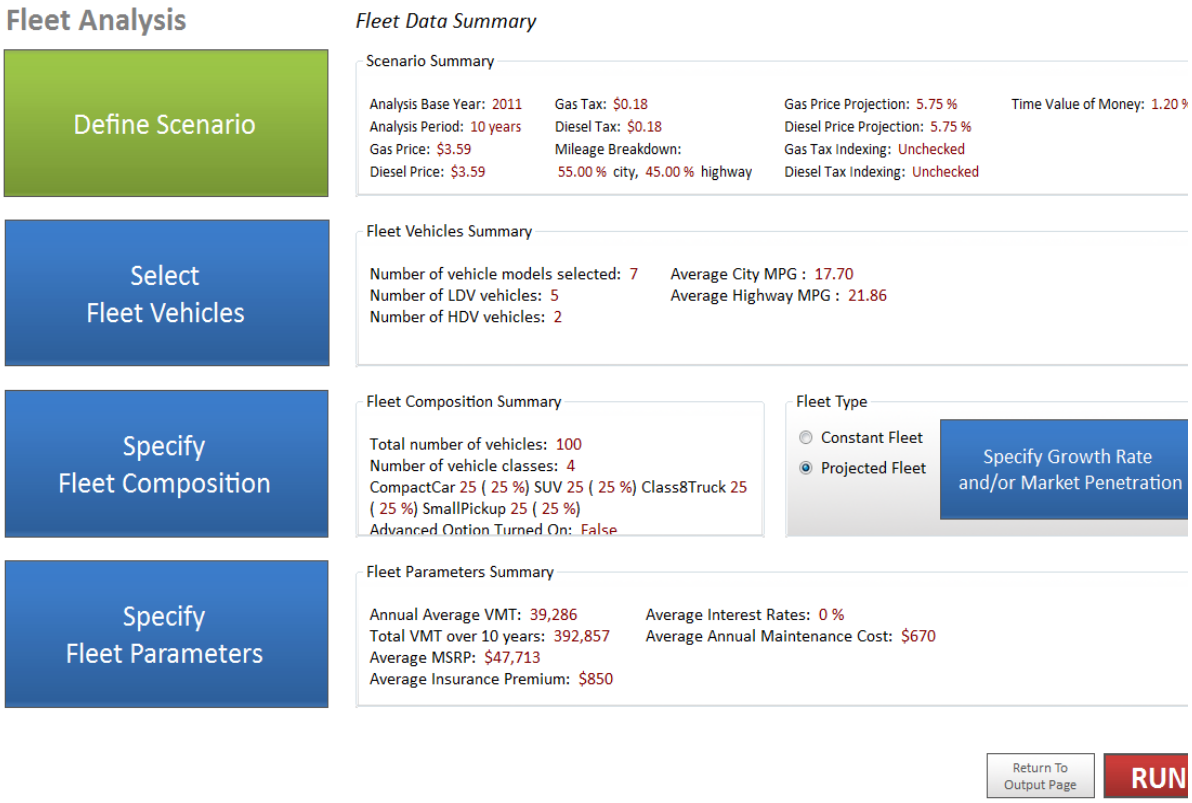

Figure 25: Fleet Analysis

Define Scenario

The Define Scenario button takes the user to the Scenario Module. See the Scenario Module section for further instructions on this module.

Select Fleet Vehicles

1. Click the **Select Fleet Vehicle** button to begin selecting vehicles for the fleet.
2. Select vehicles using either the **Filter** or **Search** options described in the Single Vehicle Analysis. It is possible to check multiple vehicles as well (see Figure 20)
3. Once the desired vehicles are checked, click the **Add Vehicles** button to select them for analysis.
4. It is also possible to navigate between **Light** and **Heavy Duty Vehicles** by clicking on their respective tabs (see Figure 26).
5. Once all the vehicles have been selected, click the **Save** button and move on to the **Specify Fleet Composition** sub-module.

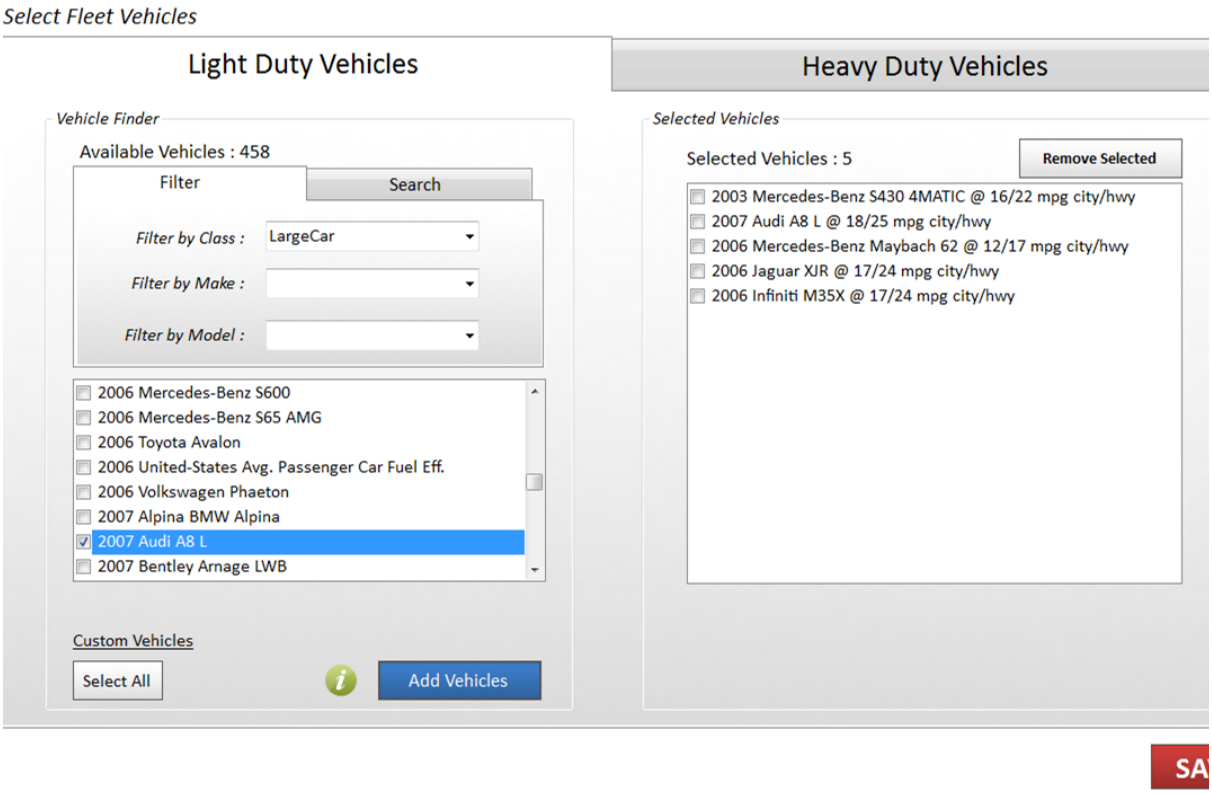

Figure 26: Select Fleet Vehicles

Specifying Fleet Composition

The Fleet Composition module allows users to specify the total number of vehicles in a fleet and the number of vehicle models in each class (see Figure 27).

1. Vehicle composition can be determined either by vehicle class or vehicle model when the user toggles the **Advanced Options** check box.
2. 100 vehicles is the default value for the total number of fleet vehicles, but this be altered by clicking on the text box and entering a different number.
3. Users can alter the percent composition of the fleet by editing the text boxes for each class or vehicle, making sure that all percent values have a sum of 100%.
4. Click "Save" to move on to the next step.

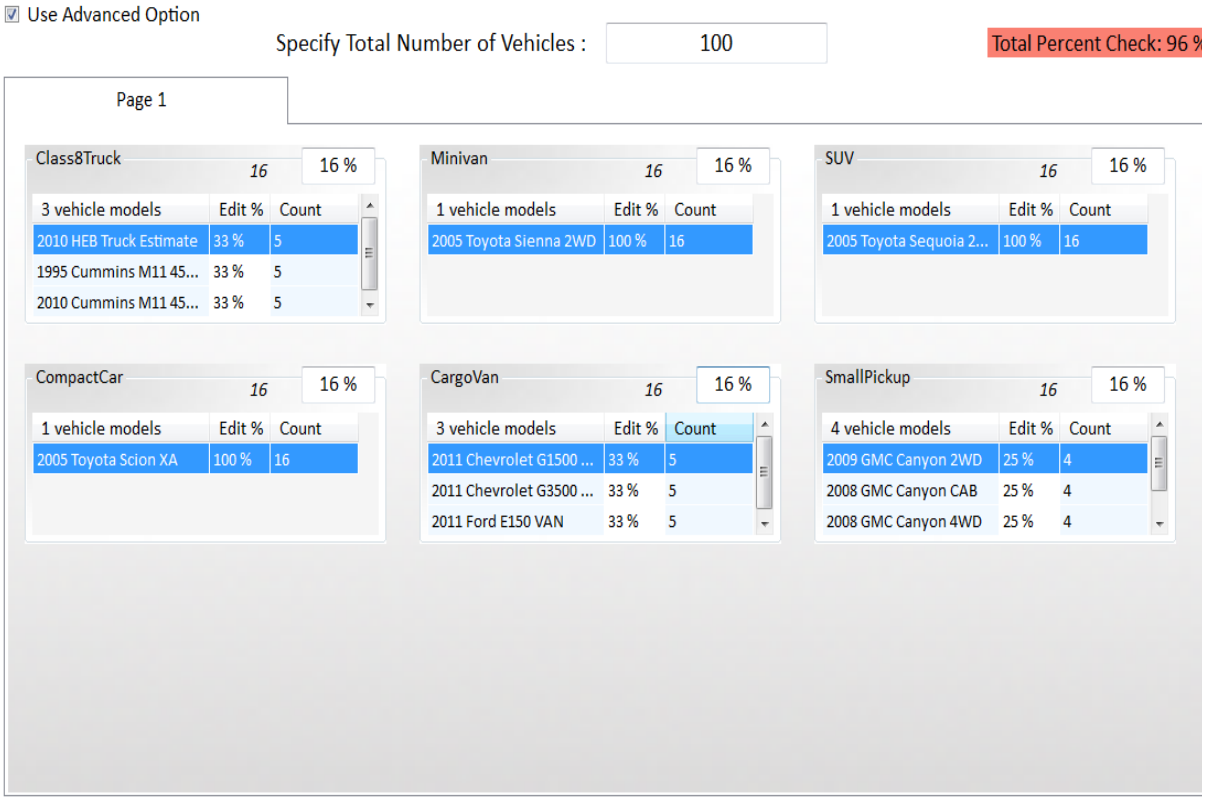

Figure 27: Fleet Composition

Specifying Fleet Parameters

Vehicle parameters can be edited much like in **Single** and **Multi Vehicle Analysis**. This can be done either by **Vehicle Class** or by **Individual Vehicles**. To navigate between the two, click on the radio button to the left of the option desired.

Vehicle Class: Users are able to adjust parameters of all the vehicles in a class by clicking on the text box for the parameter they wish to alter (see Figure 28).

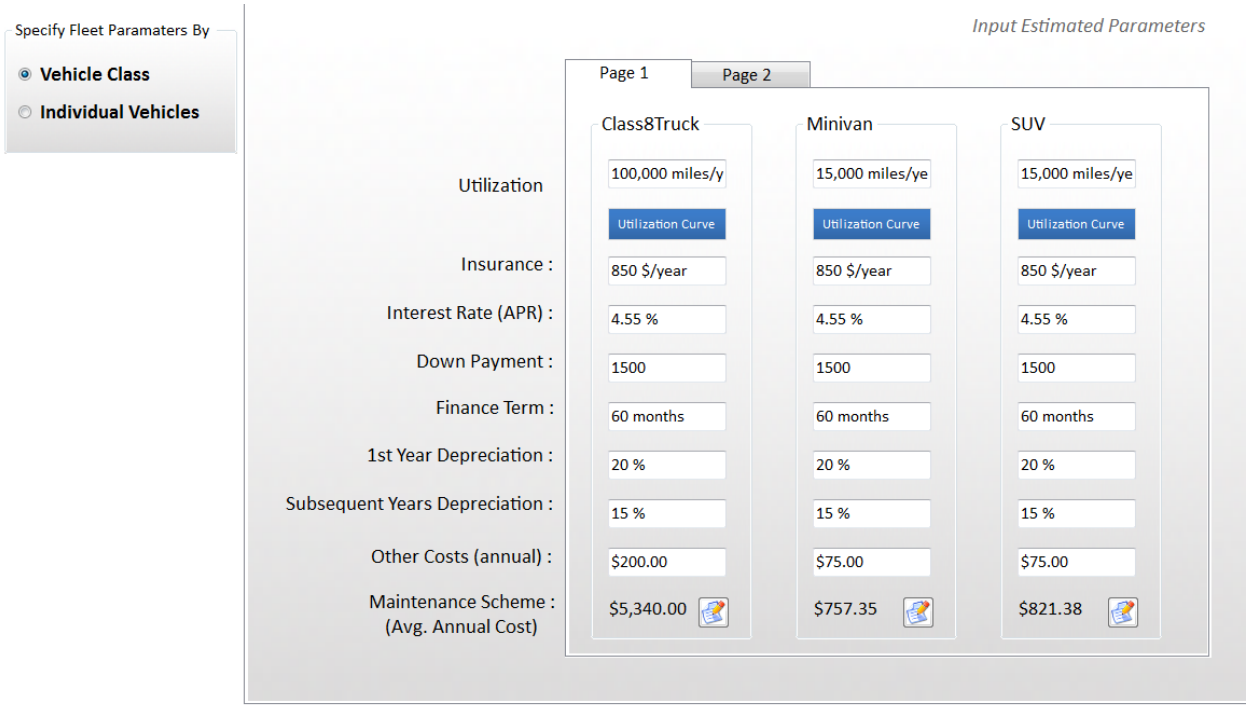

Figure 28: Vehicle Parameters by Vehicle Class

Individual Vehicles: Select vehicles by clicking the drop down arrow below **Filter by Vehicle Class**. This will generate a list of the different classes of selected vehicles. Click the class of the desired vehicle and all vehicles in this class will appear in the list below. Check the vehicles to be edited and click the **Edit** button (see Figure 29). Parameters can be edited in the same fashion as the **Vehicle Class** option.

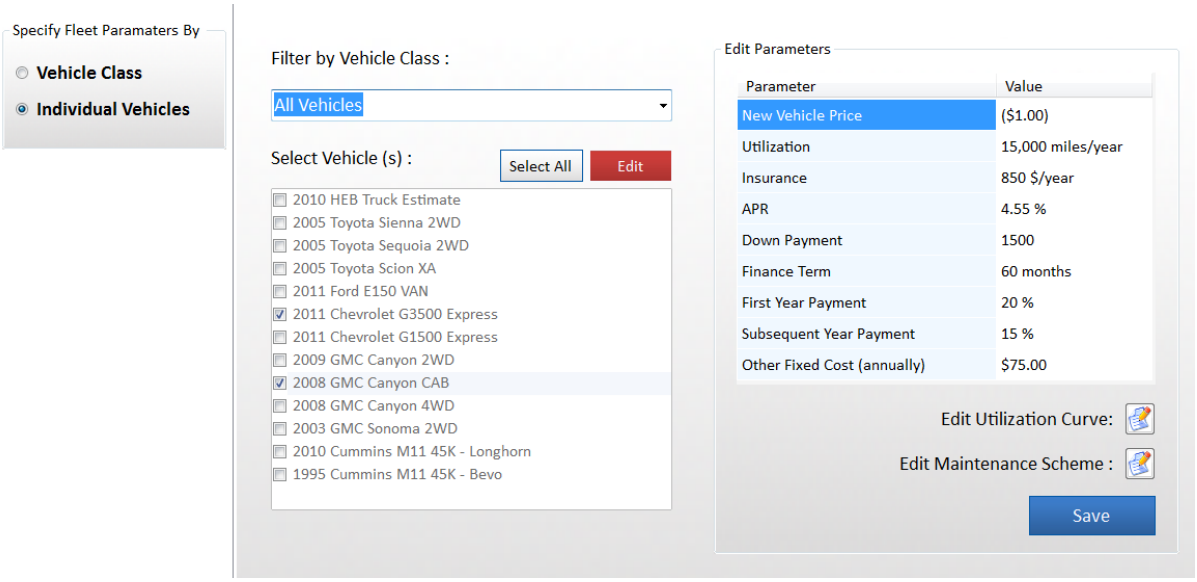

Figure 29: Fleet Parameters by Individual Vehicles

Fleet Analysis Output

Once vehicles are selected, compositions defined and parameters are specified, the user can click on the Run button 

on the **Fleet Analysis** page.

The output page for **Fleet Analysis** is much like the output pages for Single and Multi Vehicle Analysis. Fleet Analysis, however, has an additional feature that is unavailable to the other applications. This feature allows you to account for different vehicle ages.

1. Check the box to the left of the Account for different vehicle ages option.
2. Users can specify maximum life for all the vehicles in the fleet as long as the age does not exceed the length of the analysis period.
3. Once users have specified the ***Maximum Vehicle Life*** the red RE-RUN button can be clicked to generate new output data (see Figure 30).

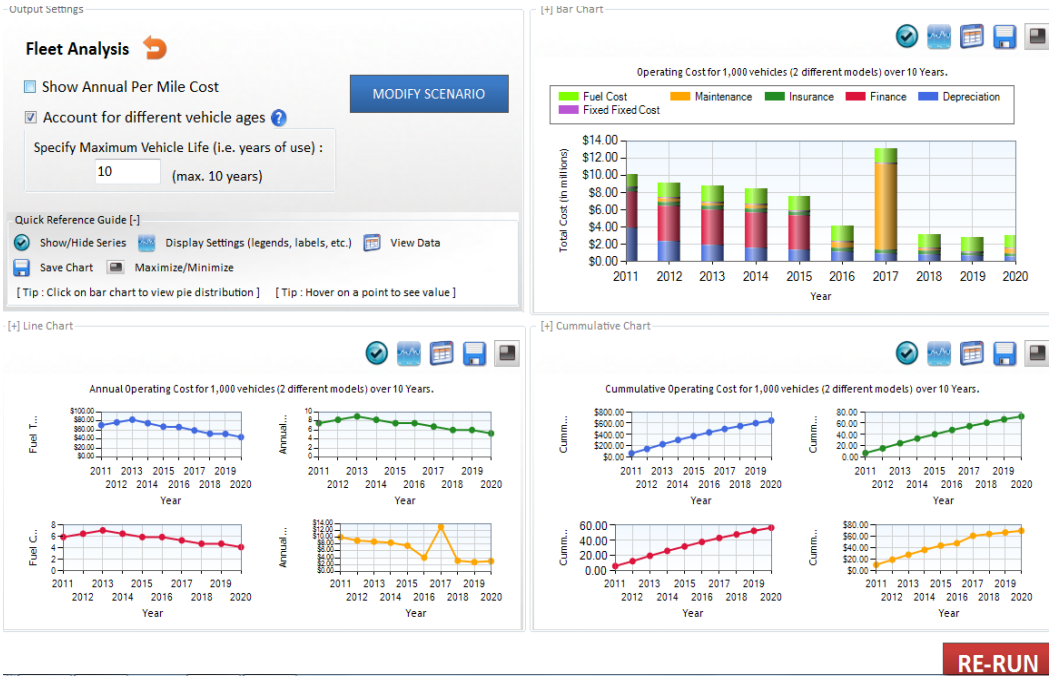

Figure 30: Fleet Analysis Output with Account for Different Vehicle Ages Turned On

Growth Rate and Market Penetration Analysis

The **Growth Rate and Market Penetration** module is an extension of **Fleet Analysis** module. It enables planners to examine how various vehicle models (such as hybrids and pure electric vehicles) and fleet growth rates may influence fuel tax revenues, fuel consumption and carbon emissions over a projected time period. The module can be accessed on the Fleet Analysis page by selecting the **Projected Fleet Option** and clicking on the **Specify Growth Rate and/or Market Penetration Button** (see Figure 31).

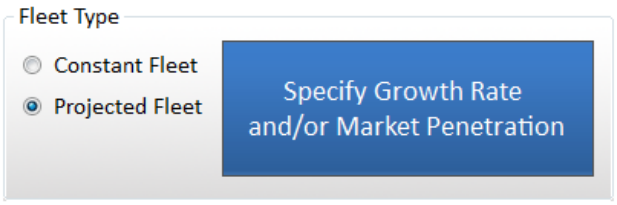

Figure 31: Access the Growth Rate and Market Penetration Module

Growth Rate

1. On the **Growth Rate/Market Penetration** page users can input expected vehicle growth rate (in percentages) into the *Growth Rate* column and the number of years that growth rate will occur in the *No. of Years* column. The *Initial Count* is equal to the specified *Total Number of Vehicles* in the **Fleet Composition** module and the default number of years is equal to the length of the analysis period (see Figure 32)

2. To add additional growth rates, click the Add Growth Rate *Add Growth Rate* button, which displays additional *Growth Rate* and *No. of Years* columns. **Note:** The total number of years specified (or the sum of the number of years specified) should not exceed the analysis period. A maximum of six growth rates can be specified by the user.

3. Clicking the *Remove Growth Rate* Remove Growth Rate button removes the last *Growth Rate* and *No. of Years* columns.

4. To view a graph of the specified projections, click on the *Plot Graph* Plot Graph button.

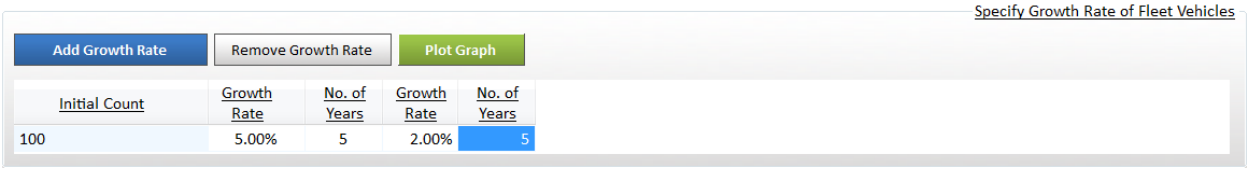

Figure 32: Growth Rate of Fleet Vehicles

Market Penetration

1. Begin by selecting a vehicle model from the *Select Vehicle* drop down column. The initial vehicle count is retrieved from the **Fleet Composition** module and displayed in the *Initial Count* column.

2. Using percentages, specify the Annual Market Penetration (MP) of the vehicle model, and the number of years that percentage change will occur.

3. Add vehicles to the market penetration table by using the *Add Vehicle* Add Vehicle button and remove vehicles from the list using the Remove Vehicle Remove Vehicle button (see Figure 33).

4. Account for changes in market penetration using the Add Market Penetration Add Market Penetration and Remove Market Penetration Remove Market Penetration buttons. **Note:** Total number of years (or the sum of the number of years) specified for each vehicle model cannot exceed the analysis period.

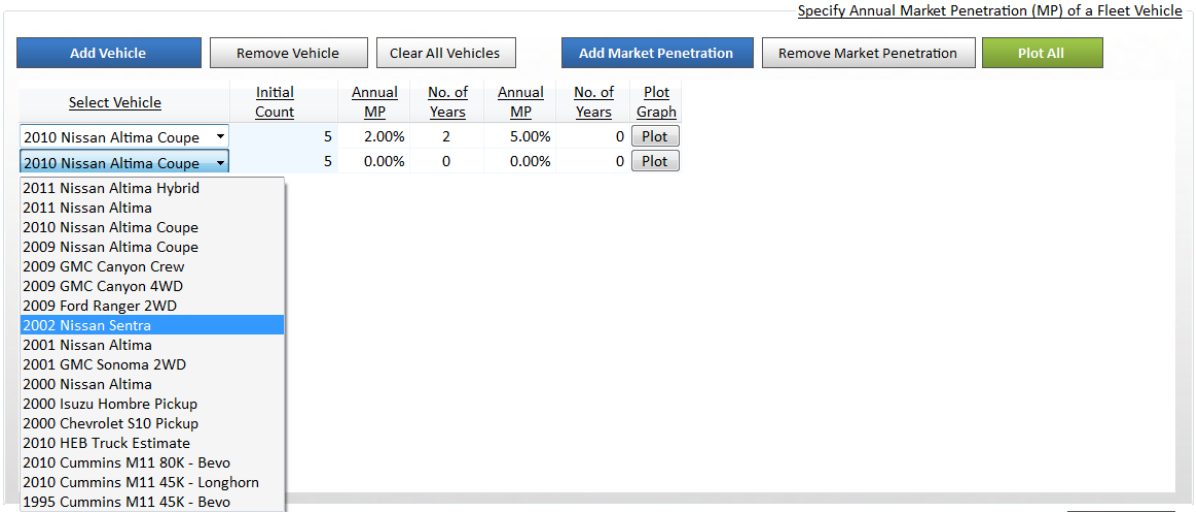

Figure 33: Annual Market Penetration of a Fleet Vehicle Model

Click the *Save* SAVE button to return to the **Fleet Analysis** screen.

Route Cost Analysis

The **Route Cost Analysis** is accessible via the **Route Cost and Drive Cycle Analyses** page (see Figure 34).

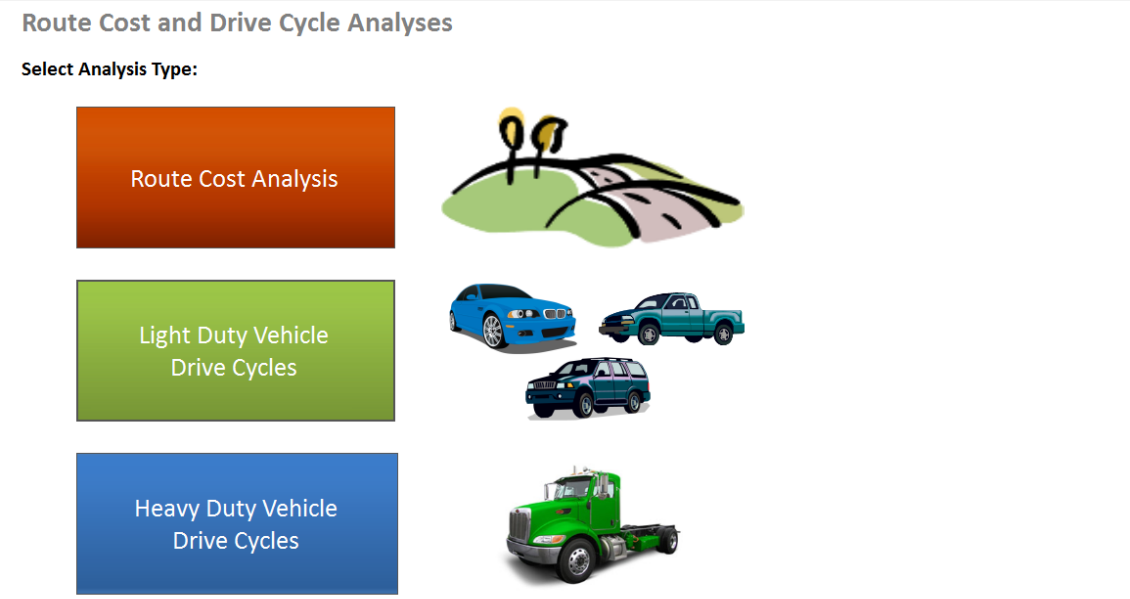

Figure 34: Route Cost and Drive Cycle Analyses

This enables users to determine the cost of driving a vehicle (or fleet of vehicles) on a particular route or multiple routes. It enables users to:

- Select a fleet of vehicles and specify the routes, average speeds, road use charges and congestion levels along the routes.
- Examine vehicle operational costs, fuel consumption, and other items of interest along the routes

Many of the steps in **Route Cost Analysis** module are similar to the **Fleet Analysis** module except that the users must define the different routes using the **Build Route** sub-module (see Figure 35).

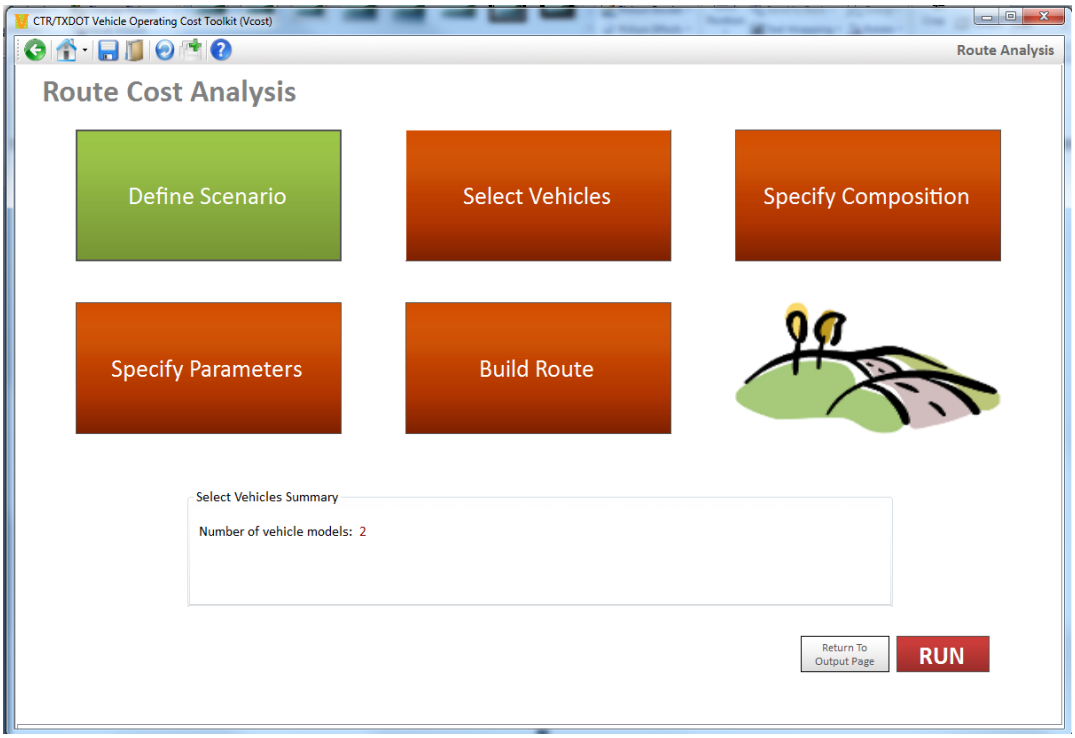

Figure 35: Route Cost Analysis

The steps to be followed with running the **Route Cost Analysis** module are

1. Define Scenario using the **Scenario Module**
2. Select fleet vehicles (see **Fleet Vehicles** section)
3. Specify vehicle compositions (see **Fleet Composition** section)
4. Specify vehicle parameters (see **Fleet Parameters** section)
5. Build Route (see Figure 36)

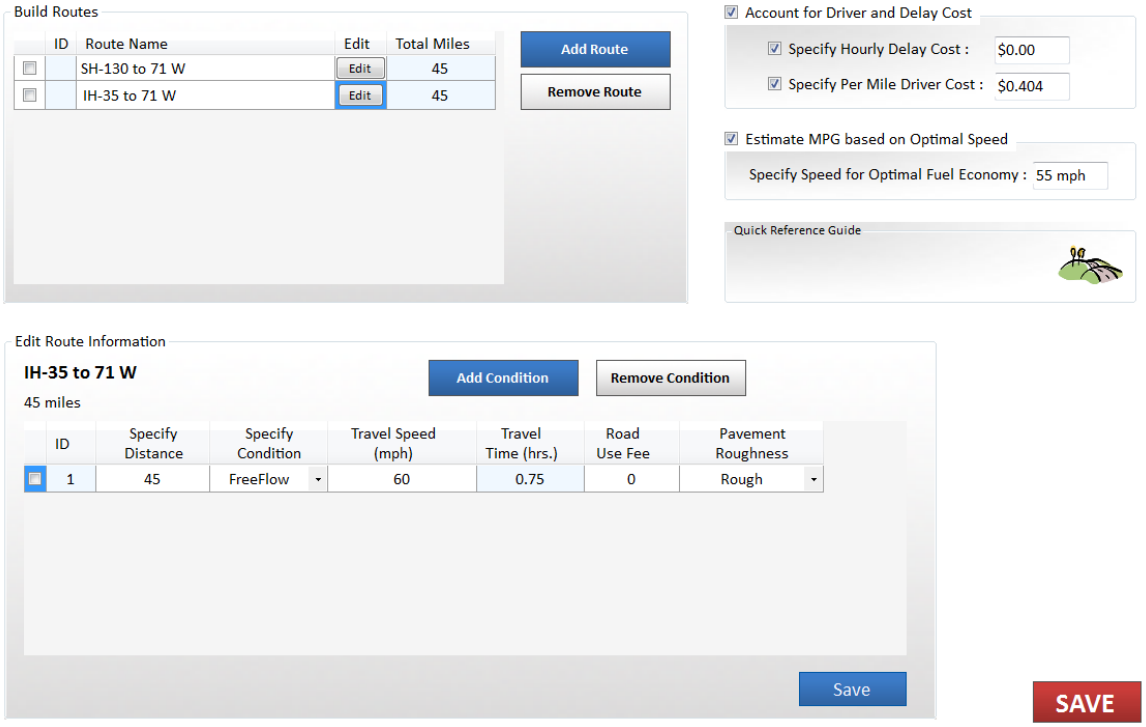

Figure 36: Route Builder Module

Building Routes

a. Begin building routes by clicking the **Add Route** button (see Figure 37)

b. Click on the text box underneath the *Route Name* column and specify the route name (e.g. T11)

c. Click the **Edit** button next to the *Route Name* to specify the route characteristics. This will generate a new window labeled "**Edit Route Information**"

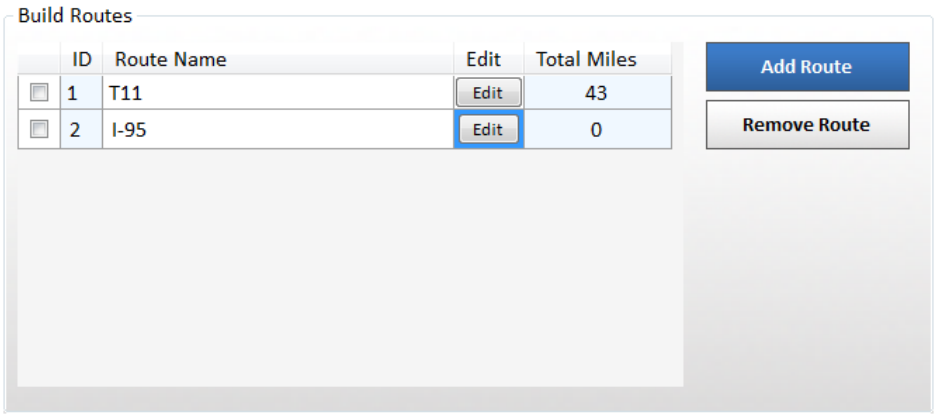

Figure 37: Building Routes

d. Edit the route characteristics by first clicking the **Add Condition** button.

e. Edit characteristics of the route such as *Distance* and *Speed* by clicking on the text boxes and entering the information.

f. Select a Traffic condition from the *Specify Condition* drop down list. Available conditions include Congested, Free-flow, and Moderate (see Figure 38).

g. Click on the **Add Condition** button again to add another route characteristic. Use the **Remove Condition** button to remove a route characteristic.

h. When done specifying all route characteristics, click the **Save** button.

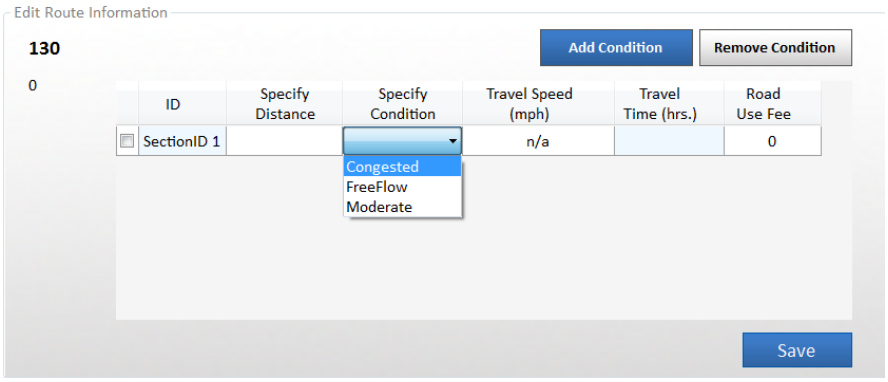

Figure 38: Specifying Route Characteristics

i. Add multiple routes by following steps a through h.

j. The Route Builder also provides users with an additional option of specifying vehicle delay cost on an hourly or per mile basis (see Figure 39). Check the appropriate box and specify an hourly or per mile cost value in their corresponding text boxes.

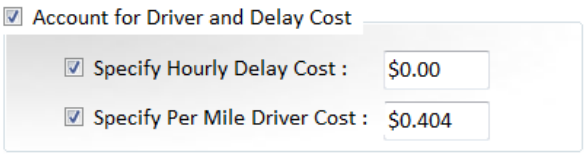

Figure 39: Accounting for Driver and Delay Cost

k. Check on the Estimate MPG based on Optimal Speed checkbox to account for a slightly more accurate depiction of vehicle MPG based on the travel speed. CT-Vcost is packaged with two different algorithms to calculate fuel consumption as a function of vehicle speed: 1) the slope-based approach and 2) the lookup table approach.

Slope-Based Approach: Fuel consumption is calculated as a function of speed using at least two known points: city miles per gallon (mpg_{city}) and highway mpg (mpg_{hwy}). This approach assumes that city mpg and highway mpg are achieved at average cycle speeds of 21.2 mph ($\bar{v}_{city}$) and 48.3 mph ($\bar{v}_{hwy}$) respectively, according to EPA tests results[10]. The user then specifies an optimum mpg speed (v_o) and using Equation 1 and 2, the possible mpg estimates are derived. As illustrated in Figure 40, the slope-based approach, though simple and replicable for most vehicles, is not entirely accurate as optimum mpg varies between 25 to 55 mph when using actual fuel economy data[11].

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[10] U.S. Environmental Protection Agency, Detailed Test Information. Available at http://www.fueleconomy.gov/feg/fe_test_schedules.shtml. Accessed July 2011

[11] B.H. West, R.N. McGill, J.W. Hodgson, S.S. Sluder, D.E. Smith, Development and Verification of Light-Duty Modal Emissions and Fuel Consumption Values for Traffic Models, Washington, DC, April 1997, and additional project data, April 1998. (Additional resources: www.fhwa-tsis.com)

$$f(v) = \begin{cases} (v * m) + mpg_{city} & if\ v \le v_o \\ f(v_o) - m * (v - v_o) & if\ v > v_o \end{cases} \quad (1)$$

where the slope (m) is defined as

$$m = \frac{mpg_{hwy} - mpg_{city}}{\bar{v}_{hwy} - \bar{v}_{city}} \quad (2)$$

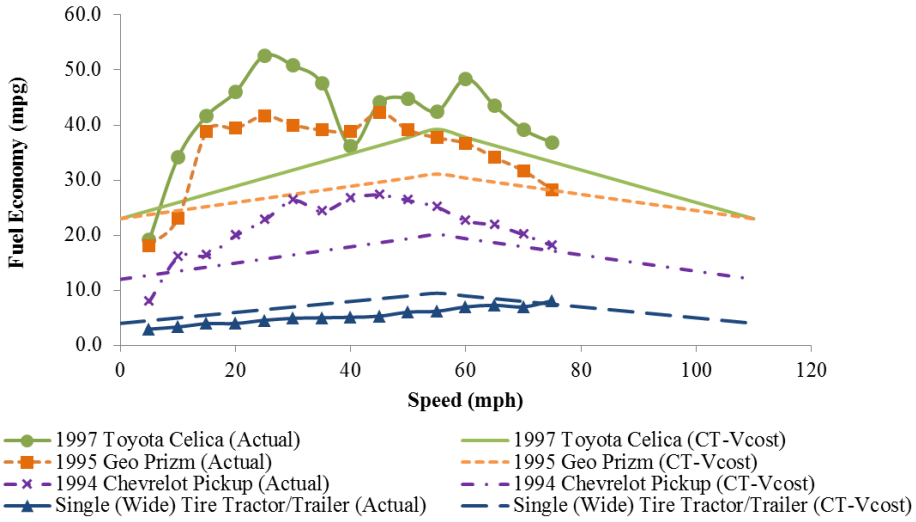


Figure 40: Comparison of slope-based approach with actual fuel economy data.

TABLE 1 Sample Lookup Table

Speed (v_i) (mph)	**1994 Chevy Pickup** (25)	**1994 Jeep Grand Cherokee** (25)	**1997 Toyota Celica** (25)	**Dual Tire Tractor/ Dual Tire Trailer** (21)	**Dual Tire Tractor/ Single (Wide) Tire Trailer** (21)	**Single (Wide) Tire Tractor/ Dual Tire Trailer** (21)	**Single (Wide) Tire Tractor/ Trailer** (21)
5	7.9	8.2	19.1	2.8	2.9	3.0	3.0
10	16	11.2	34.1	3.4	3.6	3.3	3.4
15	16.3	17.5	41.7	3.8	4.0	3.9	4.0
20	19.9	24.7	46	3.7	4.0	4.0	4.0
25	22.7	21.8	52.6	4.1	4.3	4.6	4.6
30	26.3	21.6	50.8	4.4	4.6	5.0	4.9
35	24.3	25	47.6	4.4	4.9	5.2	5.0
40	26.7	25.5	36.2	4.8	5.2	5.3	5.1
45	27.3	25.4	44.1	5.1	5.4	5.6	5.3
50	26.3	24.8	44.8	5.4	5.8	6.2	6.0
55	25.1	24	42.5	5.8	6.1	6.2	6.2
60	22.6	23.2	48.4	6.3	6.8	6.9	7.0
65	21.8	21.3	43.5	6.6	7.2	7.1	7.3
70	20.1	20	39.2	7.0	7.7	7.0	7.0
75	18.1	19.1	36.8	7.5	7.9	7.9	8.1

Lookup Table Approach: The lookup table approach provides a much better estimate of mpg as function of speed by utilizing actual mpg values (see Table 1). This approach, though more accurate, is dependent on the availability of accurate data. For each speed ($\boldsymbol{v}$) on the specified route profile, CT-Vcost iterates through each row of the column matching the vehicle model, and returns the vehicle's mpg, $\boldsymbol{f(v)}$. When the vehicle speed ($\boldsymbol{v}$) falls within the range of two successive speeds (($\boldsymbol{v_i}$) and ($\boldsymbol{v_{i+1}}$)), the mpgs of the successive speeds ($\boldsymbol{f(v_i)}$ and $\boldsymbol{f(v_{i+1})}$) are used in determining the vehicles mpg $\boldsymbol{f(v)}$ as illustrated in Equation 3.

$$f(v) = \left[\left(\frac{f(v_{i+1}) - f(v_i)}{v_{i+1} - v_i}\right) \times (v - v_i)\right] + f(v_i) \qquad (3)$$

l. Upon completion, click the *Save* SAVE button to return to the **Route Cost Analysis** home page.

m. Click the **Run** button to proceed with performing the analysis.

Route Cost Analysis Output

The data generated in the **Route Cost Analysis** output slightly differs from the output of the other applications. It is still possible to Modify Scenario from this output page, but the "*Show Annual Per Mile Cost*" and "*Account for different vehicle ages*" options are disabled (see Figure 37).

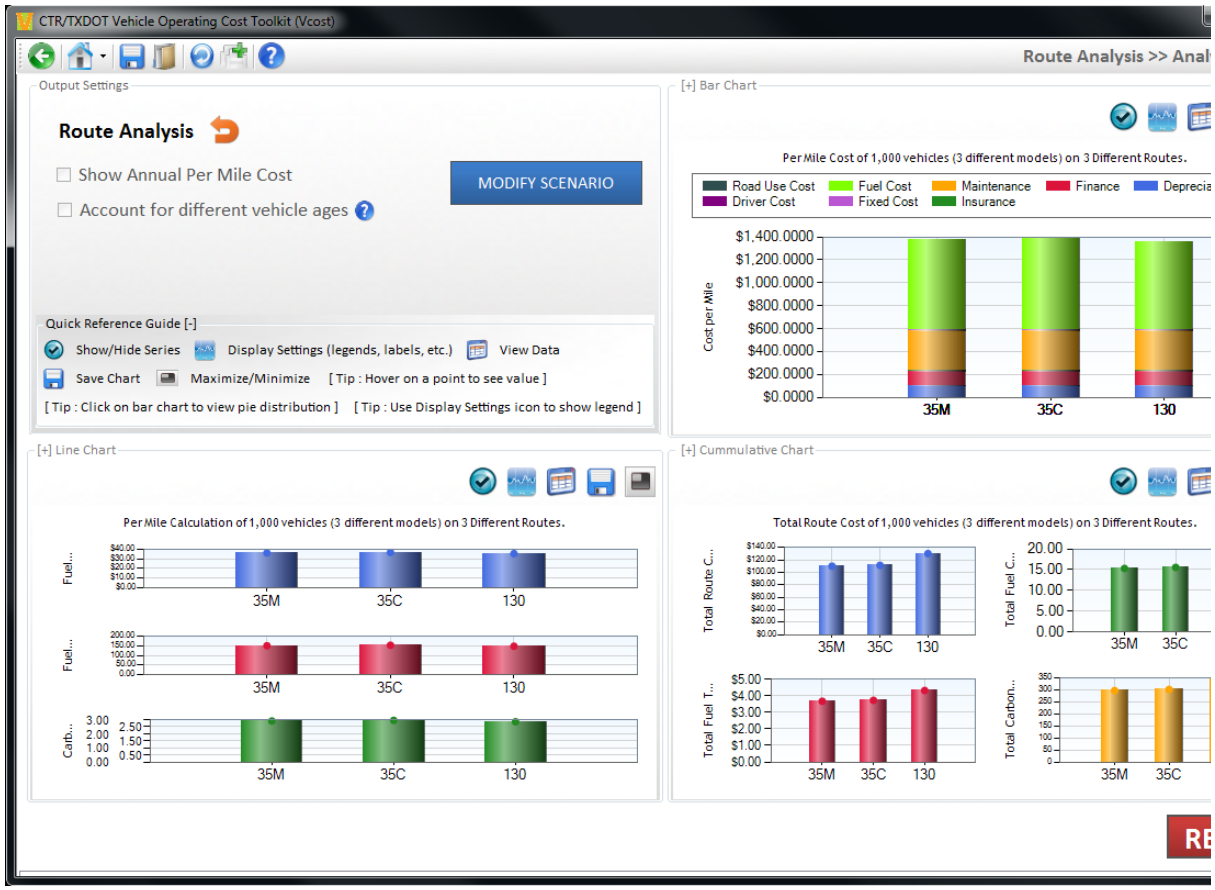


Figure 37: Route Cost Analysis Output

The *Bar Chart* group box shows total route cost of each specified route, and broken down into their various categories (Fuel Cost, Road Use Cost, Driver Cost, etc.). Clicking on each bar returns a pie distribution chart similar to the other applications.

Distinct from the other applications, the *Line Chart* group box shows bar chart data of per mile fuel cost, fuel consumption, carbon footprint, and total travel time for each specified route.

The *Cummulative Chart* group box also shows output for total route cost, total fuel tax, total fuel consumption and total carbon footprint for each specified route.

Light Duty Vehicle Drive Cycle Analysis

The Light Duty Vehicle (LDV) Drive Cycle analysis module is an integration of UT's LDV Fuel Economy Model (UT_LDV) into CT-Vcost. Users are provided the option of building vehicle input data which feeds into the UT_LDVFEM model (see Figure 38).

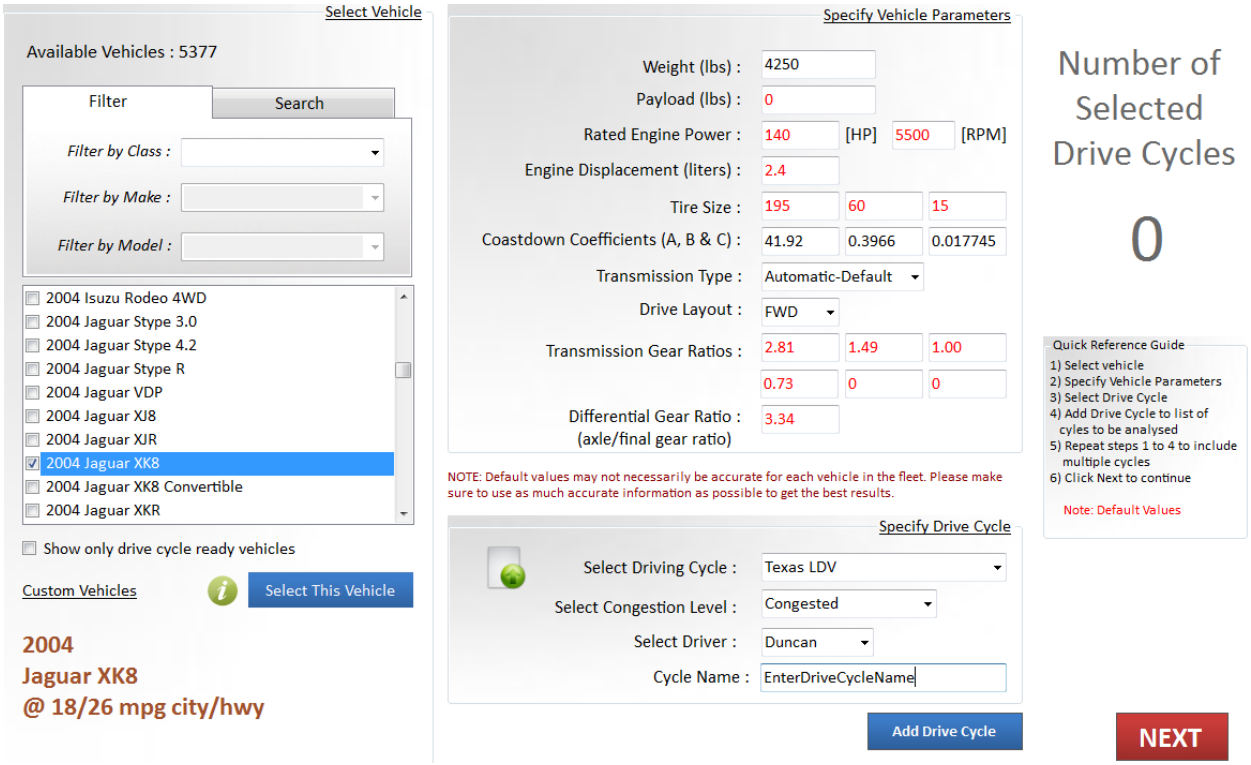


Figure 38: Light Duty Vehicle Drive Cycles Analysis

1. Similar to the **Single Analysis** module, users select a vehicle from the list of available vehicle models and advanced vehicle data from these models are transferred to the *Specify Vehicle and Drive Cycle Parameters* text boxes. Data transferred include vehicle weight (in pounds) and the coast down (target) coefficients A, B and C retrieved from the EPA database.

Note:

By default, the **Show only drive cycle ready vehicles** option is checked. This option enables users to select vehicles for which the EPA data is available.

Default values in the *Specify Vehicle and Drive Cycle Parameters* text boxes include engine Max Power (hp), Max Power RPM, Tire Specifications (uses the Section Width/Sidewall Aspect Ratio/Tire and Wheel Diameter convention), Transmission Gear Ratios, and Differential Gear Ratio. Users can change these values but need to ensure that inputs represent a realistic vehicle.

2. Users must select a drive cycle from the **Select Drive Cycle** drop down list located in the *Specify Drive Cycle* group box (see Figure 38).

Note: If the Texas LDV drive cycle is selected, users have the additional option of selecting a Congestion Level (Congested, Moderate, and Freeflow) and a Driver (Duncan, Wayne and Sandra)

3. After specifying vehicle parameters and selecting a drive cycle, click on the *Add Drive Cycle* 

button. This will update the *Number of Selected Drive Cycles* count.

4. New vehicle parameters and drive cycles can be added to the selected drive cycle list by repeating steps 1 to 4.

5. Click on the *Next* 

button to continue to next page - **LDV Drive Cycle Analysis Screen**

Adding Custom Drive Cycles

Custom drive cycles can also be loaded by users by clicking on the *Upload Custom Drive Cycle*  button and selecting the appropriate drive cycle which must be in a .TXT file. It **MUST** also meet the following standards as shown in Figure 39:

1. Contain the following headers: Time [s], Vehicle Speed [mph] and Altitude [ft]

2. Columns must be tab delimited

Note: For LDV drive cycles, Altitude[ft] columns may contain zero values as Altitude is not considered as a variable in the UT_LDV model.

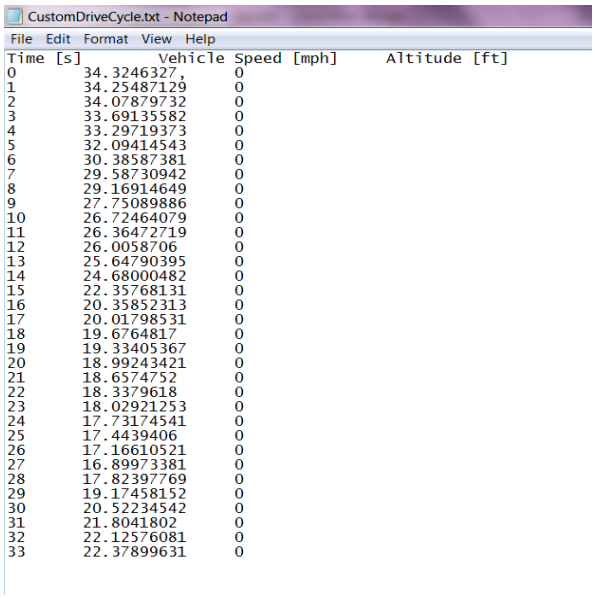


Figure 39: Custom LDV Drive Cycle Example

LDV Drive Cycle Analysis Screen

The LDV Drive Cycle Analysis Screen provides users with two types of analysis, Compare Drive Cycles and Examine Drive Cycle MPG

Compare Drive Cycles

Using the Compare Drive Cycles option, users can select from a list of twelve (12) variables to compare the different drive cycles (see Figure 40).

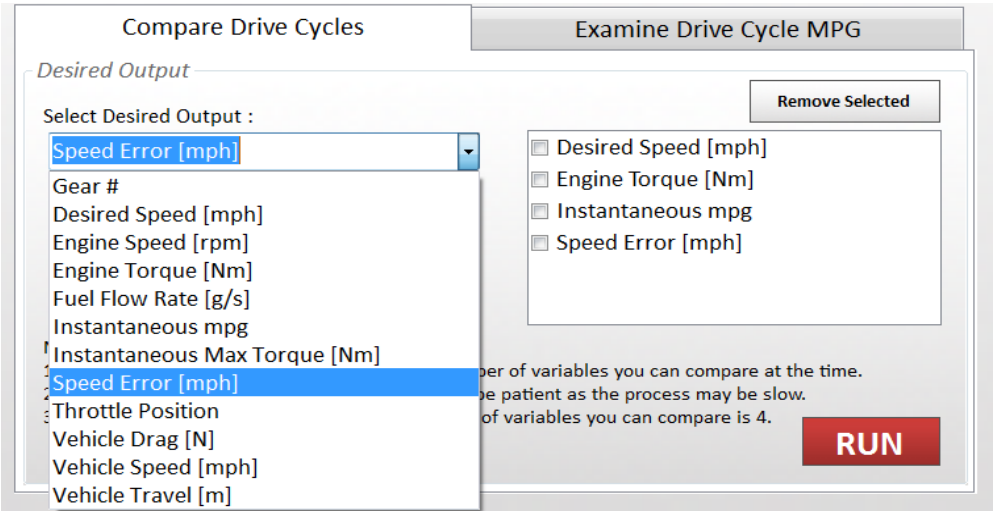


Figure 40: Compare Drive Cycles

1. Select the desired variables from the *Select Desired Output* drop down menu. The list of available variables and their respective units are:
   - Gear #
   - Desired Speed [mph]
   - Engine Speed [rpm]
   - Engine Torque [Nm]
   - Fuel Flow Rate [g/s]
   - Instantaneous mpg
   - Instantaneous Max Torque [Nm]
   - Speed Error [mph]
   - Throttle Position
   - Vehicle Drag [N]
   - Vehicle Speed [mph]
   - Vehicle Travel [m]

2. Click on the *Select Output* button to add a variable to the list of comparable variables
3. Set a Cycle Time Interval between 0.4 and 10 seconds

   Note: The smaller the time interval, the more points are displayed, and the slower the output
4. Click on the *Run* button when done to compare the various drive cycle output as illustrated in Figure 41.

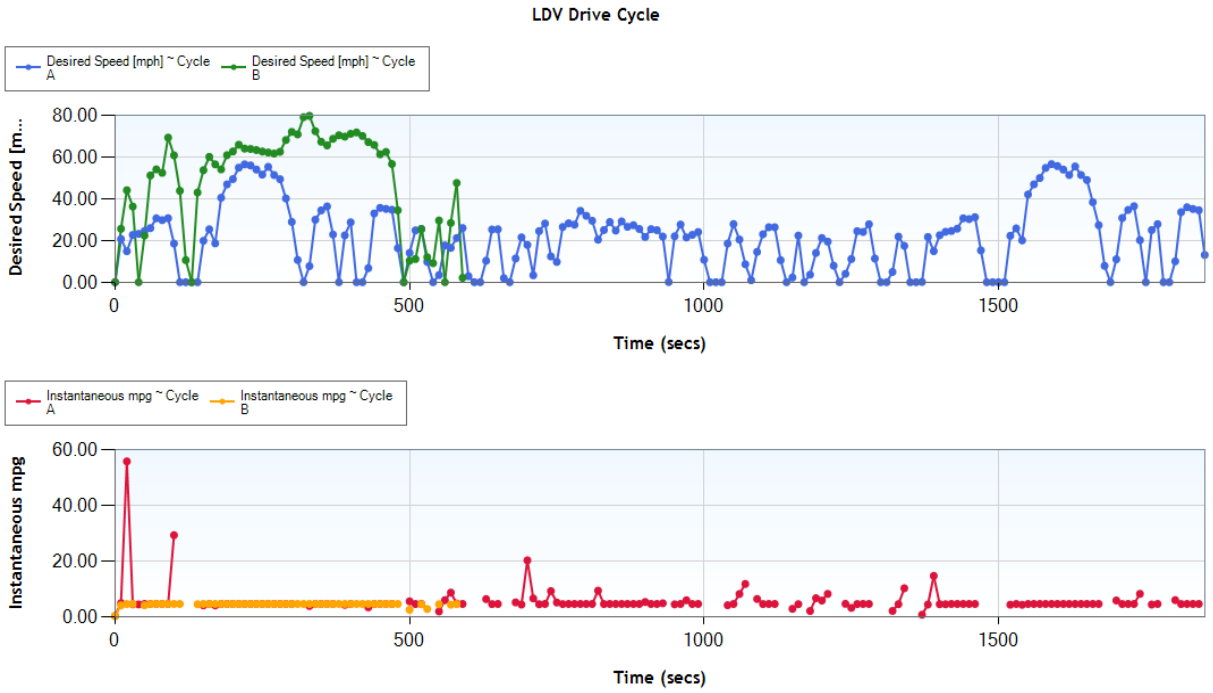


Figure 41: Compare LDV Drive Cycles

Examine Drive Cycle MPG

The Examine Drive Cycle MPG option enables users to examine a drive cycle's vehicle fuel economy, view MPG vs. Speed Curve graphs, and add MPG vs. Speed Curve data to the MPGSpeedCurves.csv which can be utilized by the **Route Cost Analysis** module.

Examining Drive Cycle

This feature enables users to examine the MPG of a vehicle over a selected section of the drive cycle rather than the entire drive cycle. This is useful for determining a vehicle's behavior over certain conditions e.g. congested versus free-flow. To proceed:

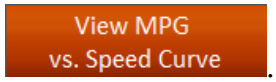
1. Select a drive cycle of interest from the *Select Desired Drive Cycle* drop down menu
2. Click on the **Examine Drive Cycle** button 

to generate a vehicle speed versus time plot of that drive cycle.

3. Using the range selector control  , move the arrows to the desired range, and the drive cycle's vehicle MPG is dynamically calculated and displayed (see Figure 42).

Figure 42: Examine Drive Cycle MPG

Viewing and Saving MPG vs. Drive Cycle

1. Click on the **View MPG vs. Speed Curve** button  . A graph showing the MPG @ Vehicle Speed and MPG @ Desired speed is shown (see Figure 43). This data can be utilized in the Route Cost Analysis module. Click on the **View Data** button  to further examine the raw data.

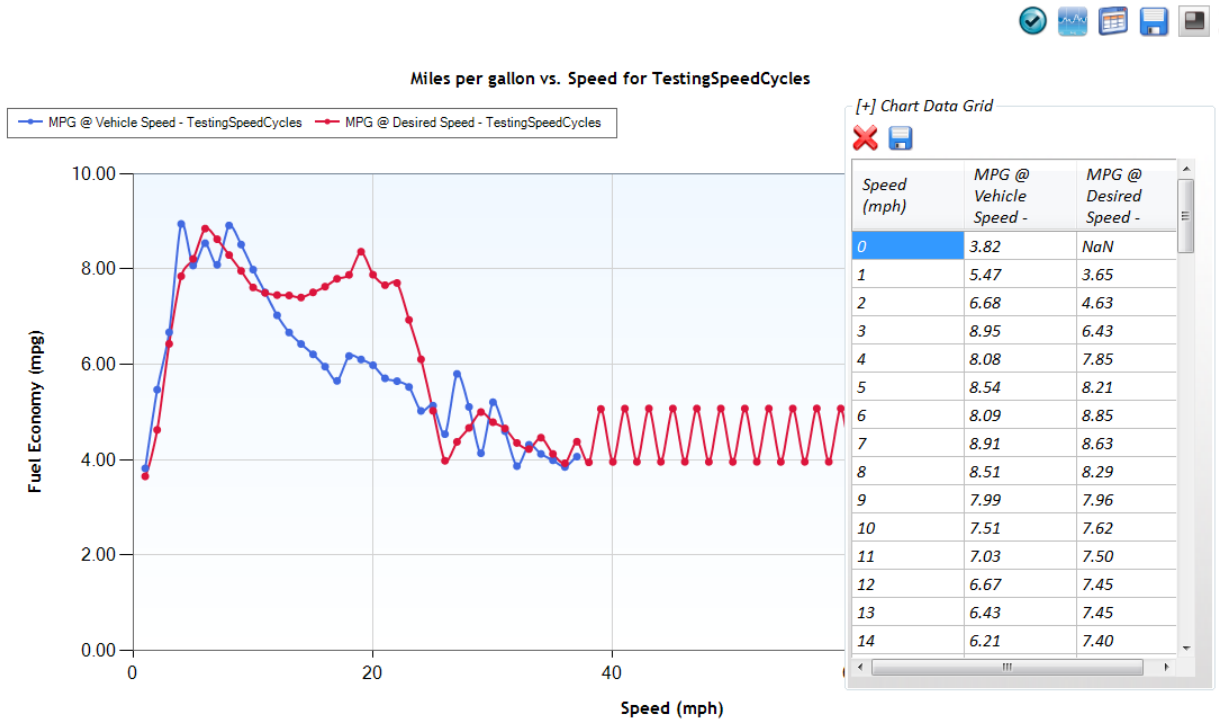


Figure 43: Sample MPG vs. Speed Curves and data for the *"TestingSpeedCycles"* scenario

2. To save the data for later use in the **Route Cost Analysis** module, click on the **Add Data to MPGSpeedCurves.csv** button 

, and a dialog box asking the user to restart the application pops-up (see Figure 44). The user is required to restart the application in order to utilize the data in the Route Cost Analysis module.

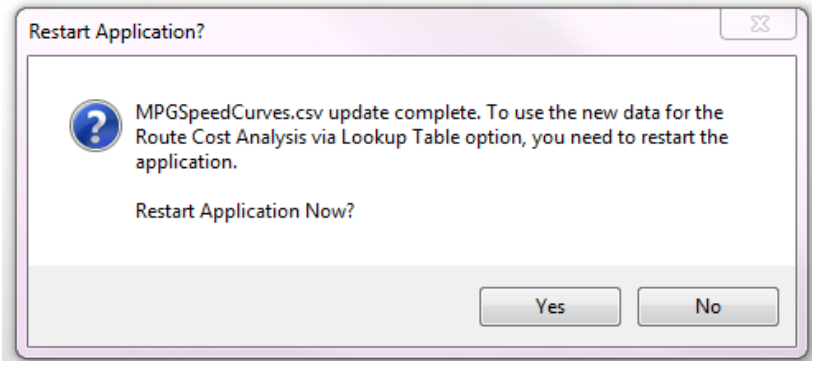


Figure 44: Restart Application Dialog Box

Heavy Duty Vehicle Drive Cycle Analysis

The HDV Drive Cycle analysis is very similar to the LDV Drive Cycle analysis except for the selection of the drive cycle and inclusion of a custom vehicle option. There are four vehicle classes built into CT-Vcost – Class 7, Class 8, Long Combination Vehicles and Heavy Duty Hybrids (see Figure 45).

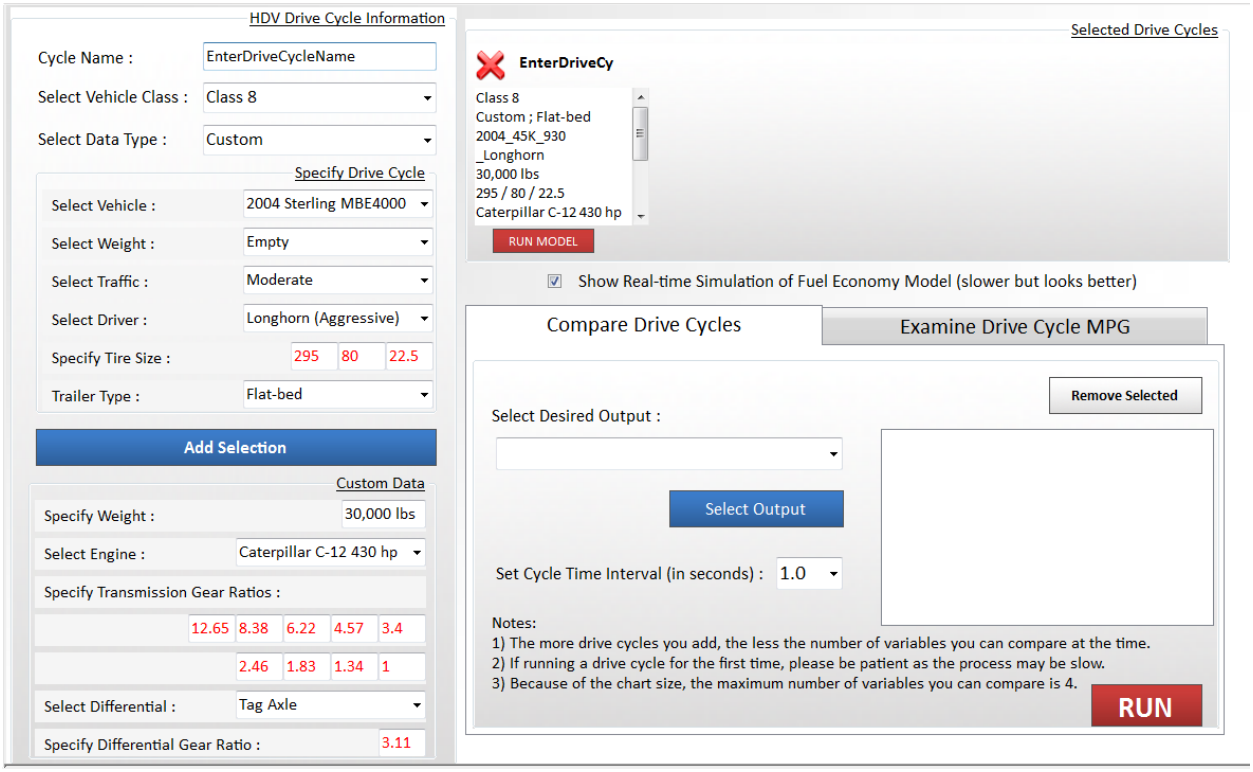


Figure 45: HDV Drive Cycle Analysis

1. Start by specifying a **Cycle Name**. This is used in identifying the drive cycle options selected by the user.

2. Select one of the four vehicle class - Class 7, Class 8, Long Combination Vehicles and Heavy Duty Hybrids.

   Note:
   Long Combination Vehicle and Heavy Duty Hybrids modules were not included in the November 2011 release of the model.

3. Select a **Data Type** i.e. Default or Custom.
    a. If ***Default*** is selected, the user is limited to the default 54 drive cycles for 3 vehicles and the options are as follows:
        i. **Vehicle:** *2004 Sterling MBE4000, 2001 Caterpillar C12,* and *1995 Cummins M11* (see Table 2)
        ii. **Weight:** *Empty (45,000 lbs.), Cubed Out (65,000 lbs.),* and *Weighed Out (80,000 lbs.)*
        iii. **Congestion Level:** *Congested, Freeflow,* and *Moderate*
        iv. **Driver:** (Bevo, Longhorn (Aggressive))
        v. **Tire Size:** Any reasonable tire size value can be specified here.
        vi. **Class 8 Trucks Only:** Trailer Type can be selected. Options include *Flat-bed* and *Box*.
    b. If ***Custom*** is selected, the user is allowed to specify additional parameters such as:
        i. **Weight**: Any custom weight value can be inputted here
        ii. **Engine**: Select between the two types of engines – *Cummins M11 330 hp* and *Caterpillar C-12 430 hp*.
        iii. **Transmission Gear Ratios**: Up to 9 ratios
        iv. **Differential**: Select one of the following – Tandem, Tag Axle, Dual Tandem, Dual Tag Axle
        v. **Differential Gear Ratio**

4. Click on the **Add Selection** button 

to include the vehicle specifications in the Selected Drive Cycles box (See Figure 45).

5. Repeat the above steps to add other cycles to the list

6. For each Custom Drive Cycle, click on the Run Model 

button to run the drive cycle through the UT Fuel Economy Model (UTFEM_HDV.exe). When the run is completed, the Run Model button will be replaced by the drive cycle's average MPG.

Note: The custom drive cycle run may take up to ten (10) or more minutes to complete.

7. Proceed with the Compare Drive Cycles and Examine Drive Cycle MPG options as desired (see the section on LDV Drive Cycle Analysis screen for further instructions).

For more information on how data is sent to UTFEM_HDV.exe, please refer to the Final Report of this study.

The following table shows some of the specifications of the vehicle types which are all Class 8 trucks.

Table 2: HDV Vehicle Types Specifications

	Cummins	Sterling (MB)	Freightliner
Engine Model	Cummins M11	MBE4000	Caterpillar C12
Engine Displacement (L)	11	12.8	11.8
Engine Year	1995	2004	2001
# of Cylinders	6	6	6
HP	330 HP @ 1800 rpm	370 HP @ 2000 rpm	410 HP @ 2100
Torque (lb-ft)	1250 @ 1200 rpm	1450 @ 1100 rpm	1450
Transmission Model	Fuller RT14609A	Eaton Fuller RTLO-14913A	Eaton Fuller FRO-14210B
# of Gears	9	13	10
Differential Axle Model	Eaton DS402	Meritor (Rockwell) Hypoid Single Reduction RT-40-145 Tandem Drive Axle	Meritor (Rockwell) Hypoid Single Reduction RT-40-145 Tandem Drive Axle

For more information on how data is sent to UTFEM_HDV.exe, please refer to the Final Report of this study.

ADVANCED OPTIONS

Creating Custom Vehicles

If a vehicle cannot be found in the database, use the Custom Vehicle option to add that vehicle.

1. Fill in the text boxes on the Builder page with vehicle information, beginning with the vehicle class.

2. Once you have included all available information, click **Add Vehicle** then **Save.**

3. The custom vehicle will now be available in the Filter or Search tabs.

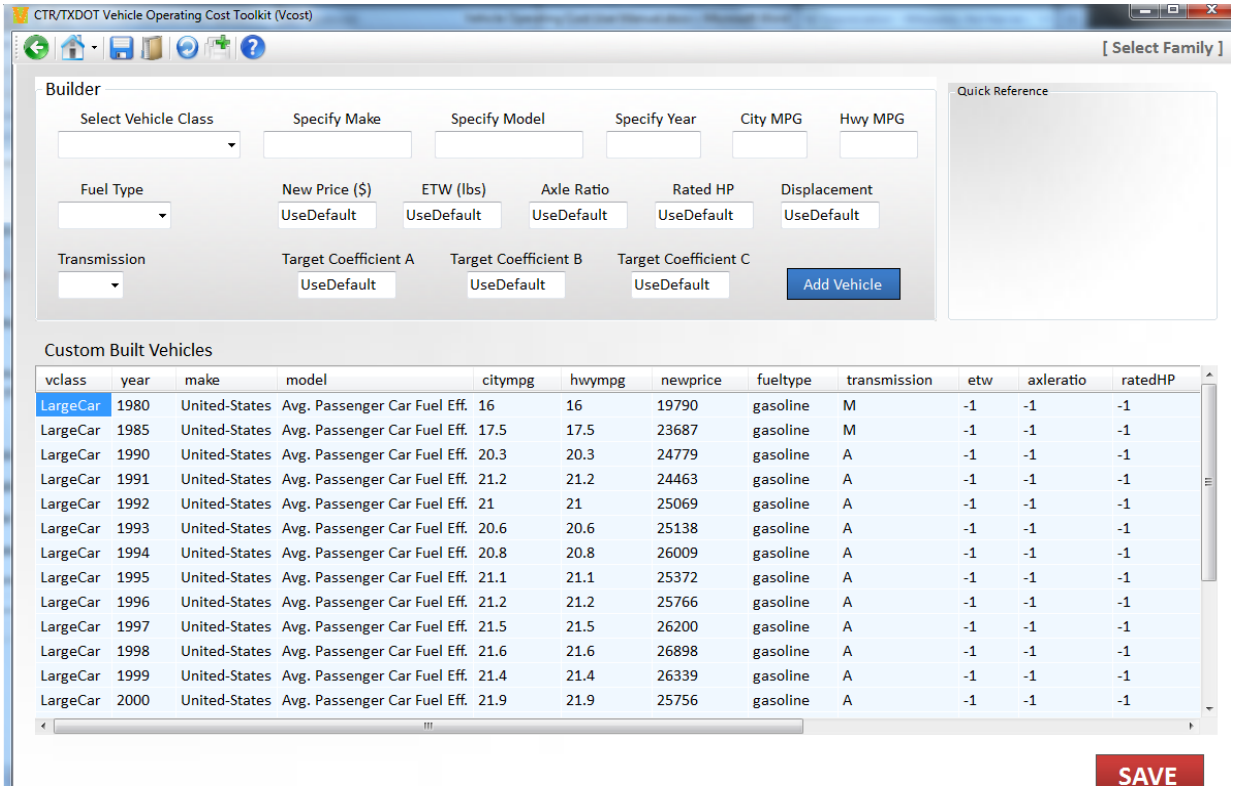


Figure 46: Custom Vehicle Builder

Updating Fleet Vehicles

Please consult the research team concerning vehicle updates. Because of the need for data integrity this feature is not publicly accessible.

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