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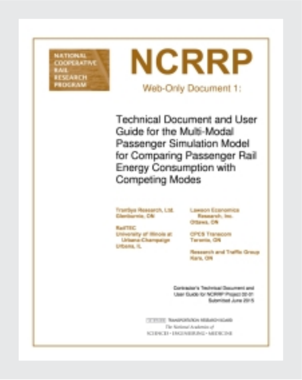

Technical Document and User Guide for the Multi-Modal Passenger Simulation Model for Comparing Passenger Rail Energy Consumption with Competing Modes

DETAILS

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NATIONAL
COOPERATIVE
RAIL
RESEARCH
PROGRAM

NCRRP

Web-Only Document 1:

Technical Document and User Guide for the Multi-Modal Passenger Simulation Model for Comparing Passenger Rail Energy Consumption with Competing Modes

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Summary

The objective of NCRRP Project 02-01, “Comparison of Passenger Rail Energy Consumption with Competing Modes,” is to provide like-for-like comparisons of energy consumption and greenhouse gas (GHG) emissions of commuter and intercity passenger rail operations with competing modes of travel. In the context of this research, “passenger rail” includes higher speed, high speed, intercity, and commuter rail operations - those rail systems that are operated under the jurisdiction of the Federal Railroad Administration (FRA). “Competing modes of travel” include passenger automobiles, light-duty trucks used for personal transportation, suburban commuter bus services, intercity bus services, and air transportation.

This research project involved a literature review to collect data on relevant passenger transportation system characteristics and performance, formulation of an analytical framework for each passenger transportation mode considered, development of a quantitative decision-support tool based on these analytical frameworks, and finally applying the decision-support tool to numerous case studies which explore a range of commuter and intercity passenger rail operations and compares their fuel/energy consumptions and GHG emissions with those of competing modes of transportation for comparable door-to-door trips. The quantitative decision-support tool developed specifically for this research is called the Multi-Modal Passenger Simulator (MMPASSIM). It is an open-source Microsoft Excel macro enabled worksheet which may be used to predict and compare fuel and energy consumption and GHG emissions for a wide range of commuter and intercity passenger transportation scenarios.

The results of this research project are documented in two parts: *NCRRP Report 3: Comparison of Passenger Rail Energy Consumption with Competing Modes* and *NCRRP Web-Only Document 1: Technical Document and User Guide for the Multi-Modal Passenger Simulation Model for Comparing Passenger Rail Energy Consumption with Competing Modes*. The purpose of this NCRRP WOD 1 is to describe the technical details of the analytical framework underlying the MMPASSIM quantitative decision-support tool and also provide documentation and guidance on how to set up and use the MMPASSIM model to evaluate passenger transportation alternatives. NCRRP Report 3 documents the findings of the literature review and details a series of rail technology evaluation and modal comparison case studies performed in this research project. The MMPASSIM spreadsheet files, together with the Technical Document and User Guide, are provided on CRP-CD 176, which accompanies NCRRP Report 3. The MMPASSIM files also may be downloaded from the NCRRP Report 3 web page at www.trb.org.

The analytic framework developed uses common energy and emissions metrics across transportation modes and fuel types in order to facilitate like-for-like comparisons. Each modal trip involves a principal leg and, optionally, up to five access and egress legs. However, the focus is on the principal modal leg of a full door-to-door trip which requires relatively detailed simulations.

The calculated energy and emissions performance over a principal leg will differ from simpler average performance measures of a transportation mode. The energy and emissions performance for access and egress legs are assessed using default average performance metrics provided for each of the access and egress modes selected.

Each transportation mode is modeled, within the limits of publicly available data, such that seasonal, regional and equipment-specific characteristics are reflected in the modal energy and emissions performance. Examples of the limitations of publicly available data in the rail mode are auxiliary power requirements for rail, resistance coefficients for specific types of rail equipment, and engine performance for recent vintage locomotives.

Intercity scheduled bus operations also do not have load factors by region or service. This document and the case study analysis in the companion document indicate where estimates were used to characterize modal characteristics.

A common element of the mode-specific simulation modules used in the spreadsheet-based model is the ability to specify the equipment and route characteristics involved in making the specific trip of interest. Default choices are available for the user to select in a quick simulation comparison; however, the user also has the ability to modify the default characteristics or define new characteristics for each transportation mode if desired.

Railway Mode Model

The passenger train simulation implemented in the MMPASSIM model, unlike a traditional Train Performance Calculator (TPC), simplifies energy and emission calculations by treating passenger trains as a lumped mass. This approach is feasible since passenger train consists are short and light with high power to weight ratios such that their performance is not limited by track grades. However, despite this simplification, the influence of gradient and train length on the calculated energy and GHG emission intensities are included in the model.

A rail trip is specified by defining the characteristics of a passenger train and the route characteristics of the track over which it is to operate. The train characterization includes: the length and masses of the vehicles, the passenger capacity and load factor, parameters defining the inherent train resistance, and the auxiliary load and traction power capabilities. Inherent train resistance is modeled using a quadratic relationship which provides for a constant term to represent rolling friction and ground hysteresis losses, a speed-sensitive term representing dynamic rolling losses, and a term associated with aerodynamic losses which varies with the square of train speed.

The variation of a locomotive or power car's maximum tractive effort with train speed is modeled using a multi-segmented relationship where each segment of the tractive effort versus speed curve is described using an equation with a constant term, a linear speed-sensitive term and a term which varies inversely with train speed. These equation coefficients used in combination with up to a maximum of 5 speed segments facilitates accurate modeling of diesel-electric locomotives and electric power cars. The tractive effort for most diesel-electric locomotives may be accurately characterized using a 2-segment curve where the first segment represents a linear low-speed torque limited region and the second segment represents a power limited region where the tractive effort decreases inversely proportional to speed. Modeling electric power car tractive effort often requires additional straight line segments between the low speed tractive effort limit and a high-speed power limited region, and the highest speed region may also exhibit a fall-off in tractive effort beyond that of a constant power relationship. The additional limitation on passenger locomotive acceleration performance due to diesel engine loading rate is also modeled.

The default rail vehicle data set included with the MMPASSIM model includes characterizations for a number of commuter and intercity passenger rail consist. These may be used directly, modified by a user or used as templates to develop new passenger rail consist.

The rail model's route characterization is based on data that will usually be available to a rail-agency and rail system operators but may not be accessible to the general public. One of the key influences of passenger train performance is the number of speed changes involved on a route. Permanent speed limits shown in railway timetables are more generally available than are track gradient profiles and we recommend that actual speed limit tables be used in simulating a passenger rail service wherever possible. These are input into the model by specifying the start location of all speed limit changes on the route. The location of all stops to be made along a route must also be specified.

Gradients have less impact on passenger train performance and for this reason the model is able to use a more generalized gradient distribution representation instead of the detailed grade profiles specified in a railway track chart. The gradient distribution used in the rail model summarizes the actual track grades in a segment of track into six gradient bins which categorize the actual average of all grades collected in a gradient bin and the percent of total track segment distance associated with all grades in each bin. A route may be characterized using up to eight separate segments having different grade distributions when there are significant differences in track profile over the route's overall length. The model is provided with several default region and service-specific rail route grade characteristics which were developed and used for case studies. These grade characteristics were developed using a range of actual track gradient profiles and may be used with reasonable accuracy when grade profiles for a specific route cannot be supplied.

The rail mode simulation uses the passenger equipment's inherent resistance and tractive effort characteristics to calculate detailed profiles of acceleration, coasting and braking performance which can be achieved on level and tangent track. These calculations are stored in one mile per hour increments in lookup tables which the model then uses as the basis for determining the duration of acceleration and braking operations required at all speed limit changes and for stops. This provides for a more computationally efficient method of evaluating passenger train performance than a second-by-second simulation of movement along the entire track.

The MMPASSIM model performs a rail mode simulation by stepping through a route and evaluating the duration of acceleration, cruising (at a constant speed limit), and braking phases for each section of track bounded by a speed limit change. The work done at the rails to overcome inherent resistance during cruise and acceleration phases is broken out into rolling, dynamic and aerodynamic components and the additional work done by brakes to maintain speed limits while traveling on downgrades or for speed reductions and stops is calculated. The rail module accumulates the energy associated with each of the sub- categories of energy dissipation such that the effectiveness of alternative technologies can be gauged from the model output for a single train run.

Highway Mode (LDV and Bus) Models

The highway modes' energy and emissions performance in MMPASSIM are derived by simulating the second-by-second movement of a specified vehicle over a set of pre-defined speed profiles (drive schedules) in urban areas and uses the vehicle's cruise performance for calculations over rural intercity segments. Vehicle resistance to motion is based on rolling and aerodynamic resistance coefficients, vehicle power and energy performance is governed by specified engine and drivetrain characteristics and auxiliary loads are associated with regional climates as specified for three seasons of the year (summer, winter, and other).

Eight drive schedules are implemented in the model to characterize the influence of traffic congestion on the movement of a simulated LDV or bus in urban areas. These were selected from a range of speed profiles developed by the U.S. Environmental Protection Agency (EPA). The specific congestion performance for a simulation is characterized by specifying the proportion of a trip which is to follow the speed profile of each of these eight drive schedules. These proportions may be individually specified for 5 different time-of-day congestion intervals to allow for traffic variability and default sets of values are provided to represent driving through typical large and small cities in these 5 time periods. The time-of-day periods include:

- a.m. peak
- p.m. peak
- mid-day
- shoulder periods (next to peak periods)

- overnight

Users of the MMPASSIM model are also able to develop customized sets of time-of-day based drive schedule proportions specifically tailored to urban areas of interest. Note that the light duty vehicle (LDV) drive schedules contain a high-acceleration performance drive schedule that is not included in the bus drive schedules; however, the simulation process is the same for both modules.

Default bus performance characteristics are provided for a limited set of four representative bus types as follows:

- 45 foot bus with 56 passenger seats
- 41 foot bus with 48 passenger seats
- double deck bus with 81 passenger seats
- hybrid commuter bus with 57 seats

These typical bus types are characterized using publicly available data for resistance coefficients, drivetrain efficiency, auxiliary loads and diesel engine efficiency and do not represent any particular manufacturer's vehicle. Commuter bus operating characteristics and energy intensity performance are calibrated using data reported for commuter buses by municipal operators in the Federal Transit Administration's (FTA) National Transit Database (NTD). The intercity buses are calibrated using data reported in the NTD for short-distance intercity commuter bus travel combined with data reported in a 2013 survey of major North American bus operators undertaken for the American Bus Association. The average fuel economy for the two sources is 42.3 L/100-km or 5.59 mpg (average of 6.09 and 5.08 mpg from the ABA and NTD sources respectively).

The default light duty vehicle performance characteristics provided in this model were derived from sales-weighted class-average values published annually by the U.S. Environmental Protection Agency (EPA). Specifically, the characteristics of 2011 model-year LDVs were grouped on the basis of similar coast-down resistance coefficients to develop a set of six representative vehicle classes as follows:

- Small cars (Sm-Car)
- Midsize cars and all station wagons (Mid-car/SW)
- Minivans and non-truck SUVs (Mini-V/sm-tSUV)
- Large cars, medium-truck SUVs and small pickup trucks (Lg-car/cSUV/smPU)
- Large pickup trucks (PU)
- Large truck SUVs (Lg-tSUV)

The six individual class-average vehicles are provided as user-selectable default vehicles in the MMPASSIM model. In addition, three composite vehicles are provided which typify the performance of the mix of vehicles used for specific types of trips which include:

- a composite based on the estimated mix of personal LDVs used in local trips
- a composite based on the estimated mix of personal LDVs used for intercity trips
- a composite based on the estimated LDV mix for taxis

Additional "sales-weighted" and "driven-fleet" composite vehicles were developed from EPA fuel economy data for the 2011 model year. These class-average performance characteristics were developed by applying class-specific modifiers to a generic engine fuel-map and a generic six-speed transmission such that the EPA's sales-weighted average performance is obtained when simulating operation over the EPA's underlying certification drive schedules. A similar process is used to characterize the 2011 "driven fleet" to reflect the relative performance of older vehicles with an appropriate vehicle age distribution. An algorithm is provided to create "sales-weighted" and "driven-fleet" composite LDV characterizations for years beyond the 2011 base data year. Default composite values for "sales-weighted" and "driven-fleets" for 2012 and 2013 are provided in MMPASSIM and the model architecture supports addition of future year composite fleet values as EPA estimates of fuel economy for those years become available.

The EPA estimates that actual driving conditions lead to fuel economies which fall below the reported values by between 12% and 15% due to various factors not considered in the 5 cycle test process. These include:

- Road and tire condition
- Effect of wind on aerodynamic drag
- Effect of temperature on aerodynamic drag
- Seasonal cold-start fuel consumption
- Seasonal auxiliary power loads
- Road grade effects

The MMPASSIM model considers the impact which these factors have on the running performance of LDVs. However, driver-behaviour, auxiliary power usage and vehicle maintenance can all affect the fuel economy of a specific vehicle and there will always be a range of fuel economy performance around any derived average. Our objective is to inherently model most parameters and provide an average in-service fuel economy that is representative of the real-world experience.

Air Mode Model

Air mode trips are analyzed differently than rail and highway mode trips. The flight of a specific aircraft is not simulated on a second-by-second basis while accumulating distance traveled and fuel consumed in moving from the origin to the destination. Rather, the fuel consumption and emissions intensities for an air trip are derived by applying fuel intensity coefficients to the distance traveled. This approach is feasible since very detailed aircraft in- service performance data is published by the U.S. Bureau of Transportation Statistics (BTS).

The route to be followed is defined by specifying a sequence of up to four IATA (International Air Transport Association) airport codes. A direct flight would involve only two IATA airport codes, one for the departure airport and the other for the destination airport, while multi-leg flights may be configured with up to three legs by specifying up to two intermediate airport codes. The air-mode model automatically computes the great-circle distance (shortest distance along the earth's sphere) traveled between two airports based on their latitude and longitude. A user may easily expand the list of available airports by adding IATA codes, latitude and longitude.

The default aircraft characterization data provided with the model are based on 2011-2012 operations of domestic U.S. scheduled air carriers and can be updated by the user as desired in future years as air technology and operations practices change. The default data is organized into the following five categories of aircraft:

1. Turboprops (TP)
2. Small Regional Jets (SRJ) (defined here as jet aircraft with less than 50 seats)
3. Regional Jets (RJ) (defined here as short-range jet aircraft with 50 to 89 seats)
4. Narrow Body Jets (NBJ) (defined here as jet aircraft with greater than 89 seats in a single aisle configuration)
5. Wide Body Jets (WBJ) (defined here as jet aircraft with greater than 89 seats configured with more than one aisle)

Air mode trips are assumed to be serviced by a distribution of these five aircraft types rather than by a specific aircraft. A default mix of aircraft types was derived from the BTS data and is provided for seven ranges of trip length. The air model automatically assigns the proportions of aircraft types used in each leg of an air trip according to the distributions associated with the applicable trip length range. However, a user may adjust the proportions of aircraft types assigned to each leg of an air trip.

Fuel intensity coefficients for each representative aircraft category have been derived separately for the LTO (landing and takeoff) and cruise phases of a flight. The cruise phase fuel intensity values have been adjusted to account for the average incremental distance traveled in excess of the shortest path between origin and destination under both peak and off-peak period conditions. The fuel consumed in the cruise phase of an air trip leg is computed by multiplying the great-circle distance traveled by the fuel intensity coefficient for the representative aircraft type. Where a distribution of aircraft types is specified, the calculation applies the fuel intensities in those proportions.

Access and Egress Modes

Only the primary transportation modes being compared are simulated in detail in the model whereas the performance attributes of access and egress modes are simple averages provided in default lookup tables. The model architecture supports specification of different performance attributes for an access/egress mode to be associated with city size, time-of-day, day-of-week and season. The attributes of public transportation modes have been derived from the 2011 National Transit Database's *Service and Energy* Tables. The electricity supply used for public transportation modes is region-dependant but all other performance metrics are based on one average applied to all regions.

Attributes for personal automobiles and taxis were derived with the detailed LDV simulation model in a one-time simulation of the 2011 driven-fleet composite vehicle. The following assumptions were made for the highway access/egress modes:

- taxis were assumed to travel 1.5 km for every km of passenger carrying travel
- drop-off and pick-up was assumed to have 60% return-to-origin travel and 40% being part of a 2-person trip that incurs 10% extra travel distance
- carpools are assumed to involve 3 persons and the trip length is 15% longer than any one-person trip

The fuel intensity of highway modes is adapted to congestion conditions via peak and off-peak multipliers, which are specified for three city sizes (large, small and rural municipality).

Regional Influences

The MMPASSIM model provides a default regional characterization for Northeast, South, Midwest and West regions of the continental U.S. and can be optionally updated by a user to include additional user defined regions. The primary regional influences are seasonal and include travel variations, temperature variations, and average use of climate controls and auxiliary power for ground transportation modes. Congestion factors for travel in urban and rural areas during peak and off-peak periods are also specified for a region. Finally, the fuel and emissions intensities of access and egress modes are defined for each region.

Electricity generation is further disaggregated into nine sub-regions with the distribution of fuels used in generating that electricity derived from U.S. Energy Information Administration data for 2011 and upstream fuels consumed were derived from the GREET model.

MMPASSIM Model Structure

The MMPASSIM model performs multi-modal door-to-door passenger trip comparisons of energy and GHG intensity. Additional details on energy dissipation sources are provided in conjunction with rail-only simulations to facilitate comparisons between different rail technologies. The model is implemented as a macro enabled Microsoft Excel worksheet which supports the following three types of analyses:

1. *Single Train Simulation* - a single train service is assessed for its performance and energy/GHG emissions breakout.
2. *Rail Technology Evaluation* - a comparison of up to four passenger rail technologies to compare and assess the energy/GHG emissions savings realized.
3. *Mode Comparison* - a comparison of up to four passenger modes (rail, bus, air, light duty vehicle) to compare and assess the energy/GHG performance in a door-to-door trip.

The primary user interface for all simulations is provided in the 'Master-I-O' worksheet (blue tab) from where a user configures all required simulations for an analysis. However each transportation mode is configured and operated as a semi-independent sub-model which may be configured and controlled independently by a user if desired. The sub-model user interfaces are provided in the 'Rail-I-O', 'Air-I-O', 'Bus-I-O' and 'LDV-I-O' worksheets (all with blue tabs). A system of pop-up user forms (menus) and Visual Basic for Applications (VBA) macros coordinates the configuration of all desired simulations as well as the transfer of data to and from the sub-model worksheets. The results are displayed to the user in formatted output tables on the 'Master-I-O' worksheet which are automatically brought into view while the simulation proceeds.

Simulations can be specified from the Master-I-O sheet using the wide range of case study defaults for routes and equipment in each mode. In addition new routes and equipment can be specified and default values can be modified within the model's other worksheets as discussed below. The model uses green to indicate model inputs, yellow to indicate default values, orange to indicate calculation formulae and blue to indicate output sheets/areas.

The 'Regional-Properties' worksheet (yellow tab) contains regional data for: average daytime temperature and air conditioning usage by season. In addition it contains default characteristics for fuel, energy and GHG emissions intensities used for the access and egress modes. The access and egress modes support differentiation by size of city and time- of-day congestion for the highway modes.

The 'Energy-Emissions' worksheet (yellow tab) provides the GHG emissions rates by fuel/energy-source and the indirect (upstream well-to-pump) energy consumption/GHG- emissions associated with each fuel/energy-source. For electricity these factors are also provided for different geographical regions.

Mode-specific equipment worksheets (green tabs named 'Rail-Consist', 'Bus-Type', 'LDV-Type' and orange tab named 'LDV-Resist') store the characteristics describing the physical attributes and capabilities of ground transportation mode vehicles. New equipment/vehicles can be introduced into the model by adding data to these worksheets.

Mode-specific 'Route' worksheets (green tabs named 'Rail-Route', 'Bus-Route' and 'LDV-Route') store the characteristics describing the routes which may be followed by a ground transportation mode. New routes can be introduced into the model by adding to these worksheets.

The highway mode drive schedule worksheets (yellow tabs named 'Bus-Drive-Schedules' and 'LDV-Drive-Schedules') define the second-by-second speed profiles used to represent movement of buses and LDVs in urban areas. The mixes of drive schedules used to represent time-of-day congestion in different urban centers are also declared in those worksheets. Default drive schedule mixes for large and small urban centers have been provided. Users may adjust these defaults and also add new city-specific drive schedule mixes to these worksheets.

The 'Engine' worksheets (yellow tabs named 'Bus-Engine' and 'LDV-Engine') provide the needed modal engine efficiency characteristics for the highway modes. Representative fuel maps are used for propulsion systems using non-continuously variable transmissions (applicable to most conventional LDV and buses) while coefficients for a single optimal performance equation are provided for representing vehicles using a continuously variable transmission (CVT).

The ‘Simulation’ worksheets (orange tabs named ‘Rail-Simulation’, ‘Bus-Simulation’, ‘LDV-Simulation’ and ‘Air-Simulation’) implement the algorithms used to simulate the movement of a modal vehicle (or a fleet-average characteristic vehicle) representative of the specific service/region being simulated.

MMPASSIM Model Outputs

The primary MMPASSIM model outputs are provided in simulation mode-specific tables located on the ‘Master-I-O’ worksheet. The output tables are different for each of the three analysis scenarios.

The output from a *Single Train Simulation* is provided in two tables with sufficient detail to permit assessment of the underlying sources of energy consumption and GHG emissions. This information is a first step in validating the input data used for the simulation and in assessing the relative impact that technological changes to specific source components of energy consumption would have. The first table provides the absolute and proportional values of energy consumption and GHG emissions for: seven categories of traction energy (three sub-elements of inherent train resistance, three sub-elements of brake dissipation, and curving resistance); for the traction system’s transmission losses; and for provision of hotel power. The second table provides performance metrics where energy and emissions intensities are output for three divisors (per-trip, per-seat-distance, and per-passenger-distance) and for two service-performance metrics (travel-time and average speed).

The output from a *Rail Technology Comparison* is provided in three tables. The first table provides the same components of energy consumption and GHG emissions as output for a single train simulation but adds additional rows which indicate the percent-reduction in energy and emissions realized by using the alternative technologies. The second table provides performance metrics and indicates the percent reduction compared with the baseline technology case. The third table outputs the total energy and emissions intensities when the indirect consumption and emissions associated with well-to-pump fuel provision are included.

The output from a *Mode Comparison* analysis focuses on performance metrics comparable across transportation modes and expands the comparison to include access and egress legs of a trip. Four tables are output with the same energy/emissions intensity values as were used in the rail technology comparison tables but with an indexed comparison to the baseline rail mode replacing the %-reduction from the baseline rail technology that was used in the technology comparison table. The first table compares direct energy/emission for the modal leg of the trip, the second table compares direct energy/emission for only the access/egress legs of the respective modal trips, the third table compares direct energy/emission for the complete door-to-door trips, and the fourth table compares the full energy/emissions (including indirect well-to-pump) for the complete door-to-door trips.

Using the MMPASSIM Model

See the front end of the User Guide in Appendix A for an overview and quick reference guide.

1 Introduction

The National Cooperative Railroad Research Program (NCRRP) is a research program administered by the Transportation Research Board (TRB) which "conducts applied research on problems of interest to freight, intercity passenger, and commuter rail practitioners." This web-only document is one of two reports which together detail the research and results of NCRRP Project 02-01 entitled "Comparison of Passenger Rail Energy Consumption with Competing Modes."

The objective of NCRRP Project 02-01, as suggested by its title, is to provide like-for-like comparisons of energy consumption and greenhouse gas (GHG) emissions of commuter and intercity passenger rail operations with competing modes of travel. In the context of this research, "passenger rail" includes higher speed, high speed, intercity, and commuter rail operations—those rail systems that are operated under the jurisdiction of the Federal Railroad Administration (FRA). "Competing modes of travel" include passenger automobiles, light-duty trucks which are often used for personal transportation, suburban commuter bus services, intercity bus services, and air transportation.

To accomplish the objectives of this research project, a targeted literature review was performed and the findings then used to inform the development of an analytical framework for equivalent comparison of mode-to-mode fuel and energy consumption and GHG emissions. The literature review covered passenger rail efficiency research, passenger rolling stock characteristics, characteristics of the modes used by passengers to access and egress from rail and bus stations and airports, and finally an examination of technologies which can improve the energy efficiency of rail equipment, infrastructure and the overall operations of a rail system. A quantitative decision-support tool, the Multi-Modal Passenger Simulator (MMPASSIM), was developed specifically for this project and used to predict and compare fuel and energy consumption and GHG emissions in a series of case studies. The MMPASSIM model is a fundamental product of this research effort and is available for use.

A range of case studies were used to calibrate the analytical model, to examine the details and sensitivities of specific passenger rail systems and to evaluate the prospective impact of improving operational strategies, rolling stock, motive power and the supply of fuel or electricity for traction power. The barriers and opportunities to improve the fuel and energy efficiency and reduce the GHG emissions from intercity and commuter passenger rail systems were also examined. Numerous case studies were developed to explore a range of commuter and intercity passenger rail operations and compared their fuel and energy consumptions and GHG emissions with those of competing modes of transportation for comparable door-to-door trips.

NCRRP Report 3: Comparison of Passenger Rail Energy Consumption with Competing Modes documents the findings of the literature review and the details of the series of rail technology evaluation and modal comparison case studies performed in this work. It also presents findings on the barriers and opportunities to improve the fuel and energy efficiency and reduce the GHG emissions from intercity and commuter passenger rail systems.

This document, *NCRRP Web-Only Document 1: Technical Document and User Guide for the Multi-Modal Passenger Simulation Model for Comparing Passenger Rail Energy Consumption with Competing Modes*, has a two-fold purpose:

a) to provide technical documentation describing the analytical framework underlying the development of the MMPASSIM model – a Microsoft Excel macro enabled spreadsheet model of fuel, energy and greenhouse gas emissions of passenger rail, highway (bus and light duty vehicles) and air travel.

b) to provide a User Guide (in this volume's Appendix A) to guide users in applying the MMPASSIM model to predict and compare the fuel and energy consumed and the greenhouse gases emitted by prospective door-to-door trips made by passenger rail services and other competing modes of travel.

The User Guide provided here in Appendix A contains its own table of contents and functions in the most part as a stand-alone document. Although some occasional references are made in the User Guide to technical details provided in the main body of this web-only document, it should not be necessary for a user to read and understand the entire technical document in order to make effective and productive use of the MMPASSIM model in answering questions of fuel and energy consumption and greenhouse gas emissions related to passenger travel modes. More advanced uses of the model involving detailed customization of equipment and route characterizations will necessarily require a more thorough understanding of the material set forth in the main body of this web-only document in addition to the User Guide in Appendix A.

2 Performance Evaluation Framework

2.1 Methodology Overview

The background section of the terms of reference for this project noted the limitations of using averages for the energy performance of rail and other competing modes. In particular it noted that:

- *Passenger rail fuel consumption data may not fully represent impacts, since they are based on broad averages that include many different variations in distance traveled, amenities provided, speeds, operating environment, type of train operated, and form of propulsion. Similarly, energy consumption estimates for competing modes usually represent broad averages that do not necessarily reflect the energy profiles of comparable trips on modes that compete with passenger rail service accurately.*
- *Using disaggregated data, linked more directly to where and how the fuel and energy attributable to specific trips is consumed, can provide a greater understanding of what is actually occurring. In addition, significant variations in fuel and energy consumption can occur by regions of the country and by individual states and metropolitan areas, and these variations should also be taken into account when analyzing comparable modes of travel, along with specific characteristics of available technologies and operating environments.*

The key objective of this project, as stated in the terms of reference, is:

> *to provide like-for-like comparisons of energy consumption and greenhouse gas emissions for commuter and intercity passenger rail operations and for competing travel modes.*

In order to accomplish the objective the terms of reference required development of:

- *A quantitative decision-support tool for evaluating and comparing fuel and energy consumption and GHG emissions by commuter and intercity passenger rail operations and by competing modes of transportation for comparable trips; and*
- *An evaluation of opportunities to improve fuel and energy efficiency and reduce GHG emissions for intercity and commuter passenger rail.*

To meet the project objective, common energy intensity metrics are used across modes and fuel types. The focus is on the principal modal leg of a full door-to-door trip and each mode is simulated in detail for this principal leg. Overcoming the shortcomings of working with readily available averages for modal performance requires development of relatively detailed simulation models that reflect the variations in performance across regions, seasons and equipment types. Each mode is modeled, within the limitations of publicly available data, such that seasonal, regional and equipment-specific characteristics are reflected in the modal energy and emissions performance. Examples of the limitations of publicly available data in the rail mode are auxiliary power requirements for rail, resistance coefficients for specific types of rail equipment, and engine performance for recent vintage locomotives. Intercity scheduled bus operations also do not have load factors by region or service. This document and the case study analysis indicate where estimates were used to characterize modal characteristics.

A common element of the mode-specific simulation modules used in the spreadsheet-based model is the ability to specify the equipment and route characteristics involved in making the specific trip of interest. Default choices are available for the user to select in a quick simulation comparison; however, the user also has the ability to modify the default characteristics or define new characteristics for each mode if desired.

The requirement for an "*evaluation of opportunities to improve fuel and energy efficiency and reduce GHG emissions for intercity and commuter passenger rail"* means that the rail simulation module requires additional details on the technological attributes of equipment such that the energy/emissions performance of alternative technologies can be assessed. Therefore, in addition to a comparison with other modes, the rail mode can be simulated in isolation and in comparison with other rail mode technologies for the same trip.

The energy/emissions intensities of modes used in access and egress legs are included and separately identified; however, simple averages are used rather than detailed simulations. Indirect 'well-to-pump' energy and emissions intensities are included as a separately identified metric for each leg of a door-to-door trip.

The principal leg of each modal trip is simulated in detail such that variations from the average performance are discernable. For example, when an automobile is used as the main leg of a trip, it is simulated in detail for the specified equipment, route and traffic congestion characteristics specified; however, when used as an access/egress leg to other modes, pre-processed averages for a composite vehicle can be used. The default average performances for access/egress by highway modes have been pre-processed for varying levels of traffic congestion. If the user wishes to simulate a new access/egress scenario in detail, it can be done as a separate one-time simulation of the relevant route and equipment used for the access/egress trip.

2.2 Mode Specific Data Constraints and Methodology Influences

The types and level of details available to characterize modal energy and GHG intensities vary across the modes. The approach taken within each mode reflects the types of data available. In general terms:

- The light-duty-vehicle (LDV) mode has very detailed performance data at the individual vehicle level but has poor in-service performance data. Traffic congestion influences are significant and the LDV module supports local commute and intercity traffic characteristics for five time-of-day periods. Seven generic LDV classes are characterized in conventional and hybrid configurations.
- The bus mode has less detail than LDVs for individual vehicle performance but has much less variability in types of vehicles available and better aggregate energy performance data. Intercity and local commuter bus services are characterized by road type and traffic congestion in the same way as the LDV module.
- Simulation of individual air mode trips on a second-by-second aircraft movement basis is a significant undertaking and beyond the scope of this project. The air mode has good in-service performance data which allows differentiation of equipment types by trip length as well as assessment of congestion effects. The equipment mix and equipment-specific energy performance are characterized by trip length for five representative types of aircraft.
- The data available for the rail mode vary across services — detailed characterization data exist for some types of equipment but not all and the level of aggregation in total-fleet performance reports does not provide enough detail to accurately calibrate/validate individual services or equipment types. Intercity and commuter services are characterized for several generic conventional equipment types and a high speed equipment type.

The mode-specific data constraints and associated methodological details for rail, bus, LDV and air are each discussed in the following subsections.

2.3 Highway Modes (LDV and Bus) Methodology

The highway modes' energy and emissions performances are derived via simulation modules which simulate second-by-second movement of a specified vehicle over a set of pre-defined speed profiles (drive schedules) in urban areas and use cruise performance for rural intercity segments. The LDV drive schedules contain a high-acceleration performance drive schedule that is not included in the bus drive schedules; however, the simulation process is the same for both modules. Vehicle resistance to motion is based on rolling and aerodynamic resistance coefficients, vehicle power and energy performance is governed by specified engine and drivetrain characteristics and auxiliary loads are associated with regional climates by three seasons of the year (summer/winter/other).

The engine efficiency of the highway modules are based on representative fuel maps from the literature – the bus module uses 2010 vintage fuel maps for 350 hp and 455 hp engines in the EPA's Greenhouse Gas Emissions Model (GEM) [EPA, 2010] while the LDV vehicles are based on 2004 vintage fuel maps noted on Appendix C to Volume 1 of this report. The fuel maps are normalized to the engine's minimum brake specific fuel consumption (bsfc) to allow different engine powers and fuel efficiency data to be used.

2.3.1 Bus Characterization

The default characterization data are generic composites rather than any one specific bus. A typical bus is characterized using publicly available data for resistance coefficients, drivetrain efficiency, auxiliary loads and diesel engine efficiency. Bus rolling resistance is based on Australian test work {Biggs, 1987] and calibrated with published test track data for trucks as reported in Appendix B of the freight mode comparison study undertaken by English and Hackston [English, G., and D.C. Hackston, 2013]. The bus aerodynamic drag coefficient is set at 0.5 based on the observations of work of Patten et al. who indicate: "it is not unrealistic to expect their [North American intercity buses] drag coefficient to be in excess of 0.50" [Patten et al. 2012, p52]. Patten also cites an advanced European bus that is in service and has achieved a Cd of 0.35.

The bus module is calibrated to a typical U.S. operating environment using two main data sources. Commuter bus operating characteristics and energy intensity performance are calibrated with data reported for commuter buses by municipal operators in the Federal Transit Administration's (FTA) National Transit Database (NTD) [Federal Transit Administration, 2011]. Intercity buses are calibrated to data reported in the NTD-Service Table for short-distance intercity commuter bus travel (total-miles/revenue-miles X revenue car-miles/gallon for commuter bus (CB) operations of the Maryland Transit Administration, 2011) combined with data reported in a 2013 survey of major N.A. bus operators undertaken for the American Bus Association (ABA) [John Dunham & Associates, for the American Bus Association Foundation, 2013, Table 2-5, pg. 13]. The average fuel economy for the two sources is 42.3 L/100-km or 5.59 mpg (average of 6.09 and 5.08 from the ABA and NTD sources respectively). In calibrating bus performance to be in this fuel efficiency range, we used a Cd of 0.5 for a standard 45 ft bus and increased the fuel consumption of the EPA's 2010 engine by 5% to reflect the mix of older less-efficient buses in service. Someone with more detailed data on specific bus performance might find a different combination of Cd and minimum bsfc that produces the same average results.

Occupancy and non-revenue travel data are reported for commuter buses in the National Transit Database; while only occupancy is reported in the ABA's 2013 survey of operators. We believe that the intercity commuter bus operations would understate the occupancy attained by longer distance intercity scheduled carriers and the average occupancy reported for all operators surveyed in the ABA would be higher than that of scheduled carriers (since charter carriers realize very high load factors and account for over 50% of the operators surveyed). In the absence of route-specific data, the default occupancy used in the present modal comparisons is the average of that realized by the intercity commuter bus travel (passenger-miles / vehicle-revenue-miles for commuter bus (CB) operations of the Maryland Transit Administration, 2011) and that reported for all bus services in the ABA survey (i.e. an average of 32.6 riders). With an estimated distribution of buses having the following seating capacity: 90% with 56 seats, 5% with 81 seats and 5% with 48 seats, the average load factor is 57%.

The model also supports simulation of hybrid buses in commuter service. Hybrid performance is characterized with lithium ion batteries having charge/discharge efficiencies based on data from Hofman et al, [2008,Table 6].

2.3.2 LDV Characterization from Test Data

The Light duty vehicle module is similar to the bus module but since there is a vast amount of certification data for LDVs, it is possible to calibrate a number of classes of vehicles. Our calibration/validation of LDVs was undertaken by modifying the minimum bsfc of our generic fuel map and the average weight of vehicles in each of the classes. The approach is similar to that taken by Ates in modeling light and medium duty vesicles and we used Ates's data for LDV transmission and differential efficiency coefficients [Ates, M, 2009, p.72]. This calibration process is described in the section. In the subsequent section we describe the steps we then took to present real-driving conditions/environment to be used in the simulations.

The EPA requires LDV manufacturers to provide coast-down data coefficients for each LDV-model sold in the U.S. In addition, EPA requires that each LDV's energy performance be measured or calculated in the generation of the EPA's city/highway fuel economy label. These publicly available characterization data are more detailed than all the other passenger modes. However, details of the in-service performance of LDVs are survey-based and have much more uncertainty than is typically available for the other passenger modes. Details of engine and transmission characteristics are not as publicly available for LDV as for the other modes. Also, the range of technologies deployed and the range of equipment types are much wider than for the other modes.

Each year the EPA publishes the sales-weighted class-average performance of LDV for several classes of new vehicle. The class-averages reflect the actual mix of vehicles sold within each class in the U.S. during that year. We grouped LDVs for MY-2011 on the basis of exhibiting similar coast-down resistance coefficients. Default parameters are developed for the following six representative vehicle classes from 2011:

- Small cars (Sm-Car)
- Midsize cars and all station wagons (Mid-car/SW)
- Minivans and non-truck SUVs (Mini-V/sm-tSUV)
- Large cars, medium truck-SUVs and small pickup trucks (Lg-car/cSUV/smPU)
- Large pickup trucks (PU)
- Large truck SUVs (Lg-tSUV)

The six individual class-average vehicles are provided as user-selectable default vehicles. In addition, four composite vehicles are provided to typify the performance of the following specific mixes of vehicles:

- the EPA's sales-weighted composite vehicle,
- a composite based on the estimated mix of personal LDVs used in local trips,
- a composite based on the estimated mix of personal LDVs used for intercity trips, and
- a composite based on the estimated LDV mix for taxis.

In relation to the EPA sales-weighted vehicle-mix, the vehicle composite for local commuting assumes a shift from large to smaller vehicles, the intercity travel mix assumes a shift from smaller to larger vehicles and the taxi mix assumes a larger proportion of midsize vehicles, no pickup trucks and a higher proportion of hybrid vehicles (Note: these alternates are illustrative estimates at this point – to be refined as data is located). In each case one must recognize that the default vehicles are representative of the composite-class of LDVs being simulated and that individual vehicle types within the class could provide significantly better or worse performance. As noted above with respect to the higher-efficiency side of the range, the model does separately simulate hybrid vehicles within each class. As discussed later, driver-behavior and other factors can also lead to variations and decreases in operational fuel economy (FE) of any one specific vehicle.

The relative 2011 MY sales distribution and the estimated distribution of derived composite vehicles are summarized in Table 1.

Table 1. LDV Class Distributions used for Composite Vehicles

Class	2011 MY Proportion of Sales[a)]	Local Travel[b)]	Intercity Travel[b)]	Taxi[b)]
Sm-car	17.70%	22.70%	14.70%	0.00%
Mid-car/SW	25.40%	28.40%	23.40%	40.00%
Mini-V/sm-tSUV	5.30%	5.30%	5.30%	50.00%
Lg-car/cSUV/smPU	28.00%	25.00%	30.00%	10.00%
PU	14.10%	11.10%	14.10%	0.00%
Lg-tSUV	9.50%	7.50%	12.50%	0.00%

Sources: a) derived from EPA data, b) TranSys Research Ltd illustrative assignments (to be refined as data is located).

The actual market shares of individual vehicles are not published and the variation of class-specific performance across manufacturers can be significant. Our analyses are based on the 2011 model year (MY) fuel economy trends report [EPA, March, 2012]. In 2011 two standard deviations of manufacturers' averages per class ranged from a low of +/-22% for midsize cars to a high of +/-27% for large cars. In all classes, the sales-weighted average demonstrated better fuel economy than the simple average of all manufacturers. Our LDV module provides class average performance characteristics which are developed by applying class-specific modifiers to a generic engine fuel-map and a generic six-speed transmission such that the EPA's sales-weighted average performance is exhibited when simulated on the EPA's underlying certification drive schedules. The variation can be due to differences in vehicle resistance parameters and/or engine/drivetrain losses. A somewhat arbitrary assignment was made to adjust the resistance coefficients and vehicle mass by 50% of the initial error and the engine/drivetrain losses by 50% of the initial error. As the model's initial average parameters were based on the simple average of published LDVs rather than the sales-weighted average, most modifiers reduce resistance parameters and loss-factors to attain the sales-weighted average performance.

A similar process is used to characterize the 2011 “driven fleet” to reflect the relative performance of older vehicles with an appropriate vehicle age distribution. The algorithm processor assumes that 50% of the difference in fleet-average fuel economy of the new model year relative to the 2011 sales-weighted fleet is due to drive-train efficiency (engine and/or transmission efficiency is scaled by 50% of the fuel economy difference) and 50% is due to vehicle body design or fleet composition (the 2011 fleet average weight and resistance coefficients are scaled by 50% of the fuel economy difference).

The LDV characterization data for the model year 2011 are summarized in Table 2.

Table 2. MY 2011 LDV Sales-Weighted Characterization Data

Model Development Phase	Class	Derived Averages for EPA Classes of MY 2011 LDVs						Derived Composites				
		small	mid/SW	MV/ Sm-tSUV	Lg/cSUV / smPU	PU-truck	Lg-tSUV	Local d)	Inter-city d)	Taxi d)	2011-Sales-weighted	2011 Driven Fleet
Initial Base Parameters a)	a (N)	141.77	171.21	164.86	211.70	225.63	238.72	185.42	194.81	172.1	191.09	N.A.
	b (Nsm^{-1})	2.407	2.416	3.256	4.462	5.963	6.360	3.659	4.066	3.04	3.907	N.A.
	c (Ns^{2}m^{-2})	0.418	0.455	0.567	0.628	0.670	0.672	0.536	0.565	0.53	0.554	N.A.
	Mass (kg)	1,496	1,590	1,828	2,040	2,397	2,554	1,856	1,958	1,75	1,917	N.A.
	Power (kW) b)	121	133	163	189	233	253	166	179	153	174	N.A.
	Hybrids c)	8.00%	1.88%	0.40%	1.88%	0.40%	0.40%	3.86%	3.86%	10%	2.2%	1.3%
	non-Hyb-CVTs	4.00%	9.99%	6.90%	9.99%	6.90%	6.90%	6.74%	6.74%	8.00%	7.8%	2.9%
Initial FE Difference		-2.8%	8.2%	-2.4%	9.8%	-9.6%	2.7%	N.A.	N.A.	N.A.	4.5%	-7.9%
Adjusted Model Parameters to get Sales-weighted FE	loss reduction	-1.4%	4.1%	-1.2%	4.9%	-4.8%	1.4%	N.A.	N.A.	1.9%	2.3%	-4.0% e)
	a (N)	143.78	164.19	166.87	201.31	236.46	235.47	182.35	191.57	169.2	187.16	194.51
	b (Nsm^{-1})	2.44	2.32	3.30	4.24	6.25	6.27	3.61	4.01	3.00	3.83	3.98
	c (Ns^{2}m^{-2})	0.42	0.44	0.57	0.60	0.70	0.66	0.53	0.56	0.52	0.54	0.56
	Mass (kg)	1,517	1,524	1,851	1,940	2,512	2,520	1,828	1,929	1,729	1,878	1,952
Final FE Difference		-0.7%	0.1%	-0.6%	0.3%	1.0%	0.0%	N.A.	N.A.	N.A.	0.3%	N.A.

Source: TranSys Research Ltd. analysis of EPA fuel economy data.

Notes:

a) Resistance Parameter Units are: N – Newton; Nsm^{-1} – Newton / (meter/second); Ns^{2}m^{-2} – Newton / (meter/second)^{2}

b) Average power for each group is based on a derived power/weight equation for the MY 2011 data: P= -86.933 + 0758W; with P (hp) and W (lb).

c) Conventional vehicles and hybrid vehicles are separately characterized and simulated in the model and default proportions of hybrid vehicles are included within each class's characterization data. If one wishes to only simulate a hybrid (or only a conventional) LDV the default proportion-of-hybrids can be set to one or zero accordingly.

d) These composites are illustrative estimates pending better data for user updates.

e) The value used in LDV-Resist sheet of the model is a different number and includes an offset by the loss-reduction already included in the Sales-weighted composite (i.e. -0.017 = -0.079/2 + 0.023) which is the reference vehicle used for 2011 and future year composite vehicles.

Source: TranSys Research Ltd., derived from data in: EPA, Fuel Economy Guide for DOE-2013; and Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2012, EPA-datasheets, 2013.

2.3.3 Adjustment of LDV Characteristics to Reflect Driving Conditions

The characteristics developed above are for the running performance of LDVs. All LDVs experience worse fuel economy on start-up and this initial fuel penalty increases with colder temperatures. The increase has a significant impact on short commuter trips but is less consequential for intercity travel. We estimated the cold-start fuel increment on the basis of dynamometer tests of hot and cold starts for a 2009 Jetta diesel published by DOE [Argonne National Laboratory, D^3 website. http://webapps.anl.gov/D3/index.html]. The 13.5% incremental fuel consumed over the 7.46 mi long UDDS test cycle when cold versus hot was adopted as representative of all LDVs. The value is pre-processed by simulating each default vehicle over the same UDDS drive schedule and applying the 13.5% factor to get the fuel/start value. The resulting 'cold start' fuel increment for the Sales-weighted 2011 MY at 22ºC is 0.1136 kg.

The influence of temperature on the cold-start fuel increment follows the EPA's derived equations assuming a 12-hr or greater soak time for the forward trip and 9 hr. for the reverse trip (100% and 87.5% of the cold-start fuel increment respectively). The ratio 'R' of cold-start fuel at ambient temperature (Ta) relative to the cold-start fuel at 75 ºF is [EPA, Final Technical Support Document Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates, EPA-420-R-06-017, December, 2006]:

$$\boldsymbol{R = 1 + a(T_a - 75) + b(T_a - 75)^2} \qquad \textbf{Equation 1}$$

where:

Ta = ambient temperature of interest in ºF

R is the ratio of cold-start fuel increment at ambient temperature Ta divided by the cold-start fuel increment at an ambient temperature of 75ºF.

a and b are estimated coefficients; which for gasoline engines are:

a = -0.01971

b =0.000219

and for diesel engines are:

a = - 0.00867

b = 0.000096

The running performance of LDVs is derived by the EPA and manufacturers via dynamometer and coast down tests. The test conditions are ideal in relation to actual driving conditions and the drive schedules are not necessarily representative of any one particular journey made on a specific time-of-day and season. The EPA discusses a wide range of factors which influence the translation of lab test results into real-world experience [EPA-420-R-06-017, December, 2006]. The assessment (Table III.A-28. of EPA-420-R-06-017) indicates about a 12%-to-15% decrement to predicted 5-cycle fuel economy due to various non-test factors; most of which EPA believes relate to wind ~ 6%, road surface ~ 1.4% – 3.2%, road gradient ~ 1.9% and fuel quality ~ 1.1 – 1.5%.

We specifically model many of these factors and others via specified trip input data. Table 3 summarizes how these FE-influencing factors are treated in the model. Still, we note that driver-behavior, auxiliary power usage and vehicle maintenance can all affect the FE of a specific vehicle. There will always be a range of FE performance around any derived average. Our objective is to inherently model most parameters and provide an average in-service FE that is representative of real-world experience.

Table 3. Adjustments Made to Test-based Characteristics to Reflect Actual Driving Conditions and the Driven Fleet

Factor	Assumption / Treatment in the Model	Source Reference
Road/tire condition resistance factors	An estimated 10/30/50/10 mix of concrete/smooth-/medium-/rough-asphalt pavement is adopted relative to an estimated 30/70 mix of concrete/smooth-asphalt for test conditions. The corresponding increase in rolling resistance coefficients (a and b) is 12%.	TranSys Research Ltd estimates of road type usage. Biggs, 1987 for relative road type influence.
Aerodynamic drag (wind effect)	Wind increases aerodynamic drag for most yaw angles except those approaching 180º (a pure tailwind) where it reduces drag. We adopt an average 3.5% increase in aerodynamic drag for LDV (and use the same factor in the bus and rail modules).	TranSys Research estimate.
Seasonal aerodynamic drag (temperature effect)	Aerodynamic drag varies directly with air density and the density of air is negatively correlated to its absolute temperature (º Kelvin or º Rankine). This temperature dependence is applied to LDV (and also bus and rail mode) simulation modules.	Marks' Handbook for Mechanical Engineers, 8th Edition, McGraw-Hill.
Seasonal cold-start fuel consumption (temperature effect on tires, and engine/ drivetrain friction losses).	EPA has developed an equation to estimate the incremental impact of colder temperatures on the 'cold start' fuel consumption. The basis of the dynamometer data used does not include the aerodynamic impact noted above so the effects are additive. We apply the EPA equations for incremental cold start fuel consumption on the basis that all our rail-competitive trips occur after 12 hr. of sitting (soak time) for the forward trip and 9 hr. for the return trip.	EPA-420-R-06-017.
Seasonal auxiliary power loads	Average base auxiliary power is set at 0.75 kW. The air conditioning compressor, when on, is estimated to add 2.67 kW when running and 1.1 kW at idle. Actual AC power varies with technology and can be higher or lower than the average default values. Usage is based on regional temperature and humidity profiles. The blower is estimated to add another 0.5 kW 100% of the time in winter and summer.	[Rugh, John P. (NREL) et al.]. for AC compressor power and usage.
Gradient	Specific road gradients are not included in the time-step drive schedules. The gradient influence on the FE of LDVs is assessed as the probability that potential energy recovery on downgrades is lost because the vehicle is braking for speed reduction purposes. The same procedure is used for the rail and bus modules.	Distributions of gradient severity are estimated by region.

The default vehicles are based on —and are thus representative of— 2011 technology and class proportions. If one wishes to consider an age distribution, the model assumes the fleet average performance enhancement that was reported by the EPA for the intervals 1990-2004, 2004-2011 [EPA-420-R-1 3-001, 2013 - Table 1 (cars and trucks) 2012 Fuel Economy Trends Report]. For the interval 1990-2004 the average trend was a 0.55% annual decrease in fuel economy (from 21.2 to 19.3 mpg), while for 2004 – 2011 the average trend was a 2.15% annual increase in fuel economy (from 19.3 to 22.4 mpg).

The EPA estimates the relative usage of various calendar years (CY) in generating its annual GHG emissions inventory. The effects of using the CY usage distribution (or the 'driven-fleet') on fuel economy and GHG emissions are summarized in Table 4. The EPA's

CY usage distribution in 2011 as adopted in its GHG inventory [EPA, 430-R-12-001, April, 2012] reduces the fleet efficiency to 91.32% of the sales-weighted 2011 MY's efficiency (or 1/.9132 = 1.095 times more fuel is consumed by the 2011 driven-fleet).

The CO_2e emissions intensity of LDVs also varies with age. While the CO_2 ratio is constant with fuel type, the N2O and CH4 emissions ratios vary with the regulatory period. The EPA's emissions factors for cars were constant from 2009 to 2011 at 3.6 mg/mi and 17.6 mg/mi for N2O and CH4 respectively [EPA, Emission Factors for Greenhouse Gas Inventories, 2011]. Even with the higher CO2-equivalency factors for these gases, the impacts are minimal — CO_2 emissions are 3.172 kg/kg-fuel and with the fuel intensity in 2011 at 0.126 kg/mi (22.4 mpg) is 0.3997 kg/mi. The CO_2-equivalent emissions were:

$$CO_2e \text{ (kg/mi)} = 0.3997 + 298 * 3.6/10^6 + 25 * 17.6/10^6 = 0.40121 \quad \textbf{Equation 2}$$

Thus, the impact of CH_4 and N_2O emissions post 2009 are a 0.37% increase over CO_2 emissions. The N_2O and CH_4 emissions rates are based on the ftp certification cycle and include a g/start factor allocated over the 7.4 mi ftp route distance. The running emission rates are an even smaller proportion than the 0.37% shown above.

Scaling the impacts for the fleet average MY composition by usage leads to a greater impact but it is still relatively small. The above cited EPA fuel economy trends report was used to estimate the 2011 fleet average emissions rate by applying MY fuel economy and MY emissions factors in the same way as the fleet-average fuel economy was derived. The resulting fleet average scale factors relative to the modelled 2011 sales mix were: 4.13 and 1.11 for N2O and CH4 respectively. We estimate the 2011 LDV driven-fleet to have a GHG emission intensity of:

$$CO_2e = 0.375 \text{ kg/start} + 3.19 \text{ kg/kg-fuel-running.} \quad \textbf{Equation 3}$$

Table 4. Performance of the 2011 Sales-weighted and 2011Driven Fleets

Fleet composition	Fuel Economy		Cold Start*	GHG emissions Intensity				
				Running				Starting
				CO_2	N_2O	CH_4	CO_2e	CO_2e
	mpg	kg/km	kg/start	kg/kg	mg/kg	mg/kg	kg/kg	kg/start
2011 sales weighted	22.37	0.126	0.114	3.172	14.19	59.85	3.178	0.363
2011 driven fleet	20.67	0.137	0.123	3.172	54.470	71.71	3.19	0.373
scale factors applied	0.913	1.095	1.095	N.A.	3.84	1.20	N.A.	N.A.

* Cold start is the incremental fuel consumed over the initial few miles of travel (before the engine, drivetrain and tires warm up) following 12 hr of sitting stopped, versus the fuel consumed over the same trip with a fully warmed vehicle. The base value shown is for an ambient temperature of 22ºC.
Source: TranSys Research; derived from EPA emissions sales-weighted and MY usage data (see text).

The EPA has developed a range of speed profiles to characterize the influence of traffic congestion on individual vehicle speed variations on freeway, urban and arterial streets. However, no single drive schedule provides a realistic characterization of a specific commuter or intercity trip. In the LDV and Bus simulation modules, the user specifies the proportion of each of eight individual drive schedules encountered in making the trip being simulated. Different congestion performance can be specified for 5 specific time-of-day congestion intervals. The user is guided with feedback of the total delay encountered when making the specified trip during each time of day. Default values for the matrix are provided for a typical large urban city and a smaller urban city as developed for the case studies undertaken within the project. Table 5 illustrates the matrix involved and the illustrative data for origin and destination (O and D) cities involved in an intercity trip.

Table 5. Illustrative Proportional Allocation of Congestion Encountered by Time-of-Day (% of route)

Location	Time Period	Creep	LOS-F	City Streets	Urban Arterial	Urban FW LOS-E	FW-cruise	FW LOS-F	FW-access US06	Delay (min / 10-km)
		~0.9 km/h	~14 km/h	~25 km/h	~40 km/h	~75 km/h	~119 km/h	~33 km/h	~100 km/h	
Arterial (O and D)	a.m. pk	3%	7%	25%	65%					30.2
	p.m. pk	3%	12%	10%	75%					25.1
	midday			15%	85%					9.0
	shoulders			5%	95%					2.9
	overnight				100%					0.0
Urban FW (O)	a.m. pk	3%	12%		30%	20%	5%	15%	15%	56.3
	p.m. pk	3%	5%		25%	27%	5%	10%	25%	38.8
	midday				20%	25%	25%	5%	25%	19.1
	shoulders					30%	50%		20%	5.8
	overnight					5%	75%		20%	0.0
Urban FW (D)	a.m. pk	3%			30%	25%	5%	20%	17%	47.0
	p.m. pk	3%			20%	35%	12%	10%	20%	31.4
	midday					20%	60%		20%	4.3
	shoulders					10%	70%		20%	2.0
	overnight					5%	85%		10%	0.0

Source: TranSys Research Ltd., for illustration only.

2.4 Air Mode Methodology

2.4.1 Air Made Analytic Framework

Simulation of individual air mode trips on a second-by-second time-step simulation is complex and requires knowledge of many parameters that are not readily available. There are a few complex simulation models that take this approach (e.g. the SAGE program sponsored by the US FAA [Federal Aviation Administration, 2005] and the BADA model in Europe [European Organisation for the Safety Of Air Navigation, 2009]. Such detail is not required for this project as the US Bureau of Transportation Statistics publishes good in-service performance data for air mode operations in the U.S. and it is the final in-service performance that is relevant for a modal comparison. The published data [Research and Innovation Technology Administration, Bureau of Transportation Statistics (BTS), 2013] are used to define congestion effects on energy performance by equipment type and trip length for typical U.S. domestic scheduled service operations.

The air mode has some complexities that require flight segmentation in order to assess GHG intensity. The warming effects of emissions from aircraft at cruise altitudes are higher than emissions on the ground and low altitudes. The effects of aviation on the atmosphere and climate were considered comprehensively in the 1999 IPCC Report [Intergovernmental Panel on Climate Change, 1999]. The effects are complex, and poorly understood in some respects, due to the complexities of the chemical processes in the atmosphere. The prime contribution to global warming is expected to be through emissions of carbon dioxide, which bear a fixed relationship to aviation fuel use, and which are assumed to be “well-mixed” with emissions from other sources, and to have the same radiation-forcing[1] potential as other emissions. In addition, emissions of nitrogen oxides from aircraft in the troposphere and lower stratosphere are expected to contribute to the formation of ozone more effectively than at ground level, further contributing to global warming. The effect is limited somewhat by the fact that in this process, nitrogen oxides reduce the atmospheric concentration of methane, which has the effect of reducing global warming. Aircraft also produce water vapor, which is eliminated rapidly in the troposphere, but in the upper atmosphere forms contrails (condensation trails) which can persist and even form cirrus clouds, and is expected to contribute further to global warming. The relative extents of these effects are uncertain, particularly the latter. The IPCC report estimated that in the mid-1990s aviation contributed about 2% of man-made CO_2, and about 3.5% of man-made radiation-forcing, excluding the possible effects of water vapor in cirrus cloud.

The report also cautioned about the uncertainty as follows:

> “The total radiative forcing due to aviation (without forcing from additional cirrus) is likely to lie within the range from 0.01 to 0.1 Wm^{-2} in 1992, with the largest uncertainties coming from contrails and methane. Hence the total radiative forcing may be about two times larger or five times smaller than the best estimate.”

Later in the summary the IPCC concluded:

> “Over the period from 1992 to 2050, the overall radiative forcing by aircraft (excluding that from changes in cirrus clouds) for all scenarios in this report is a factor of 2 to 4 [times] larger than the forcing by aircraft carbon dioxide alone. The overall radiative forcing for the sum of all human activities is estimated to be at most a factor of 1.5 [times] larger than that of carbon dioxide alone.”

That statement has proven somewhat ambiguous, with the implication of the latter sentence being overlooked, leading to interpretations that aviation emissions contribute 2 to 4 times as much to global warming as other emissions. The full statement that the ratio of radiation forcing to CO_2 from aviation was 2-4 and for other sources “at most …1.5” meant in fact that the relative radiation forcing from aviation emissions versus the worst case in other emissions could be between (2/1.5) and (4/1.5), or approximately 1.33 to 2.67.

The IPCC’s estimate that aviation contributed 2% of CO_2 and 3.5% of radiation-forcing shows that the best (circa 1999) estimate was that its radiation-forcing proportion was 1.75 times that of the proportion of CO_2 alone. In 2007 the Air Transport Bureau of the

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[1] Radiation forcing is the measure of heat flux associated with greenhouse gases (and other geophysical energy fluxes). Heat flux is defined as the amount of thermal energy transferred across a unit area over a time interval. Radiative heat flux is measured as Watts per square meter (W/m^2 or Wm^{-2}).

International Civil Aviation Organisation (ICAO) asked the Intergovernmental Panel on Climate Change (IPCC) to update its opinion to reflect that the impact is not as great as originally believed — its estimate of total radiative forcing was reduced from 3.5% to 3%, while its estimate of CO_2 contribution remained at its prior estimate of 2%.[2] Using this update, air mode GHG intensities for the cruise phase would be adjusted with a multiplier of 1.5 times CO_2 emissions. The recent IPCC Fifth Assessment appears also to have endorsed the lower estimate of radiative forcing from persistent contrails but publication is scheduled for early 2014. The draft WGI report had included a combined RF for contrails and high cirrus in 2011 to be +0.05 (+0.02 to +0.15) W m-2, but the overall estimate for aviation CO_2 in that year remained unpublished.[3] One can expect the CO_2e/CO_2 ratio to change for aviation with further scientific investigation; and the default factor of 1.5 adopted in the model should be modified as appropriate. The updated IPCC report was not available during this project and users should monitor and update the model if the IPCC's final report modifies these values.

Recognizing this higher-altitude GHG multiplier for aircraft emissions requires segmentation of the energy consumed at higher altitudes from that consumed in landing-and-takeoff (LTO), climb-out and descent phases of an air trip. Fortunately, data exist to support the segmentation of flights by equipment type. The U.S. DOT data noted above [Research and Innovation Technology Administration, Bureau of Transportation Statistics, 2013] provides information on the overall trip energy intensity by equipment type. Jet engine emissions certification data published by ICAO (ICAO Aircraft Engine Emissions Databank) includes data on fuel consumption for a typical landing and takeoff cycle and is required for all jet engines greater than 2,200 lb (9.8 kN) thrust. The ICAO engine database is maintained by and available from the European Aviation Safety Agency (http://easa.europa.eu).

The two data sets (BTS and ICAO) are used to develop a model of air mode performance by equipment type. The data are assessed to provide the energy performance by flight segment for five representative equipment types: The default characterization data provided with the model are based on 2011-2012 operations of domestic US scheduled air carriers and can be updated by the user as desired in future years as air technology and operations practices change. The following five representative types of aircraft are assessed:

6. Turboprops (TP)
7. Small Regional Jets (SRJ) (defined here as jet aircraft with less than 50 seats)
8. Regional Jets (RJ) (defined here as short-range jet aircraft with 50 to 89 seats)
9. Narrow Body Jets (NBJ) (defined here as jet aircraft with greater than 89 seats in a single aisle configuration)
10. Wide Body Jets (WBJ) (defined here as jet aircraft with greater than 89 seats configured with more than one aisle)

The Bureau of Transportation Statistics' data (Table 254, Air Carrier Traffic and Capacity Statistics by Aircraft Type) for 2011 and 2012 is filtered to remove air cargo and air charter operators, operators with fewer than 65 flights per quarter and flights greater than 3,000

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[2] ICAO website March, 2010: http://www.icao.int/icao/en/env/aee.htm.

[3] IPCC Working Group I Contribution to the IPCC Fifth Assessment Report Climate Change 2013: The Physical Science Basis, Final Draft Underlying Scientific-Technical Assessment, version September 26, 2013 (Unpublished but available at http://www.climatechange2013.org/images/uploads/WGIAR5_WGI-12Doc2b_FinalDraft_All.pdf.

great-circle miles (GC-mi) in length. The combined 2011-12 filtered dataset of US scheduled carriers is then analyzed to provide an indication of the mix of aircraft used in meeting the demand for different trip lengths. Each aircraft type is also analyzed to provide an indication of its average load factor and its per-seat fuel intensity (kg/seat-GC-mi).

The ICAO engine emissions database is used to derive the LTO fuel consumption for a sample of engines used in each of the jet aircraft types and simulation-based data in the European Environmental Agency's CORINAIR database (an inventory of air emissions) are used to derive LTO fuel consumption for a representative turboprop aircraft. The LTO data are used to identify fuel use during the landing and takeoff cycle (kg/seat-LTO) for each aircraft type thereby permitting the segmentation of fuel consumption into the LTO/climb-out/descent phase and the cruise phase of a trip. Climb-out and descent are estimated to occur at 3000 ft/minute for all aircraft and the average of the climb-out and descent fuel consumption rate is considered to be the same as the average rate during the cruise phase. All aircraft but turboprops are considered to cruise at altitudes above the 25,000 ft floor associated with exacerbated 'high altitude' impacts from emissions. Thus, emissions from all types but turboprops are assessed to have a higher effective impact at cruise altitude.

2.4.2 Air Mode Default Characterization Tables

Five aircraft types were characterized using operating reports from US domestic scheduled airlines for the years 2011 and 2012 [http://www.transtats.bts.gov]. The reports include quarterly totals of key operating metrics by aircraft. We processed the data to group individual aircraft into the five classes (TP, SRJ, RJ, NBJ, WBJ). Not all of the reports included fuel consumption data. The full dataset was assessed in determining proportional usage of aircraft type by trip length and load factor, whereas the energy intensities were derived on the basis of those reports that included fuel consumption information. Fuel consumption was reported for 35% of the turboprop seat-miles, 44% of the small regional jet seat-miles and about 49% of the three other aircraft types. The mix of operators and specific aircraft involved in fuel-reported versus not-reported did not suggest any bias in the data for jet aircraft. However, the turboprops with fuel reported tended to be larger aircraft and thus, the fuel intensity of turboprops might not be representative of the overall turboprop fleet. Nonetheless, we believe the larger turboprops are likely to provide a better representation of the turboprop fleet used in larger centers where rail services are present.

The resulting mix of aircraft usage (seat-GC-km) by seven trip length segments (GC-km) is summarized in Table 6. The upper boundary of each segment is shown in the second row (GC-mi) and the third row (GC-km). The seventh data-column indicates the upper limit of the data analyzed (i.e. 3,000 mi). For trips less than 250 GC-mi (402 GC-km) turboprops account for 81.5% of the seat-mi, small regional jets account for 16.5% and regional jets account for 1.9% of the seat-mi. For distances in segment 4 (750 to 1000 GC-mi) narrow body jets account for 94.9% and regional jets account for 4.5% of the seat-mi. This is the default distribution of aircraft used in performing a 'representative' air leg simulation. If desired, a user can override this distribution by indicating one specific aircraft type (or any alternate distribution) for the air leg of a simulated trip.

Table 6. Proportional Aircraft Usage (%-seat-miles) by Trip Segment Length

Segment No.	1	2	3	4	5	6	7
Min (GC-mi)	0	250	500	750	1000	1,500	2,000
Max (GC-mi)	250	500	750	1,000	1,500	2,000	3,000
Max (GC-km)	402	805	1,207	1,609	2,414	3,219	4,828
TP	81.5%	6.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SRJ	16.5%	6.1%	0.0%	0.0%	0.0%	0.0%	0.0%
RJ	1.9%	80.0%	22.0%	4.5%	0.0%	0.0%	0.0%
NBJ	0.1%	8.0%	78.0%	94.9%	92.1%	77.7%	0.0%
WBJ	0.0%	0.0%	0.0%	0.6%	7.9%	22.3%	100.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: TranSys Research Ltd. via analysis of Table 254 Air Traffic Data for years 2011-2012 [U.S. BTS, 2013 (http://www.transtats.bts.gov)].

The average load factor (as measured by total revenue-passenger-miles / total revenue-seat-miles) for each aircraft type for the 2011-12 interval is summarized in Table 7. Load factor is seen to increase with the size (and associated longer range) of the aircraft.

Table 7. Average Load Factor by Aircraft Type

Aircraft Type	TP	SRJ	RJ	NBJ	WBJ
Load Factor	69.93%	74.29%	78.16%	83.27%	86.76%

Source: TranSys Research Ltd. via analysis of Table 254 Air Traffic Data for years 2011-2012 [US BTS, 2013 (http://www.transtats.bts.gov)]

The energy intensity of each aircraft type was derived via regression analysis of those records in the filtered dataset that contained fuel consumption. As there is a wide range of individual aircraft sizes within each type/class, the fuel consumption data were normalized by number of seats. Regressions were performed (with a forced zero coefficient) for each aircraft type with fuel consumed (kg/seat) as the dependent variable and the number of LTO cycles and the total GC-km traveled for the aircraft/quarter as the independent variables.

Two regressions were reassessed on different metrics. The SRJ regression did not provide a good fit when done on a kg/seat basis. Upon review it was determined that all SRJs had the same engine regardless of seating capacity. Thus, a regression based on fuel consumption per aircraft gave a better fit to the data than one based on kg/seat. The regression results in kg/aircraft were then adjusted to kg/seat on the basis of the average seating capacity of 40.5 seats per SRJ in the dataset. The initial regression of WBJ was not significant in the LTO term so that term was dropped from the final regression. Also, the WBJ data displayed a meaningful proportion of cargo being carried (11.9% by weight). To facilitate allocation of fuel between cargo and passengers, the WBJ regression was undertaken on the basis of kg-fuel/payload capacity. The results were then allocated to seats on the basis of 178.6 kg-payload/seat (with 11.6% of fuel going to cargo and 88.4% going to passenger seats).

The final regression results are presented in Table 8. All regressions display a high explanation of data variation (adjusted R-square values all exceed 0.93). All final coefficients were significant (t-statistics > 2.0) though the significance was somewhat less for the SRJ and RJ categories than for the other categories.

Table 8. Direct Results from the Raw Regression Results

AC Type	Number of data points	Adjusted R Square	Coefficient	Coefficient Values	t Stat	P-value
TP	48	0.9674	kg/seat-LTO	10.62	11.30	7.16E-15
			kg/GC-skm	0.011222	4.59	3.43E-05
SRJ*	18	0.9363	kg/seat-LTO*	11.457	6.38	0.000
			kg/GC-skm*	0.045	2.53	0.022
RJ	228	0.9314	kg/seat-LTO	8.888	2.69	0.00766
			kg/GC-skm	0.039004	9.25	1.72E-17
NBJ	374	0.9850	kg/seat-LTO	6.814	8.26	2.57E-15
			kg/GC-skm	0.0224	35.06	6E-120
WBJ**	121	0.9887	kg/PL-km**	0.157325	201.02	1.4E-153

Source: TranSys Research Ltd, analysis of Table 254 Air Traffic Data for years 2011-2012 [US BTS, 2013 (http://www.transtats.bts.gov)].

Notes:

* The SRJ regressions did not provide a good fit when done on a kg/seat basis (since most SRJs have the same engine regardless of seating capacity). The regression was done on the basis of kg/aircraft and adjusted to kg/seat on the basis of the average seating capacity of 40.5 seats.

** Because WBJs had a significant proportion of cargo, the WBJ regression was done on the basis of payload capacity (kg/PL-km) so that the cargo and passenger fuel could be allocated. The WBJ regression did not provide a statistically significant result for the LTO coefficient so that term was dropped from the final regression.

While the regression results provide meaningful data, the confines of the data prevent a literal interpretation of the results (i.e. the kg-fuel / seat-LTO is not a direct measure of fuel consumed in a LTO cycle). In general the resulting coefficients had higher values for LTOs and lower values for distance traveled than would be expected from the engineering relationships. This is because the distance traveled in the data is simply the GC distance between each origin-destination (OD) pair rather than the actual distance flown. The actual distance flown will always be higher than the GC distance and involves incremental distance related to:

- takeoff and landing headings that are constrained by runway layout and wind direction and are not the direct GC alignment headings for the OD,
- following actual navigation points between the OD pair, and
- landing delays (circling an airport) while awaiting a landing slot.

These additional en route travel distances are somewhat independent of flight distance and show up as an increment in the LTO regression coefficient. While the interpretation of the regression result does not matter in generating the total fuel consumed, it does matter to the GHG emissions from aircraft since the effects of emissions at cruise altitudes are different than those emitted during the LTO cycle.

Thus, the initial regression results were adjusted to reflect the actual fuel consumed in the LTO cycle, and the en route incremental distance quantity was transferred to the cruise segment of the flight. The difference between the regression-based LTO fuel and the

ICAO-based LTO fuel was then allocated to the cruise portion of the flight. The resulting coefficient (kg/GC-km) can be interpreted as the product of two parameters:

1) the kg/km that one would get from a simulation model or direct measurement of fuel consumed and distance traveled applied to the GC-distance, and
2) the adjustment factor that scales the GC-distance to the actual miles flown.

The above interpretation is not required to make use of the data, but does allow one to assess the reasonableness of the coefficients by assessing the reasonableness of the underlying parameters. We went through this exercise for each of the aircraft types, using published SAGE simulation model predictions [FAA-EE, (Appendix C), 2005] for a sample of aircraft in each aircraft-type group.

In addition to the transfer of fuel from LTO to cruise segments, the forced zero nature of the regressions led to varying levels of bias in the total results. This bias was factored out of the final coefficients such that the application of the coefficients produced no bias in the predicted total fuel consumption. The resulting coefficients and the scale-factor inherent to the underlying kg/GC-km values are presented in Table 9. As can be seen, the largest proportional impacts are on the short-range aircraft – turboprops and small regional jets experience scale factors of 1.335 and 1.444 respectively. The long-range aircraft have decreasing multipliers — values of 1.114 for NBJ with an average GC-trip distance of 1,436 km and 1.061 for WBJ with an average GC-trip distance of 2,591 km. The results are a reflection of the impact of a relatively fixed extra distance having a greater impact on shorter trips than on longer trips. It could also reflect a lower priority being allocated to smaller aircraft when vying with larger aircraft for landing slots during times of congestion and/or the short range aircraft being used more for peak-period commuter travel and thus more frequently exposed to congestion. The higher multiple for SRJs than TPs could reflect the fact that the SRJs are mainly used in the east serving major airports, whereas the turboprops have higher usage in the Midwest and Pacific regions and service smaller airports.

The average scale factors (Implied GC Multiplier in Table 9) are composites of all flights reported for each aircraft type. One can expect the multiplier to vary between peak and off-peak travel times. Reynolds found in-flight delays lead to average extra distances flown of 14% for intra-European flights and 12% for intra-U.S. flights [Reynolds, 2008]. He also found the delays to increase with traffic density. We provide a peak versus off-peak delay calculation in the model and make estimates of the relative impact as initial default values; however, research is required to refine these estimates. In generating the parameters, we distribute the delay component such that peak-period flights receive a 25% increment to the average excess-distance and additionally estimate that 45% of all domestic seat-arrivals occur during peak periods. Based on these estimates, weekend and off-peak periods receive a 5.1% decrement from the average excess-distance while week-day peak periods receive a 6.3% increment. The resulting average, peak and off-peak fuel intensities of each aircraft type are shown in Table 10.

Table 9. Derived Fuel Intensity Coefficients by Aircraft Type

AC Type	Regression Bias due to Forced-Zero Origin	Coefficient Units	Original Coefficient Values	Derived Values[1]	Average Trip Distance (km)	Implied GC Multiplier	Implied Extra Travel (km/trip)
TP	-5.9%	kg/seat-LTO	10.62	4.70	375	1.335	126
		kg/GC-skm	0.011222	0.0294			
SRJ[2]	16.4%	kg/seat-LTO	11.457	8.34	631	1.444	281
		kg/GC-skm	0.045	0.0514			
RJ	-1.8%	kg/seat-LTO	8.888	7.50	789	1.102	80
		kg/GC-skm	0.039004	0.0325			
NBJ	-1.2%	kg/seat-LTO	6.814	6.88	1,436	1.114	164
		kg/GC-skm	0.0224	0.0228			
WBJ[3]	-2%	kg/seat-LTO	Not Significant	8.26	2,591	1.061	158
		kg/PL-km	0.157325				
		kg/GC-skm	Not Applicable	0.0219			

Source: TranSys Research Ltd, analysis of Table 254 Air Traffic Data for years 2011-2012 [US BTS, 2013 (http://www.transtats.bts.gov).

Notes:

1. Derived values adjust for regression bias and force the LTO fuel consumption to ICAO certification data (see text).
2. SRJ regressions are per-aircraft and average seats/aircraft used since per-seat values provided poor regression results (see text).
3. WBJ regressions are based on payload capacity (kg/PL-km) rather than seats since WBJ aircraft had a significant proportion of cargo. Fuel is split between cargo and seat-payload-capacity to get per-seat km fuel intensity (see text).

Table 10. Cruise-phase Fuel Intensities by Aircraft Type and Traffic Congestion.

AC Type	Trip GC-Distance Multiplier			Fuel Rate (kg/GC-skm)		
	Implied GC Multiplier	Estimated WD-peak Multiplier	Estimated non-peak Multiplier	Average	Peak Period	Off-Peak Period
TP	1.335	1.419	1.267	0.0294	0.031219	0.027866
SRJ	1.444	1.556	1.354	0.0514	0.055317	0.048133
RJ	1.102	1.127	1.081	0.0325	0.033252	0.031887
NBJ	1.114	1.143	1.091	0.0228	0.023429	0.022364
WBJ	1.061	1.076	1.048	0.0219	0.022167	0.021597

Source: TranSys Research Ltd: Average values based on analysis of BTS data. Peak and off-peak values are preliminary best-estimates requiring further research.

GHG intensities during the LTO phase are calculated on the basis of factors used in EPA's inventory model, which adopts zero emissions of CH_4 from aircraft and 0.1 g/kg of N_2O [EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010]. The CO_2-equivalent emission during the high-altitude cruise phase of flight is based on the 1.5 multiplier factor discussed above. Thus, the equations for air-mode GHG emissions are:

GHG (kg-CO_2e) = GHG(LTO) * Fuel(LTO) + GHG(cruise) * Fuel(cruise) **Equation 4**

where:

GHG(LTO) = 3.158 + 25 * 0 + 298 * 0.0001 = 3.188 kg-CO_2e/kg-fuel

GHG(Cruise) = 3.158 * 1.5 = 4.737 kg-CO_2e/kg-fuel

LTO includes fuel allocated to climb out and descent to/from 25,000 ft.

An alternate measure of Air-mode GHG emissions is provided with the high altitude impacts ignored to facilitate comparison of the impact of the high-altitude multiplier on air-mode GHG intensities.

2.5 Rail Mode Methodology

2.5.1 Analytic Overview

Since the focus of the model is on energy intensity rather than overall train performance, some simplifications can be made in the simulation model over what would be required by a detailed train performance calculator. Also, passenger services have characteristics that allow additional simplifying assumptions. Specifically, passenger consists are short relative to freight trains, which make a lumped mass approach more realistic and the power-to-weight ratio of passenger trains is much higher than freight trains, which makes the influence of gradients much less important for passenger than for freight trains. Gradient and train length influences on energy intensity are included in the model; however, due to the simplifying assumptions (which are reasonable for passenger services), the model will not provide accurate results for freight trains. It is a rail passenger service simulation model, not a general purpose railway simulation model.

The model is based on characterization data that will usually be available to a rail-agency and rail system operators; however, the data will not necessarily be publicly available. Detailed track gradient and curvature profiles that are required by most railway train performance calculators are not used as inputs; however, condensed route characteristics are included. The model has been developed with some default region-and service-specific characteristics (as developed for the case studies) built in. Nonetheless, simulation of a specific service will benefit from development of data specific to that service. One of the key influences of passenger train performance is the number of speed changes involved on a route. Permanent speed limits shown in railway timetables are more generally available than are track gradient profiles and we recommend that actual speed limit tables be used in simulating a service wherever possible. Gradients have less impact on passenger train performance and the regional gradient characteristics developed as default regional tables may be more generally applied without significant impact on the accuracy of the results. The gradient characteristics developed for the default tables were developed from a range of actual track gradient profiles and do not represent any one track subdivision or any one railway. We caution again that the regional characteristics and the model itself are not applicable to freight trains.

As with the other ground modes, energy intensity and associated emissions of GHG involve similar calculations. However, since the model supports comparisons of rail mode technologies, additional breakout details of energy dissipation components are provided for the rail mode. The rail simulation module is configured to separate the individual components of energy dissipated in overcoming inherent resistance. In addition to inherent resistance, power is required to:

1) accelerate the mass of the vehicle, its rotating elements and the load it is carrying to a desired speed, and

2) climb uphill grades encountered.

These two additional power requirements do not directly translate into energy as they are essentially stored energy. The potential energy gained in climbing grades can be partially or fully recovered to overcome inherent resistance on downgrades. Similarly, the kinetic energy/inertia gained in acceleration can be partially recovered in deceleration. It is only through braking (and to a lesser extent, drivetrain-drag during coasting) that these stored energy components are lost/consumed.

The rail module accumulates the energy associated with each of the sub-categories of energy dissipation such that the effectiveness of alternative technologies can be gauged from the model output for a single train run.

2.5.2 Rail Equipment Characterization

Table A-1 of Volume I of this report summarizes the publicly available passenger locomotive characterization data, and Table A-2 of Volume I of this report summarizes the publicly available passenger rail coach and trainset characterization data that have been located for use in the model case study simulations.

2.6 Access Egress Modes Characterization

Only the primary modes being compared are simulated in detail in the model; the performance attributes of access and egress modes are simple averages provided in default lookup tables located in the Regional-Properties worksheet. The attributes of public transport modes have been derived from the 2011 National Transit Database's *Service* and *Energy* Tables. The electricity supply is region-dependent but all other performance metrics are based on one average applied to all regions. The properties included in the calculation of the various modal averages are shown in Table 11.

Table 11. Transit Properties Included in Modal Averages

Property	MB	CB	CR (D2)	CR (el)	HR (el)	LR (el)
Central Puget Sound Regional Transit Authority		X	X			X
Maryland Transit Administration		X	X		X	X
Georgia Regional Transportation Authority		X				
City of Los Angeles Department of Transportation		X				
Massachusetts Bay Transportation Authority	X		X		X	X
Southeastern Pennsylvania Transportation Authority	X			X	X	
Washington Metropolitan Area Transit Authority	X				X	
Utah Transit Authority	X		X			X
South Florida Regional Transportation Authority			X			
Metro Transit (Minneapolis/St. Paul)			X			
Denton County Transportation Authority			X			
Peninsula Corridor Joint Powers Board dba: Caltrain			X			
Southern California Regional Rail Authority dba: Metrolink			X			

Legend: MB = Municipal Bus, CB = Commuter Bus, Cr = Commuter Rail, HR = Heavy Rail (defined as dedicated commuter tracks), LR = Light Rail, D2 = diesel, el = electricity

Attributes for personal automobiles and taxis were derived with the simulation model in a one-time simulation of the 2011 driven fleet composite vehicle. The following assumptions were made for the highway access/egress modes:

- Taxis were assumed to travel 1.5 km for every km of passenger carrying travel;
- drop-off/pick-up was assumed to have 60% return-to-origin travel and 40% being part of a 2-person trip that incurs 10% extra travel distance.
- Carpools are assumed to involve 3 persons and the trip length is 15% longer than any one-person trip.

The resulting characteristics (for the Continental U.S. electricity generating fuel mix for upstream energy and emissions) are presented in Table 12.

Table 12. Access/Egress Modes' Default Performance Data

Mode	Average Speed (mph)	Fuel Source	Direct Travel			Upstream	
			Fuel Intensity	Energy Intensity	CO2-e Emission Intensity	Energy Intensity	CO2-e Emission Intensity
			(kg/p-mi) (kWh/p-mi)	(kJ/p-mi)	(g/p-mi)	(kJ/p-mi)	(g/p-mi)
Walk	3.1	N.A.	0	0	0	0	0
Bicycle	10	N.A.	0	0	0	0	0
Walk/Bicycle	10	N.A.	0	0	0	0	0
Auto: Drive alone & park	25	Conv. gasoline	0.125	5,431	399	1,091	99.5
Auto: Drop off / Pick up	25	Conv. gasoline	0.236	10,251	753	2,060	187.7
Carpool, Van, Shuttle	25	Conv. gasoline	0.048	2,082	153	418	38.1
Taxi	25	Conv. gasoline	0.188	8,147	598	1,637	149.2
City Bus	12.4	U.S. conv. diesel	0.089	3,801	310	761	69.6
Commuter Bus	24.4	U.S. conv. Diesel	0.055	2,357	192	472	43.2
Subway	21.2	Electricity Continental U.S. Mix	0.396	3,322	228	337	23.0
Streetcar/Light Rail	13.8	Electricity Continental U.S. Mix	0.338	2,840	195	288	19.7
Commuter Rail (elec)	26.9	Electricity Continental U.S. Mix	0.373	3,129	215	317	21.7
Commuter Rail (diesel)	33.4	U.S. conv. Diesel	0.064	2,743	205	549	50.2

Source: TranSys Research analysis: public modes derived from the National Transit Database and LDV derived via commuter-trip simulation.

The fuel intensity of highway modes is adapted to congestion conditions via peak and off-peak multipliers, which can be specified for three city sizes (large, small and rural municipality).

2.7 Regional Characterization

2.7.1 Region and Season Definitions

The model provides default regional characterization data for four regions of the continental U.S. and electricity generation characteristics are further disaggregated into 9 sub-regions. Table 13 defines the state composition of each region and sub-region.

Three seasons are defined – summer, winter and 'other' being spring and fall. Summer and winter each have 3 months and 'other' has 6 months. Summer is comprised of June, July and August; winter is comprised of December, January and February; and 'other' is the remaining months.

Table 13. State Composition of Regions and Sub-regions

Region	Sub-region	States
Northeast	Middle Atlantic (MA)	NY, CT, PA, NJ
	New England (NE)	NH, VT, ME, MA, RI
South	West South Central (WSC)	OK, AR, LA, TX
	East South Central (ESC)	KY, TN, MS, AL
	South Atlantic (SA)	WV, VA, DE, MD, DC, NC, SC, GA, FL
Midwest	West North Central (WNC)	ND, SD, MN, NE, IA, KS, MO
	East North Central (ENC)	WI, MI, IL, IN, OH
West	Pacific	WA, OR, CA
	Mountain (MTN)	MT, ID, WY, NV, UT, CO, AZ, NM

Source: U.S. Energy Information Administration (Weather Data Regional Composition)

2.7.2 Emissions Intensity of Electricity Generation by Region

The distribution of fuels used in generating electricity by region was derived from the Energy Information Administration's data for fuels used in electricity generation by state in 2011 [Energy Information Administration, 2012]. The upstream fuels consumed in providing the fuels for electricity generation was derived from the GREET model [Argonne National Laboratory, GREET1_2012].

Table 14 indicates region breakdown in 2011of the energy content of carbon fuels usage in electricity generation (Direct) and the incremental upstream carbon fuels consumed in getting fuels to the electricity generation stations.

Table 14. Direct and Upstream Carbon Fuels Usage in Electricity Generation by Region in 2011

Region	Electricity Generation		Upstream Fuel Increment	
	Carbon fuels (BTU/kWh)	CO2e (kg/kWh)	Carbon fuels (BTU/BTU)	CO2e (kg/kWh)
Northeast	6,976	0.397	16.7%	0.066
South	8,297	0.614	12.2%	0.075
Midwest	8,623	0.730	7.0%	0.051
West	6,865	0.421	13.1%	0.055
Continental U.S.	7,938	0.577	11.2%	0.065

Source: TranSys Research Ltd, derived from Energy Information Administration’s state data for fuels used in generating electricity and GREET1_2012 data for fuel properties and upstream fuel intensities.

2.7.3 Climate-Influences by Region

Seasonal climate properties influence auxiliary power usage and aerodynamic drag for all modes. Seasonal daytime temperatures for each region were derived from the National Climate Data Center’s (NCDC) hourly readings data for 1981-2010 [National Climate Data Center, 2013]. Air conditioning usage by LDVs was derived from previous work undertaken by Rugh et al. [Rugh, 2004], who derived estimates of annual air conditioning usage by state for automobiles and light duty trucks (LDTs). Their analysis derived average air conditioning usage weighted by the total light duty vehicle registrations in each state. The analysis concluded that 7 billion gallons of fuel (about 5.5% of total LDV consumption) was consumed annually by LDVs for air conditioning usage. We applied the same vehicle registration weighting by state to get weighted average values of daytime temperatures for each of our four defined regions and for the continental U.S. We derived seasonal variations of air conditioning usage on the basis of these temperatures and Rugh’s data on average temperature while air conditioning was on for each state. The resulting seasonal values are shown by region in Table 15.

Table 15. Regional Climate Related Characteristics

Region	Measure	Season		
		Winter	Summer	Other
Northeast	Temperature C	-0.1	23.3	11.9
	Temperature F	31.8	74.0	53.3
	LDV Air conditioning time on	0.0%	82.0%	2.3%
South	Temperature C	9.5	27.9	19.4
	Temperature F	49.2	82.2	67.0
	LDV Air conditioning time on	0.0%	90.9%	39.6%
Midwest	Temperature C	-2.4	23.9	11.6
	Temperature F	27.6	75.0	52.9
	LDV Air conditioning time on	0.0%	92.7%	2.2%
West	Temperature C	7.5	24.5	16.0
	Temperature F	45.6	76.1	60.8
	LDV Air conditioning time on	0.0%	77.8%	19.5%

Continental U.S.	Temperature C	4.4	25.4	15.4
	Temperature F	39.8	77.6	59.7
	LDV Air conditioning on	0.0%	87.0%	19.2%

Source: TranSys Research Ltd., derived from NCDC climate data and Rugh's AC-usage data (see text).

2.7.4 Infrastructure Gradient by Region

Highway and Railway gradient data are in the model for a sample of specific routes assessed in the case studies that were undertaken. Appendix D of Volume of this report discusses he development of highway gradient data. Railway gradient data were derived from railway profiles and from the literature as discussed in Section 2.7.4 of Volume I of this report. A preprocessor is provided with the model to process distance based gradient profiles into the gradient severity matrix structure used in the model.

3 Simulation Model Structure

3.1 Run-type Scenarios and Associated Outputs

The model supports multi-modal door-to-door passenger trip comparisons of energy and GHG intensity. Added details of energy dissipation sources are provided in support of rail-only simulations. The user can choose from the following three formats in running the simulation model:

4. A single train service to assess its performance and energy/GHG breakout;
5. A comparison of up to four passenger rail technologies to compare and assess the energy/GHG savings realized.
6. A comparison of up to four passenger modes (rail, bus, air, light duty vehicle) to compare and assess the energy/GHG performance in a door-to-door trip.

The outputs are different for each of the three scenarios as indicated in the illustrative output tables presented over the following five pages.

The output format from a single-train service simulation, as indicated in Table 16, allows one to assess the underlying sources of energy consumption and GHG emissions. This information is a first step in validating the input data used for the simulation and in assessing the relative impact that technological changes to specific source components of energy consumption would have. Absolute and proportional values of energy consumption and GHG emissions are output for seven categories of traction energy (three sub-elements of inherent train resistance, the three sub-elements of brake dissipation and curving resistance), for the traction system's transmission losses and for hotel power provision.

A second Table provides the performance metrics for the single-train simulation. As indicated in Table 17, energy and emissions intensities are output for three divisors (per-trip, per-seat-distance and per-passenger-distance) and for two service-performance metrics (travel-time and average speed).

The same information is provided for a technology comparison simulation; however, an additional row with the percent-reduction realized by the alternative technology is added for each alternative simulated (see Table 18 and Table 19). An additional table of performance metrics is output for technology comparisons (Table 20) to indicate the total energy and emissions when the indirect consumption/emissions associated with well-to-pump fuel provision are included.

The outputs from a modal comparison simulation focus on the performance metrics and expand the comparison to include access and egress legs of a trip. Four tables are output with the same energy/emissions intensity values as were used in the technology comparison tables but with an indexed comparison to the rail mode replacing the %-reduction from the baseline rail technology that was used in the technology comparison table. Table 21 compares direct energy/emission for the modal leg of the trip, Table 22 compares direct energy/emission for only the access/egress legs of the respective modal trips, Table 23 compares direct energy/emission for the complete door-to-door trips, and Table 24 compares the full energy/emissions (including indirect well-to-pump) for the complete door-to-door trips. Table 22, Table 23 and Table 24 include columns for per-seat-distance intensity; however, seat-distance (seat-km or seat-mi) data are not available for all access/egress modes and thus these columns are not filled in in the present model. The columns exist in the tables in the event future research provides source data.

Table 16. Single Train Simulation Output Table Showing Energy Dissipation Components

Component	Units	Inherent Resistance			Brake Dissipation			Track Curve Resistance	Total Traction (after combustion)	Traction Power Transmission Losses	Total Hotel (after combustion)	Total per round trip
		Rolling	Dynamic	Aerodynamic	Scheduled Stops/ Permanent Slow-Orders	Other Stops/ Temporary Slow-Orders	Down Grades					
Energy	(kJ)											
	(%-traction)											
	(%-total)											
	(%-sub-total)											
GHG emissions	(kg-CO2-eq)											
	(%-traction)											
	(%-total)											
	(%-sub-total)											

Note: Metric units shown, U.S. units provide (Btu) and (lb-CO2-eq)

Table 17. Single Train Simulation Output Table Showing Performance Metrics

Category	Intensity Measures*						Service Metrics	
Divisor	per trip		per seat-km		per passenger-km		travel time	average speed
Units of Measure	(kJ)	(kg - GHG)	(kJ)	(g - GHG)	(kJ)	(g - GHG)	(hrs)	(km/h)
Parameter Values								

* GHG is measured in kg of CO_2-equivalent

Note: Metric units shown, U.S. units provide intensities per seat-mi and per passenger-mi, (Btu), (lb-GHG) and (mph).

Table 18. Technology Comparison Simulation Output of Absolute Values and Proportional Savings for a Round Trip

Component	Alternative	Units	Inherent Resistance			Brake Dissipation			Track Curve Resistance	Total Traction (after combustion)	Traction Power Transmission Losses	Total Hotel (after combustion)	Total per round trip
			Rolling	Dynamic	Aerodynamic	Scheduled Stops/ Permanent Slow-Orders	Other Stops/ Temporary Slow-Orders	Down Grades					
Energy	Baseline	(kJ)											
	Alt-1	(kJ)											
		(%-reduction)											
	Alt-2	(kJ)											
		(%-reduction)											
	Alt-3	(kJ)											
		(%-reduction)											
GHG emissions	Baseline	(kg-CO2-eq)											
	Alt-1	(kg-CO2-eq)											
		(%-reduction)											
	Alt-2	(kg-CO2-eq)											
		(%-reduction)											
	Alt-3	(kg-CO2-eq)											
		(%-reduction)											

Note: Metric units shown, U.S. units provide (Btu) and (lb-CO2-eq)

Table 19. Technology Comparison Table of Performance Metrics I (Direct Transportation Activity)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger-km		travel time	average speed
Units of Measure		(kJ)	(kg - GHG)	(kJ)	(g - GHG)	(kJ)	(g - GHG)	(hrs)	(km/h)
Baseline	value								
Alt.1	value								
	%-reduction								
Alt.2	value								
	%-reduction								
Alt.3	value								
	%-reduction								

* GHG is measured in kg of CO_2-equivalent

Note: Metric units shown, U.S. units provide intensities per seat-mi and per passenger-mi, (Btu), (lb-GHG) and (mph)

Table 20. Technology Comparison Table of Performance Metrics II (Including Well-to-Pump Energy and Emissions)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger-km		travel time	average speed
Units of Measure		(kJ)	(kg - GHG)	(kJ)	(g - GHG)	(kJ)	(g - GHG)	(hrs)	(km/h)
Baseline	value								
Alt.1	value								
	%-reduction								
Alt.2	value								
	%-reduction								
Alt.3	value								
	%-reduction								

* GHG is measured in kg of CO_2-equivalent

Note: Metric units shown, U.S. units provide intensities per seat-mi and per passenger-mi, (Btu), (lb-GHG) and (mph)

Table 21. Modal Comparison Performance Metrics I (Modal Leg Only / Direct Transportation Energy/Emissions)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger-km		travel time	average speed
Units of Measure		(kJ)	(kg - GHG)	(kJ)	(g - GHG)	(kJ)	(g - GHG)	(hrs)	(km/h)
Rail	value								
Mode1	value								
	Indexed-to-Rail								
Mode 2	Value								
	Indexed-to-Rail								
Mode 3	Value								
	Indexed-to-Rail								

* GHG is measured in kg of CO_2-equivalent

Note: Metric units shown, U.S. units provide intensities per seat-mi and per passenger-mi, (Btu), (lb-GHG) and (mph)

Table 22. Modal Comparison Performance Metrics II (Access/Egress Legs Only / Direct Transportation Energy/Emissions)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger-km		travel time	average speed
Units of Measure		(kJ)	(kg - GHG)	(kJ)	(g - GHG)	(kJ)	(g - GHG)	(hrs)	(km/h)
Baseline	value								
Mode 1	value								
	Indexed-to-Rail								
Mode 2	value								
	Indexed-to-Rail								
Mode 3	value								
	Indexed-to-Rail								

* GHG is measured in kg of CO_2-equivalent

Note: Metric units shown, U.S. units provide intensities per seat-mi and per passenger-mi, (Btu), (lb-GHG) and (mph)

Table 23. Modal Comparison Performance Metrics III (Door-to-Door / Direct Transportation Energy/Emissions)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger-km		travel time	average speed
Units of Measure		(kJ)	(kg - GHG)	(kJ)	(g - GHG)	(kJ)	(g - GHG)	(hrs)	(km/h)
Baseline	value								
Mode 1	value								
	Indexed-to-Rail								
Mode 2	value								
	Indexed-to-Rail								
Mode 3	value								
	Indexed-to-Rail								

* GHG is measured in kg of CO_2-equivalent

Note: Metric units shown, U.S. units provide intensities per seat-mi and per passenger-mi, (Btu), (lb-GHG) and (mph)

Table 24. Modal Comparison Performance Metrics IV (Door-to-Door, Including Indirect Well-to-Pump Energy/Emissions)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger-km		travel time	average speed
Units of Measure		(kJ)	(kg - GHG)	(kJ)	(g - GHG)	(kJ)	(g - GHG)	(hrs)	(km/h)
Baseline	value								
Mode 1	value								
	Indexed-to-Rail								
Mode 2	value								
	Indexed-to-Rail								
Mode 3	value								
	Indexed-to-Rail								

* GHG is measured in kg of CO_2-equivalent

Note: Metric units shown, U.S. units provide intensities per seat-mi and per passenger-mi, (Btu), (lb-GHG) and (mph)

3.2 Worksheet Roles and Interfaces

The structure of the MS-EXCEL© spreadsheet based model is illustrated in Figure 1. The worksheets in Figure 1 are color coded to reflect their primary purpose: green sheets require user input to define a simulation scenario, yellow sheets provide technical default data that can be optionally expanded and/or modified by the user, orange sheets are calculation procedures at the core of the simulation and blue sheets are output sheets. More details of the user interfaces and data inputs are presented in the MMPASSIM User Guide (included as Appendix A of this document). This Chapter provides an overview and general description of the simulation process.

3.2.1 User Interface Sheets

The main user interface is the '*Master-I-O'* worksheet (green box at lower left of Figure 1). For a user who wishes to draw from the existing list of pre-defined default datasets or who has created the various input data for a desired simulation, this will be the main interface sheet. As noted in the previous section, the first step required by the 'Master-I-O*'* worksheet is the selection of the type of simulation to be performed (single-train, rail technology comparison or modal comparison). In all cases the second step is to identify the rail service to be simulated. The menu form provided allows the user to select from pre-defined trips, consists and routes. The simulation automatically generates a mirror image of the selected trip for the return trip. If a different return trip is desired it must be separately selected.

In a rail technology comparison scenario, up to three additional consists and/or routes can be selected for comparison with the base case rail consist/route. Similarly, in a modal comparison scenario the user can select up to three other modes to be compared with the base-case rail consist/route. In all cases a trip is defined by selecting a route and the equipment which operates over that route, and may be either selected from a list of previously defined trips or a new trip may be created by the user using the system of pop-up menus.

In addition to the 'Master-I-O' worksheet, there are individual 'Modal- I-O' worksheets ('Air-I-O', 'Rail-I-O', 'LDV-I-O' and 'Bus-I-O' which are collectively represented by the green box at the upper left of Figure 1) from which a user can define and run simulations of the selected individual mode.

For a modal comparison, some of the information provided for the base-case rail trip characteristics are applied to other modes being compared. Specifically, time-of-day, day-of-week, and region lead to a pre-defined set of default characteristics for the alternate modes and the access/egress modes applicable to each primary mode. The modal comparison is the only simulation scenario that incorporates access and egress legs of a trip into the simulation results, the other rail-only simulation scenarios only simulate the rail leg of the trip. The inputs for access and egress legs of each modal trip are selected on a "Trip Access and Egress Leg Selection" menu *and stored on the mode specific '*Modal I-O' worksheet. As with the rail-only trip, modal trips are defined as round-trips and the default characteristics of the return trip (including access/egress legs) are mirror images of the forward trip. If the user wishes to modify the characteristics of the return trip a separate simulation data set must be created for that trip.

With the simulation scenario selected and the applicable datasets selected, the simulation is initiated by selecting the "Calculate Selections" button at the top of the 'Master-I-O' worksheet. The user will then be taken to the appropriate output results tables region of the 'Master-I-O' worksheet associated with the selected simulation scenario.

3.2.2 Macro Supervisory Control

The '*Macro'* (orange box in the top middle of Figure 1) transfers the appropriate parameters for each mode/trip-leg/drive-schedule/trip-direction combination into the required locations within the model, initiates recalculation of the mode-specific '*Simulation'* worksheet (orange box in middle of Figure 1) and transfers the mode-specific '*Simulation'* worksheet outputs to an accumulation area in the mode –specific 'Modal-I-O*'* worksheet specific to the type of simulation scenario being run.

3.2.3 Default Data Sheets

Default input data sheets are highlighted in yellow in Figure 1. The '*Regional-Properties'* worksheet (yellow box at central left of Figure 1) and the '*Energy-Emissions'* worksheet (yellow box at right side of Figure 1) are common to all modes.

The 'Regional-Properties' worksheet contains regional data for: average daytime temperature and air conditioning usage by season. In addition it contains default characteristics for fuel, energy and GHG emissions intensities used for the access and egress modes. The access and egress modes support differentiation by size of city and time of day congestion for the highway modes.

The 'Energy-Emissions*'* worksheet provides the GHG emissions rates by fuel/energy-source and the indirect (upstream well-to-pump) energy consumption/GHG-emissions associated with each fuel/energy-source and for electricity these factors are also provided for different geographical regions. The 'Macro' identifies in step sequence the appropriate fuel characteristics for the mode being simulated in the overall simulation process and calculates the direct and upstream GHG emissions associated with that mode/leg of trip being simulated.The physical characteristics and capabilities of each ground mode are specified in mode-specific 'Equipment' worksheets (collectively represented by the yellow box in the upper right of Figure 1). The rail mode equipment data is maintained in the 'Rail-Consist' worksheet. The bus mode equipment data is maintained in two worksheets: 'Bus-Type' which characterizes parameters for several representative classes of buses and 'Bus-Resist' which define rolling resistance coefficients applicable to all bus types. The light duty vehicle mode equipment data is also maintained in two worksheets: the 'LDV-Resist' worksheet which contains a master table of all vehicle characteristics and the 'LDV-Type' worksheet which facilitates customization of the regionally specified auxiliary (climate control) load for individual vehicles. The air mode is handled differently and has one properties sheet, 'Air-Default-Data', which combines both equipment and route information. The 'Macro*'* identifies in step sequence the appropriate pointer to the resistance and propulsion characteristics of the mode being simulated in the overall simulation process.

The '*Modal Route Information*' (yellow box in middle of right hand side of Figure 1) represents the collection of mode-specific 'Route' worksheets which provide default route characteristics for the ground modes by region (named 'Rail-Route', 'Bus-Route' and 'LDV-Route' in the MMPASSIM model). The 'Macro' identifies in step sequence the appropriate pointer to the route characteristics (for example grade classification, scheduled stop locations, posted speed table and unscheduled delay frequency/severity) for the mode being simulated in the overall simulation process.

'Highway and Bus Drive Schedules' (represented by the green block near the upper left of Figure 1) worksheets are used by the highway modes and contain a number of second-by-second speed profiles (drives schedules) depicting either LDV or bus speed variation on various types of roads and at various levels of traffic congestion. The LDV drive schedules are defined in the 'LDV-Drive-Schedules' worksheet while the bus drive schedules are defined in the 'Bus-Drive-Schedules' worksheet. The drive schedules are selected from the

EPA database of drive schedules. The ‘Macro’ brings in the appropriate drive schedules from the mode-specific drive schedule worksheet in a proportional distribution that best matches the average speed expected at the time-of-day and road type being simulated. The drive schedules are discussed in more detail in the Highway Modes Simulation Chapter (Subsection 5.3).

The ‘*Engine’* worksheets (yellow box near lower right hand corner in Figure 1) provide the needed modal engine efficiency characteristics for the highway modes (they are named ‘Bus-Engine’ and ‘LDV-Engine’). Representative fuel maps are used for propulsion systems using non-continuously variable transmissions (most conventional LDV and buses) while coefficients for a single optimal performance equation are provided for vehicles using a continuously variable transmission (CVT). This is the case for most non-electrified railway propulsion systems as well as hybrid and non-hybrid CVT highway vehicles). The engine information for the rail and air modes is part of the equipment data worksheets. The ‘Macro*’* identifies in step sequence the appropriate pointer to the engine characteristics for the mode being simulated in the overall simulation process.

3.2.4 Simulation Sheets Overview

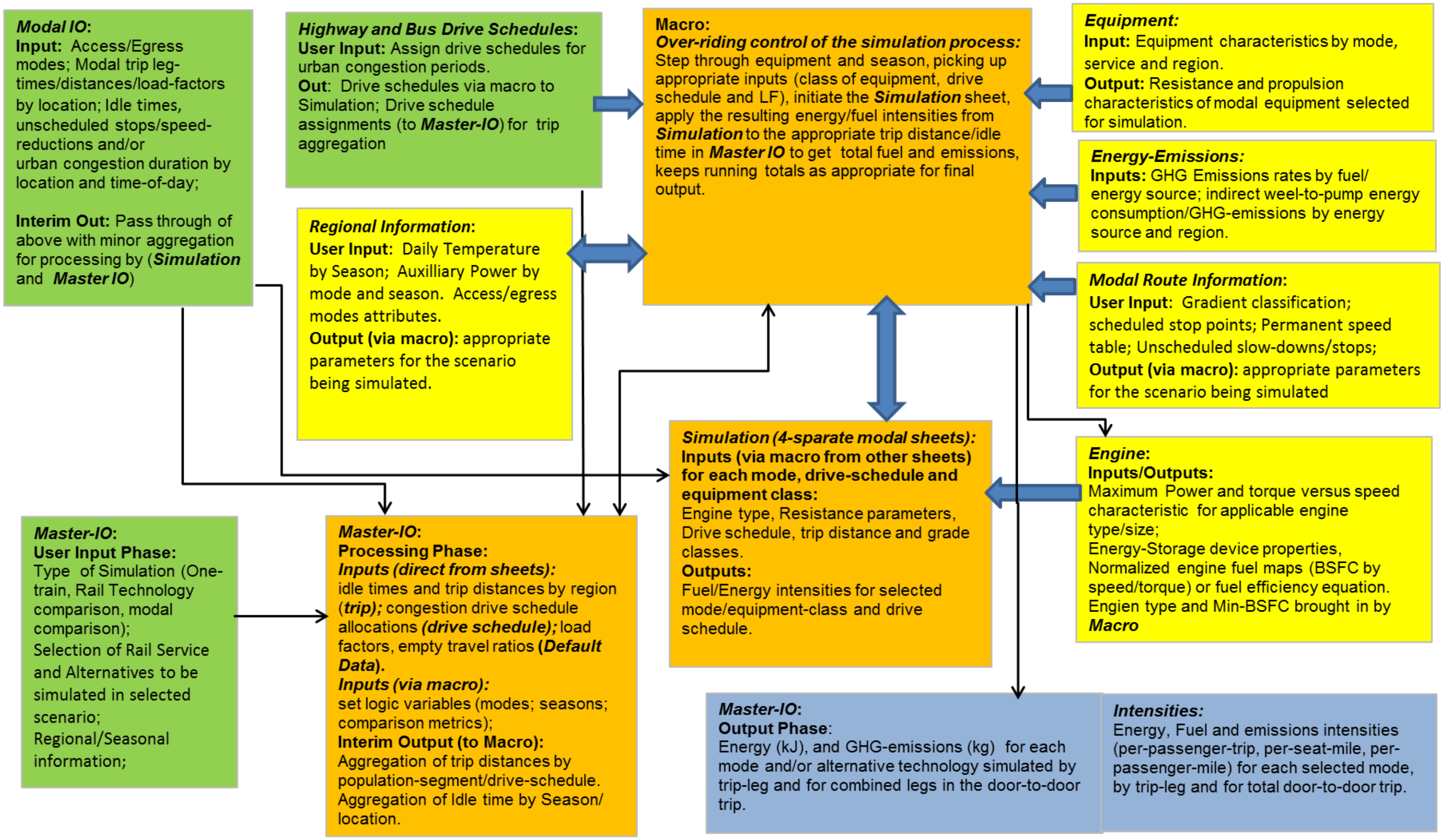
At the core of the MMPASSIM model are the ‘*Simulation’* worksheets (the orange block near the center of Figure 1), which simulate the movement of a modal vehicle (or a fleet-average characteristic vehicle) representative of the specific service/region being simulated. The details of each mode’s simulation sheet are provided in separate modal chapters to follow. This chapter describes the overall structure and purpose of the various worksheets and only a brief overview of the modal simulation sheets is provided in the remainder of this section.

The highway modes include personal light duty vehicles (LDV) and buses. The urban portion of LDV and bus trips is simulated via a second-by-second time-based simulation over a user-selectable distribution of drive schedules (with default proportions by time-of-day). The drive schedules are drawn from the U.S. Environmental Protection Agency’s (EPA) database of drive schedules to typify various levels of urban congestion and queue delays. The drive schedules selected have decreasing average speeds with increasing congestion and proportional allocation of different drive schedules can be made to attain a close relationship to average speed observations on the urban highway segments of interest. The duration of, and drive schedule distribution for, each of the following five time-of-day periods are specified for each urban area to depict urban highway congestion:

- a.m. peak;
- p.m. peak;
- midday;
- shoulder periods;
- overnight;

The urban trip simulation is the only component of the highway simulation sheet that is used for comparisons with commuter rail and for access egress legs of intercity trips. The intercity portion of highway mode trips is simulated in a similar way to the long haul portion of all modal trips. The energy and emissions associated with long segments at cruise speed are determined with a single calculation for each speed. The energy and emissions associated with scheduled stops are also determined via a single calculation for the applicable cruise speed. Unscheduled stops and slow speed-segments are treated as a combination of designated delay incident frequency, with drive schedules attached to the highway delays. Gradient influences are simulated via a pre-processed frequency/severity distribution of gradient applicable to the specific modal route(s) or general regional characteristics associated with the selected simulation.

Figure 1. Overall Model Structure (Worksheet Data Flows and Interaction)



***Modal IO*:**
Input: Access/Egress modes; Modal trip leg-times/distances/load-factors by location; Idle times, unscheduled stops/speed-reductions and/or urban congestion duration by location and time-of-day;

Interim Out: Pass through of above with minor aggregation for processing by (***Simulation*** and ***Master IO***)

***Highway and Bus Drive Schedules*:**
User Input: Assign drive schedules for urban congestion periods.
Out: Drive schedules via macro to Simulation; Drive schedule assignments (to ***Master-IO***) for trip aggregation

Macro:
Over-riding control of the simulation process: Step through equipment and season, picking up appropriate inputs (class of equipment, drive schedule and LF), initiate the ***Simulation*** sheet, apply the resulting energy/fuel intensities from ***Simulation*** to the appropriate trip distance/idle time in ***Master IO*** to get total fuel and emissions, keeps running totals as appropriate for final output.

Equipment:
Input: Equipment characteristics by mode, service and region.
Output: Resistance and propulsion characteristics of modal equipment selected for simulation.

***Regional Information*:**
User Input: Daily Temperature by Season; Auxilliary Power by mode and season. Access/egress modes attributes.
Output (via macro): appropriate parameters for the scenario being simulated.

Energy-Emissions:
Inputs: GHG Emissions rates by fuel/ energy source; indirect weel-to-pump energy consumption/GHG-emissions by energy source and region.

***Modal Route Information*:**
User Input: Gradient classification; scheduled stop points; Permanent speed table; Unscheduled slow-downs/stops;
Output (via macro): appropriate parameters for the scenario being simulated

Simulation (4-sparate modal sheets):
Inputs (via macro from other sheets) for each mode, drive-schedule and equipment class:
Engine type, Resistance parameters, Drive schedule, trip distance and grade classes.
Outputs:
Fuel/Energy intensities for selected mode/equipment-class and drive schedule.

***Engine*:**
Inputs/Outputs:
Maximum Power and torque versus speed characteristic for applicable engine type/size;
Energy-Storage device properties,
Normalized engine fuel maps (BSFC by speed/torque) or fuel efficiency equation.
Engien type and Min-BSFC brought in by ***Macro***

***Master-IO*:**
User Input Phase:
Type of Simulation (One-train, Rail Technology comparison, modal comparison);
Selection of Rail Service and Alternatives to be simulated in selected scenario;
Regional/Seasonal information;

***Master-IO*:**
Processing Phase:
Inputs (direct from sheets):
idle times and trip distances by region (***trip); ***congestion drive schedule allocations ***(drive schedule);*** load factors, empty travel ratios (***Default Data***).
Inputs (via macro):
set logic variables (modes; seasons; comparison metrics);
Interim Output (to Macro):
Aggregation of trip distances by population-segment/drive-schedule.
Aggregation of Idle time by Season/ location.

***Master-IO*:**
Output Phase:
Energy (kJ), and GHG-emissions (kg) for each mode and/or alternative technology simulated by trip-leg and for combined legs in the door-to-door trip.

Intensities:
Energy, Fuel and emissions intensities (per-passenger-trip, per-seat-mile, per-passenger-mile) for each selected mode, by trip-leg and for total door-to-door trip.

color legend (primary purpose of Sheet):

🟩 User input,

🟨 Optional User overrides of technical defaults;

🟧 Calculation processing Sheets/Macro;

🟦 Output

4 Rail Mode Simulation Module

4.1 Rail Module Layout and Equations

4.1.1 User Inputs

The overall model structure was illustrated in Figure 1. Those worksheets specific to simulating the rail passenger mode are discussed in more detail here. The rail mode will normally be simulated in all simulation scenarios (although non-rail modes could be simulated in isolation if desired). As discussed in Chapter 3, two of the simulation scenarios only involve the rail mode.

Input data required to make a rail-only simulation run are the train consist characteristics, and the route characteristics. The list of data required for a train consist and rail route are provided in the MMPASSIM Spreadsheet Model User Guide provided in Appendix A of this document.

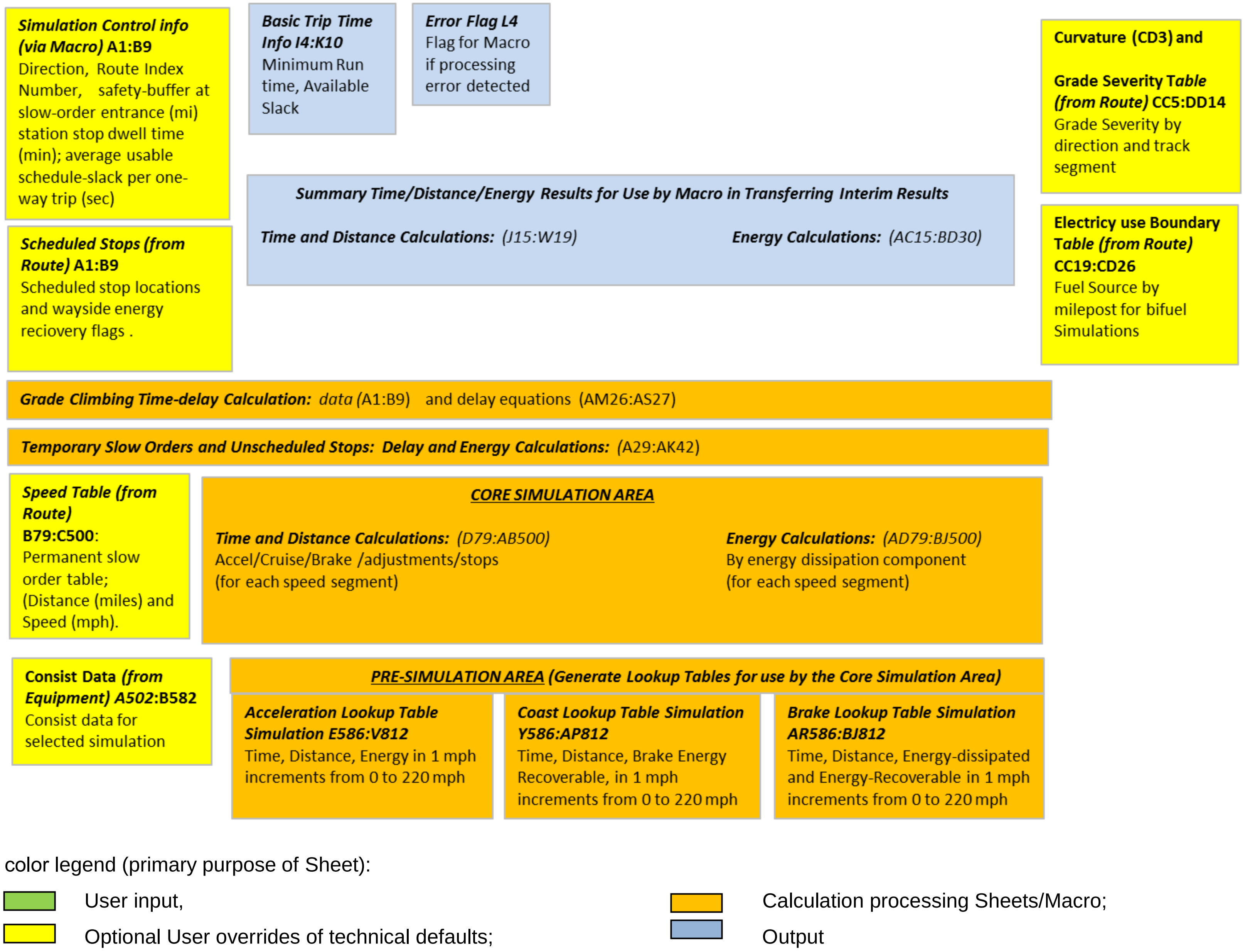
4.1.2 Rail Simulation Worksheet Layout

The structure of the 'Rail-Simulation' worksheet and its direct interface to default datasets is illustrated in Figure 2. The areas of the worksheet are color coded to reflect their primary purpose: green indicates it is a user input (not applicable for the 'Rail-Simulation' worksheet), yellow indicates technical default data that can be optionally modified by the user, orange indicates calculation procedures at the core of the simulation, and blue indicates interim output data for transfer and/or aggregation by the 'Macro'.

The 'Rail-Simulation' worksheet simulates the movement of a train (or a fleet-average characteristic train) which is representative of the specific service/region being simulated. Since speed changes are a key factor in passenger train performance, the simulation processes each speed segment on one row of the simulation area of the worksheet. The worksheet functions in a bottom-up sequence. The Pre-processed lookup tables for acceleration, coasting and braking are created at the bottom of the worksheet. The core simulation area (in the middle of the worksheet) uses these lookup tables in simulating the time-and-distance and energy-dissipated in each speed segment of the route. Finally at the top of the sheet the aggregations are made for the complete route and formatted for use by the 'Macro'.

Movement over each permanent slow order segment of track (taken from the route's Speed Table which in turn would be derived from the applicable Railway Operating Timetable*)* is simulated for the three phases of movement as applicable to that section (i.e. acceleration, cruise and braking). Scheduled stops occurring within a speed segment are also simulated on that row of the worksheet. Average expected temporary slow orders and interference delays (speed reductions and/or stops) are treated in a separate location ('Rail-Simulation'!A29:AK42) and are based on departures from the average cruise speed.

Figure 2. Rail Simulation Sheet Layout



4.1.3 Rail Simulation Process and Equations

4.1.3.1 Pre-processed lookup tables

Acceleration, coasting and braking lookup tables (at ‘Rail-Simulation’!E583:V804, ‘Rail-Simulation’!Y583:AP804 and ‘Rail-Simulation’!AR583:BJ804 respectively) are calculated for zero-gradient and zero-curvature conditions and used as look-up tables by the core-simulation module. The three lookup tables are generated with rows of one-mph increments (0.447 m/s) up to the balance speed for the consist, or a maximum speed of 220 mph (354 km/h). The columns of each table provide cumulative distance, time and traction energy by resistance component for each speed-step row of the tables. The equations used in generating the tables are based on the inherent resistance components and traction performance of the train consist, as follows:

$$IR = C_{ra} + \mathrm{C}_{\mathrm{rb}}\,\mathrm{V} + \mathrm{C}_{\mathrm{rc}}V^2$$ **Equation 5**

where:

IR = Inherent Resistance Force (N);

V = speed (m/s);

C_{ra}, C_{rb} and C_{rc} are coefficients.

C_{ra} is normally associated with rolling friction and ground hysteresis losses. C_{rb} is a dynamic factor associated with speed-sensitive rolling losses and is often set to zero. C_{rc} is associated with aerodynamic drag and can be further expanded as follows:

$$C_{rc} = {}^{1}\!/_{2} \cdot \rho \cdot C_d \cdot A \cdot V^2$$ **Equation 6**

where:

ρ = density of air (kg/m^3);

C_d = drag coefficient;

A = Frontal Area (m^2);

V = speed (m/s).

The density of air is temperature dependent, such that it can be scaled for departures from 20º Celsius (C) with the following formula:

$$SF = {}^{(273+20)}\!/_{(273+\mathrm{T})}$$ **Equation 7**

where:

SF = scale factor for aerodynamic drag;

T = the ambient temperature (in degrees C) to be used in the simulation.

Tractive effort (TE) can be characterized for most diesel locomotives by two regions: one torque limited and the other power-limited. Electric high speed rail locomotives, push the boundaries farther and the tractive effort envelope is often more complex. The model supports characterization of up to five speed segments with a nonlinear equation of the form:

$$TE_i = C_{rai} + \mathrm{C}_{\mathrm{rbi}}\,\mathrm{V} + \mathrm{C}_{\mathrm{rci}} / V^{C_{rdi}}$$ **Equation 8**

where:

TE_i = Tractive Effort (N) from all power axles in the consist in speed segment i;

V = train speed (m/s);

C_{rai}, C_{rbi}, C_{rci} and C_{rdi} are coefficients applicable to each speed range i.

For a conventional diesel locomotive consist characterized with two regions the data would be:

1) a fixed torque-limited region where C_{ra1} has the locomotives low speed traction limit in Newtons and all other coefficients are set to 0, and;
2) a power limited region where C_{rc2} is set to the locomotives power rating at the wheels in Watts, the speed exponent coefficient C_{rd2} is set to 1.0 and all other coefficients are set to zero.

For electric locomotive consists additional straight line segments are often introduced between the low speed TE limit and the power limited region and the highest speed region has a fall-off in TE beyond that of constant power and thus the coefficient C_{rd2} is set to a value greater than 1.0. All other coefficients are set to zero. The speed segments must be set in sequence of increasing speed and the lower speed limit associated with a range must be set to yield a continuous profile. If only two segments are used, the upper segments should have a high speed value setting (for example 999) such that the coefficients are never called in by the simulation sheet. Table 25 illustrates the input format for the tractive effort curve with illustrative values for a conventional diesel locomotive consist with 4 power axles and a Very High Speed Rail (VHSR) consist with 12 power axles; while Figure 3 illustrates the corresponding TE curves.

Table 25. Input Data for Two Illustrative Consists

Equipment	Item	Speed Region				
		1	2	3	4	5
VHSR	lower speed limit (m/s)	0	21.7	38.3	63.9	77.8
	Cra	273,000	409,500	203,255		
	Crb		-6,300	-900		
	Crc				9,266,000	18,596,413
	Crd	1	1	1	1	1.16
Diesel	lower speed limit (m/s)	0	15.1	999	999	999
	Cra	178,291		0	0	0
	Crb			0	0	0
	Crc		2,688,942	0	0	0
	Crd	1	1	1	1	1.16

Source: TranSys Research Ltd. - derived illustrative estimates for an Alstom AGV-11 with 6 traction units (Alstom Transport Brochure) and a 4,000 hp diesel locomotive with separate hotel power gen-set.

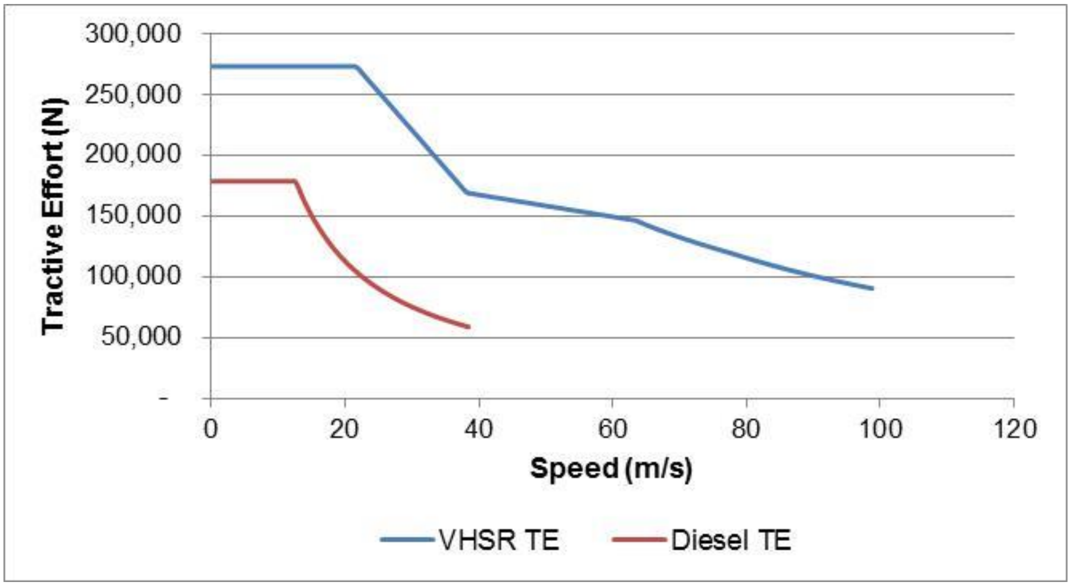


Figure 3. Illustrative Tractive Effort Curves for Conventional Diesel and VHSR Consists

For diesel passenger locomotives, the loading rate of the engine is a relevant factor in its performance as the rate at which the engine can be loaded can constrain its ability to attain the rated torque during acceleration. Thus, the characteristic engine loading time-constant is added as a constraint to initial acceleration. The tractive effort envelope as calculated above is modified at initial loading from a stop by the following equation:

$$TE = MIN[1, 0.25 + a \times MAX(1, t - 10)^{b}] \times TE_{i}$$ **Equation 9**

where:

TE =Tractive Effort (N) from all power axles at time (t);

MIN[] = an operator to select the minimum of the two calculated values in the brackets;

MAX() = an operator to select the maximum of the two calculated values in the brackets;

TE_i = Tractive effort envelope without loading time constraint;

t = time since power was applied (s);

a and b are coefficients with default values specified in the model.

The acceleration between steps is calculated as:

$$\boldsymbol{A} = {}^{(\boldsymbol{TE} - \boldsymbol{IR})}\Big/_{(\boldsymbol{M} + \boldsymbol{N_a K_r})}$$ **Equation 10**

where:

A = acceleration (m/s^2)

TE = tractive Effort (N)

IR = inherent train resistance (N)

M = Mass of the consist (kg)

N_a = number of axles

K_r = mass-equivalent rotational inertia of each axle (kg)

Time is cumulated in seconds with each step's duration calculated as the speed step-increment divided by the acceleration. The distance traveled is cumulated with an incremental travel distance of V dt +1/2 A dt^2.

Acceleration traction energy is cumulated in kilojoules (kJ) (also equal to kW-seconds), for four components (rolling resistance, dynamic resistance, aerodynamic resistance and stored kinetic energy) as well as for the combined energy of all components.

The coast table ('Rail-Simulation'!Y586:AP812) is generated with a TE value of zero. For braking, the contribution of the powered axles is driven by the negative value of the tractive effort characteristic data input (Figure 3), with the power P set to the appropriate brake power capacity of the powered axles in the consist. In addition, airbrakes can be blended with the powered brakes to attain a specified target brake rate, with an adhesion/power limiting characteristic that falls off with increasing speed.

The Coast table includes a calculation of brake energy recoverable and the slack time required in the schedule to coast from cruise speed to the present row's simulation speed before applying brakes at a stop. These two parameters (brake energy recoverable and the associated slack time required) are then sorted into ascending sequence of slack-required to facilitate a table lookup by the core simulation.

In the brake table, brake energy is cumulated on the basis of all braking sources. In addition, the proportion of brake energy available from the powered axles is calculated to provide an indication of the proportion of brake energy recoverable via regenerative braking at the same consist braking rate. A second scenario of utilizing only regenerative braking can also be simulated as an option (by setting the locomotive-only brake flag in the consist input data), but will result in lower braking rates and an associated longer trip time.

Figure 4 illustrates the cruise and brake speed profile of a 1 locomotive/4 bilevel coach consist braking from (80 mph) and overlays the coast characteristic that could be utilized if the stop had 20 seconds of schedule slack available. As illustrated about 2 miles of cruise-speed traction power (and a portion of brake pad wear) could be eliminated if the coast strategy was implemented at the stop.

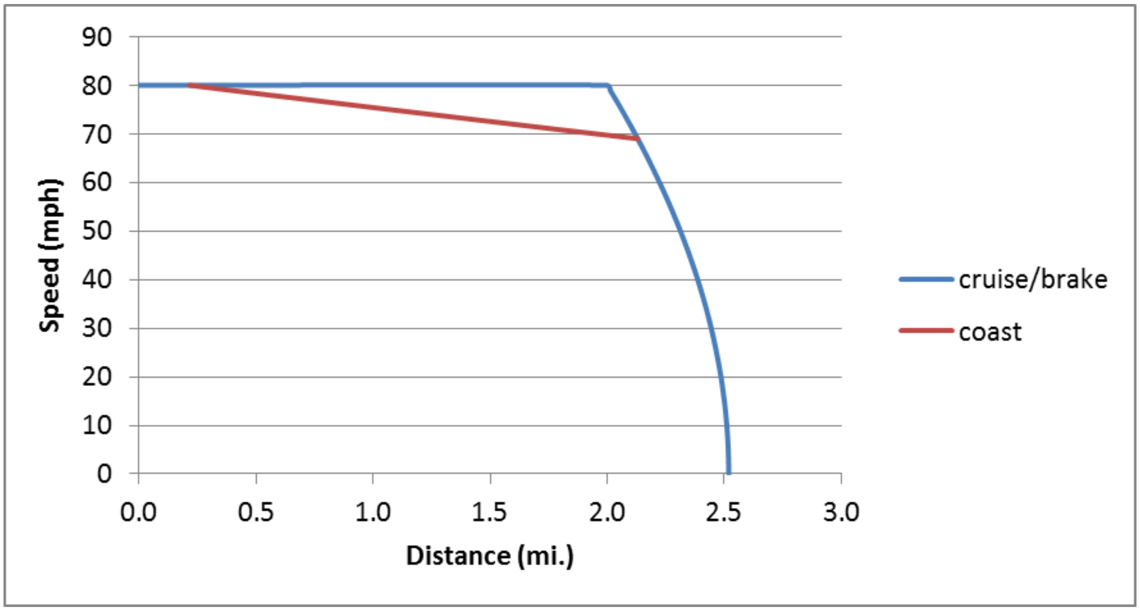


Figure 4. Speed/Distance Profile of 1L/4BLC Consist With And Without Coasting Source: derived from MMPASSIM brake and coast curves for a 1L/4BLC consist.

4.1.3.2 Core Simulation of Timetable Speed Segments

4.1.3.2.1 Time and Distance

With these pre-processed look-up tables calculated, the segment simulation can begin. The model accommodates up to 480 speed changes in one simulated route. The permanent slow order speed table (in miles from origin and associated speed in mph for the upcoming segment) is loaded into cells 'Rail-Simulation'!B79:C500. 'Macro' specified pointers are also used to load the relevant consist and route characteristic data. With these data loaded, distance, time and energy consumption are calculated for each of the three driving phases (i.e. accelerate, cruise, brake) as appropriate for the speed-segment.

While the train is simulated as a lumped mass with respect to gradient profile, train length is included in the treatment of the effective length of slow order segments. An approach buffer is also included at the entrance boundary of a slow order. Thus, the length of slow order segment is increased by the entrance buffer at the entrance and by the train length at the exit into a higher speed segment (and the adjacent two segments are shortened by the corresponding lengths). The indication of whether a speed segment involves a speed increase or a speed reduction from the previous segment is determined in column 'Rail-Simulation'!D81:D500 and an appropriate flag is set (+1 for increase, -1 for decrease).

Columns 'Rail-Simulation'!J82:K500 calculate the distance and times associated with acceleration, columns 'Rail-Simulation'!L82:M500 the distance and times for cruising and columns 'Rail-Simulation'!N82:O500 calculate the distance and times during braking which apply to each speed segment. The distance and times for acceleration and brake phases are found by table lookup of the pre-processed tables. Also, if one or more scheduled stops are indicated for the segment, the stop time and distance and the re-acceleration times and distances are found by table lookup of the brake and acceleration tables. These calculations are performed in columns 'Rail-Simulation'!T82:W500. With all of the transition distances known, the length of the segment transited at cruise speed is calculated (in column 'Rail-Simulation'!L82:L500) as the remaining distance in the segment, with an adjustment for train length at a boundary with a prior lower-speed segment and an approach buffer at a boundary with an upcoming lower speed segment.

It is possible that some short segments might produce a negative value for the cruise phase distance. In this case, an adjustment is made (in column 'Rail-Simulation'!P82:P600) to the acceleration distance such that a zero cruise distance is set, the acceleration distance is shortened and the associated lower speed noted. If the segment is so short that the revised acceleration distance is also negative, the prior segment cruise speed is shortened (in column 'Rail-Simulation'!R82:R500) and braking begins in the prior segment. Similarly, the re-acceleration distance from a scheduled stop is compared with the distance to the next speed segment boundary and if the distance is constrained, a new exit speed is calculated for the boundary and the distance/time for the re-acceleration from the stop is shortened (in columns 'Rail-Simulation'!Z82:AB500).

A single iteration is undertaken for short segments. The model applies some filtering of input speed tables in the 'Rail-Route' worksheet to avoid unrealistically short speed segments. The 'Rail-Route' worksheet logic checks user inputs for increased speed segments between two lower speed segments where the high speed segment is less than 0.25 miles. When such a situation exists, the higher of the two adjacent speed limits is extended into the highest speed segment. Nonetheless, some problematic situations may still arise. If a constraint remains after the simulation sheet takes the iterative steps, the associated negative distance is ignored and the 'Macro*'* flags the simulation run, advising the user to review the input speed table and manually merge any remaining short segments with an adjacent lower speed segment and then rerun the simulation with the revised speed table.

Short inter-stop distances within one speed segment are accommodated in an area beside the scheduled stop table – the average of the acceleration speed attainable between stops in a multi-stop speed segment is calculated (at 'Rail-Simulation'!F46:M70) and used in the stop re-acceleration calculation (at column 'Rail-Simulation'!V82:V500).

4.1.3.2.2 Energy Consumption

With the times and distances know for each of the movement phases in the segment, the energy consumed in the segment is calculated. The inherent resistance is relevant to the acceleration and cruise phases and is separately calculated (columns 'Rail-Simulation'!AD82:AI500) for each resistance component (i.e. rolling, dynamic and aerodynamic). The energy that is inherently stored in the train as kinetic energy (1/2 MV^2) during the acceleration phase is used to overcome inherent resistance during braking and the rest is either dissipated in the brakes (as heat energy in either friction brakes or dynamic brake resistance grids) or regenerated to onboard storage devices, wayside storage devices or for use in wayside consumption. The total energy consumed in the train's braking systems is calculated (column 'Rail-Simulation'!AJ82:AJ500) and the total recoverable energy available from the powered axles via regeneration is separately identified for the locomotive power limits (column 'Rail-Simulation'!AK82:AK500) and for onboard storage power limits (column 'Rail-Simulation'!AL82:AL500).

The last of the energy components are those associated with track profile — the energy dissipated in brakes to maintain speed limits on down grades and the energy required to overcome curving resistance on curves. The gradient component is calculated on the basis of the segment speed and the track gradient characteristics. Representative default route characteristics are provided for several regions. Downgrades are cumulated for each direction of travel into severity classes of -0.2% grade decrements. The average grade for all grades within each severity class is provided. Depending on the concentration of grades along a route and the availability of detailed data, the gradient profiles can be specified by route segment. Up to eight segments can be accommodated by the model; however, many routes can be adequately characterized by one uniformly applied gradient distribution profile.

The process of calculating energy dissipated in braking on downgrades involves the following steps:

1) Calculate the break-even downgrade for the segment speed (column 'Rail-Simulation'AM82:AM500):

$$G_{be} = {(C_{ra} + \mathrm{C}_{\mathrm{rb}}\,\mathrm{V} + \mathrm{C}_{\mathrm{rc}} V^2)}\Big/{Mg} \qquad \textbf{Equation 11}$$

where:

G_{be} = Break-even downgrade beyond which braking is required

C_{ra}, $C_{rb,}$ C_{rc} are resistance coefficients

V = train speed (m/s)

M = Mass of the consist (kg)

g = acceleration due to gravity

2) Cumulate all downgrades of breakeven severity or greater on the basis of the gradient severity distribution for that segment.

   This is done via lookup of the grade severity table ('Rail-Simulation'!CC5:DD14) which is loaded from the 'Rail-Route' worksheet. Indices for the lookup are calculated in columns 'Rail-Simulation'!AN27:AO27.

3) Calculate the brake energy to maintain speed for non-train-acceleration segments as the downgrade energy can be recovered in those segments and add the probability of all down grade energy recovery for the proportion of the route that involves speed reductions as the downgrade energy cannot be recovered in these segments.

4) Calculate the brake force associated with the cumulative downgrades and convert to energy by multiplying the force by the distance traveled under braking:

   (steps 2, 3 and 4 are combined in one formula in Column 'Rail-Simulation':AP82:AP500).

Curves on the route are pre-aggregated into total change of central angle for the route. Curving resistance is characterized by 0.04% gradient-equivalent per degree of central angle (which is equivalent to 0.8 lb/ton/degree of curvature). Curving resistance is calculated once for the whole route rather than individual speed segments. Similar to gradient, curve resistance is adjusted to eliminate those segments where traction energy is not required (i.e. during braking, when the curve resistance contributes to the brake effort and traction energy is not being used). Curving energy is calculated (at 'Rail-Simulation'!AP19), excluding the proportional distance involving braking (at cell 'Rail-Simulation'!AP25).

4.1.3.2.3 Braking Energy Recovery

Brake energy recovery systems are considered in columns 'Rail-Simulation'!AS82:AY500. Column 'Rail-Simulation'!AS82:AS500 brings in the data provided in the '*Rail-Route*' worksheet on wayside storage use at scheduled stops (a positive value indicates the receptivity of the wayside storage device at a scheduled stop, while a zero indicates no wayside storage is used). Since smaller capacity onboard storage devices could be considered for hotel power provision in diesel locomotives, the next column ('Rail-Simulation'!AT82:AT500) calculates the hotel power required in each segment. Column 'Rail-Simulation'!AU82:AU500 calculates the regenerative energy available with an electric locomotive for the powered axle component of braking at speed reductions and stops (from column 'Rail-Simulation'!AK82:AK500) and 100% of the braking required for speed maintenance on downgrades (from column 'Rail-Simulation'!AP82:AP500). The energy saving potential is calculated as the sum of these two components multiplied by the receptivity factor and the cycle efficiency factor (both of which are input as part of the consist data).

Column 'Rail-Simulation'!AV82:AV500 calculates energy recovery potential of the selected wayside energy storage sites. This is done via a brake table lookup for the segment cruise speed multiplied by the receptivity value at the stop (column 'Rail-Simulation'!AS82:AS500 via data input on the 'Rail-Route' worksheet) and the cycle efficiency (input as part of the consist data).

Column 'Rail-Simulation'!AW82:AW500 calculates energy recovery potential of an onboard energy storage device (from column 'Rail-Simulation'!AL82:Al500 for device-power-limited energy at speed reductions and from column 'Rail-Simulation'!AP82:AP500 for 100% of the braking energy used in speed maintenance on downgrades). The minimum value (column 'Rail-Simulation'!AX82:AX500) and maximum value (column 'Rail-Simulation'!AY82:AY500) of the storage device's charge state are calculated on the basis of brake energy recovered and hotel energy provided in each segment. The net loss or gain in stored energy over the full trip is later calculated at 'Rail-Simulation'!AW26 and the difference is accommodated by an increase (or reduction) in the energy provided by the traction engine for hotel power.

4.1.3.2.4 Fuel Consumption

The above steps have provided the traction energy consumed at the wheels and the hotel energy at the engine shaft or pantograph. The next steps taken in the simulation are determination of the energy required at the power-source and the fuel consumed by the power source. Energy for both traction and hotel power are considered in the fuel calculations.

The efficiency of the traction system's transmission is characterized by two modes: acceleration, which involves a high load factor of the components and cruise which involves a lower load factor. These values are read from the 'Rail-Consist' worksheet on rows 38 and 39, respectively, and may be adjusted to suit the performance characteristics of the traction system being simulated. Application of the transmission efficiencies leads to the energy required at the engine for a diesel locomotive and at the pantograph for an electric locomotive.

A diesel-electric locomotive has a continuously variable transmission. This allows the engine's efficiency characteristic to be simplified into a single load-factor-dependent equation rather than a complex fuel mapping. The efficiency characteristic is specified by two factors, the minimum brake specific fuel consumption (bsfc) and the efficiency penalty incurred as the engine load factor departs from the load-factor associated minimum brake specific fuel consumption. The engine efficiency of the diesel locomotives identified in the literature search can be characterized (at column 'Rail-Simulation'!BB82:BB500) with a simplified straight line equation for efficiency loss below a threshold load factor. If future engines demonstrate a different characteristic these parameters can be modified.

Hotel power requirements are specified on a per-car basis for three seasons (summer, winter and other). Most dg-set manufacturers provide a fuel consumption characteristic of the type:

$$\boldsymbol{F_h = a + bP} \qquad \textbf{Equation 12}$$

where:

F_h = Hotel diesel generator fuel consumption rate (lb/hr)

P = Hotel Power output (kW)

a and b are equipment-specific coefficients.

This is the equation that is applied at column 'Rail-Simulation'!BC82:BC500 if the hotel power is provided by a separate dg-set. If it is provided by the traction engine then the traction engine's average fuel rate is used. The traction engine's fuel rate is influenced by the nature of hotel provision as specified in the consist data ('Rail-Consist' worksheet). If hotel power is provided via an inverter, the traction engine operates at variable speed, and if it is provided by a coupled generator directly, which requires a constant engine speed, a higher fuel penalty characteristic is incurred for decreasing engine load factors. This fuel penalty is incurred by the traction engine in providing both traction and hotel power.

Columns 'Rail-Simulation'!BD82:BD500 and 'Rail-Simulation'!BE82:BE500 provide calculations of traction and hotel energy required at the pantograph by electric locomotives or EMUs.

The last columns of the core simulation area identify dual fuel boundaries ('Rail-Simulation'!BF82:BF500) and allocate segment energy requirements between on-board fuel and wayside electricity ('Rail-Simulation'!BG82:BJ500).

4.1.3.3 Grade Climbing and Unscheduled Delays

The delay involved in grade climbing is calculated at ‘Rail-Simulation’!AM27:AS27. Delays are based on the assumption that all grades are climbed at the average cruise speed for the route. The break-even grade for climbing is the maximum grade where cruise speed can be maintained at full traction power. The breakeven upgrade is calculated at ‘Rail-Simulation’!AM27 as:

$$G_{mx} = {(P/V - (C_{ra} + \mathrm{C}_{\mathrm{rb}}\,\mathrm{V} + \mathrm{C}_{\mathrm{rc}} V^2))} \big/ {Mg} \qquad \textbf{Equation 13}$$

where:

G_{mx} = the maximum grade that can be climbed at cruise speed

P = traction power (kW)

V = train speed (m/s)

C_{ra}, $C_{rb,}$ C_{rc} are resistance coefficients

M = Mass of the consist (kg)

g = acceleration due to gravity

The indices for the grade-severity lookup table are set at ‘Rail-Simulation’!AN27:AO27 and the total height attained on grades exceeding the breakeven grade is calculated at ‘Rail-Simulation’!AP27 (based on the grade severity and corresponding length provided in the grade severity table at ‘Rail-Simulation’!CC5:DD14). The average grade force on grades exceeding the breakeven grade severity threshold is calculated at ‘Rail-Simulation’!AP27 and the average steady state speed attained is found by lookup at AQ27. The total distance involving grades exceeding the breakeven grade is calculated at AQ29 and the time lost due to speed reductions on upgrades greater than G_{mx} is calculated at AS27 by assuming there is one upgrade segment for route segments less than 100 miles and 3 separate upgrade segments for longer route segments. The delay is the difference between the time required to transit the upgrades at cruise speed versus the transit time at the average of the deceleration distance/speed and the balance speed for the remaining distance to the top of the grades. The energy costs of grade climbing are captured via the brake dissipation calculation made elsewhere and the energy savings for inherent resistance to motion at lower speed is considered to be small and is ignored.

The delay and energy cost due to unscheduled stops are calculated at row 31 of the ‘Rail-Simulation’ worksheet using data provided on the ‘Rail-Route*’* worksheet. An unscheduled stop is characterized by the expected number of occurrences in a one-way trip across the route being simulated, as well as the average length of siding and speed limit in the siding (if used when making a stop) and the average dwell time-per-stop spent idling at unscheduled stop locations. The relevant data are brought into ‘Rail-Simulation!B29:G29, while the calculations (performed in cells ‘Rail-Simulation’!J29:O29 and ‘Rail-Simulation’!AC29:AK29) follow similar table lookup procedures as discussed above in the core simulation of speed segments.

The delay and energy cost due to temporary slow orders (TSO) are calculated at rows 35 to 40 of the 'Rail-Simulation' worksheet. TSOs are characterized by the average number of occurrences per one-way trip and the average distance imposed for each of up to 6 TSO speed limits. The delay and energy cost calculations are performed in a similar fashion to the unscheduled stops in columns 'Rail-Simulation'!J35:O40 and 'Rail-Simulation'!AC35:AK40.

4.1.3.4 Output Area

The output area provides interim results for the 'Macro' to use in aggregating/transferring results to the final 'Master-I-O' worksheet. Some additional details are provided on the worksheet to assist in scenario creation and data checking. The basic trip time performance of the run is provided at 'Rail-Simulation'!I4:K10. The minimum run time (without unscheduled stops and excluding station dwell times at scheduled stops) is output as well as the simulation run time with these components included. The run times are compared to the scheduled trip time and the 'schedule slack' associated with each runtime is calculated. The total calculated trip time is also shown and compared with the input data. An 'error flag' is shown at 'Rail-Simulation'!L4 if the calculated distance differs from the input data. Such an occurrence could happen if unrealistically short speed-segments exist in the route data. If an error is flagged, the 'Macro' provides an indication in the header of the output results table on the 'Master-I-O' worksheet (red message at 'Master-I-O'!AB606, 'Master-I-O'!AB706 or 'Master-I-O'!AB806) associated with the type of analysis being performed. The error is also flagged in the detailed rail results tables for the affected rail trip on the 'Rail-I-O' worksheet ('Rail-I-O'!EX100, 'Rail-I-O'!EX150, 'Rail-I-O'!EX200, 'Rail-I-O'!EX250, 'Rail-I-O'!EX300, 'Rail-I-O'!EX350, 'Rail-I-O'!EX400 and 'Rail-I-O'!EX450).

The other interim results from the time and distance calculations are calculated for each of the core simulation columns, with time and distance summaries at 'Rail-Simulation'!J15:W19 and Energy totals at 'Rail-Simulation'!AC15:BD30. The 'Macro' takes the final energy/fuel results for the simulated route/consist scenario from cells 'Rail-Simulation'!BA27:BD28. However, each simulation also provides calculations of what the potential performance would be if the same train was run under a different energy-recovery or energy-source scenario. The table at 'Rail-Simulation'!AZ20:BD26 provides results for the energy dissipated under seven different technology scenarios (provided the relevant data were input on the consist worksheet). The table is always output but some rows will not be applicable to all simulations – for example high speed trains and wayside storage devices would normally be associated with electric trains, while onboard storage would be an option for diesel-electric trains. Table 26 illustrates the output format for the comparisons. The first data column is applicable to either an electric or a diesel consist (of the same power and weight characteristics) and provides the traction energy at the engine shaft or electric pantograph for each of the identified energy-recovery scenarios. The last three data columns provide the fuel consumption for an assumed diesel powered consist. The output is intended to provide some insight into the relative performance of different energy recovery technologies for the simulated service. Simulation of an actual alternative technology would require a dedicated simulation run with other changes to the consist data (e.g. weight increase for onboard storage devices and/or interface equipment) that use of the technology would necessitate.

Table 26. Illustrative Summary Output Within the Rail-Simulation Worksheet

Energy Recovery System	Traction Energy at shaft/ pantograph	Fuel Consumed		
		Traction	Hotel	Combined*
	(kWh)	(kg)	(kg)	(kg)
None	5,716	1,525	146	1,671
Regen to electricity grid	5,426	N.A.	N.A.	N.A.
Regen to wayside storage (all stops)	5,644	1,506	146	1,652
Wayside at one-max-site	5,681	1,516	146	1,662
Selected stops (Route input data)	5,687	1,517	146	1,664
Onboard storage	5,471	1,525	20	1,546
Optimal Coast at Scheduled Stops	5,453	1,455	146	1,601

* In addition to the traction fuel and hotel fuel consumed during the simulated trip, the ‘Combined’ fuel includes locomotive auxiliary power and extra idle fuel consumed before and after a trip and any incremental fuel consumed in non-revenue movements.

5 Highway Modes Simulation Modules

5.1 Common Elements to All Highway Vehicles

The ‘Bus-Simulation’ and ‘LDV-Simulation’ worksheets are structured in a similar way to one another. The main difference is due to the fact that intercity and commuter coaches do not vary significantly by manufacturer while light duty vehicles vary significantly by class and by manufacturer within specific classes. For bus simulations, only four representative coaches are characterized in the default dataset and one coach is selected for a simulation. The ‘LDV-Simulation’ worksheet is organized to simulate representative composite vehicles, including proportions of hybrid vehicles and non-hybrid CVT vehicles within the composite class being simulated. Functionally, the ‘Bus-Simulation’ worksheet has one core simulation area while the ‘LDV-Simulation’ worksheet repeats the simulation area such that three separate variations of drivelines can be simulated for each vehicle (i.e. conventional, hybrid and non-hybrid CVT). In addition, the ‘LDV-Simulation’ worksheet uses higher performance drive schedules than does the ‘Bus-Simulation’ worksheet.

Figure 5 illustrates the layout of the highway simulation modules (‘Bus-Simulation’ and ‘*LDV-Simulation*’). The top left corner of the spreadsheet contains vehicle characteristics as loaded by the ‘Macro’, including the following:

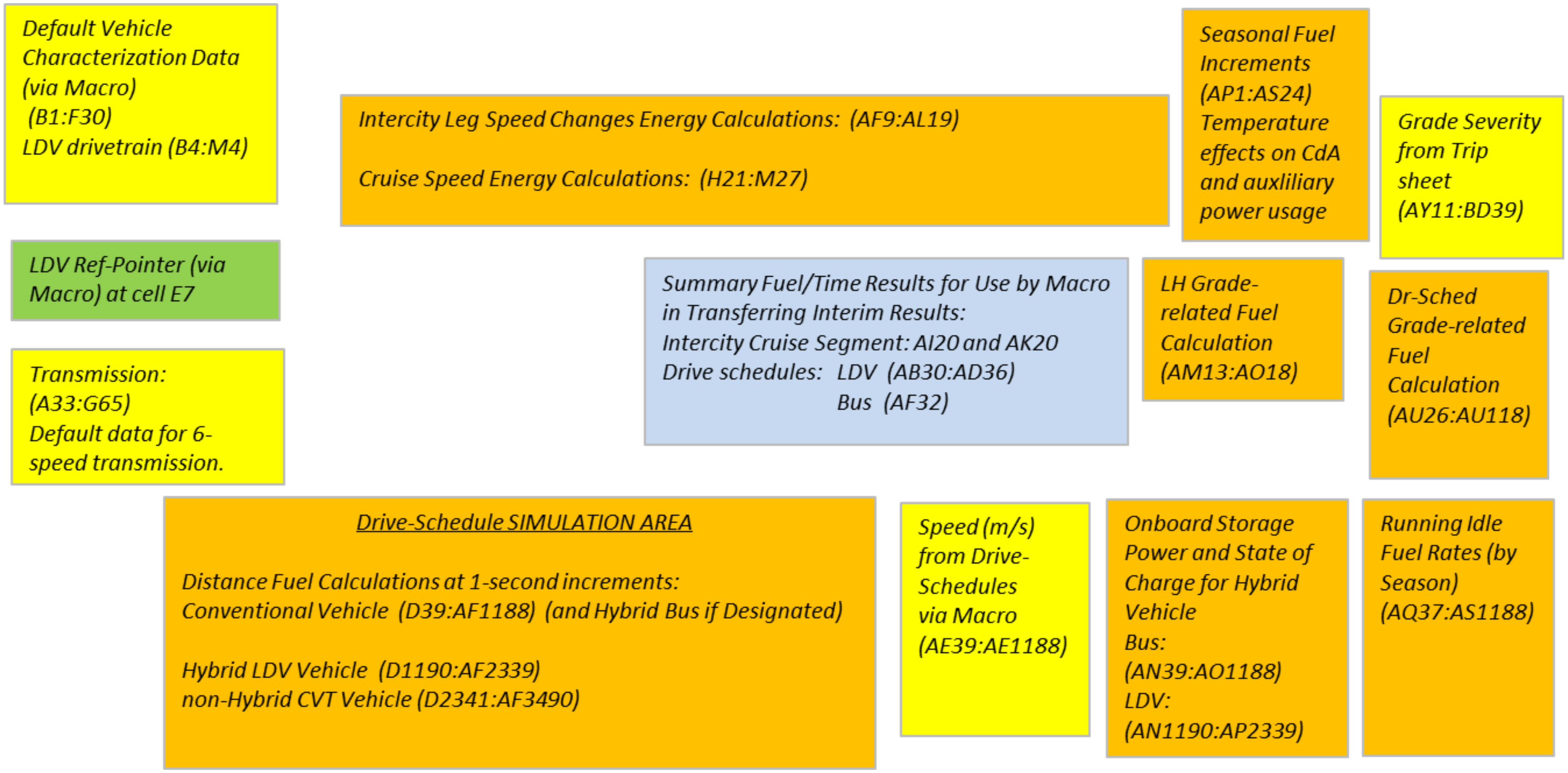
engine power,
transmission loss coefficients,
vehicle mass and coast-down resistance coefficients,
auxiliary power, and
onboard storage characteristics (for a hybrid vehicle).

Below the basic vehicle characteristics, a default 6-speed transmission is defined (with fixed gear ratios and shift points for all coaches in the ‘Bus-Simulation’ worksheet but with ratios and shift points varying with engine power for the ‘LDV-Simulation’ worksheet).

After the ‘Macro*’* loads the appropriate drive schedule and vehicle type, the core simulation proceeds in the following sequence:

- Define the operating-mode (accelerate, cruise, decelerate, stop) in column H;
- Select a gear (given the mode, speed and acceleration rate) in column J;
- Determine the restive and inertial force/power on the vehicle (columns L – O);
- Determine the engine speed (column P) and its fractional value in relation to the fuel map lookup table (column Q);
- Determine the power required at the wheels (column R);
- Determine the power provided by the engine (given any energy recovery from onboard storage and engine performance limits) (column S);
- Determine the engine torque at the shaft (given the power provided at the wheels and the engine speed) (column W);
- Normalize the engine torque and do a double interpolation of the engine’s normalized fuel map (in the ‘LDV-Engine’ or ‘Bus-Engine’ worksheet);
- Apply the fuel increment above the engine’s minimum bsfc and adjust the fuel for the generic engine fuel map with factors developed for the vehicle being simulated (column AF).

Figure 5. Highway Vehicle Simulation Sheets Layout



color legend (primary purpose of Sheet):

🟩 User input,

🟨 Optional User overrides of technical defaults;

🟧 Calculation processing Sheets/Macro;

🟦 Output

The top part of the simulation area simulates vehicle performance at fixed cruise speeds (as input in the 'Bus-Route' or 'LDV-Route' worksheet) in 'cruise' mode with fuel output in kg/km-of-travel. The lower part of the simulation area performs a second-by-second movement of the vehicle over a drive-schedule (speed profile) brought in by the 'Macro'. The equations used in the step-by-step movement of the vehicle over the drive schedule are the same as those described for the rail vehicle pre-processed acceleration profile (see Section 4.1.3.1) with the exception of the locomotive tractive effort envelope and fuel efficiency equation which do not apply. The locomotive's properties are replaced by the highway vehicle engine's torque/speed envelope and its fuel map of relative fuel efficiency for all torque-speed combinations within that envelope.

The 'Bus-Simulation' worksheet calculates the power flow and energy storage state of a hybrid vehicle (if one is being simulated) at columns 'Bus-Simulation'!AN39:AO1187 while the 'LDV-Simulation' worksheet performs a separate simulation of the drive schedule for a hybrid version of the vehicle (on rows 1190 through 2339). The 'LDV-Simulation' worksheet also performs a separate simulation of a non-hybrid vehicle with a CVT (on rows 2341 to 3490). Either individual or composite LDVs can be simulated. The default is a composite vehicle (e.g. the 2011 CY driven fleet) with appropriate proportions of hybrid and non-hybrid CVT vehicles as specified on rows 44 and 45 of the 'LDV-Resist' worksheet. The resulting fuel intensity is the performance of the composite mix. If one wishes to simulate a sole-hybrid (or conventional or CVT) vehicle, either the proportion needs to be set to 100% in the input data column for that vehicle in the 'LDV-Resist' worksheet data table or the default mix can be temporarily overridden using the "Engine Option" selection available on the 'Auto/LDV Type Selection' pop-up menu. Selecting "default mix" will use the mix as defined in the 'LDV-Resist' data table while selecting the "Hybrid" option sets 100% hybrid and 0% non-hybrid CVT or selecting the "Non-hybrid" option sets 0% hybrid and 100% non-hybrid CVT.

The output from the simulation sheet is the fuel intensity (kg/vkm) for the particular drive schedule being simulated. The 'Macro' iteratively brings in each drive schedule and builds up the total trip fuel intensity in proportion to the allocated drive schedules as defined in the 'LDV-Route' or 'Bus-Route' worksheets and the 'LDV-Drive-Schedules' or 'Bus-Drive-Schedules' worksheets.

Gradient influences are calculated at cells AM13:AO18 for the intercity leg of a trip and at cells AU26:AU118 for the drive-schedule part of a trip on both the 'LDV-Simulation' and 'Bus-Simulation' worksheets..

Seasonal variations (temperature influence on aerodynamic drag and auxiliary power usage) are calculated on the upper right side of both the bus and LDV simulation worksheets (cells *AP1:AS24)*. The 'Macro' selects the appropriate values for the season and region being simulated.

5.2 LDV Characteristics Sheet and Future-Year Preprocessor

The 'LDV-Resist' worksheet contains the default characterization data for LDVs. Default data exist for different classes of 2011 vehicles as well as composite vehicles for the sales-weighted and driven fleets for the years 2011, 2012 and 2013.

The ‘LDV-Resist’ worksheet also includes a processor to generate data for fleet average composite vehicles in future years. The algorithm of the preprocessor assumes that 50% of the difference in fleet-average fuel economy of the new model year relative to the 2011 sales-weighted fleet is due to drive-train efficiency (engine and/or transmission efficiency is scaled by 50% of the fuel economy difference) and 50% is due to vehicle body design or fleet composition (the 2011 fleet average weight and resistance coefficients are scaled by 50% of the fuel economy difference). The lower part of the worksheet contains the necessary data and formulae. Use of the preprocessor is described in more detail in the User Guide (Sections A.6.8 and A.7.16).

5.3 Highway Drive Schedules

A series of fixed drive schedules (speed – time) are used to represent urban travel. Speed is specified at 1-second intervals for each representative drive schedule. All are derived from EPA drive schedules, either as direct copies or with slight modifications. MMPASSIM simulates the movement of a vehicle over each drive schedule and scales the kg/Vkm fuel intensity output to the total distance for that road condition as specified by the user for a given trip. The model is responsive and thus, acceleration and braking rates are held within the capability of the vehicle rather than purely following the speed-time profiles. The drive schedules are derived from EPA drive schedules for Heavy Duty, Medium Duty and LDVs.

Traffic congestion is typically characterized by the level of service (LOS) which is based on the level of reduction below free-running speed of the traffic. For a freeway with an average 110 km/h (68 mph) free flow speed, increasing congestion leads to decreasing average speed. LOS A through LOS D involve modest decreases, while LOS E depicts traffic at capacity conditions and LOS F depicts traffic beyond capacity covering a range of conditions from frequent slow-downs to full stop-and-go progress. Non-freeway travel involves intersection stops and idle periods.

The bus and LDV modules use some common drive schedules and some performance-specific drive schedules for urban travel. There are seven drive schedules in each vehicle’s worksheet as illustrated below.

A Creep drive schedule is used for queuing delays or fully congested travel and the output is presented in fuel consumption per unit time. Queue delays can be encountered at manual toll booths, some maintenance activities, congested arterial and city-street intersections and severely congested freeways. The Creep Schedule is composed of intermittent short advances and long idle periods as illustrated in Figure 6. The drive schedule is derived from the front end of EPA’s LOS-F drive schedule and is used by both the bus and LDV modules.

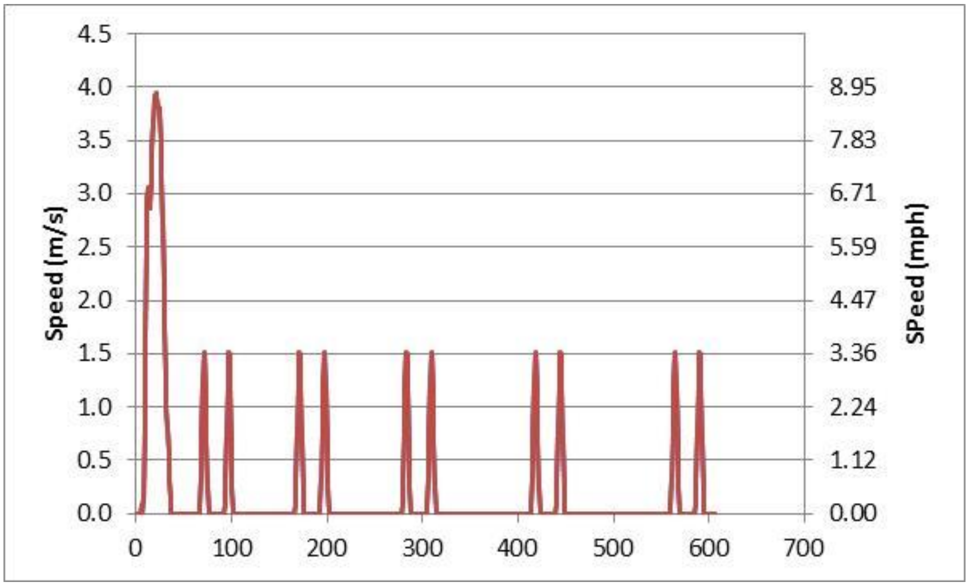


Figure 6. Creep Drive Schedule (0.9 km/h)

Source: Derived from EPA Drive Schedules used in MOVES.

There are two non-freeway drive schedules, with stops and speed variation from a shared-traffic in an urban environment. An arterial road (see Figure 7) is depicted by an average speed of about 40 km/h (25 mph) with stops at about 2 km intervals. The drive schedule is EPA's non-Freeway HDD25 drive schedule. The user input specifies the total distance traveled on intermediate urban access roads (more for bus intermediate stops than for LDVs) for the intercity segment and as a proportional incurrence by time-of-day for the urban origin and destination. The same drive schedule is present in both 'Bus-Drive-Schedules' and 'LDV-Drive-Schedules'.

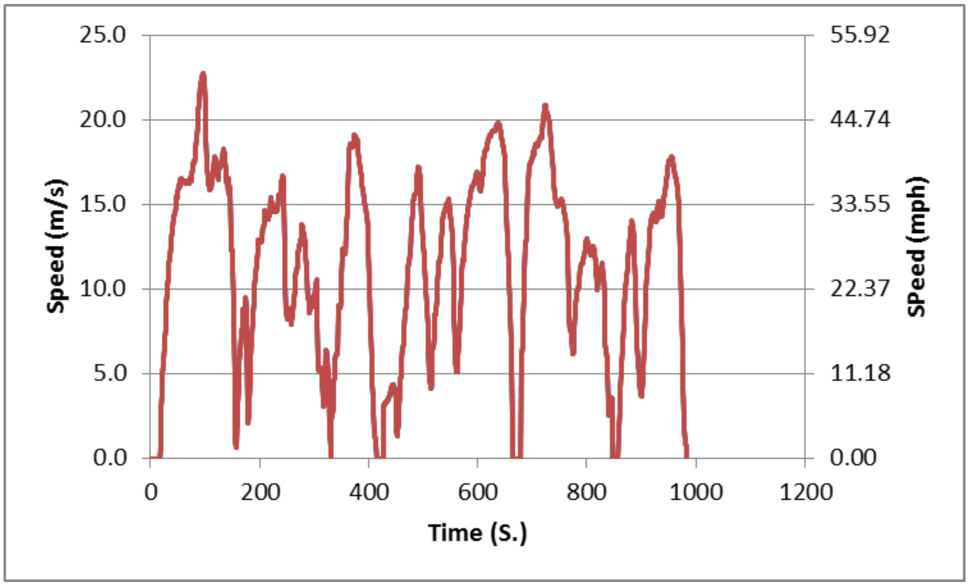


Figure 7. Urban Arterial/City Drive Schedule (40 km/h)

Source: Derived from EPA Drive Schedules used in MOVES.

Figure 8 illustrates a congested traffic condition which could be encountered on either freeway or non-freeway roads. The LOS-F (14 km/h) is present in both the 'Bus-Drive-Schedules' and 'LDV-Drive-Schedules' worksheets.

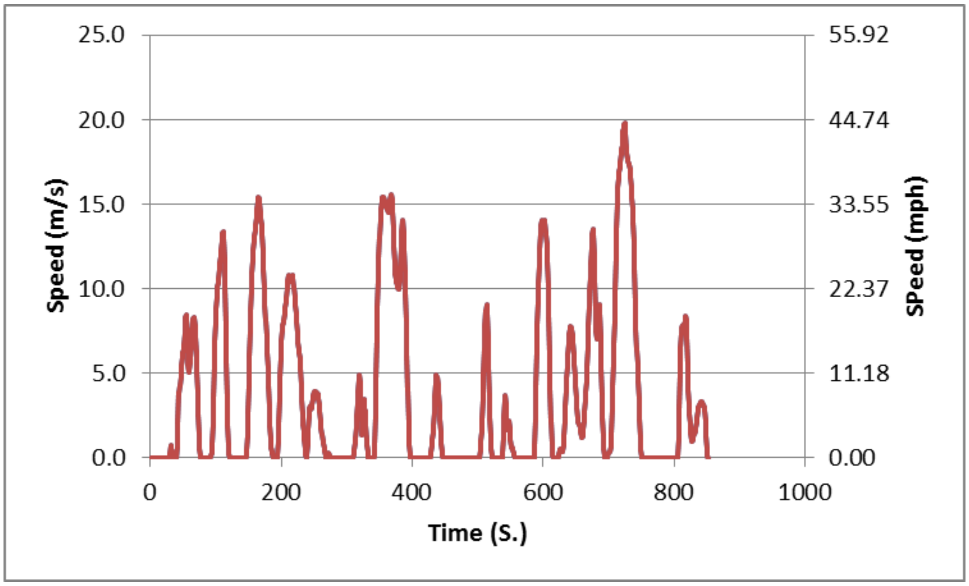


Figure 8. LOS-F Stop and Go Drive Schedule (14 km/h)

Source: Derived from EPA Drive Schedules used in MOVES.

The 'LDV-Drive-Schedules' worksheet also has a city street as depicted in Figure 9.

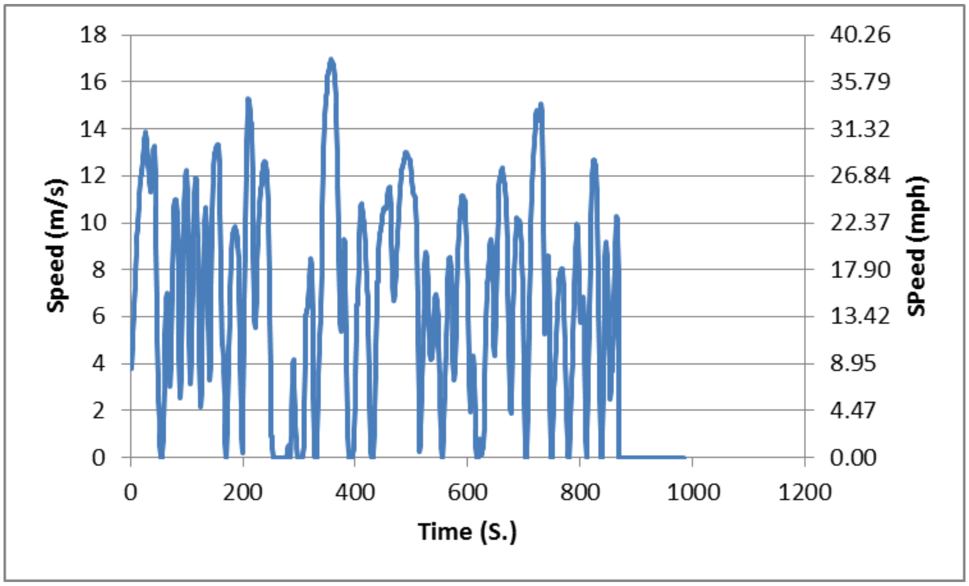


Figure 9. City Street Drive Schedule for LDVs (25 km/h) Source: Derived from EPA Drive Schedules used in MOVES.

Urban freeways have several drive schedules to simulate the degree of congestion. Each has an average speed associated with congestion conditions. The approximate average speeds involved for each drive schedule used in the 'Bus-Drive-Schedules' and 'LDV-Drive-Schedules' worksheets are:

Bus Freeflow	117 km/h (73 mph), (see Figure 10)
LDV Freeflow	119 km/h (74 mph), (see Figure 11)
LOS-B/C	105 km/h (65 mph), (see Figure 12)
LOS-E	75 km/h (47 mph), (see Figure 13)
LOS-E (Bus)	50 km/h (30 mph), (see Figure 14)
Access/exit urban freeway	100 km/h (62 mph), (see Figure 15)

New drive schedules can be used in place of the seven drive schedules in the middle of the Table. The creep drive schedule (col C) and cruise drive schedule (col K) cannot be replaced. The length limitation is a maximum of 1149 seconds duration and the active length of the intended drive schedule must be entered in row 29 at the top of the replacement drive schedule. The user can also manually introduce a speed governor for buses in the 'Bus-Drive-Schedules' by capping the maximum speed of the existing speed profiles with the appropriate speed limit. Thus for example, a 65 mph (25.058 m/s) governor setting would cap the maximum speed at 65 mph rather than the 79 mph (35.32 m/s) attained in the non-governed "Bus Freeflow" drive schedule of Figure 10 and the 67 mph (29.95 m/s) attained in the 'LOS-E 75 km/h' drive schedule of Figure 13.

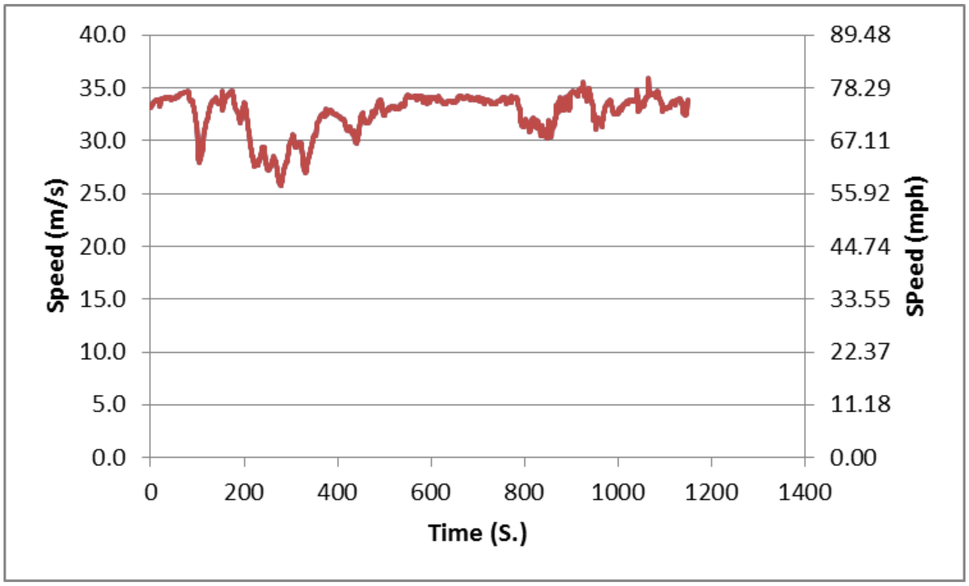


Figure 10. Urban Freeway Bus Free-flow - 117 km/h Drive Schedule Source: Derived from EPA Drive Schedules used in MOVES.

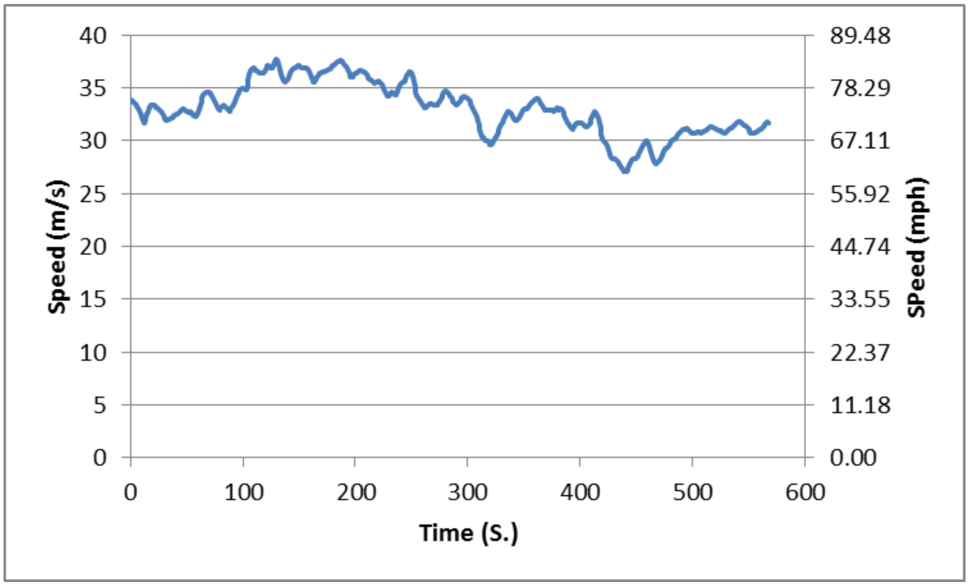


Figure 11. Urban Freeway LDV Free-flow - 119 km/h Drive Schedule Source: Derived from EPA Drive Schedules used in MOVES.

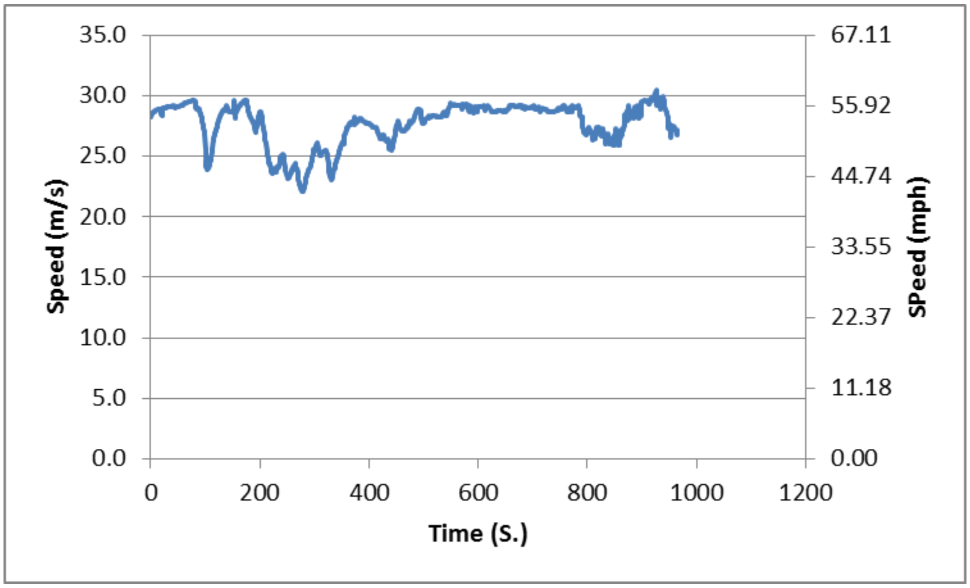


Figure 12. Urban Freeway LOS-B/C - 105 km/h Drive Schedule Source: Derived from EPA Drive Schedules used in MOVES.

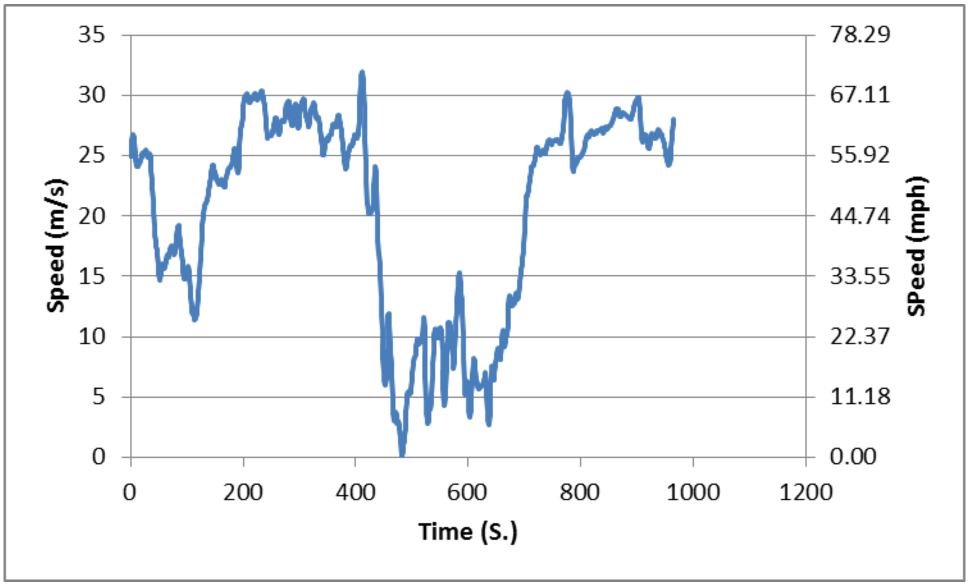


Figure 13. Urban Freeway LOS-E - 75 km/h Drive Schedule

Note: This is the LDV drive schedule, the Bus drive schedule is the same except the speed peaks are capped at 65 mph (29 m/s).
Source: Derived from EPA Drive Schedules used in MOVES.

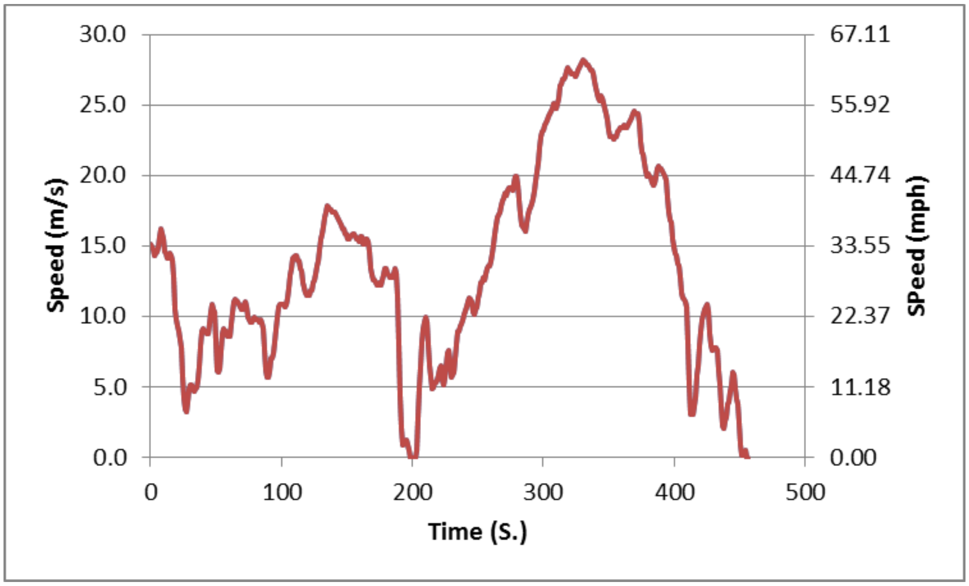


Figure 14. Urban Freeway – LOS-E 50 km/h Drive Schedule Note: This drive schedule is used in the Bus simulation.
Source: Derived from EPA Drive Schedules used in MOVES.

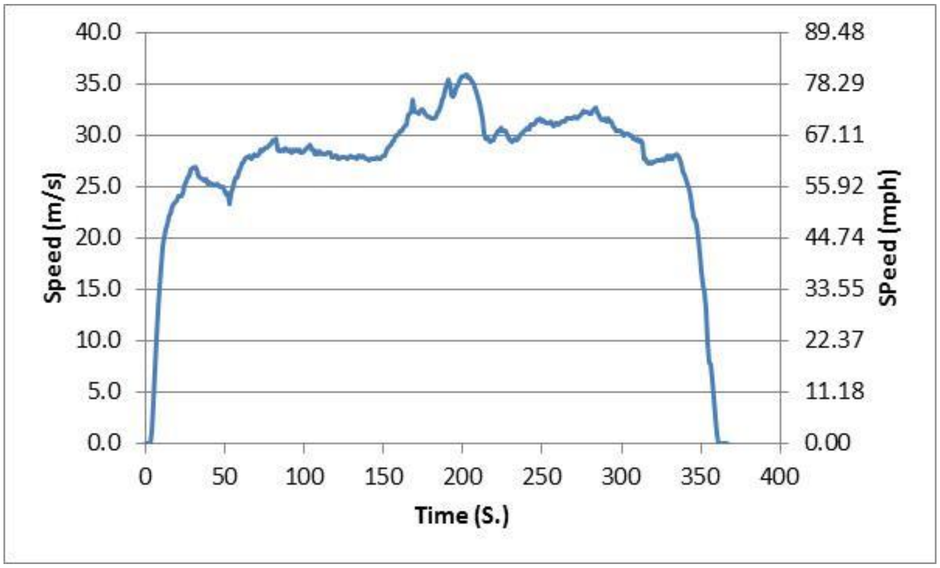


Figure 15. Short Urban Freeway Access LDV Drive Schedule (EPA-US06)

Source: EPA's Fuel Economy Certification Drive Schedule US06.

5.4 Inter-City Road Maintenance/Weather Delays

The congestion drive schedules described in the previous section are also used to depict maintenance delays for the intercity segment of the intercity long haul trip. The user specifies the distribution of trips by time-of-day congestion conditions and the model determines the average fuel intensity in relation to the input distribution. Long haul maintenance activity is also characterized by the same fixed duty cycles. The user specifies the distance and probability of occurrence for maintenance and/or weather delays. The LOS-E 75 km/h drive schedule is assumed to characterize these delays.

6 Air Mode Simulation Module

6.1 Overview

The air simulation module simulates the air leg of a full door-to-door passenger trip generating the energy and emissions intensities of the air leg of the passenger trip. The air module is unlike the other modal simulation modules as it does not 'simulate' the movement of an aircraft but uses energy intensity characterization data that are published each year by the US Bureau of Transportation Statistics [Research and Innovation Technology Administration, Bureau of Transportation Statistics, 2013]. The default characterization data provided with the model are based on 2011-2012 operations of domestic US scheduled air carriers and can be updated by the user as desired in future years as air technology and operations practices change. The following five types of aircraft were assessed:

1. Turboprops (TP)
2. Small Regional Jets (SRJ) (defined here as jet aircraft with less than 50 seats)
3. Regional Jets (RJ) (defined here as jet aircraft with 50 to 89 seats)
4. Narrow Body Jets (NBJ) (defined here as jet aircraft with greater than 89 seats in a single aisle configuration)
5. Wide Body Jets (WRJ) (defined here as jet aircraft with greater than 89 seats configured with more than one aisle)

The data were analyzed to provide an indication of the mix of aircraft used in meeting the demand for different trip lengths. Each aircraft type was analyzed to provide an indication of its average load factor, its per-seat fuel intensity during the landing and takeoff cycle (kg/seat-LTO) and for the cruise segment (kg/seat-GC-mi).

The default coefficients used in the Air Simulation sheet are presented in the Air Mode Methodology (Section 2.4).

6.2 Air Module Layout

6.2.1 User Inputs

The overall model structure was illustrated in Figure 1 of Chapter 3. Those worksheets specific to simulating the air passenger mode are discussed in more detail here.

The minimum input data required to make an air simulation run are the coordinates for the origin, destination and any intermediate airports involved in the trip. A database of airport coordinates is not published; however, the data can be obtained for individual airports from publicly available websites. The co-ordinates for a sample of airports (i.e. those involved in our case study locations) are included with the model and the user can build an internal dataset as new trips are defined and simulated.

With the airport coordinates specified, the model calculates the GC-distance for each leg of the trip, applies the average proportions of each aircraft type used for the trip distance involved and then calculates the aircraft specific energy and emissions intensities for the air legs of the trip.

The 'Air-Simulation' worksheet simulates the energy intensity of an air mode trip using a default distribution of aircraft types typical of the trip leg distances. A user can specify a single aircraft type or alternative mix of aircraft types. Similarly, representative proportions of direct and indirect (hub and spoke or multi-stop) trips can be specified or a 100% allocation to one or the other trip scenario can be made. Also, the default mirror-image return trip can be overridden with a user-specified trip if desired.

The default data are presented in Subsection 2.4.2.

6.2.2 Air Simulation Worksheet Layout

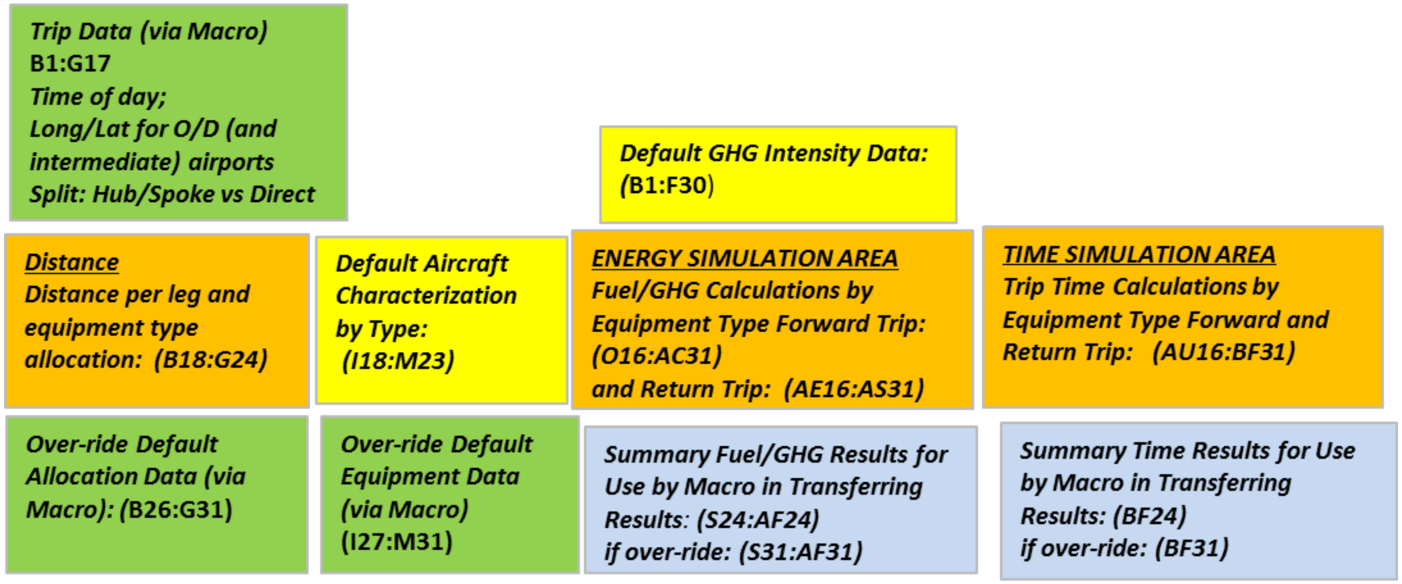
The structure of the 'Air-Simulation' worksheet and its direct interface to default datasets is illustrated in Figure 16. The areas of the worksheet are color coded to reflect their primary purpose: green indicates it is a user input, yellow indicates technical default data that can be optionally modified by the user, orange indicates calculation procedures at the core of the simulation, and blue indicates interim output data for transfer and/or aggregation by the 'Macro'.

The LTO and cruise legs of the air trip are calculated separately such that the differentiated impact of cruise-altitude emissions can be applied. The following fuel, energy and GHG intensities are calculated for the defined origin-destination trip:

- kg-fuel consumed per seat-Great Circle-km traveled (kg/sGCkm),
- kg-fuel consumed per passenger-Great Circle-km traveled (kg/pGCkm),
- kg-fuel consumed per passenger-trip (kg/trip),
- kJ of energy consumed per seat-Great Circle-km traveled (kJ/sGCkm),
- kJ of energy consumed per passenger-Great Circle-km traveled (kJ/pGCkm),
- kJ of energy consumed per passenger-trip (kJ/trip).
- Grams CO_2e emitted per seat-Great Circle-km traveled (g/sGCkm),
- Grams CO_2e emitted per passenger-Great Circle-km traveled (g/pGCkm), and
- kilograms CO_2e emitted per passenger-trip (kg/trip).

In addition, the travel time of the air leg(s) of the trip is calculated, including dwell time at intermediate stops and airport arrival / departure processing/waiting times.

Figure 16. Air-Simulation Worksheet Layout



Trip Data (via Macro)
B1:G17
Time of day;
Long/Lat for O/D (and intermediate) airports
Split: Hub/Spoke vs Direct

Default GHG Intensity Data:
(B1:F30)

Distance
Distance per leg and equipment type allocation: (B18:G24)

Default Aircraft Characterization by Type:
(I18:M23)

ENERGY SIMULATION AREA
Fuel/GHG Calculations by Equipment Type Forward Trip: (O16:AC31)
and Return Trip: (AE16:AS31)

TIME SIMULATION AREA
Trip Time Calculations by Equipment Type Forward and Return Trip: (AU16:BF31)

Over-ride Default Allocation Data (via Macro): (B26:G31)

Over-ride Default Equipment Data (via Macro)
(I27:M31)

Summary Fuel/GHG Results for Use by Macro in Transferring Results: (S24:AF24)
if over-ride: (S31:AF31)

Summary Time Results for Use by Macro in Transferring Results: (BF24)
if over-ride: (BF31)

color legend (primary purpose of Sheet):

🟩 User input,

🟨 Optional User overrides of technical defaults;

🟧 Calculation processing Sheets/Macro;

🟦 Output

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Appendix A

MMPASSIM Spreadsheet Model User Guide

Table of Contents

Appendix A MMPASSIM Spreadsheet Model User Guide

Appendix B Terms, Abbreviations and Equation Variables

List of Tables

List of Figures

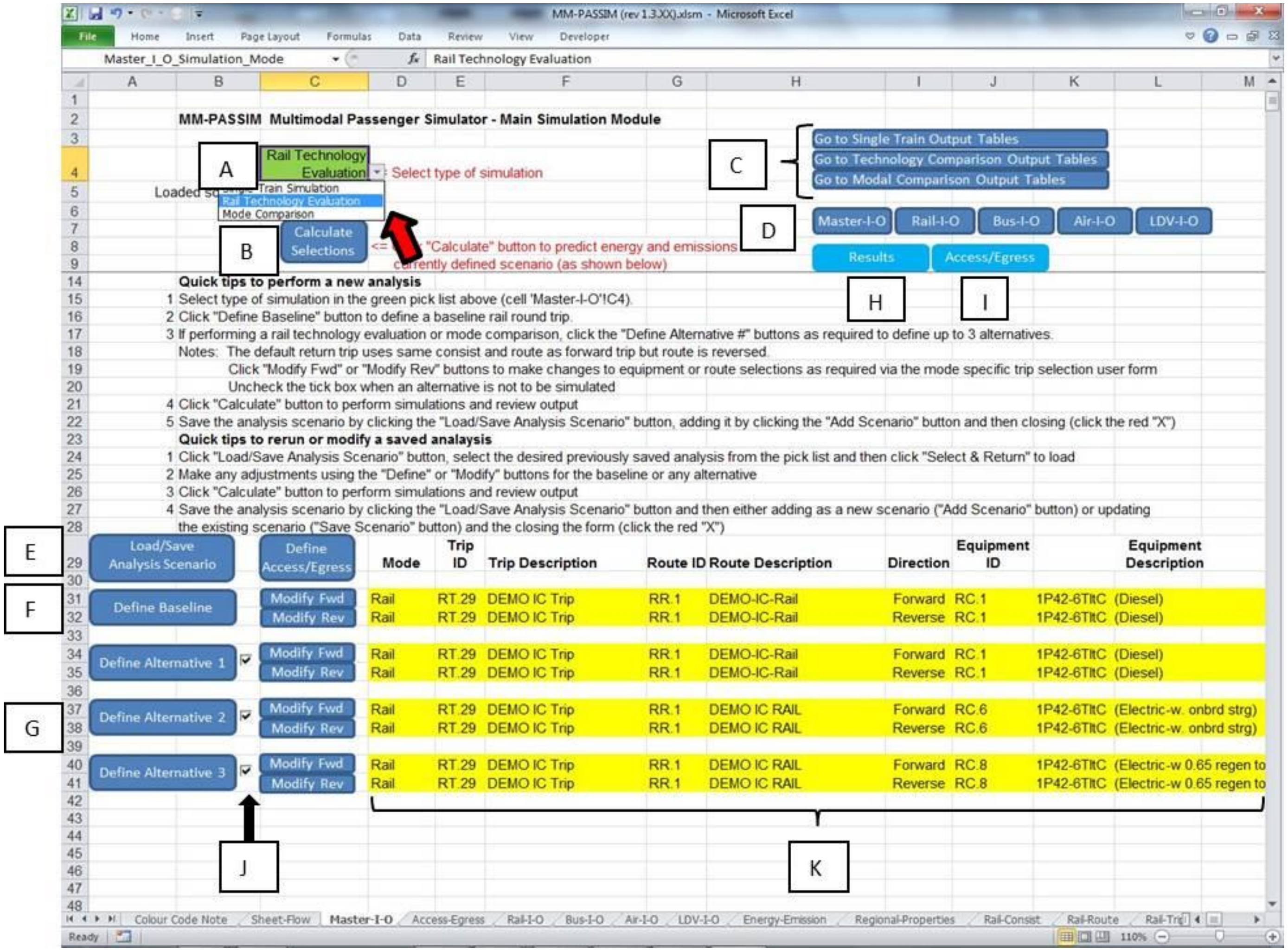
SUMMARY AND QUICK-REFERENCE GUIDE

Overview to Using the MMPASSIM Model

The main user interface of the MMPASSIM model is the '*Master-I-O'* worksheet and is as depicted in the figure on the following page. A simulation scenario may be easily configured from the 'Master-I-O' worksheet using default (or previously stored) data by following these steps:

1. Select the desired simulation mode from the green drop-down list (at cell 'Master-I-O'!$C$4, highlight A in the figure).
2. Define the baseline rail round trip (applicable in all three simulation modes) by clicking the blue "Define Baseline" button (at cell 'Master-I-O'!$A$31, highlight F in the figure).
3. Define each alternative round trip by clicking the blue "Define Alternative 1/2/3 button(s) located below the "Define Baseline" button. A maximum of 3 alternatives can be selected for rail technology comparisons or transportation mode comparisons.
4. Click the blue "Calculate Selections" button (at cell 'Master-I-O'!$B$7, highlight B in the figure) to initiate the simulation of the baseline rail round trip followed by each defined alternative in a rail technology evaluation or mode comparison analysis.
5. Review the simulation results table which is automatically brought into view at the conclusion of all simulations as defined for the selected analysis type.

Pop-up user forms are provided to assist users with managing and configuring the data required for an analysis. The VBA macros will coordinate accessing data from the various worksheets required for the type of analysis being defined. In some cases, an experienced user may also find it more expedient to directly modify vehicle and route data or define new trips. The fuel and emissions intensity data for all transportation modes are provided in the 'Energy-Emission' worksheet and include default values (in yellow highlighted cells) and "used" values (in green highlighted cells). The default values should not normally be modified. The green "used" values are those which the simulation modules use when performing calculations and can be safely modified by a knowledgeable user to adjust for better known values to be used in their simulated scenarios.



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

<= "Calculate" button to predict energy and emissions currently defined scenario (as shown below)

Quick tips to perform a new analysis

1 Select type of simulation in the green pick list above (cell 'Master-I-O'!C4).
2 Click "Define Baseline" button to define a baseline rail round trip.
3 If performing a rail technology evaluation or mode comparison, click the "Define Alternative #" buttons as required to define up to 3 alternatives.
Notes: The default return trip uses same consist and route as forward trip but route is reversed.
Click "Modify Fwd" or "Modify Rev" buttons to make changes to equipment or route selections as required via the mode specific trip selection user form
Uncheck the tick box when an alternative is not to be simulated
4 Click "Calculate" button to perform simulations and review output
5 Save the analysis scenario by clicking the "Load/Save Analysis Scenario" button, adding it by clicking the "Add Scenario" button and then closing (click the red "X")

Quick tips to rerun or modify a saved analaysis

1 Click "Load/Save Analysis Scenario" button, select the desired previously saved analysis from the pick list and then click "Select & Return" to load
2 Make any adjustments using the "Define" or "Modify" buttons for the baseline or any alternative
3 Click "Calculate" button to perform simulations and review output
4 Save the analysis scenario by clicking the "Load/Save Analysis Scenario" button and then either adding as a new scenario ("Add Scenario" button) or updating the existing scenario ("Save Scenario" button) and the closing the form (click the red "X")

	Mode	Trip ID	Trip Description	Route ID	Route Description	Direction	Equipment ID	Equipment Description
	Rail	RT.29	DEMO IC Trip	RR.1	DEMO-IC-Rail	Forward	RC.1	1P42-6TltC (Diesel)
	Rail	RT.29	DEMO IC Trip	RR.1	DEMO-IC-Rail	Reverse	RC.1	1P42-6TltC (Diesel)
☑	Rail	RT.29	DEMO IC Trip	RR.1	DEMO-IC-Rail	Forward	RC.1	1P42-6TltC (Diesel)
	Rail	RT.29	DEMO IC Trip	RR.1	DEMO-IC-Rail	Reverse	RC.1	1P42-6TltC (Diesel)
☑	Rail	RT.29	DEMO IC Trip	RR.1	DEMO IC RAIL	Forward	RC.6	1P42-6TltC (Electric-w. onbrd strg)
	Rail	RT.29	DEMO IC Trip	RR.1	DEMO IC RAIL	Reverse	RC.6	1P42-6TltC (Electric-w. onbrd strg)
☑	Rail	RT.29	DEMO IC Trip	RR.1	DEMO IC RAIL	Forward	RC.8	1P42-6TltC (Electric-w 0.65 regen to
	Rail	RT.29	DEMO IC Trip	RR.1	DEMO IC RAIL	Reverse	RC.8	1P42-6TltC (Electric-w 0.65 regen to

Notes:

A	Simulation type selection
B	Calculate selections button
C	Go to the indicated mode specific output table
D	Go to modal IO worksheet
E	Load an existing trip configuration or save current trip configuration
F	Define the baseline trip
G	Define up to 3 alternate trips(s)
H	Display results table for the current analysis type
I	View the access/egress leg results
J	Check the tick box to activate an alternative trip calculation
K	Summarizes the currently configured trips

MMPASSIM Main User Interface is on `Master-I-O` Worksheet.

For the ground transportation modes (rail, LDV and bus), a trip is defined in terms of its route and the vehicle which operates over that route. Vehicle and route data for the ground transportation modes are specified in separate mode-specific vehicle and route worksheets, all of which have green coloured tabs. The route data specifies characteristics such as trip distance, grade profile, speed limits, location and duration of intermediate stops, and other operational factors. The vehicle data specifies the physical properties used by the model to characterize the vehicle's passenger capacity, weight, inherent resistance to motion, and its engine characteristics.

Three “builder” worksheets are also included to provide casual users of MMPASSIM with a quick and easy method to construct simple trips from only very basic trip information. These include the ‘Build-Simple-Rail-Trip’, ‘Build-Simple-Bus-Trip’ and ‘Build-Simple-LDV-Trip’ worksheets (all with green tabs). The basic information required to specify a simple trip using these worksheets include the trip length, average trip speed (or speed limit), number of intermediate stops, scheduled trip time (for rail and bus modes), season, geographical region, origin and destination urban area sizes (for highway modes) and the approximate time of day of departure and arrival. Modal simulations based on trips created using these “builder” worksheets assume various mode-specific default values and do not consider the influence of grades and curves along a route.

Air mode trips are specified differently and do not use data stored on vehicle and route worksheets. Rather, air trips are specified in terms of the sequence of IATA airport codes visited from the origin to destination and the distribution of aircraft types used to travel over each leg of that trip. The model uses default aircraft data provided in the ‘Air-Default-Data’ worksheet (with a yellow coloured tab). A list of IATA airport codes and their longitude and latitude is also maintained on the ‘Air-Default-Data’ worksheet and users may update that list by adding new IATA airport codes and locations.

MMPASSIM Analysis Quick Reference Guide

The following pages present a series of lists which summarize the basic steps involved in performing analyses using the MMPASSIM model. In most cases, the sections in the User`s Guide which provide more details on the steps required for an analysis task are noted.

To Perform a Single Train Simulation

A Single Train Simulation is configured and run from the ‘Master-I-O’ worksheet. Section A.3.1 of this document provides a brief overview of the process while Section A.5.1 discusses the analysis process in greater detail.

The basic steps required to perform a Single Train Simulation are as follows:

1. Click the green ‘Master-I-O’ worksheet tab along the bottom of the Excel window to bring the ‘Master-I-O’ worksheet into view.

2. Select “Single Train Simulation” from the green drop-down list at ‘Master-I-O’!C4

3. Open the “Rail Trip Selection” menu by clicking on the blue “Define Baseline” button on the ‘Master-I-O’ worksheet.

4. Choose a pre-existing rail trip from the green drop-down list just below the yellow “Trip ID” box at the top.

5. Modify trip as needed by
   - selecting a different route from the “Route ID” drop-down list
   - selecting a different consist from the “Consist ID” drop-down list
   - adjusting trip departure & arrival times, season, region, etc. as required
   - adjusting access & egress legs by clicking on the gray “Access & Egress”

6. Save or add as a new trip as desired.
   - to save as a new trip, click gray “Add Rail Trip” and then “Save Rail Trip”
   - to save modifications with old name, click gray “Save Rail Trip”
   - you may use modifications temporarily without saving to ‘Rail-Trip-List’ worksheet

7. Click gray “Select & Return” button to load the displayed trip on the ‘Master-I-O’ worksheet for analysis.

8. Click blue “Calculate Selections” button to start the simulation

9. Review the results displayed in the Single Train Simulation output tables on the ‘Master-I-O’ worksheet (automatically brought into view), or by clicking the blue “Go to Single Train Output Tables” button.

To Perform a Rail Technology Evaluation from Existing Characterization Data

A Rail Technology Evaluation is configured and run from the ‘Master-I-O’ worksheet. A Rail Technology Evaluation compares the energy and emissions performance of up to four rail round trips. Section A.3.2 of this document provides a brief overview of the process while Section A.5.1 discusses the details of setting up a new rail trip simulation.

The basic steps required to perform a Rail Technology Evaluation are as follows:

1. Click the green ‘Master-I-O’ worksheet tab along the bottom of the Excel window to bring the ‘Master-I-O’ worksheet into view.

2. Select “Rail Technology Evaluation” from the green drop-down list at ‘Master-I-O’!C4

3. Define baseline rail trip by clicking the blue “Define Baseline” button and using the “Rail Trip Selection” menu

4. Tick the check box for each required alternative. Define the alternative rail trip by clicking the blue “Define Alternative 1/2/3” button and using the “Rail Trip Selection” menu. Note – click on any ticked check box to clear it if an alternative is not to be included in this simulation.

5. Review the access and egress defined for the baseline and each alternative. Click on the blue “Define Access/Egress” button on the ‘Master-I-O’ worksheet to display the “Trip Access and Egress Leg Selection” menu and scroll through the definitions. Adjustments can be made and then saved by clicking the gray “Save” button, but note that they are only saved to the ‘Master-I-O’ definition (not to the underlying rail trip stored on the ‘Rail-Trip-List’ worksheet).

6. Click the blue “Calculate Selections” button to start the rail technology evaluation.

7. Review the results displayed in the Rail Technology Evaluation output tables on the ‘Master-I-O’ worksheet (automatically brought into view), or by clicking the blue “Go to Technology Comparison Output Tables” button.

To Perform a Modal Comparison from Existing Characterization Data

A Modal Comparison is configured and run from the ‘Master-I-O’ worksheet and Section A.3.3 of this document provides a brief overview of the process. Performing a Modal Comparison requires setting up a baseline rail trip (see Section A.5.1) and up to three trips for competing modes which may include an air trip (see Section A.5.2), a bus trip (see Section A.5.3) and a light duty vehicle trip (see Section A.5.4).

The basic steps required to perform a Modal Comparison are as follows:

1. Click the green ‘Master-I-O’ worksheet tab along the bottom of the Excel window to bring the ‘Master-I-O’ worksheet into view.

2. Select “Mode Comparison” from the green drop-down list at ‘Master-I-O’!C4

3. Define baseline rail trip by clicking the blue “Define Baseline” button and using the “Rail Trip Selection” menu.
    a. Select a pre-existing trip,
   or
    b. Select a rail route from drop-down list
    c. Select a rail consist from the drop-down list
    d. Make any further modifications to green fields
   and
    e. Click the gray “Select & Return” button to write the updated trip parameters to the ‘Master-I-O’ worksheet

4. Tick the check box for each required alternative. Define the alternative modal trip by clicking the blue “Define Alternative 1/2/3” button and using the mode-specific “Trip Selection” menu – click on any ticked check box to clear it if an alternative is not to be used in this simulation. Note that for alternative trips, you must select the desired mode from the green drop-down list presented and then click the gray “Select & Edit” button to access the mode-specific trip selection menu.
    – rail trips use the “Rail Trip Selection” menu
    – air trips use the “Air Trip Selection” menu
    – bus trips use the “Bus Trip Selection” menu
    – auto/LDV trips use the “Auto/LDV Trip Selection” menu
   Click the gray “Select & Return” button when finished with a “Trip Selection” menu

5. Review the access and egress defined for the baseline and each alternative. Click on the blue “Define Access/Egress” button on the ‘Master-I-O’ worksheet to display the “Trip Access and Egress Leg Selection” menu and then scroll through the definitions. Note: adjustments can be made and saved by clicking the gray “Save” button, but are only saved to the ‘Master-I-O’ definition (not to the underlying rail trip stored on the ‘Rail-Trip-List’ worksheet).

6. Click the blue “Calculate Selections” button to start the mode comparison.

7. Review the results in the Mode Comparison output tables on the ‘Master-I-O’ worksheet (automatically brought into view), or by clicking the blue “Go to Modal Comparison Output Tables” button.

To Create a New ‘Simple’ Rail Trip

The ‘Build-Simple-Rail-Trip’ worksheet provides a straight forward method of creating a rail trip when little specific information is known about the train makeup and route. The process is as follows (refer to Section A.4.1 for more detail):

1. Click the green ‘Build-Simple-Rail-Trip’ worksheet tab along the bottom of the Excel window to bring the ‘Build-Simple-Rail-Trip’ worksheet into view.

2. Select either “U.S.” or “metric” from the green drop-down list.

3. Define the rail
    a. Select a locomotive type from the green locomotive drop-down list and indicate the number of locomotives to include
    b. Select up to three types of coaches from the three green coach drop-down lists and indicate the number of each coach type to include
    c. Select the locomotive fuel type from the green “Fuel Type” drop-down list
    d. Adjust the assumed passenger load factor in the green input field
    e. Click the blue “Save to ‘Rail-Consist’” button to access the “Simple Rail Consist Selection” menu
    f. Enter a consist description into the green “Description” input box and click the gray “Add Rail Consist” button.
    g. Click the gray “Select & Return” button to return to the ‘Build-Simple-Rail-Trip’ worksheet.

4. Define the rail route
    a. Set the trip length, average track speed and number of stops in the correspondingly labeled green data input fields.
    b. Click the blue “Save to ‘Rail-Route’” button to access the “Simple Rail Route Selection” menu
    c. Enter a route description into the green “Description” input box and click the gray “Add Rail Route” button.
    d. Click the gray “Select & Return” button to return to the ‘Build-Simple-Rail-Trip’ worksheet.

5. Define the rail trip
    a. Select the region, season, departure and arrival time-of-day and the day-of-week from the correspondingly named green drop-down lists.
    b. Set the number of travelers, schedule trip time and station stop time allowance in the correspondingly named green input data fields.
    c. Select the target ‘Rail-I-O’ trip from the green drop-down list (this controls if the simple rail trip is loaded as a baseline or alternative trip).
    d. Click the blue “Create Rail Trip” button to access the “Rail Trip Selection” menu
    e. Click the gray “Add Rail Trip” to create a new rail trip.
    f. Enter a trip description into the green “Description” input box and click the gray “Save Rail Trip” button to save to the ‘Rail-Trip-List’ worksheet.
    g. Click the gray “Select & Return” button to load the new trip parameters onto the ‘Rail-I-O’ worksheet (and also on the ‘Master-I-O’ worksheet).

To Create a New ‘Simple’ Bus Trip

The ‘Build-Simple-Bus-Trip’ worksheet provides a simple means to create a basic bus trip. Details may be found in Section A.4.2 of this document. The process is a follows:

1. Click the green ‘Build-Simple-Bus-Trip’ worksheet tab along the bottom of the Excel window to bring the ‘Build-Simple-Bus-Trip’ worksheet into view.

2. Select either “U.S.” or “metric” from the green drop-down list.

3. Choose a type of bus from the green drop-down list.

4. Set rural freeway distance in the green input field and select speed limit from green drop-down list.

5. Select urban area sizes from the green drop-down lists, and set distances traveled on urban freeway and arterial roads in the green input fields.

6. Set number of intermediate stops while leaving origin urban area, along intercity leg and entering destination urban area in the green input fields.

7. Set scheduled trip time.

8. Select region and season from the respective green drop-down lists.

9. Select departure & arrival times and day of week from the green drop-down lists.

10. Enter a description for the route to be created in the green input field and then click the blue "Save to 'Bus-Route'" button.

11. Click the blue "Create Bus Trip" button to open the “Bus Trip Selection” menu

12. Click the gray "Add Bus Trip" button and enter a trip description into the green “Description” field.

13. Click the gray "Save Bus Trip" button to save the trip to the ‘Bus-Trip-List’ worksheet.

14. Click the gray “Select & Return” button to load the new trip parameters onto the ‘Bus-I-O’ worksheet (and ‘Master-I-O’ worksheet when a bus trip is selected for analysis).

To Create a New ‘Simple’ Light Duty Vehicle Trip

The ‘Build-Simple-LDV-Trip’ worksheet provides a simple means to create a basic light duty vehicle trips. Details may be found in Section A.4.3 of this document and the process is summarized as follows:

1. Click the green ‘Build-Simple-LDV-Trip’ worksheet tab along the bottom of the Excel window to bring the ‘Build-Simple-LDV-Trip’ worksheet into view.
2. Select either “U.S.” or “metric” from the green drop-down list.
3. Choose a type of light duty vehicle from the green drop-down list.
4. Set rural freeway distance in the green input field and select speed limit from green drop-down list.
5. Select urban area sizes from the green drop-down lists, and set distances traveled on urban freeway and arterial roads in the green input fields.
6. Set the number of intermediate wayside stops and the cumulative duration of those stops in the green input fields.
7. Select region and season from the respective green drop-down lists.
8. Select departure & arrival times and day of week from the green drop-down lists.
9. Set the number of travelers in the green input field.
10. Enter a description for the route to be created in the green input field and then click the blue "Save to 'LDV-Route'" button.
11. Click the blue "Create LDV Trip" button to open the “Auto/LDV Trip Selection” menu.
12. Click the gray "Add LDV Trip" button and enter a trip description into the green “Description” field.
13. Click the gray "Save LDV Trip" button to save the trip to the ‘LDV-Trip-List’ worksheet.
14. Click the gray “Select & Return” button to load the new trip parameters onto the ‘LDV-I-O’ worksheet (and ‘Master-I-O’ worksheet when an LDV trip is selected for analysis).

To Create a New Rail Route

The columns of the ‘Rail-Route’ worksheet hold all data used by MMPASSIM to represent the physical characteristics of a rail route. Section A.6.6 of this document discusses details of how to create a new rail route. The basic process is as follows:

1. Click the green ‘Rail-Route’ worksheet tab along the bottom of the Excel window to bring the ‘Rail-Route’ worksheet into view.

2. Choose an existing route on the worksheet to use as a template to customize with new route data.

3. Copy the 13 columns of route data to be used as a template into the open columns to the right of last route defined in the worksheet by:
    a. Click on the column label directly above the “Rail Route Index” of the source data.
    b. Hold the shift key and click on the column label of the 13th column to the right.
    c. Release the shift key.
    d. Place mouse pointer anywhere in the highlighted area and click right mouse button.
    e. Select copy from the pop-up menu.
    f. Find the 14th cell to the right of the last “Rail Route Index” defined in the worksheet, right click on it and select paste from the pop-up menu.
    g. Verify the copy is pasted in the correct position by ensuring the new “Rail Route Index” is an integer number 1 greater than the previous route
        – if it is an integer number then the data is pasted in the correct position
        – if it is less, click the undo paste icon (top left corner) and paste to a cell one further to the right
        – if it is more, click the undo paste icon (top left corner) and paste to a cell one further to the left

4. Modify the yellow “Rail Route ID” and green “Description” fields
    – The “Rail Route ID” must be a unique alpha-numeric string

5. Modify data values for the new route as required
    a. The route gradient table is located in rows 5 through 34
        – Can re-use an existing gradient profile by adjusting the milepost and elevation to suit or create a new profile from track chart data using the MMPASSIM track preprocessor and pasting data into this location
    b. The locations of stops are entered in rows 50 through 85 as follows
        – Location of forward direct stops in 1st column (green) in miles
        – Wayside receptivity of forward stops in 3rd column (green)
        – Location of reverse direct stops in 8th column (green) in miles
        – Wayside receptivity of reverse stops in 9th column (green)
        – Clear any unused cells in green columns only
    c. The locations of speed limit changes are input in rows 141 through 561
        – Location in 1st column (green) in miles
        – Conventional speed limit in 3rd column (green) in mph
        – Tilt-body speed limit in 4th column (green) in mph
        – Clear any unused cells in green columns only

To Create a New Rail Consist

The columns of the ‘Rail-Consist’ worksheet hold all data used by MMPASSIM to represent the physical characteristics of a rail consist. Section A.6.2 of this document describes how to build a new train from an existing base train, Section A.6.3 discusses how to build a new train with a new locomotive and Section A.6.4 details how to build a new train with new coaches. The basic process is as follows:

1. Click the green ‘Rail-Consist’ worksheet tab along the bottom of the Excel window to bring the ‘Rail-Consist’ worksheet into view.

2. Choose an existing rail consist on the worksheet to use as a template to customize with new vehicle data.

3. Copy the 7 columns of vehicle data to be used as a template into the empty columns to the right of the last vehicle route defined in the worksheet by:
    a. Click on the column label directly above the “Rail Consist Index” of the source data.
    b. Hold the shift key and click on the column label of the 7th column to the right.
    c. Release the shift key.
    d. Place mouse pointer anywhere in highlighted area and click right mouse button.
    e. Select copy from the pop-up menu.
    f. Find the 8th cell to the right of the last “Rail Consist Index” defined in the worksheet, right click on it and select paste from the pop-up menu.
    g. Verify the copy is pasted in the correct position by ensuring the new “Rail Consist Index” is an integer number 1 greater than the previous route
        – if it is an integer number then the data is pasted in the correct position
        – if it is less, click the undo paste icon (top left corner) and paste to a cell one further to the right
        – if it is more, click the undo paste icon (top left corner) and paste to a cell one further to the left

4. Modify the yellow “Rail Consist ID” and green “Description” fields
    – The “Rail Consist ID” must be a unique alpha-numeric string

5. Modify data values for the new vehicle as required
    a. Number of locomotives & cars, masses, lengths in rows 5 through 20
    b. Resistance coefficients in rows 26 through 28
    c. Tractive effort in rows 42 through 48
    d. Traction engine characteristics in rows 49 through 61

To Create a New Rail Trip

Before creating a new rail trip you should first create any new rail routes or rail consists that will be required (refer to the steps outlined previously). The following outlines the process for selecting a rail route and a rail consist to be used for a rail trip.

1. Click the green ‘Master-I-O’ worksheet tab along the bottom of the Excel window to bring the ‘Master-I-O’ worksheet into view.

2. Open the “Rail Trip Selection” menu by clicking on any of the blue “Define Baseline”, “Define Alternative 1”, “Define Alternative 2” or “Define Alternative 3” buttons on the ‘Master-I-O’ worksheet.

   Note: if the analysis type is set to “Mode Comparison” then you will need to select “Rail” from the green drop-down list presented on the “Transportation Mode Selection” menu and click the gray “Select & Edit” button to open the “Rail Trip Selection” menu.

3. Choose a rail trip to serve as a template by selecting it from the green drop-down list just below the yellow “Trip ID” box at the top.

4. Click the gray “Add Rail Trip” button at the bottom to create a new “Trip ID”.

5. Enter a description in the green “description” field at the top.

6. Select a “Route ID” from the green “Route ID” drop-down list to assign it to this new rail trip.

7. Select a “Consist ID” from the green “Consist ID” drop-down list to assign it to this new rail trip.

8. Make any desired changes to the green user definable/selectable fields.

9. Assign/modify access and egress by clicking the gray “Access & Egress” button and making selections on the “Trip Access and Egress Leg Selection” menu – click the gray “Select & Return” button to return to the “Rail Trip Selection” menu.

10. Click the gray “Save Rail Trip” button to save the newly configured rail trip data to the ‘Rail-Trip-List’ worksheet.

11. Click the gray “Select & Return” button to load the displayed rail trip onto the ‘Master-I-O’ worksheet.

A.1 Multi-Modal Passenger Simulator Model Introduction

The **M**ulti **M**odal **Pas**senger **Sim**ulator (MMPASSIM) supports three types of analyses: *Single Train Simulations*, *Rail Technology Evaluations* and *Transportation Mode Comparisons*. In each type of analysis, mode-specific trips are defined as a combination of a vehicle travelling along a route. The analyses comprising the *Single Train Simulation* mode considers a two-way trip involving a single train operating over a single route and essentially underlies those of the other two analysis modes whereby a *Rail Technology Evaluation* may combine results obtained from up to four (4) single train analyses (a baseline plus three alternatives) while a *Transportation Mode Comparison* will use the results of a single train simulation in combination with results from simulations of up to three (3) competing transportation modes. The transportation modes which may be considered in a mode comparison analysis include rail, air and highway – where the highway mode encompasses travel by both bus and light duty vehicles.

The method by which passengers access the departure station as well as egress from the arrival station of a transportation mode are also considered, although with less detail than used for the primary transportation legs. Each access trip in a simulation may be comprised of up to five (5) modes encompassing walking, the use of private automobiles and taxis and various forms of public transportation such as buses, light rail and subway systems. Egress trips are similarly, but independently, configured to the access trips.

Within the MMPASSIM workbook, a number of worksheets support four (4) sub-modules which estimate travel times, energy consumption and GHG emissions for round-trips made via rail, air, bus and light duty vehicles. The primary user interface for all simulations is provided in the 'Master-I-O' worksheet (blue tab) from where a user configures all required simulations for an analysis. However each transportation mode is configured and operated as a semi-independent sub-model which may be configured and controlled independently by a user if desired. The sub-model user interfaces are provided in the 'Rail-I-O', 'Air-I-O', 'Bus-I-O' and 'LDV-I-O' worksheets (all with blue tabs). A system of pop-up user forms (menus) and Visual Basic for Applications (VBA) macros coordinates the configuration of all desired simulations as well as the transfer of data to and from the sub-model worksheets. The results are displayed to the user in formatted output tables on the 'Master-I-O' worksheet which are automatically brought into view while the simulation proceeds.

Three "builder" worksheets are also included to provide casual users of MMPASSIM with a quick and easy method to construct simple trips from only very basic trip information. These include the 'Build-Simple-Rail-Trip', 'Build-Simple-Bus-Trip' and 'Build-Simple-LDV-Trip' worksheets (all with green tabs). The basic information required to specify a simple trip using these worksheets include the trip length, average trip speed (or speed limit), number of intermediate stops, scheduled trip time (for rail and bus modes), season, geographical region, origin and destination urban area sizes (for highway modes) and the approximate time of day of departure and arrival. Modal simulations based on trips created using these "builder" worksheets assume various mode-specific default values and do not consider the influence of grades and curves along a route.

A.1.1 System Requirements and Trouble Shooting

MMPASSIM is implemented as a macro enabled Microsoft Excel workbook (with an ".xlsm" file extension). The workbook requires Microsoft Excel 2007 or later to function properly since its worksheet structure uses more than 256 columns (which was the column limit in versions prior to Excel 2007). In addition to macros, the MMPASSIM workbook uses ActiveX controls in its worksheets and user forms.

> **Note:** *Macros must be enabled since the MMPASSIM workbook makes extensive use of macros to perform its analyses. Users must select "Enable Macros" in response to Microsoft Excel's security notice when opening the workbook.*

There is no installation process required to use the MMPASSIM model other than having a working copy of Microsoft Excel 2007 or later installed. However, it is necessary that Excel be configured to permit macros and ActiveX controls to be executed. The necessary security settings may be set in Excel's "Trust Centre" following these steps:

1. In Excel 2010, click the File tab (or click the Office button in Excel 2007).
2. Click Options.
3. Click Trust Center, and then click Trust Center Settings.
4. Click ActiveX Settings.
5. Select either

   "Prompt me before enabling all controls with minimum restrictions" (recommended)

   or

   "Enable all controls without restrictions…" (not recommended)
6. Click Macro Settings.
7. Select either

   "Disable all macros with notification" (recommended)

   or

   "Enable all macros…" (not recommended)
8. Click OK.

In December of 2014 Microsoft issued a security update which interfered with Excel's ability to use ActiveX controls in worksheets. When this happened, an "Error 438" condition occurred shortly after clicking the "Calculate Selections" button on the 'Master-I-O' worksheet. If you encounter this problem you may be able to resolve the error by following these instructions:

1. Close all open Microsoft Office applications.
2. Using Windows Explorer, search for any "*.exd" files and delete any you find. Make sure to include hidden and system files and folders in the search. This should locate one or more files named "MSForms.exd".
3. Reboot the computer (not always necessary)
4. Restart Microsoft Excel and test.

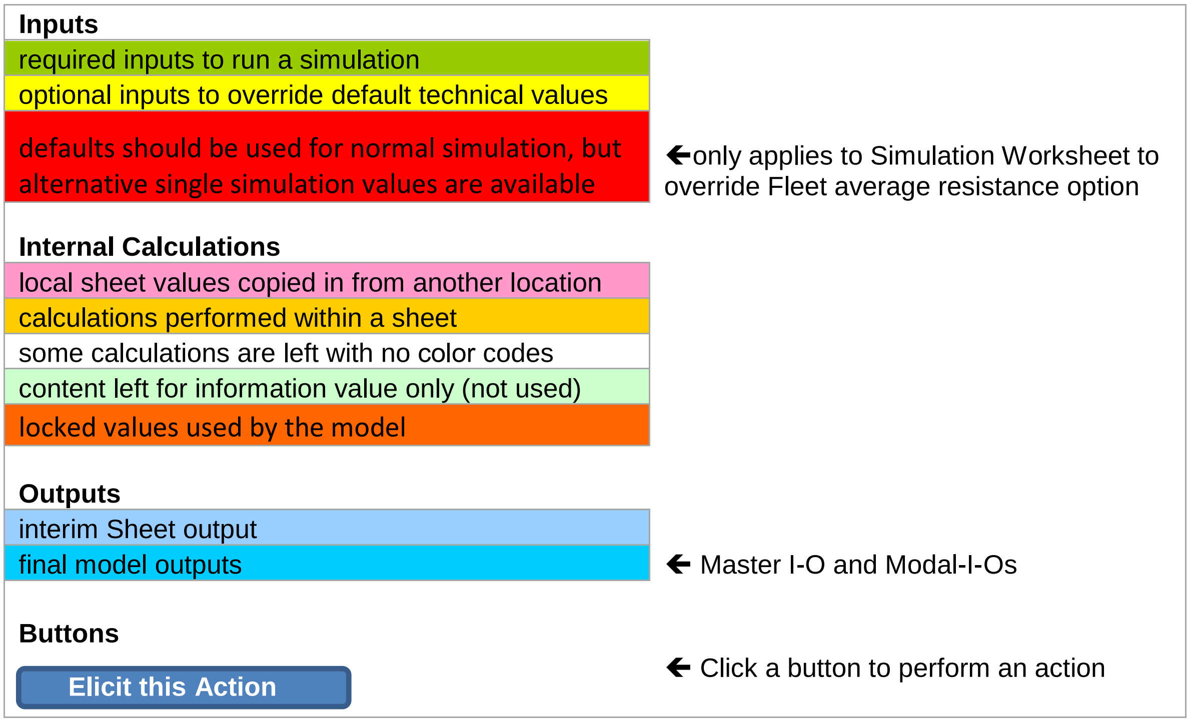
In March of 2015 Microsoft released new security fixes for Excel 2007, Excel 2010 and Office 2013 which should have resolved this issue.

A.2 MMPASSIM Workbook Structure

MMPASSIM is implemented as a Microsoft Excel (2010) macro enabled workbook and may have a structure less familiar to some. This section contains information that will help a user become familiar with the organization and visual cues used throughout the MMPASSIM workbook. This information appears as the first two worksheets, “Color Code Note” and “Sheet-Flow” and so can be quickly referred to when using MMPASSIM.

The first worksheet, “Color Code Note” (see Figure A-1), explains MMPASSIM’s use of color to indicate the general function of its’ active cells. Green and yellow cells allow a user to input simulation information, while function “buttons” open detailed simulation input forms, initiate a simulation, or help the user quickly navigate the workbook. Buttons also provide direct access to the current simulation outputs. Cells of other colours, or no color (white), are not to be modified by a user.

The second worksheet, “Sheet-Flow”, gives a road map that depicts both the logic flow and the physical layout of information on the main I-O (input-output) worksheets. It also uses color cueing to help indicate what occurs in each functional area.



Inputs

required inputs to run a simulation

optional inputs to override default technical values

defaults should be used for normal simulation, but alternative single simulation values are available

← only applies to Simulation Worksheet to override Fleet average resistance option

Internal Calculations

local sheet values copied in from another location

calculations performed within a sheet

some calculations are left with no color codes

content left for information value only (not used)

locked values used by the model

Outputs

interim Sheet output

final model outputs

← Master I-O and Modal-I-Os

Buttons

← Click a button to perform an action

Figure A-1 MMPASSIM Worksheet 'Color Code Guide'

Cell colours indicate how the contents are used within the MM-PASIM analysis program.

A.3 The Basics of Configuring and Running a Simulation Scenario

Begin an MMPASSIM modal simulation by opening an MMPASSIM macro enabled workbook and selecting "Enable Marcos" in response to the Microsoft Excel Security Notice if displayed. It is recommended that you work with a copy of the MMPASSIM workbook so that you will always have a clean copy of the original workbook on hand in case, for example, cell formulas become lost due to inadvertent copying and pasting. The workbook will open and automatically display the 'Master-I-O' worksheet which functions as the main user interface.

Figure A-2 on page A-5 provides a flowchart overview of the simulation process for the three categories of analyses which MMPASSIM may be configured to perform. Dashed lines delineate the three analyses categories that can be configured. Note the consistent process structure across analysis types. A user selects the type of analysis, configures the trips to be analyzed and then clicks the "Calculate Selections" button to initiate the simulation.

Figure A-3 illustrates the layout of the 'Master-I-O' worksheet while Table A-1 provides a summary of its' top level functions. The 'Master-I-O' worksheet allows selection of the simulation category (*Single Train*, *Rail Technology Evaluation* or *Transportation Mode Comparison*) and assists a user in constructing the individual trips of a simulation scenario. This is done by: selecting from lists of available vehicle configurations and routes; choosing the time and season when trips take place; and selecting from other mode-specific configuration options – all accomplished on pop-up mode-specific trip selection forms. The list of available vehicles and routes can be expanded by adding vehicle and route data sets that are stored in mode-specific worksheets. For example the 'Rail-Consist' worksheet stores train consist definitions while the 'Rail-Route' worksheet stores the track characterization. Many pre-defined vehicle configurations and routes are provided from which a user may build representative trips. These can also be used as templates to build customized vehicles and routes. More detail on each of these steps is provided in the following sections.

A simulation scenario may be easily configured from default (or previously stored) data by following these steps:

1. Select the desired simulation mode from the green drop-down list (at cell 'Master-I-O'!$C$4, see Figure A-3, highlight "A").

2. Define the baseline rail round trip (applicable in all three simulation modes) by clicking the blue "Define Baseline" button (at cell 'Master-I-O'!$A$31 see Figure A-3, highlight "F").

3. Define each alternative round trip by clicking the blue "Define Alternative 1/2/3 button(s) located below the "Define Baseline" button (see Figure A-3, highlight "G"). A maximum of 3 alternatives can be selected for rail technology comparisons or transportation mode comparisons.

4. Click the blue "Calculate Selections" button (at cell 'Master-I-O'!$B$7 see Figure A-3, highlight "B") to initiate the simulation of the baseline rail round trip followed by each defined alternative in a rail technology evaluation or mode comparison analysis.

5. Review the simulation results table which is automatically brought into view at the conclusion of all simulations as defined for the selected analysis type.

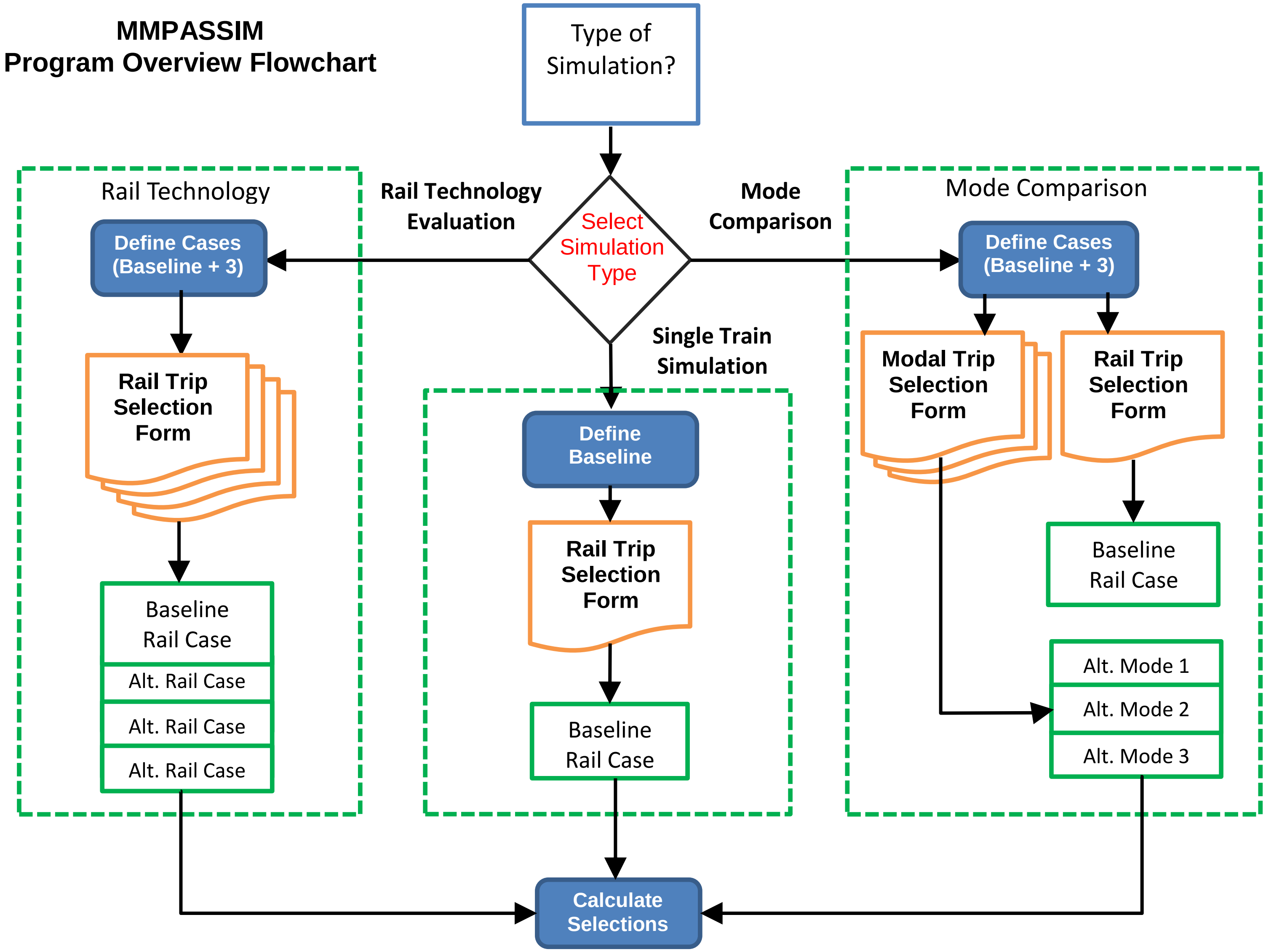
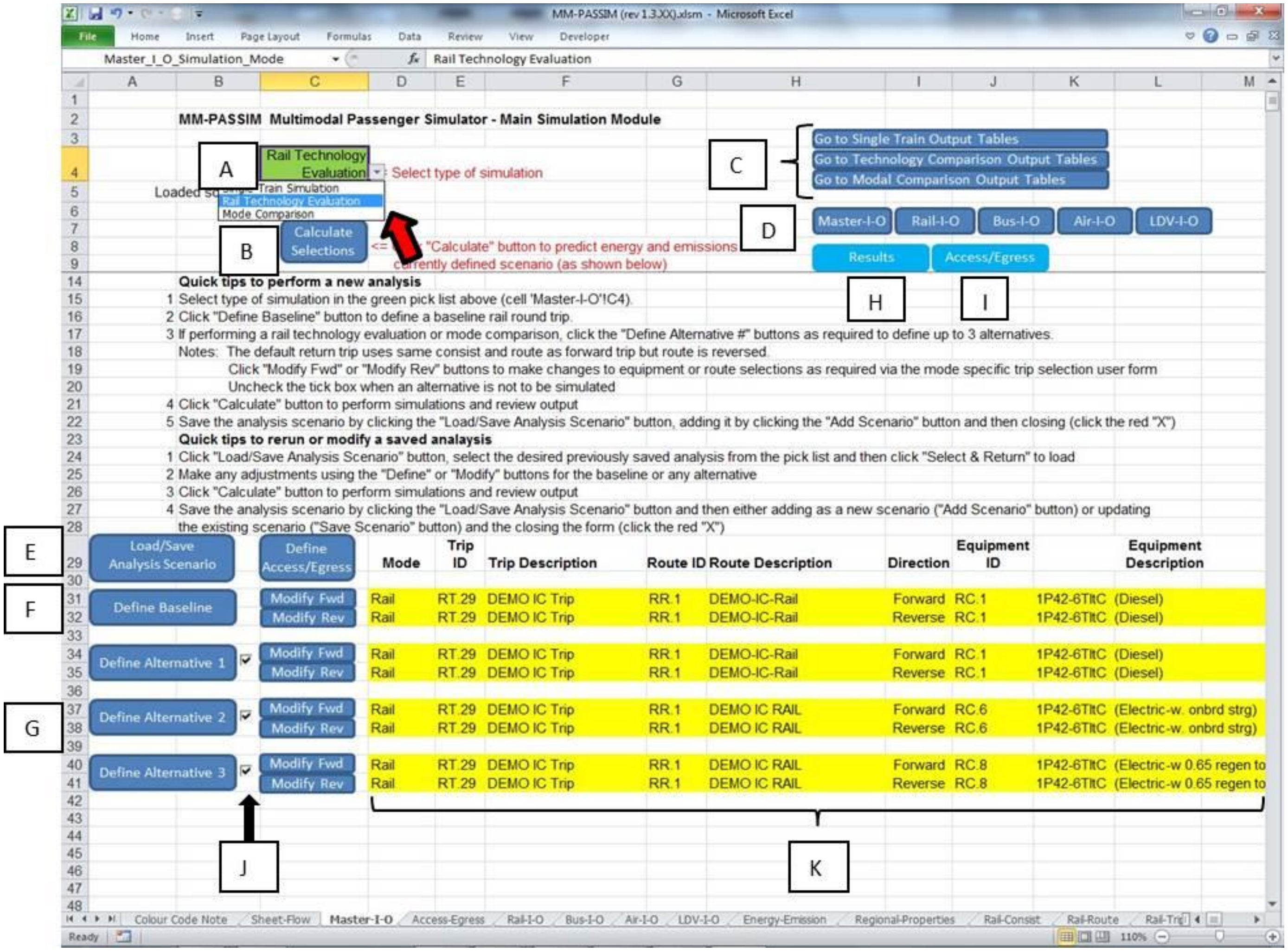


Figure A-2 MMPASSIM Program Overview Flowchart

Pop-up user forms are provided to assist the simulation program user in managing and configuring the data required for an analysis. The VBA macros will coordinate accessing data from the various worksheets required for the type of analysis being defined. In some cases, an experienced user may also find it more expedient to directly modify vehicle and route data or define new trips. The fuel and emissions intensity data for all transportation modes are provided in the ‘Energy-Emission’ worksheet and include default values (in yellow highlighted cells) and “used” values (in green highlighted cells). The default values should not normally be modified. The green “used” values are those which the simulation modules use when performing calculations and can be safely modified by a knowledgeable user to adjust for better known values to be used in their simulated scenarios.

The check boxes located immediately to the right of each “Define Alternative #” button (Figure A-3, highlight “J”) are used to enable simulation of that alternative. This allows rail technology and mode comparison analyses involving fewer than the maximum number of alternatives to be performed. Unchecking a box will cause the configuration data for an alternative to be hidden and the associated simulation will not be performed when calculations are initiated. However, the configuration data is preserved and checking the box again will reveal the data and the corresponding simulation will be performed when calculations are next initiated (by clicking on the blue “Calculate Selections” button).



Quick tips to perform a new analysis

1 Select type of simulation in the green pick list above (cell 'Master-I-O'!C4).
2 Click "Define Baseline" button to define a baseline rail round trip.
3 If performing a rail technology evaluation or mode comparison, click the "Define Alternative #" buttons as required to define up to 3 alternatives.
Notes: The default return trip uses same consist and route as forward trip but route is reversed.
Click "Modify Fwd" or "Modify Rev" buttons to make changes to equipment or route selections as required via the mode specific trip selection user form
Uncheck the tick box when an alternative is not to be simulated
4 Click "Calculate" button to perform simulations and review output
5 Save the analysis scenario by clicking the "Load/Save Analysis Scenario" button, adding it by clicking the "Add Scenario" button and then closing (click the red "X")

Quick tips to rerun or modify a saved analaysis

1 Click "Load/Save Analysis Scenario" button, select the desired previously saved analysis from the pick list and then click "Select & Return" to load
2 Make any adjustments using the "Define" or "Modify" buttons for the baseline or any alternative
3 Click "Calculate" button to perform simulations and review output
4 Save the analysis scenario by clicking the "Load/Save Analysis Scenario" button and then either adding as a new scenario ("Add Scenario" button) or updating the existing scenario ("Save Scenario" button) and the closing the form (click the red "X")

		Mode	Trip ID	Trip Description	Route ID	Route Description	Direction	Equipment ID	Equipment Description
Define Baseline	Modify Fwd	Rail	RT.29	DEMO IC Trip	RR.1	DEMO-IC-Rail	Forward	RC.1	1P42-6TltC (Diesel)
	Modify Rev	Rail	RT.29	DEMO IC Trip	RR.1	DEMO-IC-Rail	Reverse	RC.1	1P42-6TltC (Diesel)
Define Alternative 1 ☑	Modify Fwd	Rail	RT.29	DEMO IC Trip	RR.1	DEMO-IC-Rail	Forward	RC.1	1P42-6TltC (Diesel)
	Modify Rev	Rail	RT.29	DEMO IC Trip	RR.1	DEMO-IC-Rail	Reverse	RC.1	1P42-6TltC (Diesel)
Define Alternative 2 ☑	Modify Fwd	Rail	RT.29	DEMO IC Trip	RR.1	DEMO IC RAIL	Forward	RC.6	1P42-6TltC (Electric-w. onbrd strg)
	Modify Rev	Rail	RT.29	DEMO IC Trip	RR.1	DEMO IC RAIL	Reverse	RC.6	1P42-6TltC (Electric-w. onbrd strg)
Define Alternative 3 ☑	Modify Fwd	Rail	RT.29	DEMO IC Trip	RR.1	DEMO IC RAIL	Forward	RC.8	1P42-6TltC (Electric-w 0.65 regen to
	Modify Rev	Rail	RT.29	DEMO IC Trip	RR.1	DEMO IC RAIL	Reverse	RC.8	1P42-6TltC (Electric-w 0.65 regen to

Notes:

- A Simulation type selection
- B Calculate selections button
- C Go to the indicated mode specific output table
- D Go to modal IO worksheet
- E Load an existing trip configuration or save current trip configuration
- F Define the baseline trip
- G Define up to 3 alternate trips(s)
- H Display results table for the current analysis type
- I View the access/egress leg results
- J Check the tick box to activate an alternative trip calculation
- K Summarizes the currently configured trips

Figure A-3 'Master-I-O' Worksheet Simulation Configuration Screen Layout

Table A-1 Active components of the "Master-I-O" worksheet identified in Figure A-3

Top Level Functions – Visible and Active from all Worksheets and Output Screens		
ID	Name of Button(s)	Action When Selected
A	Simulation Type Selection Single Train Simulation	Displays drop-down list of analyses choices: 1. Single Train Simulation 2. Rail Technology Evaluation 3. Mode Comparison
B	Calculate Calculate	Initiates analysis for the defined scenarios. Outputs: Energy and Emissions
C	Go To Output Buttons Single Train Output tables Rail Technology Output Mode Comparison Output	Takes user directly to analysis output summary tables. Provides quick navigation between the configuration screen and the analysis output screens. Note: Depending on screen zoom level, some output tables may be below the visible screen window. Simply scroll downwards.
D	I-O Buttons Master-I-O Rail-I-O Bus-I-O Air-I-O LDV-I-O	Takes user directly to the I-O worksheet selected. Provides quick navigation between configuration and analysis output screens.
E	Load/Save Analysis Scenario	Allows user to load an existing (previously saved) analysis setup. And Allows user to save the current trip analysis setup.
F	Define Baseline	Opens the Rail Trip Selection Form to define the baseline rail trip. 1. Consist 2. Route 3. Time of Day and Season
G	Define Alternative #	Opens an Alternative Mode Selection window and then a mode specific Trip Selection Form to define the Alternative Mode trip. 1. Vehicle type 2. Route 3. Time of Day and Season
H	Results	Takes user to the Output Results Table for the current Analysis
I	Access/Egress	Takes user to the Access/Egress Leg Results
J	☑	Activates (i.e. includes in the analysis) the trip shown.
K	Rail RT 29 Demo	Summary information for the trips as currently defined. **Note**: These yellow cells contain formulas used to display the trip information and should not be modified by the user.

A.3.1 Overview of Steps Required for a Single Train Simulation

A Single Train Simulation, as outlined in Figure A-4 on page A-10, requires only the baseline case be defined via the ‘Rail Trip Selection’ form.

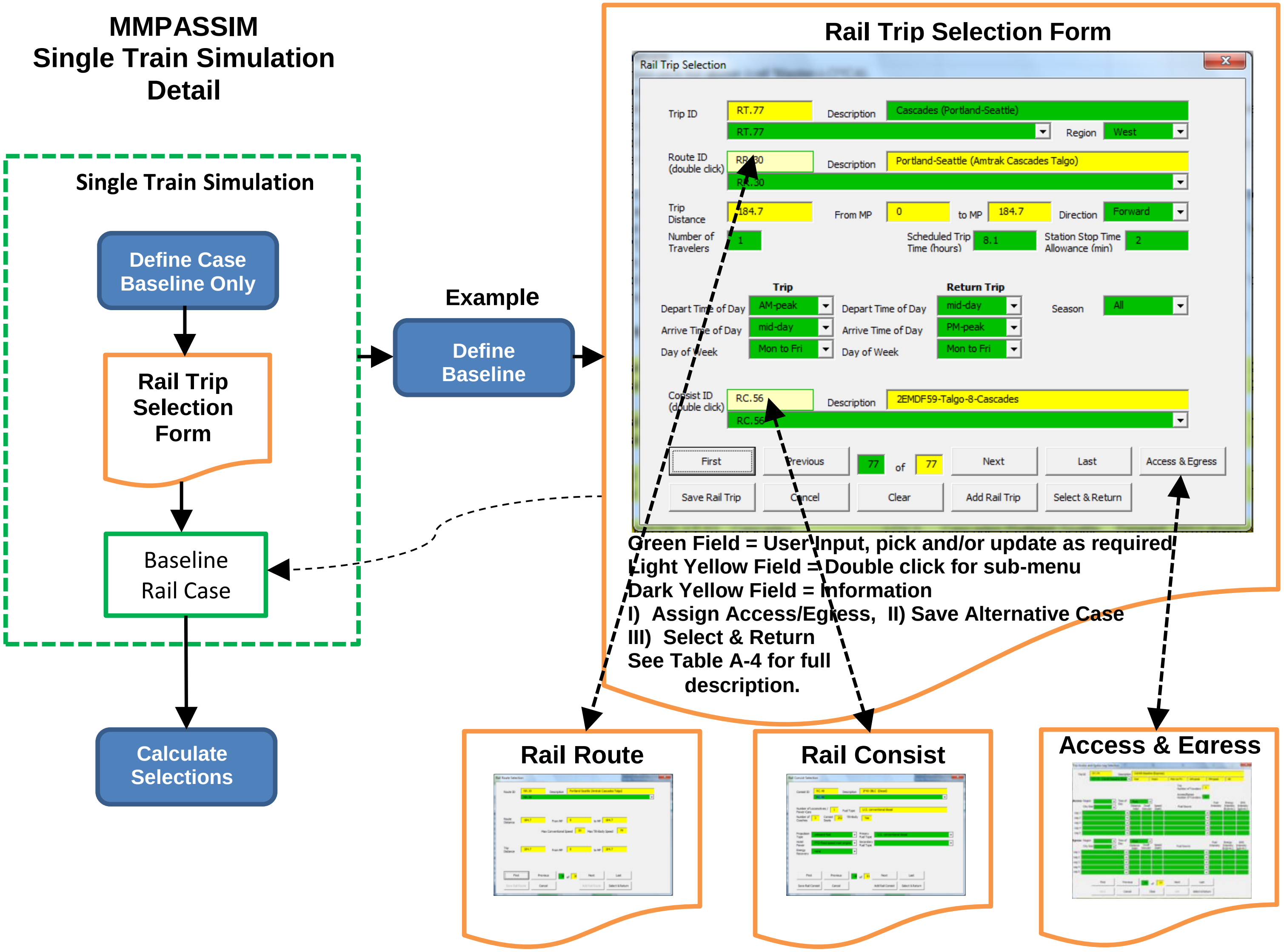
The process of defining a baseline rail trip begins by clicking the blue “Define Baseline” button located at ‘Master-I-O’!A29:B30 (see Figure A-2) to open the ‘Rail Trip Selection Form’. An existing rail trip may be selected by picking it from the green drop-down list found immediately below the yellow “Trip ID” information field. A different route may be chosen by selecting it from the green drop-down list positioned immediately below the light yellow “Route ID” information field. A different train consist may be chosen by selecting it from the list of all those currently defined in the green drop-down list positioned below the light yellow “Consist ID” information field.

Further adjustments may be made to any of the green input fields on the form. Some require numerical input while others are selected from the values presented on the drop-down list. If changes have been made, the currently displayed trip may be saved under a new name by clicking on the “Add Rail Trip” button which automatically increments its “Trip ID”, then edit the green “Description” field as required and finally click on the “Save Rail Trip” button to store the new trip – please note that an added trip is not saved until the “Save Rail Trip” button has been clicked. Clicking the “Select & Return” button passes the current baseline rail trip configuration to the baseline trip definition area on the ‘Rail-I-O’ worksheet and returns focus to the ‘Master-I-O’ worksheet. Clicking the blue “Calculate Selections” button executes the Single Train Simulation and displays the Single Train output tables. A more detailed description of setting up and running rail mode simulations may be found in Section A.5.1 beginning on page A-33.

A.3.2 Overview of Steps Required for a Rail Technology Evaluation

A Rail Technology Evaluation, as outlined in Figure A-5 on page A-11, requires definition of a baseline rail trip and up to three additional rail trips, all of which are defined using the ‘Rail Trip Selection’ form. The baseline rail trip is defined by clicking the blue “Define Baseline” button located at ‘Master-I-O’!A29:B30 (see Figure A-2) and then following the same procedure as outlined for defining the baseline rail trip for a Single Train Simulation (see Figure A-4 and Table A-4).

Definition of each alternative rail trip is initiated by clicking on the corresponding “Define Alternative #” button on the ‘Master-I-O’ worksheet and again following the same process through the ‘Rail Trip Selection’ form to define the trip and then upon clicking the “Select & Return” button the trip definition is passed back to be stored on the ‘Rail-I-O’ worksheet. If all three alternatives are not required in an analysis then uncheck the tick box adjacent to any alternative not required and a macro will hide the selections. Once all trips are defined, clicking on the blue “Calculate Selections” button which overlays ‘Master-I-O’!C7:C8 instructs a macro to start the Rail Technology Evaluation which will sequentially set up and execute each rail trip simulation and finish by displaying the Rail Technology Evaluation output tables for review. A more detailed description of setting up and running rail mode simulations may be found in Section A.5.1 beginning on page A-33.



Rail Trip Selection

Trip ID	RT.77	Description	Cascades (Portland-Seattle)				
	RT.77					Region	West
Route ID (double click)	RR.30	Description	Portland-Seattle (Amtrak Cascades Talgo)				
	RR.30						
Trip Distance	184.7	From MP	0	to MP	184.7	Direction	Forward
Number of Travelers	1			Scheduled Trip Time (hours)	8.1	Station Stop Time Allowance (min)	2

	Trip		Return Trip		
Depart Time of Day	AM-peak	Depart Time of Day	mid-day	Season	All
Arrive Time of Day	mid-day	Arrive Time of Day	PM-peak		
Day of Week	Mon to Fri	Day of Week	Mon to Fri		

Consist ID (double click)	RC.56	Description	2EMDF59-Talgo-8-Cascades
	RC.56		

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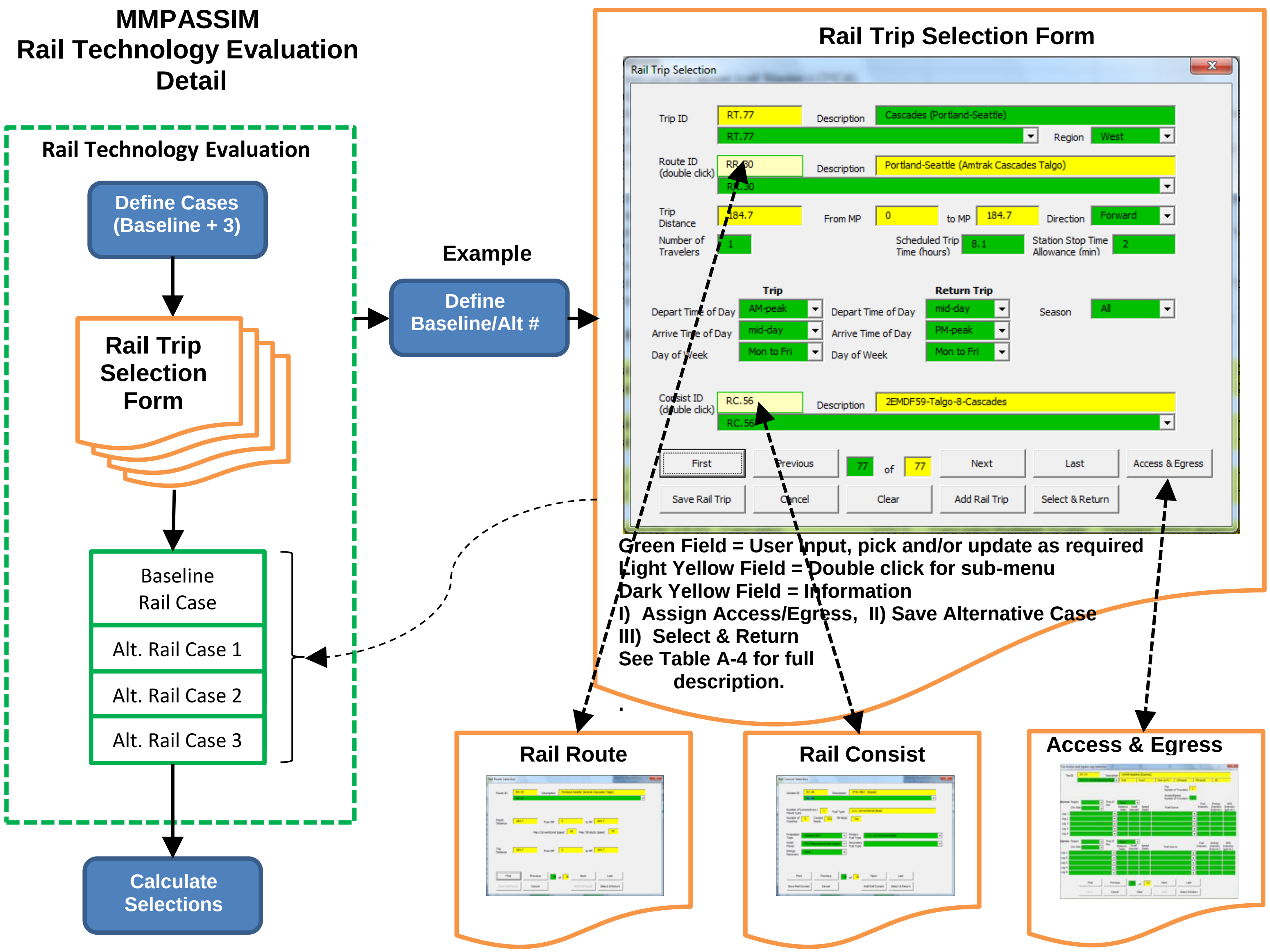
Green Field = User Input, pick and/or update as required
Light Yellow Field = Double click for sub-menu
Dark Yellow Field = Information
I) Assign Access/Egress, II) Save Alternative Case
III) Select & Return
See Table A-4 for full description.

Figure A-4 MMPASSIM Single Train Simulation Configuration



Rail Trip Selection

Trip ID	RT.77	Description	Cascades (Portland-Seattle)		
	RT.77	Region	West		
Route ID (double click)	RR.30	Description	Portland-Seattle (Amtrak Cascades Talgo)		
	RR.30				
Trip Distance	184.7	From MP	0	to MP	184.7
Direction	Forward				
Number of Travelers	1	Scheduled Trip Time (hours)	8.1	Station Stop Time Allowance (min)	2

	Trip		Return Trip		
Depart Time of Day	AM-peak	Depart Time of Day	mid-day	Season	All
Arrive Time of Day	mid-day	Arrive Time of Day	PM-peak		
Day of Week	Mon to Fri	Day of Week	Mon to Fri		

Consist ID (double click)	RC.56	Description	2EMDF59-Talgo-8-Cascades
	RC.56		

Green Field = User input, pick and/or update as required
Light Yellow Field = Double click for sub-menu
Dark Yellow Field = Information
I) Assign Access/Egress, II) Save Alternative Case
III) Select & Return
See Table A-4 for full description.

Figure A-5 MMPASSIM Rail Technology Evaluation Simulation

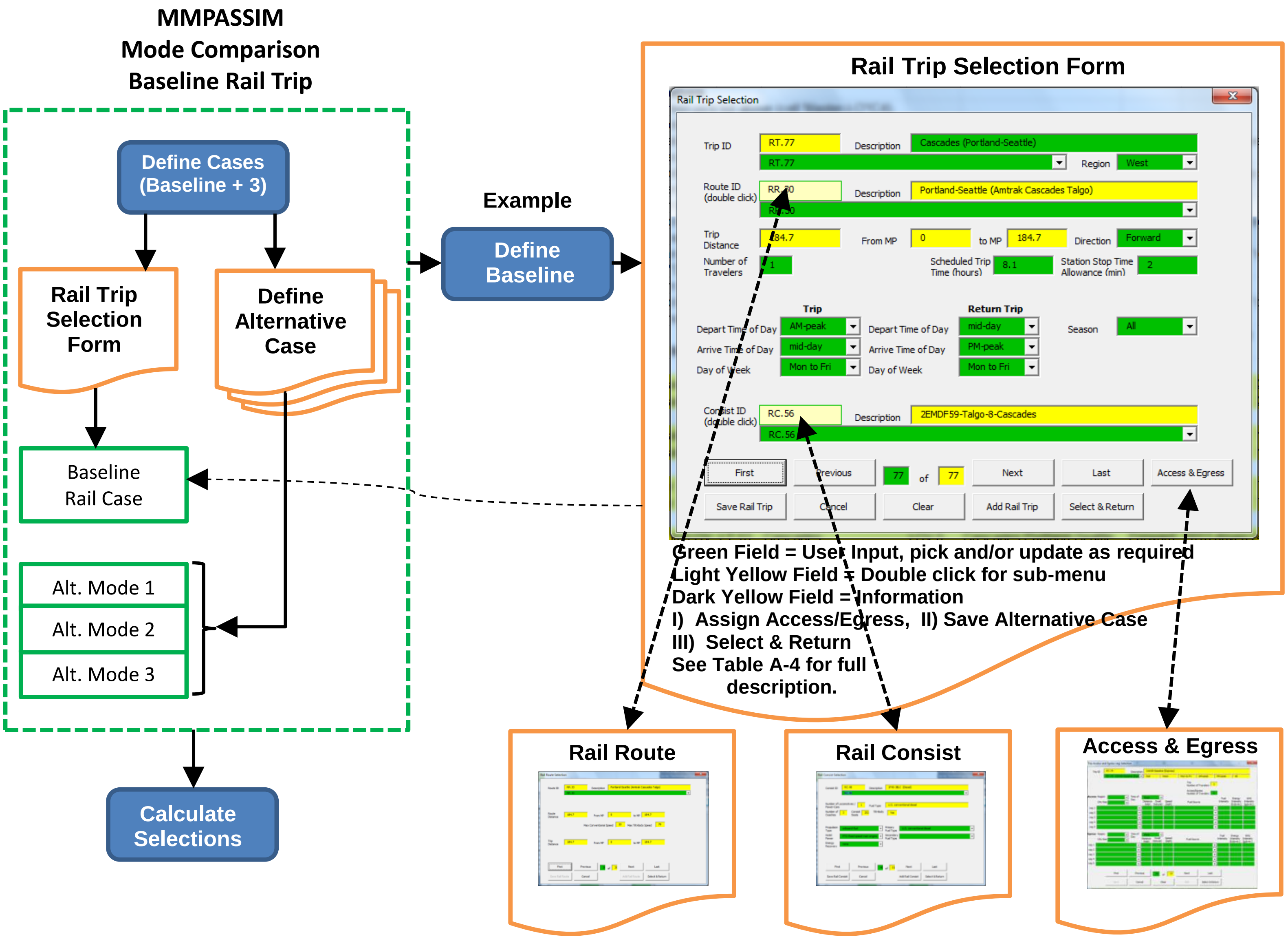
A.3.3 Overview of Steps Required for a Mode Comparison

A Mode Comparison requires definition of a baseline rail trip and up to three additional two-way trips for comparison which may include a single return bus trip, a single return LDV trip, a single return air trip and alternate return rail trips as required (where the term return trip refers to a complete two-way trip comprised of an outbound trip from the origin to destination and then an inbound trip from the outbound trip's destination back to its origin). Please note that only one two-way trip for each non-rail transportation mode may be selected for analysis in a mode comparison but several two-way alternative rail trips can be specified if desired. Begin by selecting "Mode Comparison" from the drop-down list at 'Master-I-O'!C4 and then defining the baseline rail trip case by clicking the blue "Define Baseline" button and then selecting a rail trip, rail routes and rail consists as required from the 'Rail Trip Selection' user form. The procedure for selecting the baseline trip for a Mode Comparison is outlined in Figure A-6 on page A-13 and is the same as that discussed previously for configuring a Single Train Simulation.

Definition of each alternative trip is initiated by clicking on the corresponding "Define Alternative #" button on the 'Master-I-O' worksheet and a macro will prompt the user to select the desired transportation mode from the green drop-down list presented in a small pop-up menu. The drop-down list will by default indicate the mode which was last configured for that alternative but you are free to make another selection by clicking on the gray arrow and selecting from the "Rail", "Bus", "Air" and "Auto/LDV" choices as desired. Then clicking on the "Select & Edit" button will open the transportation-mode-specific trip selection menu from which the alternative trip is configured. Figure A-7 (page A-14) outlines selecting and configuring an alternative rail trip, Figure A-8 (page A-15) a bus trip, Figure A-9 (page A-16) an air trip and finally Figure A-10 (page A-17) outlines selecting and configuring an alternative auto/LDV trip. Clicking the "Select & Return" button on any of the transportation-mode-specific trip selection menus causes a macro to pass the trip definition back to be stored on the mode-specific '<mode>-I-O' worksheet (where <mode> is either "Rail", "Bus", "Air" or "LDV"). If all three alternatives are not required for an analysis then uncheck the tick box adjacent to the definition button on the 'Master-I-O' worksheet of any alternative not required and a macro will hide the selections. Once all trips are defined, clicking on the blue "Calculate Selections" button which overlays 'Master-I-O'!C7:C8 instructs a macro to start the Mode Comparison which will sequentially set up and execute each modal trip simulation and finish by displaying the Mode Comparison output tables for review.

The upper right hand area of the 'Master-I-O' display (see Figure A-3) contains several navigation buttons which may be used to access the results summary tables (upper medium blue buttons), the detailed results for the main trip leg and access/egress legs (lower light blue buttons) or to jump to the user interface of one of the simulation sub-models (middle medium blue buttons). The yellow highlighted area provides a summary of the baseline trip and any alternative trips defined in a scenario. Please note that these yellow highlighted cells contain formulas used to display mode-specific trip information and should not be modified by the user.

More detailed discussions on using the mode-specific trip and vehicle selection menus required to configure trips for a mode comparison are discussed in later sections. Section A.5.1 outlines rail trip configuration, Section A.5.2 outlines air trip configuration, Section A.5.3 outlines bus trip configuration and Section A.5.4 outlines configuration of light duty vehicle trips.



Trip ID RT.77 Description Cascades (Portland-Seattle)

RT.77 Region West

Route ID (double click) RR.30 Description Portland-Seattle (Amtrak Cascades Talgo)

RR.30

Trip Distance 184.7 From MP 0 to MP 184.7 Direction Forward

Number of Travelers 1 Scheduled Trip Time (hours) 8.1 Station Stop Time Allowance (min) 2

	Trip		Return Trip		
Depart Time of Day	AM-peak	Depart Time of Day	mid-day	Season	All
Arrive Time of Day	mid-day	Arrive Time of Day	PM-peak		
Day of Week	Mon to Fri	Day of Week	Mon to Fri		

Consist ID (double click) RC.56 Description 2EMDF59-Talgo-8-Cascades

RC.56

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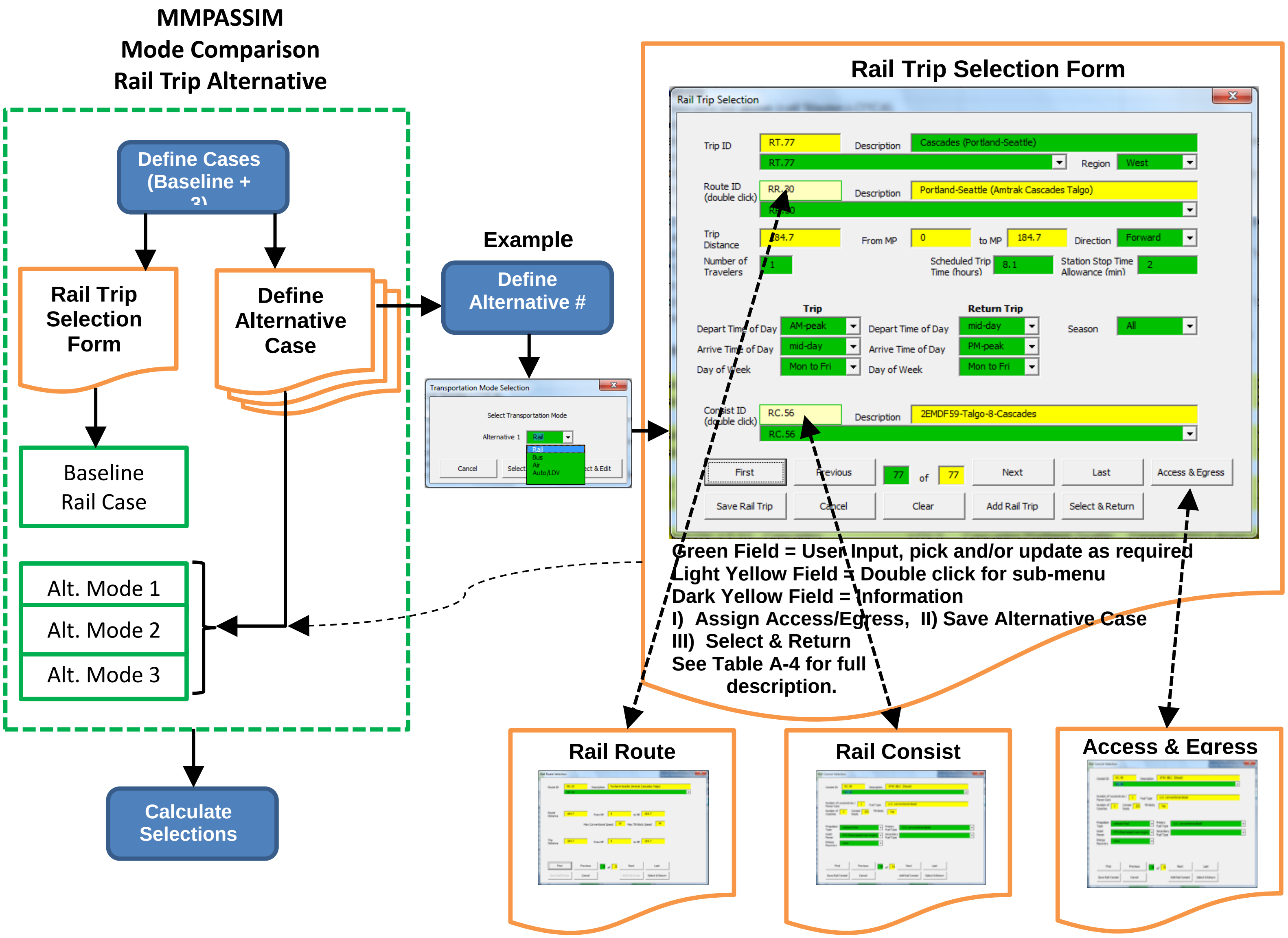
Green Field = User Input, pick and/or update as required
Light Yellow Field = Double click for sub-menu
Dark Yellow Field = Information
I) Assign Access/Egress, II) Save Alternative Case
III) Select & Return
See Table A-4 for full description.

Figure A-6 MMPASSIM Mode Comparison Baseline Rail Trip Configuration



Trip ID: RT.77
Description: Cascades (Portland-Seattle)
RT.77
Region: West
Route ID (double click): RR.30
Description: Portland-Seattle (Amtrak Cascades Talgo)
RR.30
Trip Distance: 184.7
From MP: 0
to MP: 184.7
Direction: Forward
Number of Travelers: 1
Scheduled Trip Time (hours): 8.1
Station Stop Time Allowance (min): 2

	Trip		Return Trip
Depart Time of Day	AM-peak	Depart Time of Day	mid-day
Arrive Time of Day	mid-day	Arrive Time of Day	PM-peak
Day of Week	Mon to Fri	Day of Week	Mon to Fri

Season: All
Consist ID (double click): RC.56
Description: 2EMDF59-Talgo-8-Cascades
RC.56
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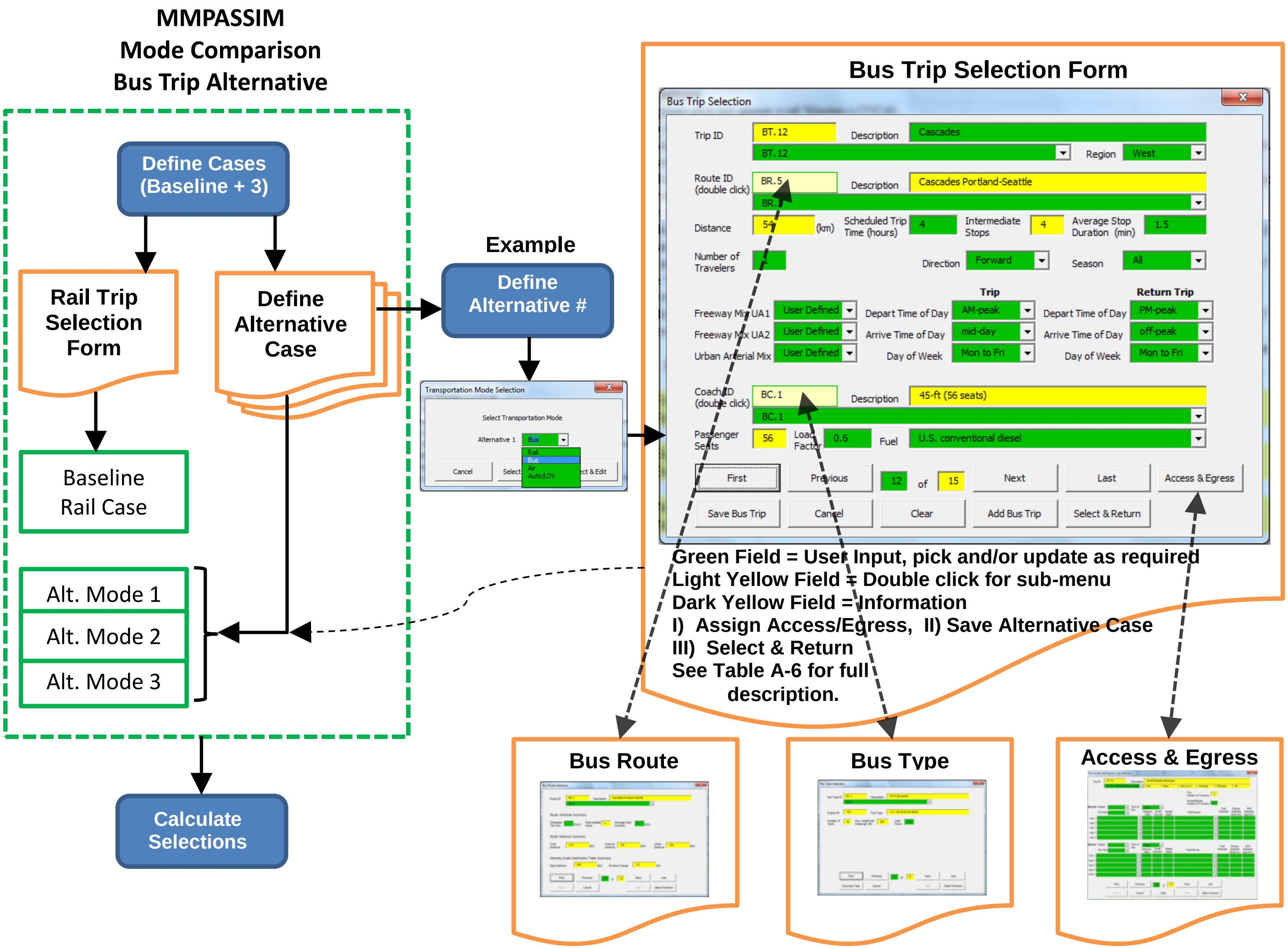
Green Field = User Input, pick and/or update as required
Light Yellow Field = Double click for sub-menu
Dark Yellow Field = Information
I) Assign Access/Egress, II) Save Alternative Case
III) Select & Return
See Table A-4 for full description.

Figure A-7 MMPASSIM Mode Comparison Alternative Rail Trip Configuration



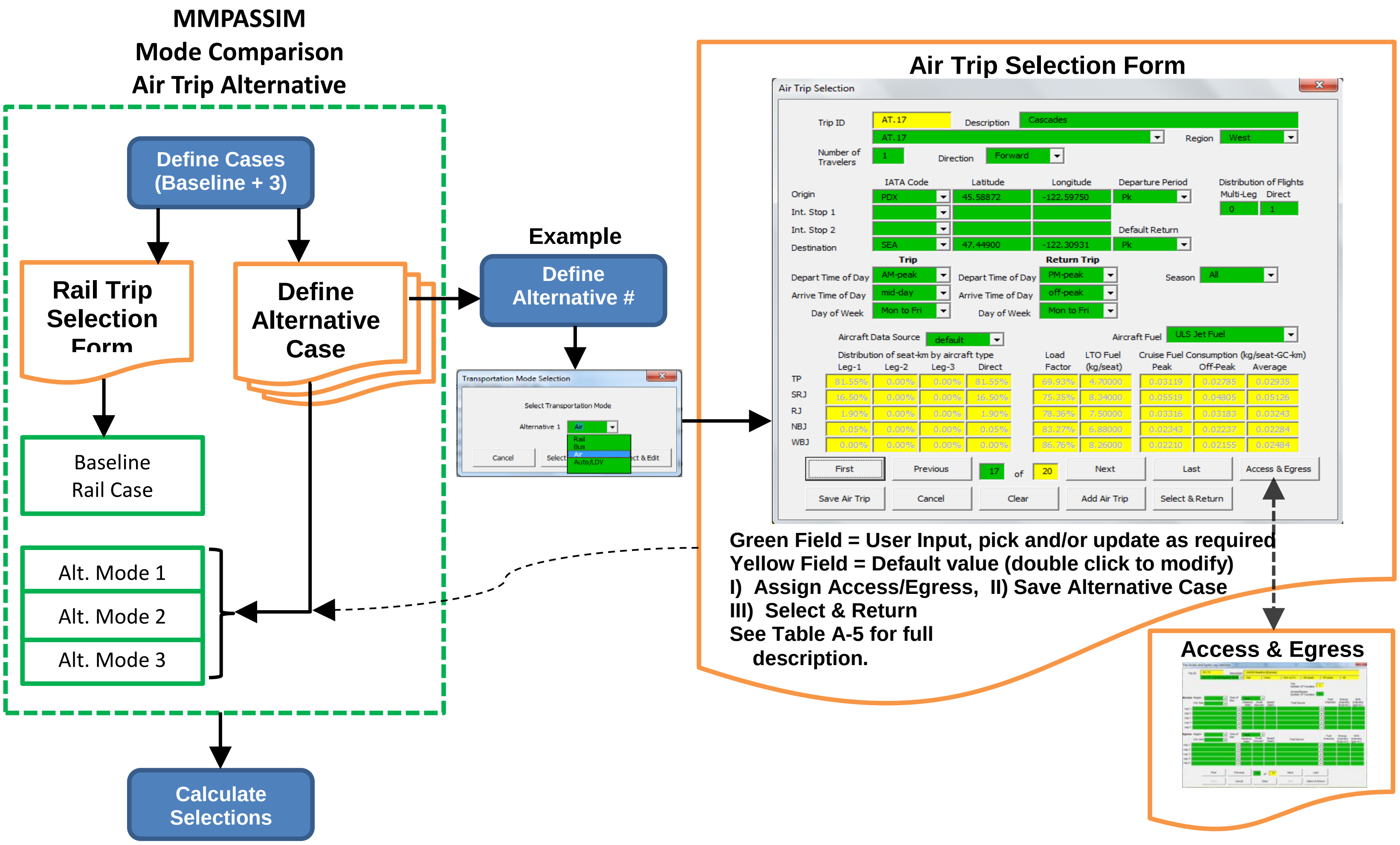
Trip ID: BT.12 Description: Cascades
BT.12 Region: West
Route ID (double click): BR.5 Description: Cascades Portland-Seattle
BR.5
Distance: 54 (km) Scheduled Trip Time (hours): 4 Intermediate Stops: 4 Average Stop Duration (min): 1.5
Number of Travelers: 1 Direction: Forward Season: All

		Trip		Return Trip	
Freeway Mix UA1	User Defined	Depart Time of Day	AM-peak	Depart Time of Day	PM-peak
Freeway Mix UA2	User Defined	Arrive Time of Day	mid-day	Arrive Time of Day	off-peak
Urban Arterial Mix	User Defined	Day of Week	Mon to Fri	Day of Week	Mon to Fri

Coach ID (double click): BC.1 Description: 45-ft (56 seats)
BC.1
Passenger Seats: 56 Load Factor: 0.6 Fuel: U.S. conventional diesel
12 of 15

Green Field = User Input, pick and/or update as required
Light Yellow Field = Double click for sub-menu
Dark Yellow Field = Information
I) Assign Access/Egress, II) Save Alternative Case
III) Select & Return
See Table A-6 for full description.

Figure A-8 MMPASSIM Mode Comparison Alternative Bus Trip Configuration



Alternative 1: Air

Trip ID: AT.17
Description: Cascades
AT.17
Region: West
Number of Travelers: 1
Direction: Forward

	IATA Code	Latitude	Longitude	Departure Period
Origin	PDX	45.58872	-122.59750	Pk
Int. Stop 1				
Int. Stop 2				
Destination	SEA	47.44900	-122.30931	Pk

Default Return (Destination): Pk

Distribution of Flights: Multi-Leg 0, Direct 1

Trip
Depart Time of Day: AM-peak
Arrive Time of Day: mid-day
Day of Week: Mon to Fri

Return Trip
Depart Time of Day: PM-peak
Arrive Time of Day: off-peak
Day of Week: Mon to Fri

Season: All
Aircraft Data Source: default
Aircraft Fuel: ULS Jet Fuel

	Distribution of seat-km by aircraft type Leg-1	Leg-2	Leg-3	Direct	Load Factor	LTO Fuel (kg/seat)	Cruise Fuel Consumption (kg/seat-GC-km) Peak	Off-Peak	Average
TP	81.55%	0.00%	0.00%	81.55%	69.93%	4.70000	0.03119	0.02785	0.02935
SRJ	16.50%	0.00%	0.00%	16.50%	75.35%	8.34000	0.05519	0.04805	0.05126
RJ	1.90%	0.00%	0.00%	1.90%	78.36%	7.50000	0.03316	0.03183	0.03243
NBJ	0.05%	0.00%	0.00%	0.05%	83.27%	6.88000	0.02343	0.02237	0.02284
WBJ	0.00%	0.00%	0.00%	0.00%	86.76%	8.26000	0.02210	0.02155	0.02484

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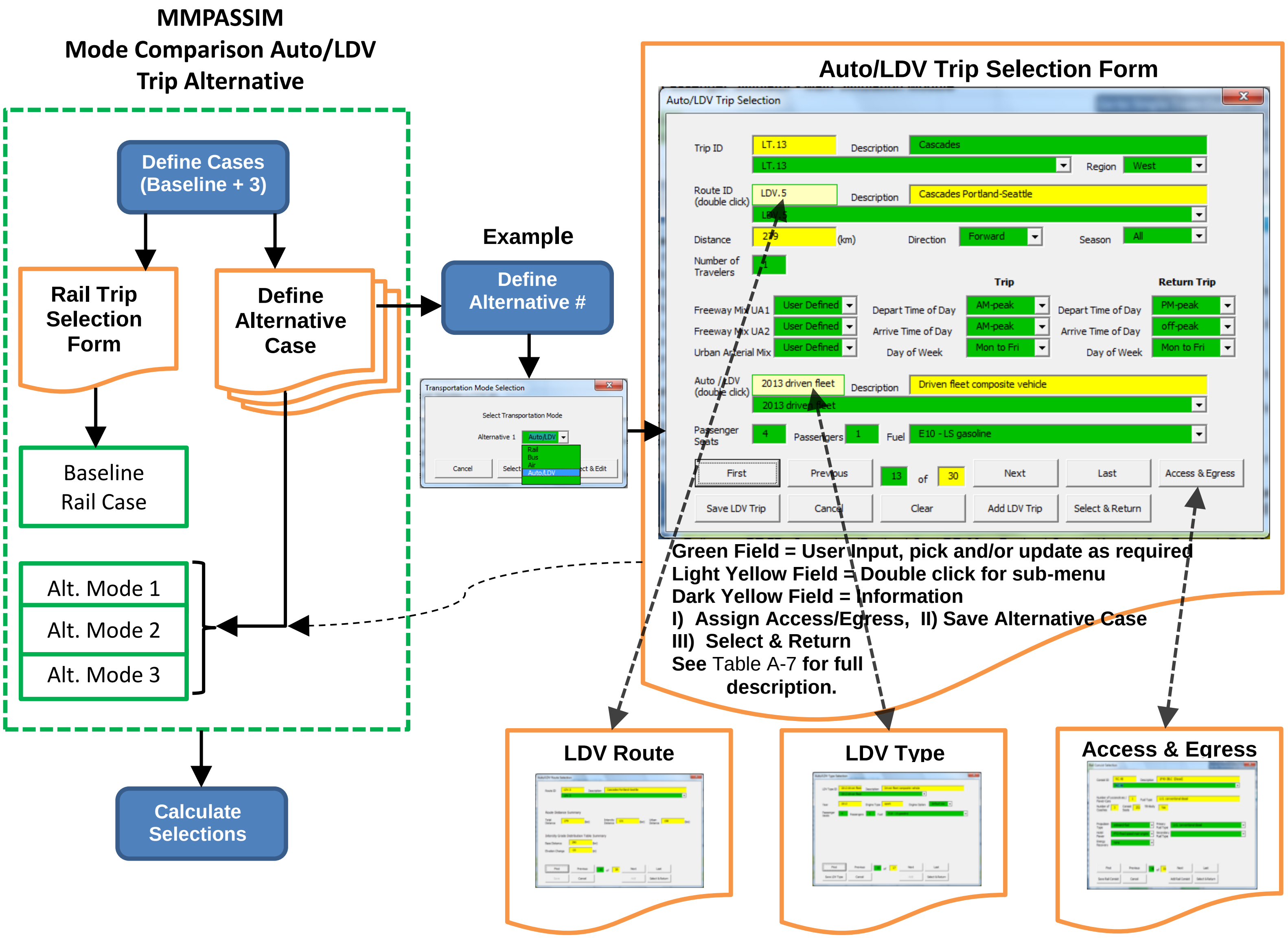
Green Field = User Input, pick and/or update as required
Yellow Field = Default value (double click to modify)
I) Assign Access/Egress, II) Save Alternative Case
III) Select & Return
See Table A-5 for full description.

Figure A-9 MMPASSIM Mode Comparison Alternative Air Trip Configuration



Trip ID: LT.13 — Description: Cascades
LT.13 — Region: West
Route ID (double click): LDV.5 — Description: Cascades Portland-Seattle
LDV.5
Distance: 279 (km) — Direction: Forward — Season: All
Number of Travelers: 1

	Trip	Return Trip
Freeway Mix UA1: User Defined	Depart Time of Day: AM-peak	Depart Time of Day: PM-peak
Freeway Mix UA2: User Defined	Arrive Time of Day: AM-peak	Arrive Time of Day: off-peak
Urban Arterial Mix: User Defined	Day of Week: Mon to Fri	Day of Week: Mon to Fri

Auto / LDV (double click): 2013 driven fleet — Description: Driven fleet composite vehicle
2013 driven fleet
Passenger Seats: 4 — Passengers: 1 — Fuel: E10 - LS gasoline
13 of 30

Green Field = User Input, pick and/or update as required
Light Yellow Field = Double click for sub-menu
Dark Yellow Field = Information
I) Assign Access/Egress, II) Save Alternative Case
III) Select & Return
See Table A-7 **for full description.**

Figure A-10 MMPASSIM Mode Comparison Alternative Auto/Light Duty Vehicle Trip Configuration

A.4 Building Simple Trips from Limited Information

This section provides guidance on building simple rail, bus and light duty vehicle trips with the minimum amount of input data. For rail trips, a simple train consist may be built by selecting from basic locomotive and car types. For rail and highway modes, simple routes can be created by specifying a trip distance and average speed and MMPASSIM will then create a properly formatted mode-specific route using default values.

A.4.1 Building a Simple Rail Trip

The ‘Build-Simple-Rail-Trip’ worksheet provides a straight forward method of creating a rail trip when little specific information is known about the train makeup and route. Figure A-11 depicts the layout of the worksheet. The light green box on the right hand side provides a brief list of instructions to follow. The process involves:

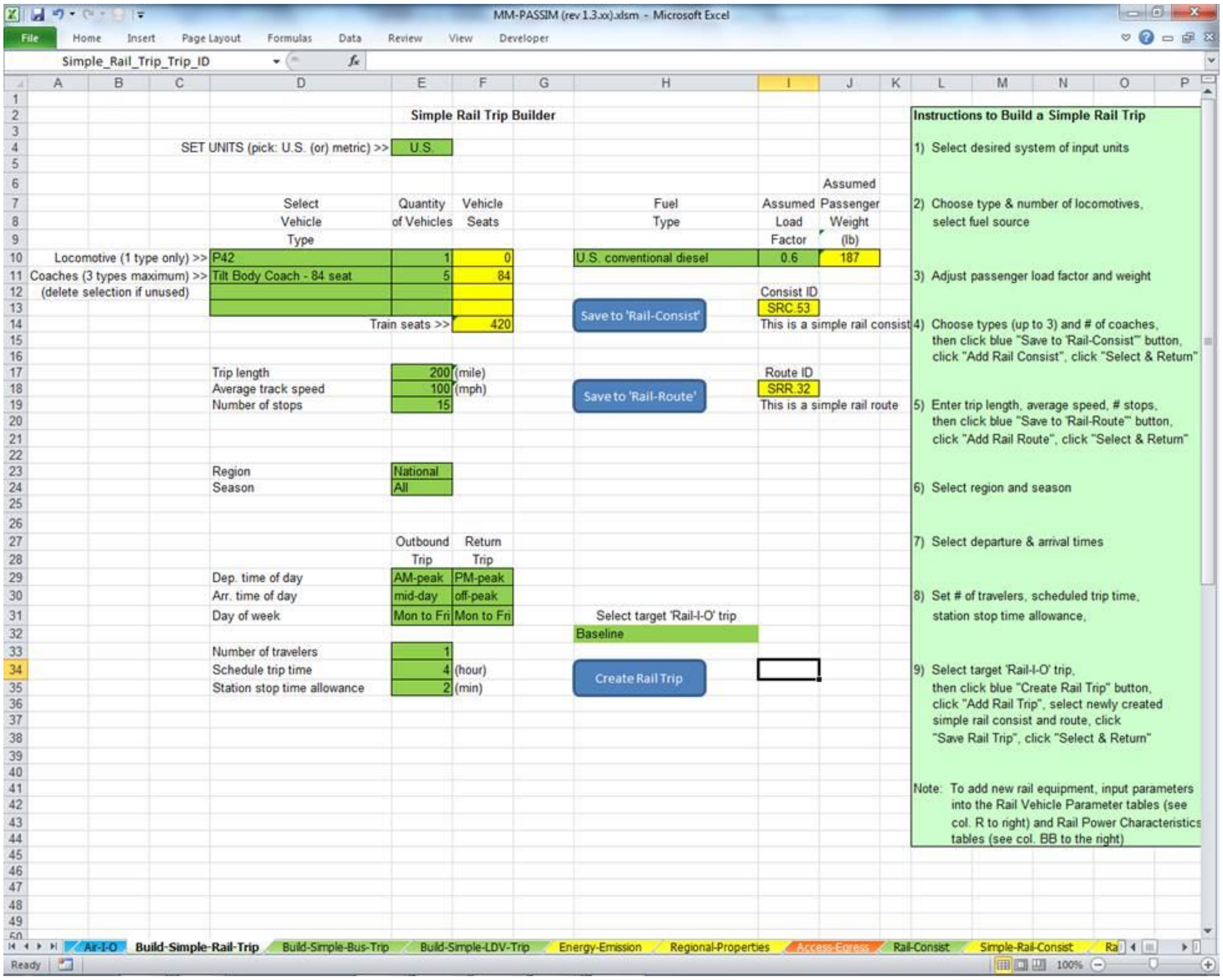
1) Selecting the vehicles in a rail consist and then creating a simple rail consist by clicking on the blue “Save to ‘Rail-Consist’” button.
2) Specifying the trip distance, speed limit and number of stops to be made during the trip and then creating a simple rail route by clicking on the blue “Save to ‘Rail-Route’” button.
3) Specifying other trip parameters such as region, season, departure and arrival times and the scheduled trip time and then creating the trip by clicking on the blue “Create Rail Trip” button.

Defining the Simple Rail Consist

To build a simple rail consist, begin by selecting a system of units from the green pulldown list located at ‘Build-Simple-Rail-Trip’!E4. Then, select a locomotive type from the green pulldown list at ‘Build-Simple-Rail-Trip’!D10. Please note that there can only be one type of locomotive included in a simple rail consist, but you may select multiple units in the green quantity field at ‘Build-Simple-Rail-Trip’!E10. For most locomotive types the number of passenger seats indicated in the yellow information field at ‘Build-Simple-Rail-Trip’!F10 will be zero. However, self-propelled vehicles, such as rail diesel cars (RDC) and diesel multiple units (DMU), are treated as locomotives with passenger seats. Select the desired locomotive fuel type from the green pulldown list at ‘Build-Simple-Rail-Trip’!H10.

You can continue to build up a simple rail consist by selecting up to three types of rail coaches from the pulldown lists at ‘Build-Simple-Rail-Trip’!D11:D13 and specifying the quantity of each of those coaches in the adjacent green fields located in cells ‘Build-Simple-Rail-Trip’!E11:E13. The number of passenger seats in each of the selected rail coach types is indicated in the yellow information cells at ‘Build-Simple-Rail-Trip’!F11:F13 while the total number of passenger seats in the train consist is indicated in the yellow cell at ‘Build-Simple-Rail-Trip’!F14.

The final inputs required to specify a simple rail consist are the passenger load factor, input in the green cell at ‘Build-Simple-Rail-Trip’!I10, and the passenger weight (including all luggage), indicated in the yellow cell at ‘Build-Simple-Rail-Trip’!J10. Please be aware that a default passenger weight of 85 kg is used to calculate the passenger weight which is displayed in the selected system of units. You may adjust the calculated value by editing the formula but do not simply overwrite the contents of the cell with a value.



Simple Rail Trip Builder

SET UNITS (pick: U.S. (or) metric) >> U.S.

	Select Vehicle Type	Quantity of Vehicles	Vehicle Seats	Fuel Type	Assumed Load Factor	Assumed Passenger Weight (lb)
Locomotive (1 type only) >>	P42	1	0	U.S. conventional diesel	0.6	187
Coaches (3 types maximum) >>	Tilt Body Coach - 84 seat	5	84			
(delete selection if unused)						
		Train seats >>	420			

Consist ID: SRC.53
This is a simple rail consist

Trip length 200 (mile)
Average track speed 100 (mph)
Number of stops 15

Route ID: SRR.32
This is a simple rail route

Region National
Season All

	Outbound Trip	Return Trip
Dep. time of day	AM-peak	PM-peak
Arr. time of day	mid-day	off-peak
Day of week	Mon to Fri	Mon to Fri

Select target 'Rail-I-O' trip: Baseline

Number of travelers 1
Schedule trip time 4 (hour)
Station stop time allowance 2 (min)

Instructions to Build a Simple Rail Trip

1) Select desired system of input units
2) Choose type & number of locomotives, select fuel source
3) Adjust passenger load factor and weight
4) Choose types (up to 3) and # of coaches, then click blue "Save to 'Rail-Consist'" button, click "Add Rail Consist", click "Select & Return"
5) Enter trip length, average speed, # stops, then click blue "Save to 'Rail-Route'" button, click "Add Rail Route", click "Select & Return"
6) Select region and season
7) Select departure & arrival times
8) Set # of travelers, scheduled trip time, station stop time allowance,
9) Select target 'Rail-I-O' trip, then click blue "Create Rail Trip" button, click "Add Rail Trip", select newly created simple rail consist and route, click "Save Rail Trip", click "Select & Return"

Note: To add new rail equipment, input parameters into the Rail Vehicle Parameter tables (see col. R to right) and Rail Power Characteristics tables (see col. BB to the right)

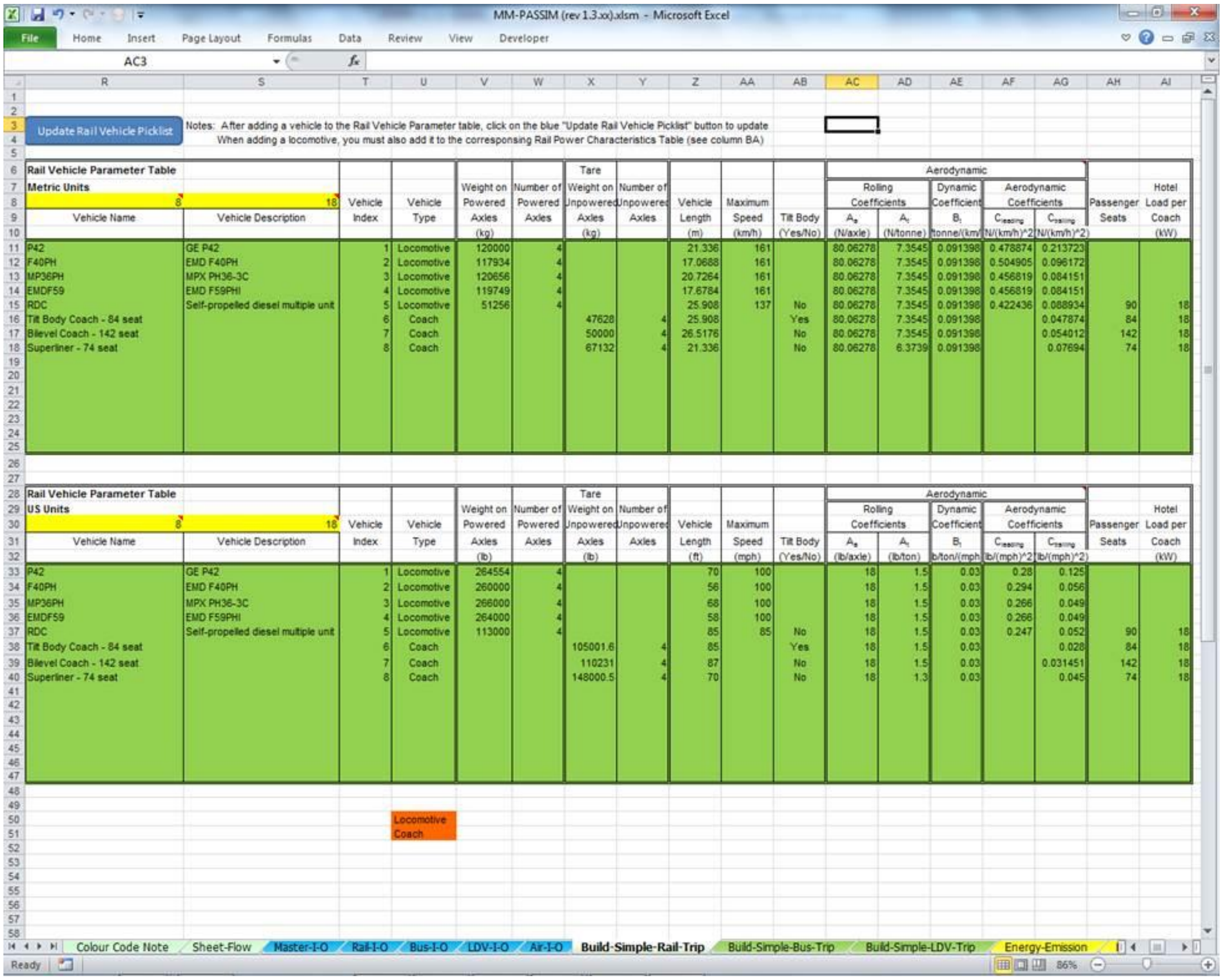
Figure A-11 'Build-Simple-Rail-Trip' Worksheet

Clicking the blue “Save to ‘Rail-Consist’” button displays a ‘Simple Rail Consist Specification’ menu. You may interactively adjust the vehicle selections and quantities and the passenger load factor in the appropriately labeled green fields. You may also adjust the fuel type to be used onboard the locomotive and the method by which hotel power is generated. However, you may not change the propulsion type from “onboard-fuel”. Once all desired adjustments have been made you should input a description of the train consist in the green “Description” field at the top of the menu and then click on the gray “Add Rail Consist” button to instruct a VBA macro to add the displayed simple rail consist into the list of consists defined in the ‘Rail-Consist’ worksheet. Clicking the gray “Select & Return” button will close the menu and record the automatically assigned “Consist ID” and description to cells ‘Build-Simple-Rail-Trip’!I13 and ‘Build-Simple-Rail-Trip’!I14, respectively.

While in the ‘Simple Rail Consist Specification’ menu, you may create as many simple rail consists as you wish by changing the selections as desired, entering a new consist description in the green field at the top and then clicking on the gray “Add Rail Consist” button. The yellow “Consist ID” information field will be automatically incremented to a new unique value and written to the “Consist ID” at the top (in row 3) of the newly added rail consist in the ‘Rail-

Consist' worksheet (refer to Section A.7.3 for more details on the content of the 'Rail-Consist' worksheet). However, it is not possible to automatically alter the composition of a simple rail consist once it has been added into the 'Rail-Consist' worksheet. This is a consequence of how the simple rail consist is built in the 'Simple-Rail-Consist' worksheet and the fact that cells which calculate the combined properties of an entire consist are copied by value into destination cells in the 'Rail-Consist' worksheet.

The 'Simple-Rail-Consist' worksheet provides a template of the rail consist data which is copied into the 'Rail-Consist' worksheet. Many of the data fields in the 'Simple-Rail-Consist' are calculated by formulas which combine the properties of the individual rail vehicle types as selected on the 'Build-Simple-Rail-Trip' pulldown lists. The parameters defining the characteristics of individual rail vehicles are specified in two "Rail Vehicle Parameter" tables located on the 'Build-Simple-Rail-Trip' worksheet at 'Build-Simple-Rail-Trip'!R6:AI25 for metric units and at 'Build-Simple-Rail-Trip'!R28:AI47 for U.S. units (see Figure A-12).



Notes: After adding a vehicle to the Rail Vehicle Parameter table, click on the blue "Update Rail Vehicle Picklist" button to update
When adding a locomotive, you must also add it to the corresponsing Rail Power Characteristics Table (see column BA)

Rail Vehicle Parameter Table
Metric Units
8 18

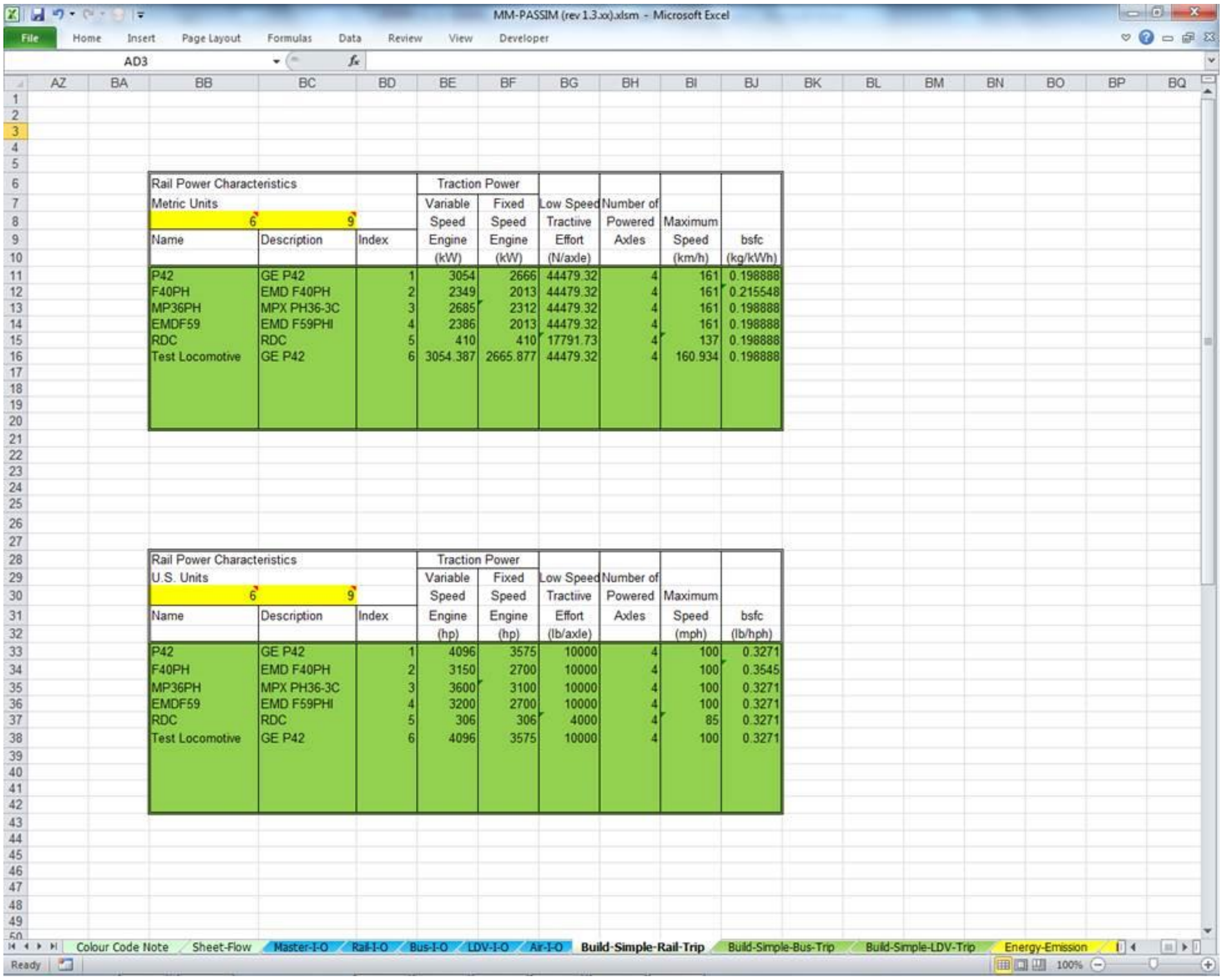
Vehicle Name	Vehicle Description	Vehicle Index	Vehicle Type	Weight on Powered Axles (kg)	Number of Powered Axles	Tare Weight on Unpowered Axles (kg)	Number of Unpowered Axles	Vehicle Length (m)	Maximum Speed (km/h)	Tilt Body (Yes/No)	Aerodynamic Rolling Coefficients A_a (N/axle)	Aerodynamic Rolling Coefficients A_t (N/tonne)	Aerodynamic Dynamic Coefficient B_t tonne/(km/	Aerodynamic Aerodynamic Coefficients $C_{leading}$ N/(km/h)^2	Aerodynamic Aerodynamic Coefficients $C_{trailing}$ N/(km/h)^2)	Passenger Seats	Hotel Load per Coach (kW)
P42	GE P42	1	Locomotive	120000	4			21.336	161		80.06278	7.3545	0.091398	0.478874	0.213723		
F40PH	EMD F40PH	2	Locomotive	117934	4			17.0688	161		80.06278	7.3545	0.091398	0.504905	0.096172		
MP36PH	MPX PH36-3C	3	Locomotive	120656	4			20.7264	161		80.06278	7.3545	0.091398	0.456819	0.084151		
EMDF59	EMD F59PHI	4	Locomotive	119749	4			17.6784	161		80.06278	7.3545	0.091398	0.456819	0.084151		
RDC	Self-propelled diesel multiple unit	5	Locomotive	51256	4			25.908	137	No	80.06278	7.3545	0.091398	0.422436	0.088934	90	18
Tilt Body Coach - 84 seat		6	Coach			47628	4	25.908		Yes	80.06278	7.3545	0.091398		0.047874	84	18
Bilevel Coach - 142 seat		7	Coach			50000	4	26.5176		No	80.06278	7.3545	0.091398		0.054012	142	18
Superliner - 74 seat		8	Coach			67132	4	21.336		No	80.06278	6.3739	0.091398		0.07694	74	18

Rail Vehicle Parameter Table
US Units
8 18

Vehicle Name	Vehicle Description	Vehicle Index	Vehicle Type	Weight on Powered Axles (lb)	Number of Powered Axles	Tare Weight on Unpowered Axles (lb)	Number of Unpowered Axles	Vehicle Length (ft)	Maximum Speed (mph)	Tilt Body (Yes/No)	Aerodynamic Rolling Coefficients A_a (lb/axle)	Aerodynamic Rolling Coefficients A_t (lb/ton)	Aerodynamic Dynamic Coefficient B_t lb/ton/(mph	Aerodynamic Aerodynamic Coefficients $C_{leading}$ lb/(mph)^2	Aerodynamic Aerodynamic Coefficients $C_{trailing}$ lb/(mph)^2)	Passenger Seats	Hotel Load per Coach (kW)
P42	GE P42	1	Locomotive	264554	4			70	100		18	1.5	0.03	0.28	0.125		
F40PH	EMD F40PH	2	Locomotive	260000	4			56	100		18	1.5	0.03	0.294	0.056		
MP36PH	MPX PH36-3C	3	Locomotive	266000	4			68	100		18	1.5	0.03	0.266	0.049		
EMDF59	EMD F59PHI	4	Locomotive	264000	4			58	100		18	1.5	0.03	0.266	0.049		
RDC	Self-propelled diesel multiple unit	5	Locomotive	113000	4			85	85	No	18	1.5	0.03	0.247	0.052	90	18
Tilt Body Coach - 84 seat		6	Coach			105001.6	4	85		Yes	18	1.5	0.03		0.028	84	18
Bilevel Coach - 142 seat		7	Coach			110231	4	87		No	18	1.5	0.03		0.031451	142	18
Superliner - 74 seat		8	Coach			148000.5	4	70		No	18	1.3	0.03		0.045	74	18

Figure A-12 The Simple Rail Vehicle Parameter Tables

The list of rail vehicles available for use in building simple rail consist may be easily expanded by adding data into these data tables. When adding new vehicle parameters, you must be sure to select the vehicle type (column U) to be either “Locomotive” or “Coach” and then click on the blue “Update Rail Vehicle List” button which instructs a VBA macro to update the sorted lists of locomotive and coaches available in both metric and U.S. units. Guidance in developing suitable resistance coefficients is provided in the light green shaded area at ‘Build-Simple-Rail-Trip’!AL6:AY68. The power characteristics of each vehicle identified as a “Locomotive” in a “Rail Vehicle Parameter” table must also be defined in the corresponding “Rail Power Characteristics” table located at ‘Build-Simple-Rail-Trip’!BB6:BJ20’ in metric units and ‘Build-Simple-Rail-Trip’!BB28:BB42 in U.S. units (see Figure A-13). The name specified for each locomotive in column R of a “Rail Vehicle Parameter” table must also be defined in column BB of the companion “Rail Power Characteristics” table.



Rail Power Characteristics
Metric Units
6 9

Name	Description	Index	Traction Power Variable Speed Engine (kW)	Fixed Speed Engine (kW)	Low Speed Tractive Effort (N/axle)	Number of Powered Axles	Maximum Speed (km/h)	bsfc (kg/kWh)
P42	GE P42	1	3054	2666	44479.32	4	161	0.198888
F40PH	EMD F40PH	2	2349	2013	44479.32	4	161	0.215548
MP36PH	MPX PH36-3C	3	2685	2312	44479.32	4	161	0.198888
EMDF59	EMD F59PHI	4	2386	2013	44479.32	4	161	0.198888
RDC	RDC	5	410	410	17791.73	4	137	0.198888
Test Locomotive	GE P42	6	3054.387	2665.877	44479.32	4	160.934	0.198888

Rail Power Characteristics
U.S. Units
6 9

Name	Description	Index	Traction Power Variable Speed Engine (hp)	Fixed Speed Engine (hp)	Low Speed Tractive Effort (lb/axle)	Number of Powered Axles	Maximum Speed (mph)	bsfc (lb/hph)
P42	GE P42	1	4096	3575	10000	4	100	0.3271
F40PH	EMD F40PH	2	3150	2700	10000	4	100	0.3545
MP36PH	MPX PH36-3C	3	3600	3100	10000	4	100	0.3271
EMDF59	EMD F59PHI	4	3200	2700	10000	4	100	0.3271
RDC	RDC	5	306	306	4000	4	85	0.3271
Test Locomotive	GE P42	6	4096	3575	10000	4	100	0.3271

Figure A-13 The Simple Rail Power Characteristics Table

Defining the Simple Rail Route

To build a simple rail route, a user must specify the trip's length in the green cell 'Build-Simple-Rail-Trip'!E17, the average track speed (interpreted as the track speed limit) in the green cell 'Build-Simple-Rail-Trip'!E18 and the total number of stops to be made in the green cell 'Build-Simple-Rail-Trip'!19. These user inputs are used in the 'Simple-Rail-Route' worksheet to define the default stop table and speed limit table. The default speed limit table in the 'Simple-Rail-Route' worksheet is constructed assuming an initial half mile segment with a 15 mph speed limit, a final half mile segment with a 15 mph speed limit and the middle segment between these end segments set to the user indicated average track speed. The initial location is always set to 0 miles and the final location in set to the user assigned trip length in miles (as converted when specified in kilometers). The default stop table is constructed by assuming that each stop is evenly spaced along the trip's length. It is assumed that the track in a simple rail route is both level and straight, so the grade table is populated with zeros and the total degrees of central angle is also zero.

Clicking the blue "Save to 'Rail-Route'" button displays the 'Simple Rail Route Specification' menu. The trip length, average track speed and number of stops to be used in building the simple rail route are displayed in the correspondingly labeled green input fields, each of which can be modified interactively by the user. A simple rail route is built by entering a description in the green "Description" field at the top of the menu and clicking the gray "Add Rail Route" button which instructs a VBA macro to create a unique "Route ID" and copy the simple rail route template from 'Simple-Rail-Route' to the next available location in the 'Rail-Route' worksheet. The yellow "Route ID" field and the green "Description" field are copied to the top of the newly created route in the 'Rail-Route' worksheet. While in the 'Simple Rail Route Specification' menu a user may create and add as many simple rail routes as they wish by adjusting the length, speed and number of stops and clicking the gray "Add Rail Route" button. Clicking the gray "Select & Return" button will close the menu and record the automatically assigned "Route ID" and user assigned "Description" to cells 'Build-Simple-Rail-Trip'!I18 and 'Build-Simple-Rail-Trip'!I19, respectively.

Creating the Simple Rail Trip

With both a simple rail consist and a simple rail route built and added, the user must provide additional details of the desired trip to complete its' specification. The geographical region is set by selecting it from the green pulldown list at 'Build-Simple-Rail-Trip'!E23. The season is selected from the green pulldown list at 'Build-Simple-Rail-Trip'!E24. Selecting "All" for the season will result in the rail simulation calculating a combined result for individual trips made in each season and weighted for the seasonal traffic distributions specified in the 'Regional-Properties' worksheet. The departure time-of-day, arrival time-of-day and day-of-week of the outbound trip are selected from the green pulldown lists at 'Build-Simple-Rail-Trip'!E29:E31 while those same inputs for the return trip are selected from 'Build-Simple-Rail-Trip'!F29:F31. The number of people assumed to be traveling together in a party is input in the green input cell at 'Build-Simple-Rail-Trip'!E33. Finally, the scheduled trip time is input in the green cell at 'Build-Simple-Rail-Trip'!E34 while the station stop time allowance is input at 'Build-Simple-Rail-Trip'!E35.

Clicking on the blue "Create Rail Trip" button brings the 'Rail-I-O' worksheet into view and displays the 'Rail Trip Selection' menu preloaded with the simple rail route, simple rail consist and simple rail trip specifications transferred from the 'Build-Simple-Rail-Trip' worksheet. From that menu, the new trip is created by clicking the gray "Add Rail Trip" button which creates and displays a unique rail trip ID in the yellow “Trip ID” field in the top left of the menu. Enter a description for this new simple rail trip in the green “Description” field at the top of the menu and then click the gray “Save Rail Trip” to write it onto the bottom of the list or rail trips stored in the ‘Rail-Trip-List’ worksheet.

> ***Note:*** T*he new trip will not be automatically saved if the “Save Rail Trip” button is not clicked. Clicking on the gray “Select & Return” button will populate the rail trip fields on the ‘Rail-I-O’ worksheet. The particular rail trip to be saved to (either Baseline, Alternative-1, Alternative-2 or Alternative-3) is controlled by the target ‘Rail-I-O’ trip as selected from the green pulldown list at ‘Simple-Rail-Trip-Builder’!H32.*

A.4.2 Building a Simple Bus Trip

The ‘Build-Simple-Bus-Trip’ worksheet provides a simple means to create a basic bus trip. Figure A-14 depicts the worksheet layout. The light green box on the right hand side (‘Build-Simple-Bus-Trip’!K5:O43) provides a brief list of instructions to follow. The process involves:

1) Selecting the bus.
2) Specifying the distances traveled, speed limit, number of intermediate stops, duration of stops, origin and destination urban area sizes, trip departure and arrival periods, scheduled trip time and then creating a simple bus route by clicking on the blue “Save to ‘Bus-Route’” button.
3) Specifying other trip parameters such as region, season, number of persons travelling together in a party and then creating the trip by clicking on the blue “Create Bus Trip” button.

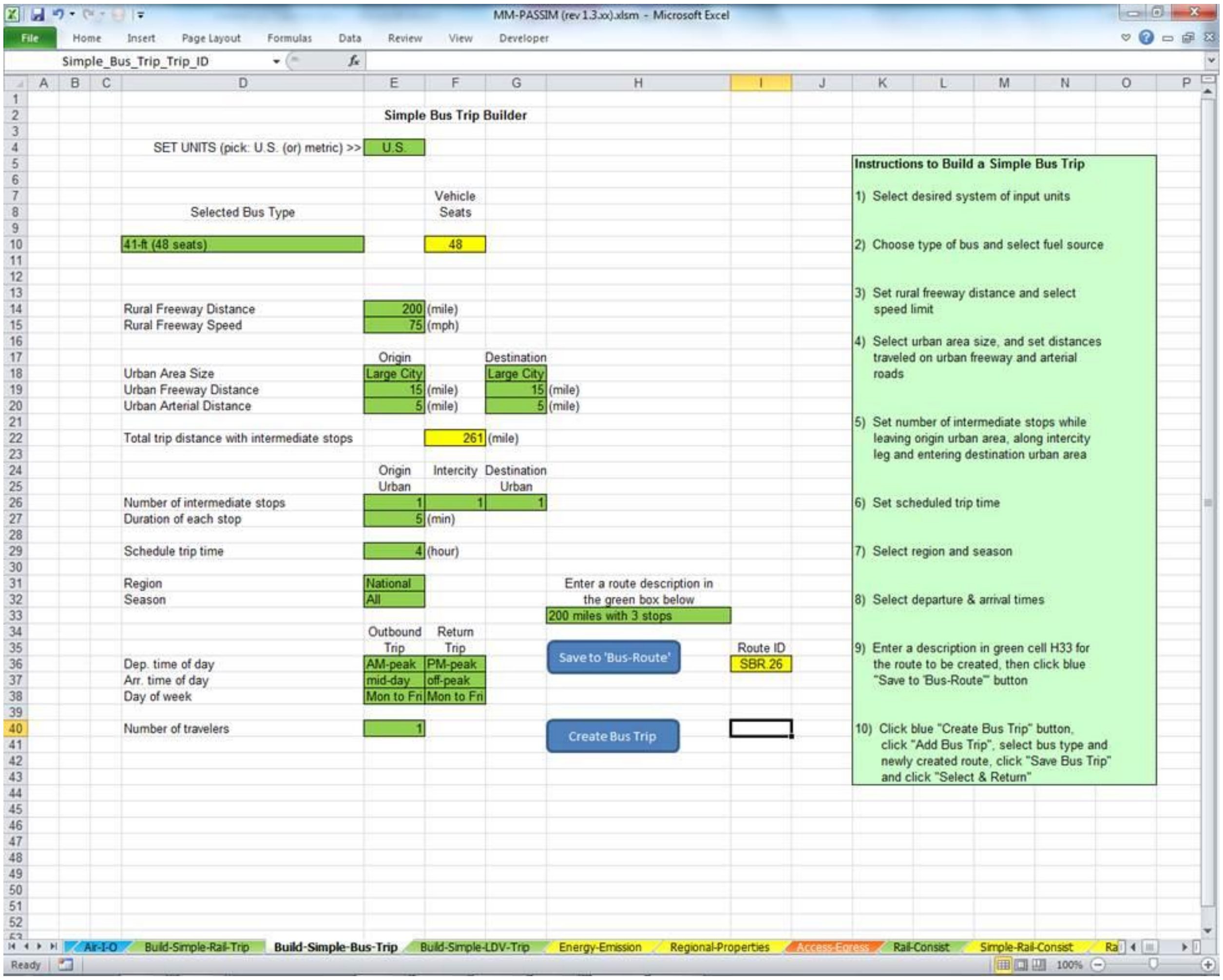
Selecting a Bus Type

To build a simple bus trip, begin by selecting a system of units from the green pulldown list located at ‘Build-Simple-Bus-Trip’!E4. Then, select a bus type from the green pulldown list at cell ‘Build-Simple-Bus-Trip’!D10. Default parameters appropriate for the selected bus type will be used for the simple bus trip. These parameters may be reviewed in the yellow information cells at ‘Build-Simple-Bus-Trip’!Q10:X10 (page to the right).

The list of bus types available in the green pulldown list at ‘Build-Simple-Bus-Trip’!D10 and their corresponding default parameters are defined in two Excel VLOOKUP tables; ‘Build-Simple-Bus-Trip’!Q15:X24 when U.S. units are selected and ‘Build-Simple-Bus-Trip’!Q31:X40 when metric units are selected (see Figure A-15). These two tables are populated by cell references to source data contained in the ‘Bus-Type’ worksheet. MMPASSIM provides U.S. and metric parameters for four (4) representative buses which include:

- a 45 foot bus with 56 seats
- a 41 foot bus with 48 seats
- a double deck bus with 81 seats
- a hybrid commuter bus with 57 seats

Users may expand the list of buses available for selection in the ‘Build-Simple-Bus-Trip’ by adding data into the ‘Bus-Type’ worksheet (see Section A.7.8 on page A-146 for an explanation of layout and content) and then adding lines of cell references into these VLOOKUP tables. The VLOOKUP statements used in cell formulas are constructed using offsets which automatically adjust when new lines of bus type data are added.



Simple Bus Trip Builder

SET UNITS (pick: U.S. (or) metric) >> U.S.

Selected Bus Type	Vehicle Seats
41-ft (48 seats)	48

Rural Freeway Distance 200 (mile)
Rural Freeway Speed 75 (mph)

	Origin		Destination	
Urban Area Size	Large City		Large City	
Urban Freeway Distance	15	(mile)	15	(mile)
Urban Arterial Distance	5	(mile)	5	(mile)

Total trip distance with intermediate stops 261 (mile)

	Origin Urban	Intercity	Destination Urban
Number of intermediate stops	1	1	1
Duration of each stop	5	(min)	

Schedule trip time 4 (hour)

Region National
Season All

Enter a route description in the green box below
200 miles with 3 stops

	Outbound Trip	Return Trip
Dep. time of day	AM-peak	PM-peak
Arr. time of day	mid-day	off-peak
Day of week	Mon to Fri	Mon to Fri

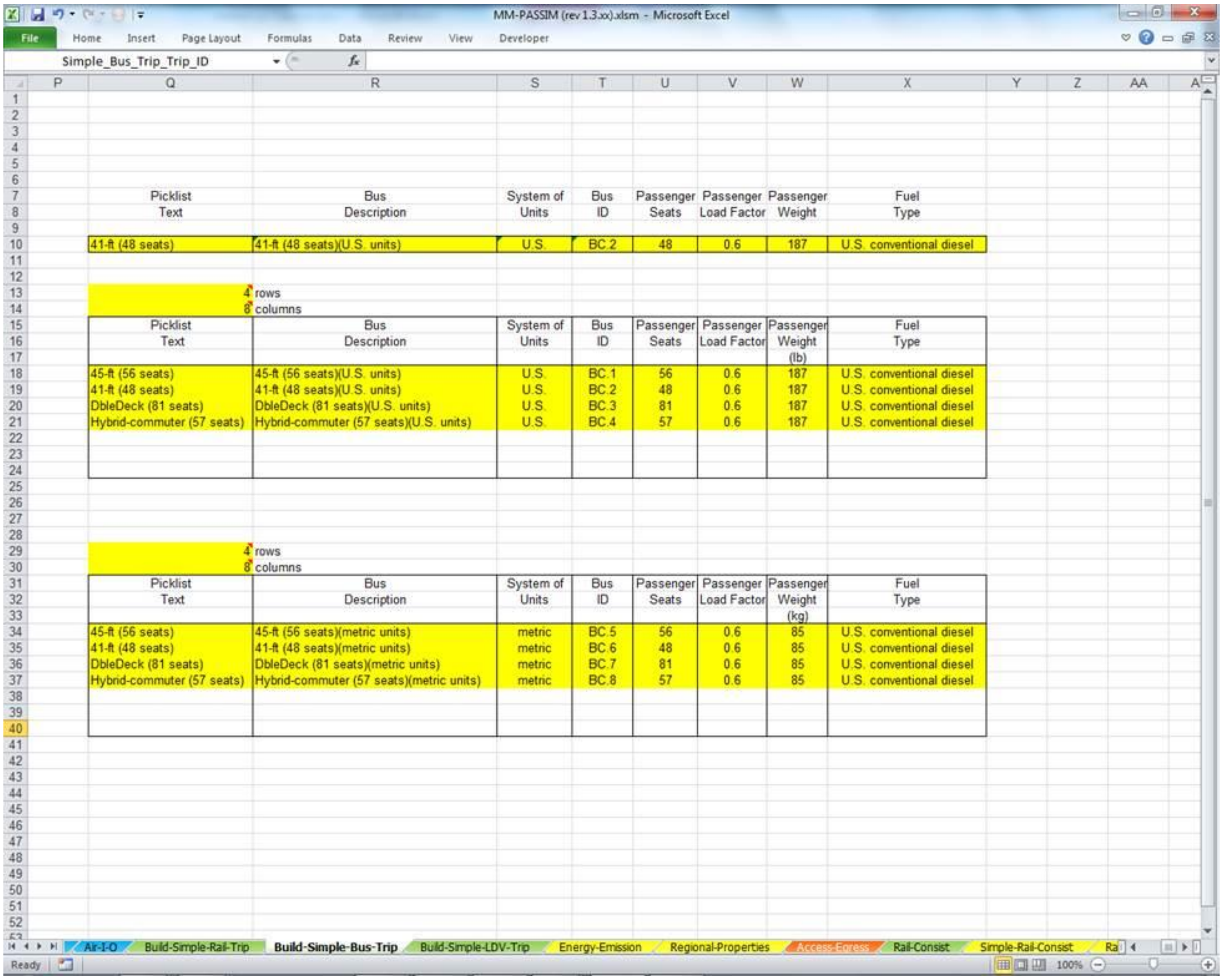
Route ID SBR 26

Number of travelers 1

Instructions to Build a Simple Bus Trip

1) Select desired system of input units
2) Choose type of bus and select fuel source
3) Set rural freeway distance and select speed limit
4) Select urban area size, and set distances traveled on urban freeway and arterial roads
5) Set number of intermediate stops while leaving origin urban area, along intercity leg and entering destination urban area
6) Set scheduled trip time
7) Select region and season
8) Select departure & arrival times
9) Enter a description in green cell H33 for the route to be created, then click blue "Save to 'Bus-Route'" button
10) Click blue "Create Bus Trip" button, click "Add Bus Trip", select bus type and newly created route, click "Save Bus Trip" and click "Select & Return"

Figure A-14 The 'Build-Simple-Bus-Trip' Worksheet



Picklist Text	Bus Description	System of Units	Bus ID	Passenger Seats	Passenger Load Factor	Passenger Weight	Fuel Type
41-ft (48 seats)	41-ft (48 seats)(U.S. units)	U.S.	BC.2	48	0.6	187	U.S. conventional diesel

4 rows
8 columns

Picklist Text	Bus Description	System of Units	Bus ID	Passenger Seats	Passenger Load Factor	Passenger Weight (lb)	Fuel Type
45-ft (56 seats)	45-ft (56 seats)(U.S. units)	U.S.	BC.1	56	0.6	187	U.S. conventional diesel
41-ft (48 seats)	41-ft (48 seats)(U.S. units)	U.S.	BC.2	48	0.6	187	U.S. conventional diesel
DbleDeck (81 seats)	DbleDeck (81 seats)(U.S. units)	U.S.	BC.3	81	0.6	187	U.S. conventional diesel
Hybrid-commuter (57 seats)	Hybrid-commuter (57 seats)(U.S. units)	U.S.	BC.4	57	0.6	187	U.S. conventional diesel

4 rows
8 columns

Picklist Text	Bus Description	System of Units	Bus ID	Passenger Seats	Passenger Load Factor	Passenger Weight (kg)	Fuel Type
45-ft (56 seats)	45-ft (56 seats)(metric units)	metric	BC.5	56	0.6	85	U.S. conventional diesel
41-ft (48 seats)	41-ft (48 seats)(metric units)	metric	BC.6	48	0.6	85	U.S. conventional diesel
DbleDeck (81 seats)	DbleDeck (81 seats)(metric units)	metric	BC.7	81	0.6	85	U.S. conventional diesel
Hybrid-commuter (57 seats)	Hybrid-commuter (57 seats)(metric units)	metric	BC.8	57	0.6	85	U.S. conventional diesel

Figure A-15 The Simple Bus Type VLOOKUP Tables

Creating a Simple Bus Route

To specify a simple bus route, you must first determine the overall trip distance and then divide that distance into 5 individual distances traveled on the following road types:

- Origin urban area freeways
- Origin urban area arterial roads
- Rural freeways (outside of the origin and destination urban areas)
- Destination urban area freeways
- Destination urban area arterial roads

Enter the distance traveled along rural freeways (between the origin and destination urban areas) into the green cell at ‘Build-Simple-Bus-Trip’!E14 and select the most appropriate speed limit from the green pulldown list at ‘Build-Simple-Bus-Trip’!E15. Note that the rural freeway speed limits are provided in 5 mph increments between 60 and 75 mph, or when using metric units those values are converted to km/h. Choose the value closest to the anticipated speed of travel.

Select the size of the origin urban area (“Small City” or “Large City”) from the green pulldown list at cell ‘Build-Simple-Bus-Trip’!E18 and enter the distances traveled along freeways and arterial roads in the origin urban area in the green cells at ‘Build-Simple-Bus-Trip’!E19:E20. Then select the urban area size and input the distances traveled on freeways and arterial roads in the destination urban area at cells ‘Build-Simple-Bus-Trip’!G18:G20. The origin and destination urban area size will affect the mix of drive schedules used to simulate bus travel in the urban areas. The total distance traveled is indicated in the yellow information cell at ‘Build-Simple-Bus-Trip’!F22. Note that the total trip distance reported may include additional distances automatically added if intermediate stops are to be included in the trip (a default of 7 miles per intermediate stop is used).

The total number of intermediate stops made along a bus trip are split into individual numbers made in the origin urban area, along the rural freeway and in the destination urban area. These are input in the green cells at ‘Build-Simple-Bus-Trip’!E26:G26. All stops are assumed to have the same duration (a delay in trip minimum run time) which is input in the green cell at ‘Build-Simple-Bus-Trip’!E27. The scheduled trip time is input in the green cell at ‘Build-Simple-Bus-Trip’!E29.

The departure time-of-day, arrival time-of-day and day-of-week for the outbound trip are all selected from green pulldown lists at ‘Build-Simple-Bus-Trip’!E36:E38 and for the return trip from cells ‘Build-Simple-Bus-Trip’!F36:F38. These selections are used by the bus simulation in determining the mix of drive schedules used when simulating movement in urban areas.

A simple bus route may now be created by entering a description in the green cell at ‘Build-Simple-Bus-Route’!H33 and then clicking on the blue “Save to ‘Bus-Route’” button. This invokes a VBA macro which automatically assigns a unique bus route ID and then copies the new bus route from the template in the ‘Simple-Bus-Route’ worksheet to the next available position in the ‘Bus-Route’ worksheet. The unique identifier assigned to the newly added bus route is indicated in the yellow “Route ID” cell at ‘Build-Simple-Rail-Trip’!I36.

The simple bus route is created from the data specified on the ‘Build-Simple-Bus-Trip’ worksheet using the ‘Simple-Bus-Route’ worksheet as a template. Some cells of this bus route template are built using formulas which reference data cells on the ‘Build-Simple-Bus-Trip’ worksheet while others provide default values. It is assumed that there are no grades on a simple bus route.

The automated process of copying the ‘Simple-Bus-Route’ template into the ‘Bus-Route’ worksheet replaces the contents of cells having formulas which reference cells on the ‘Build-Simple-Bus-Trip’ worksheet with their values. Users may modify the data once added for a simple bus route by editing the cells in the ‘Bus-Route’ worksheet using the information provided in Section A.7.9 on page A-148 as a guide.

> ***Note:*** *Do not manually copy the ‘Simple-Bus-Route’ template and paste into the ‘Bus-Route’ worksheet as errors will result.*

Creating the Simple Bus Trip

The final inputs which must be provided before a simple bus trip can be created include the geographical region selected from the green pulldown list at ‘Build-Simple-Bus-Trip’!E31, the season for the trip selected from the green pulldown list at ‘Build-Simple-Bus-Trip’!E32 and the number of people assumed to be traveling together in a party which is input in the green input cell at ‘Build-Simple-Bus-Trip’!E40.

Clicking on the blue “Create Bus Trip” button brings the ‘Bus-I-O’ worksheet into view and displays the ‘Bus Trip Selection’ menu preloaded with the simple bus route, the bus type selection and the balance of the simple bus trip specifications transferred from the ‘Build-Simple-Bus-Trip’ worksheet. From that menu, the new trip is created by clicking the gray “Add Bus Trip” button which creates and displays a unique bus trip ID in the yellow “Trip ID” field in the top left of the menu. Enter a description for this new simple bus trip in the green “Description” field at the top of the menu and then click the gray “Save Bus Trip” to write it onto the bottom of the list of bus trips stored in the ‘Bus-Trip-List’ worksheet. Please note that the new trip will not be automatically saved if the “Save Bus Trip” button is not clicked. Clicking on the gray “Select & Return” button will populate the bus trip fields on the ‘Bus-I-O’ worksheet.

A.4.3 Building a Simple Light Duty Vehicle (LDV) Trip

The ‘Build-Simple-LDV-Trip’ worksheet provides a simple means to create a basic light duty vehicle trip. Figure A-16 depicts the worksheet layout. The light green box on the right hand side (‘Build-Simple-LDV-Trip’!K5:O40) provides a brief list of instructions to follow. The process involves:

1) Selecting the light duty vehicle type.
2) Specifying the distances traveled, speed limit, number of wayside stops, duration of stops, origin and destination urban area sizes, trip departure and arrival periods and then creating a simple LDV route by clicking on the blue “Save to ‘LDV-Route’” button.
3) Specifying other trip parameters such as region, season, number of people traveling together in party and then creating the trip by clicking on the blue “Create LDV Trip” button.

Selecting a Light Duty Vehicle Type

To build a simple light duty vehicle trip, begin by selecting a system of units from the green pulldown list located at ‘Build-Simple-LDV-Trip’!E4. Then, select a light duty vehicle type from the green pulldown list at cell ‘Build-Simple-LDV-Trip’!D10. The number of passenger seats provided in the selected vehicle type is indicated in the yellow cell at ‘Build-Simple-LDV-Trip’!F10. Other default parameters associated with the selected light duty vehicle type which will be used for the simple LDV trip may be reviewed in the yellow information cells located at ‘Build-Simple-Bus-Trip’!R10:W10 (page to the right).

The list of vehicle types available in the green pulldown list at ‘Build-Simple-LDV-Trip’!D10 and their corresponding default parameters are defined in an Excel VLOOKUP table located at ‘Build-Simple-LDV-Trip’!R14:W36 (see Figure A-17). This table is populated by cell references to the source data contained in the ‘LDV-Type’ worksheet. MMPASSIM provides parameters for the following light duty vehicles:

- Small automobile
- Midsize automobile or station wagon
- Minivan or small Sport Utility Vehicle
- Large auto or medium SUV or small pickup
- Pickup truck
- Large Sport Utility Vehicle
- Composite local vehicle
- Composite intercity vehicle
- Composite taxi
- 2011 sales weighted
- 2011 driven fleet
- 2012 sales weighted
- 2012 driven fleet
- 2013 sales weighted
- 2013 driven fleet

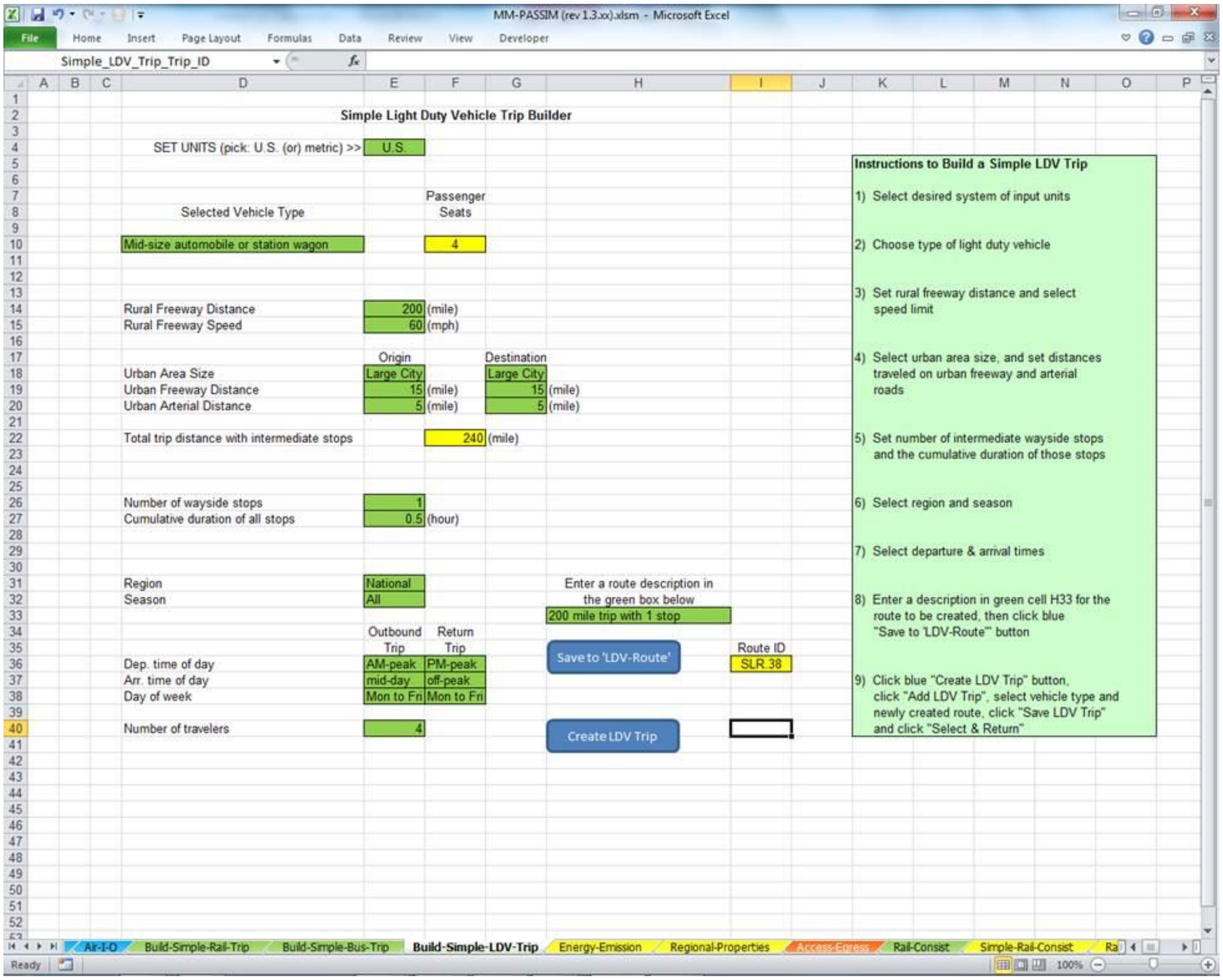
Note: *If new light duty vehicles are added into the ‘LDV-Type’ worksheet, for example by updating with sales weighted and driven fleets for a new year, then new lines containing the appropriate cell references must be added into this VLOOKUP table in order for them to be selected from the ‘Build-Simple-LDV-Trip’ pulldown list. The VLOOKUP statements used in cell formulas are constructed using offsets which automatically adjust when new lines of LDV type data are added.*

Creating a Simple Light Duty Vehicle Route

To specify a simple LDV route, you must first determine the overall trip distance and then divide that distance into 5 individual distances traveled on the following road types:

- Origin urban area freeways
- Origin urban area arterial roads
- Rural freeways (outside of the origin and destination urban areas)
- Destination urban area freeways
- Destination urban area arterial roads

Enter the distance traveled along rural freeways (between the origin and destination urban areas) into the green cell at ‘Build-Simple-LDV-Trip’!E14 and select the most appropriate speed limit from the green pulldown list at ‘Build-Simple-LDV-Trip’!E15. Note that the rural freeway speed limits are provided in 5 mph increments between 60 and 75 mph, or when using metric units those values are converted to km/h. Choose the value closest to the anticipated speed of travel.



Simple Light Duty Vehicle Trip Builder

SET UNITS (pick: U.S. (or) metric) >> U.S.

Selected Vehicle Type	Passenger Seats
Mid-size automobile or station wagon	4

	Origin		Destination	
Rural Freeway Distance	200	(mile)		
Rural Freeway Speed	60	(mph)		
Urban Area Size	Large City		Large City	
Urban Freeway Distance	15	(mile)	15	(mile)
Urban Arterial Distance	5	(mile)	5	(mile)
Total trip distance with intermediate stops		240	(mile)	
Number of wayside stops	1			
Cumulative duration of all stops	0.5	(hour)		
Region	National			
Season	All			

Enter a route description in the green box below
200 mile trip with 1 stop

Route ID
SLR.38

	Outbound Trip	Return Trip
Dep. time of day	AM-peak	PM-peak
Arr. time of day	mid-day	off-peak
Day of week	Mon to Fri	Mon to Fri
Number of travelers	4	

Instructions to Build a Simple LDV Trip

1) Select desired system of input units

2) Choose type of light duty vehicle

3) Set rural freeway distance and select speed limit

4) Select urban area size, and set distances traveled on urban freeway and arterial roads

5) Set number of intermediate wayside stops and the cumulative duration of those stops

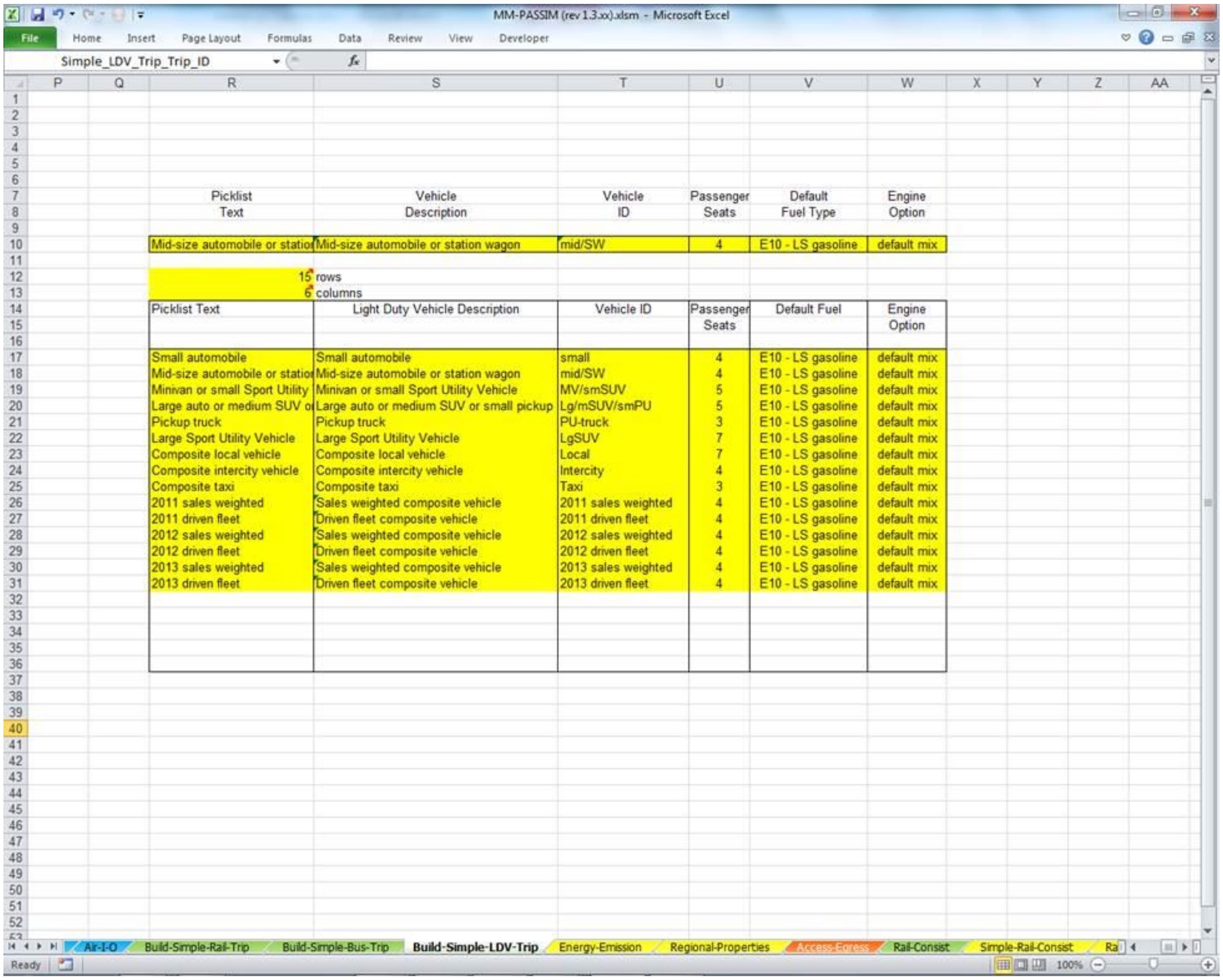
6) Select region and season

7) Select departure & arrival times

8) Enter a description in green cell H33 for the route to be created, then click blue "Save to 'LDV-Route'" button

9) Click blue "Create LDV Trip" button, click "Add LDV Trip", select vehicle type and newly created route, click "Save LDV Trip" and click "Select & Return"

Figure A-16 The 'Build-Simple-LDV-Trip' Worksheet



Picklist Text	Vehicle Description	Vehicle ID	Passenger Seats	Default Fuel Type	Engine Option
Mid-size automobile or statio	Mid-size automobile or station wagon	mid/SW	4	E10 - LS gasoline	default mix

15 rows
6 columns

Picklist Text	Light Duty Vehicle Description	Vehicle ID	Passenger Seats	Default Fuel	Engine Option
Small automobile	Small automobile	small	4	E10 - LS gasoline	default mix
Mid-size automobile or statio	Mid-size automobile or station wagon	mid/SW	4	E10 - LS gasoline	default mix
Minivan or small Sport Utility	Minivan or small Sport Utility Vehicle	MV/smSUV	5	E10 - LS gasoline	default mix
Large auto or medium SUV o	Large auto or medium SUV or small pickup	Lg/mSUV/smPU	5	E10 - LS gasoline	default mix
Pickup truck	Pickup truck	PU-truck	3	E10 - LS gasoline	default mix
Large Sport Utility Vehicle	Large Sport Utility Vehicle	LgSUV	7	E10 - LS gasoline	default mix
Composite local vehicle	Composite local vehicle	Local	7	E10 - LS gasoline	default mix
Composite intercity vehicle	Composite intercity vehicle	Intercity	4	E10 - LS gasoline	default mix
Composite taxi	Composite taxi	Taxi	3	E10 - LS gasoline	default mix
2011 sales weighted	Sales weighted composite vehicle	2011 sales weighted	4	E10 - LS gasoline	default mix
2011 driven fleet	Driven fleet composite vehicle	2011 driven fleet	4	E10 - LS gasoline	default mix
2012 sales weighted	Sales weighted composite vehicle	2012 sales weighted	4	E10 - LS gasoline	default mix
2012 driven fleet	Driven fleet composite vehicle	2012 driven fleet	4	E10 - LS gasoline	default mix
2013 sales weighted	Sales weighted composite vehicle	2013 sales weighted	4	E10 - LS gasoline	default mix
2013 driven fleet	Driven fleet composite vehicle	2013 driven fleet	4	E10 - LS gasoline	default mix

Figure A-17 Simple LDV Type VLOOKUP Tables

Select the size of the origin urban area (“Small City” or “Large City”) from the green pulldown list at cell ‘Build-Simple-LDV-Trip’!E18 and enter the distances traveled along freeways and arterial roads in the origin urban area in the green cells at ‘Build-Simple-LDV-Trip’!E19:E20. Then select the urban area size and input the distances traveled on freeways and arterial roads in the destination urban area at cells ‘Build-Simple-LDV-Trip’!G18:G20. The origin and destination urban area size will affect the mix of drive schedules used to simulate light duty vehicle travel in the urban areas. The total distance traveled is indicated in the yellow information cell at ‘Build-Simple-LDV-Trip’!F22.

The total number of wayside stops along the rural freeway portion of a light duty vehicle trip is input in the green cell at ‘Build-Simple-LDV-Trip’!E26. The total cumulative duration of all wayside stops is specified in hours and input in the green cell at ‘Build-Simple-LDV-Trip’!E27.

The departure time-of-day, arrival time-of-day and day-of-week for the outbound trip are all selected from green pulldown lists at ‘Build-Simple-LDV-Trip’!E36:E38 and for the return trip from cells ‘Build-Simple-LDV-Trip’!F36:F38. These selections are used by the light duty vehicle simulation in determining the mix of drive schedules used when simulating movement in urban areas.

A simple light duty vehicle route may now be created by entering a description in the green cell at ‘Build-Simple-LDV-Route’!H33 and then clicking on the blue “Save to ‘LDV-Route’” button. This runs a VBA macro which automatically assigns a unique light duty vehicle route ID and then copies the new light duty vehicle route from the template in the ‘Simple-LDV-Route’ worksheet to the next available position in the ‘LDV-Route’ worksheet. The unique identifier assigned to the newly added light duty vehicle route is indicated in the yellow “Route ID” cell at ‘Build-Simple-LDV-Trip’!I36.

The simple light duty vehicle route is created from the data specified on the ‘Build-Simple-LDV-Trip’ worksheet using the ‘Simple-LDV-Route’ worksheet as a template. Some cells of this light duty vehicle route template are built using formulas which reference data cells on the ‘Build-Simple-LDV-Trip’ worksheet while others provide default values. It is assumed that there are no grades on a simple light duty vehicle route.

The process of copying this template into the ‘LDV-Route’ worksheet replaces the contents of cells having formulas which reference the ‘Build-Simple-LDV-Trip’ worksheet with their values. Users may modify the data added for a simple light duty vehicle route by editing the cells in the ‘LDV-Route’ worksheet using the information provided in Section A.7.13 on page A-159 as a guide.

> ***Note:*** *Do not manually copy the ‘Simple-LDV-Route’ template and paste into the ‘LDV-Route’ worksheet as errors will result.*

Creating the Simple LDV Trip

The final inputs required before a simple light duty vehicle trip can be created include the geographical region selected from the green pulldown list at ‘Build-Simple-LDV-Trip’!E31, the season for the trip selected from the green pulldown list at ‘Build-Simple-LDV-Trip’!E32 and the number of people assumed to be traveling together in a party which is input in the green input cell at ‘Build-Simple-LDV-Trip’!E40.

Clicking on the blue “Create LDV Trip” button brings the ‘LDV-I-O’ worksheet into view and displays the ‘Auto/LDV Trip Selection’ menu preloaded with the simple light duty vehicle route, the selected light duty vehicle type and the balance of the simple light duty vehicle trip specifications transferred from the ‘Build-Simple-LDV-Trip’ worksheet. From that menu, the new trip is created by clicking the gray “Add LDV Trip” button which creates and displays a unique light duty vehicle trip ID in the yellow “Trip ID” field in the top left of the menu. Enter a description for this new simple light duty vehicle trip in the green “Description” field at the top of the menu and then click the gray “Save LDV Trip” to write it onto the bottom of the list of light duty vehicle trips stored in the ‘LDV-Trip-List’ worksheet.

> ***Note:*** *A newly created trip will not be automatically saved if the “Save LDV Trip” button is not clicked.*

Clicking on the gray “Select & Return” button will populate the light duty vehicle trip fields on the ‘LDV-I-O’ worksheet and close the ‘Auto/LDV Trip Selection’ menu.

A.5 Details of Configuring and Running Modal Simulations

This section provides details of how the MMPASSIM menu system is used to configure simulations of rail, air, bus and light duty vehicle trips. Only rail trips are simulated in *Single Train Simulations* and *Rail Technology Evaluations*. Rail, air, bus and light duty vehicle trips can be simulated in *Mode Comparisons*. Table A-2 and Table A-3 identify the major configuration steps for each of these analysis types.

Table A-2 Major Configuration Steps Required for a MMPASSIM Analysis

Type of Analysis	Major Configuration Steps Required
Single Train Simulation	• Pick "Single Train Simulation" at 'Master-I-O'!C4 • Define Baseline Rail Case – click on "Define Baseline" and refer to 'Define Rail Case' (Table A-4) • Click "Calculate Selections" button
Rail Technology Evaluation	• Pick "Rail Technology Evaluation" at 'Master-I-O'!C4 • Define Baseline Rail Case – click on "Define Baseline" and refer to 'Define Rail Case' (Table A-4) • Define Alternative Rail Case 1 (optional, check box to activate) – click on "Define Alternative 1" and refer 'Define Rail Case' (Table A-4) • Define Alternative Rail Case 2 (optional, check box to activate) – click on "Define Alternative 2" and refer 'Define Rail Case' (Table A-4) • Define Alternative Rail Case 3 (optional, check box to activate) – click on "Define Alternative 3" and refer to 'Define Rail Case' (Table A-4) • Click "Calculate Selections" button
Mode Comparison	• Pick "Mode Comparison" at 'Master-I-O'!C4 • Define Baseline Rail Case – click on "Define Baseline" and refer to 'Define Rail Case' • Define Alternative 1 (optional, check box to activate) – click on "Define Alternative 1", refer to 'Define Alternative Case' (Table A-3) • Define Alternative 2 (optional, check box to activate) – click on "Define Alternative 2", refer to 'Define Alternative Case' (Table A-3) • Define Alternative 3 (optional, check box to activate) – click on "Define Alternative 3", refer to 'Define Alternative Case' (Table A-3) • Click "Calculate Selections" button

Table A-3 Selecting an Alternative Mode Trip

Define Alternative Case	Configuration Steps Required
Define Alternative Case	• Click "Define Alternative #" button (where # is 1, 2 or 3) • Pick desired transportation mode from drop-down list • Either select the current trip defined on a '<modal>-I-O' worksheet by clicking "Select & Return" button or • Select an existing modal trip as a template and edit by clicking "Select & Edit" – see appropriate mode specific trip selection form steps

A.5.1 Configuring and Running a Rail Simulation

The Rail-Simulation module serves as the backbone of the MMPASSIM simulator. It is implemented using five (5) primary user accessible worksheets which, in addition to the 'Master-I-O' worksheet, together provide for complete simulation configuration, user input and results output. These user accessible worksheets include the 'Rail-I-O', 'Energy-Emission', 'Regional-Properties', 'Rail-Consist' and 'Rail-Route' worksheets. An additional 'Rail-Trip-List' worksheet, used to maintain the list of all configured rail trips, is accessible to the user but is typically maintained by the application. The 'Energy-Emission' worksheet specifies the energy and emissions characteristics of all fuel/energy sources used for all transportation modes and is therefore shared by all transportation mode sub-models. The 'Regional-Properties' worksheet defines factors which often vary with geographical location, such as seasonal temperatures, traffic distributions, heating/cooling loads, urban congestion and energy and emission intensities for local urban area access and egress modes. The rail simulation calculations are performed on another worksheet named 'Rail-Simulation' which should not normally be modified by a user. That worksheet predicts the energy use, GHG emissions produced and travel time associated with a single rail leg of a rail trip. Simulation of a return rail trip requires two successive simulation sequences involving transfer of configuration data to the worksheet, recalculation of the worksheet and then transfer of results from the worksheet.

Defining the baseline rail round trip (applicable in all simulation modes) is initiated by clicking the blue "Define Baseline" button (at cell 'Master-I-O'!$A$31, see highlight 1 on Figure A-18). This displays the pop up "Rail Trip Selection" user form from which a trip can either be selected from the list of all currently defined rail trips or a new trip may be added and configured. Table A-4 summarizes the steps involved in configuring a rail trip.

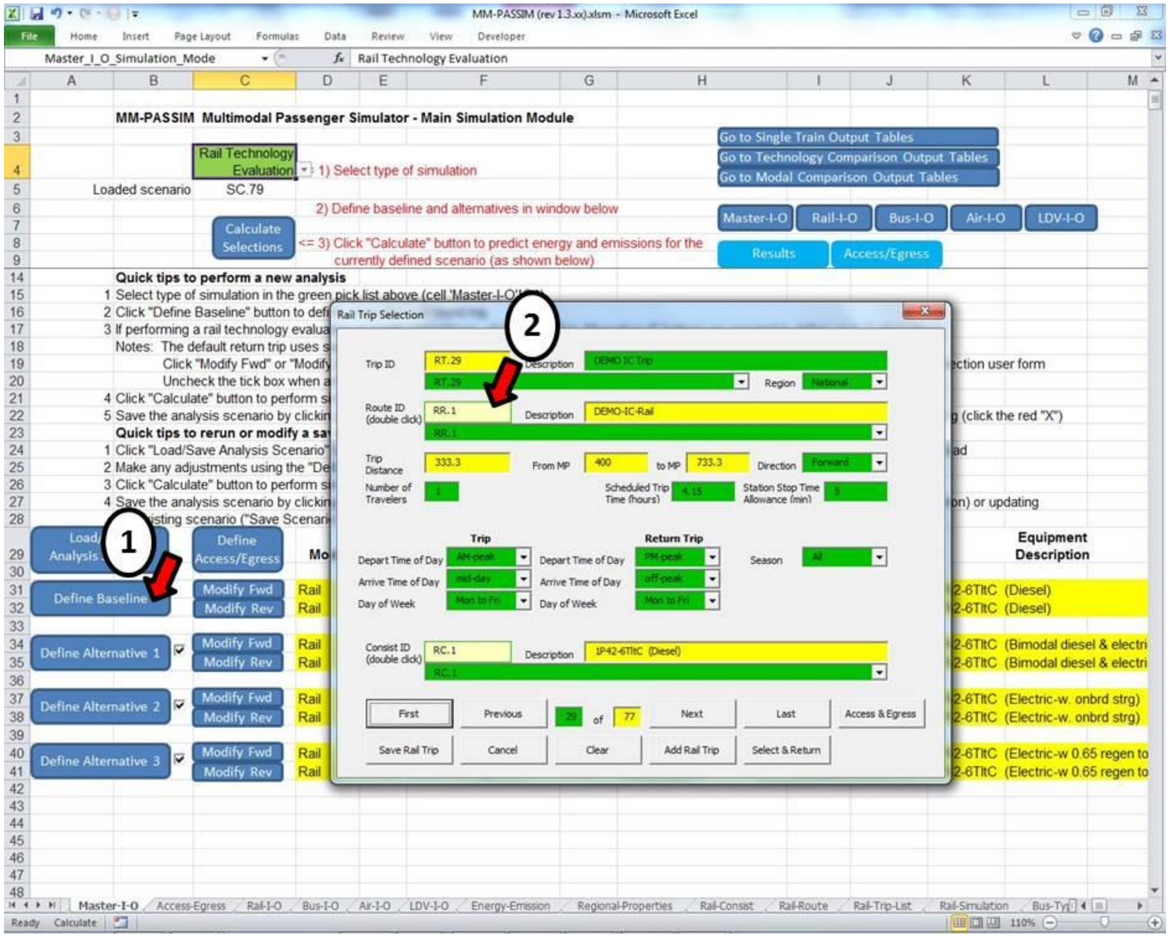
For a rail simulation, a trip definition involves specifying a route and a rail consist. The trip being displayed is identified by its unique 'Trip ID' (upper left yellow field) and a user modifiable 'Description' (upper right green field). The 'Route ID' associated with a trip is displayed in the green-bordered light yellow field located immediately below the 'Trip ID' field (see highlight 2 in Figure A-19). The 'Route ID' is not directly modifiable by a user, but is changed using the 'Rail Route Selection' pop up user form which is accessed by double clicking within the boundaries of the 'Route ID' field (see highlight 3 in Figure A-19). Navigation through that user form follows the same procedures described above and once the desired route is displayed, clicking on the 'Select & Return' will return the selected 'Route ID' back to the previous 'Rail Trip Selection' form. A rail route may also be conveniently selected directly from the Rail Trip Selection user form by picking it from a list of route descriptions available on the green drop-down list located immediately below the yellow Route ID and Description information fields.

Most parameters of a route specification are defined in the 'Rail-Route' worksheet and are not modifiable from either the Rail Trip Selection or the Rail Route Selection user forms. The yellow 'Route ID', 'Description', 'Route Distance', 'From MP' and 'to MP' and speed limit fields on the Rail Route Selection user form are filled in by the VBA macro to offer sufficient information to the user to identify and confirm the route selection. The lower 'Trip Distance', 'From MP' and 'to MP' values differ from the upper 'Route' values because a rail trip can be configured to use only a portion of a longer rail route as specified in the 'Rail-Route' worksheet.

Table A-4 Configuration Steps for a Rail Trip

Define Rail Case	Configuration Steps Required
Rail Trip Selection Form	• Either select an existing rail trip from the 'Trip ID' drop-down list and click "Select & Return" or • Create a new trip by clicking "Add Rail Trip" button • Pick a rail route from the "Route ID" drop-down list • Pick direction of travel • Set number of travelers • Set scheduled trip time in hours (if desired) • Set station stop time allowance in minutes (if desired) • Pick time of day for departure of outbound trip • Pick time of day for arrival of outbound trip • Pick day of week for outbound trip • Pick time of day for departure of return trip • Pick time of day for arrival of return trip • Pick day of week for return trip • Pick season of both outbound and return trips • Pick a rail consist from the "Consist ID" drop-down list • Assign access and egress legs by clicking the "Access & Egress" button • Save the new rail trip by clicking "Save Rail Trip" button • Select the newly added rail trip by clicking "Select & Return" button

The yellow 'Trip Distance', 'From MP' and 'to MP' fields associated with the currently selected rail route are displayed on the Rail Trip Selection user form for information purposes. There are eleven additional user modifiable green fields available to configure the operational parameters of a rail trip. These fields are identified as 'Direction', 'Number of travelers', 'Scheduled Trip Time (hours)', 'Station Stop Time Allowance (min)', 'Season', 'Departure Time of Day', 'Arrival Time of Day', and 'Day of Week' for the forward trip along with 'Departure Time of Day', 'Arrival Time of Day' and 'Day of Week' for the return trip. All of these values are stored with the rail trip record when saved to the rail trip list by clicking on the gray 'Save' button located in the lower left hand corner of the user form.



Master_I_O_Simulation_Mode — Rail Technology Evaluation

MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Rail Technology Evaluation 1) Select type of simulation

Loaded scenario SC.79

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Quick tips to perform a new analysis

1 Select type of simulation in the green pick list above (cell 'Master-I-O'!

2 Click "Define Baseline" button to defi

3 If performing a rail technology evalua

Notes: The default return trip uses s

Click "Modify Fwd" or "Modify

Uncheck the tick box when a

4 Click "Calculate" button to perform si

5 Save the analysis scenario by clickin

Quick tips to rerun or modify a sa

1 Click "Load/Save Analysis Scenario"

2 Make any adjustments using the "De

3 Click "Calculate" button to perform si

4 Save the analysis scenario by clickin

isting scenario ("Save Scenari

Rail Trip Selection

Trip ID RT.29 Description DEMO IC Trip

RT.29 Region National

Route ID (double click) RR.1 Description DEMO-IC-Rail

RR.1

Trip Distance 333.3 From MP 400 to MP 733.3 Direction Forward

Number of Travelers 1 Scheduled Trip Time (hours) 4.15 Station Stop Time Allowance (min) 5

	Trip		Return Trip		
Depart Time of Day	AM-peak	Depart Time of Day	PM-peak	Season	All
Arrive Time of Day	mid-day	Arrive Time of Day	off-peak		
Day of Week	Mon to Fri	Day of Week	Mon to Fri		

Consist ID (double click) RC.1 Description 1P42-6TltC (Diesel)

RC.1

29 of 77

ction user form

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on) or updating

Equipment Description

2-6TltC (Diesel)

2-6TltC (Diesel)

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2-6TltC (Electric-w 0.65 regen to

Figure A-18 Defining the Baseline Round Trip

Usage Notes:

On the "Master-I-O" worksheet:

a) Click blue "Define Baseline" button on left hand side of worksheet (see highlight 1) to open the "Rail Trip Selection" form.

On the "Rail Trip Selection" form:

b) Pick a rail trip from the green "Trip ID" drop-down list at the top.
or
Use the gray navigation buttons at the bottom to display a desired trip

c) Click gray "Add Rail Trip" button if you wish to create a new trip by modifying the currently displayed trip.

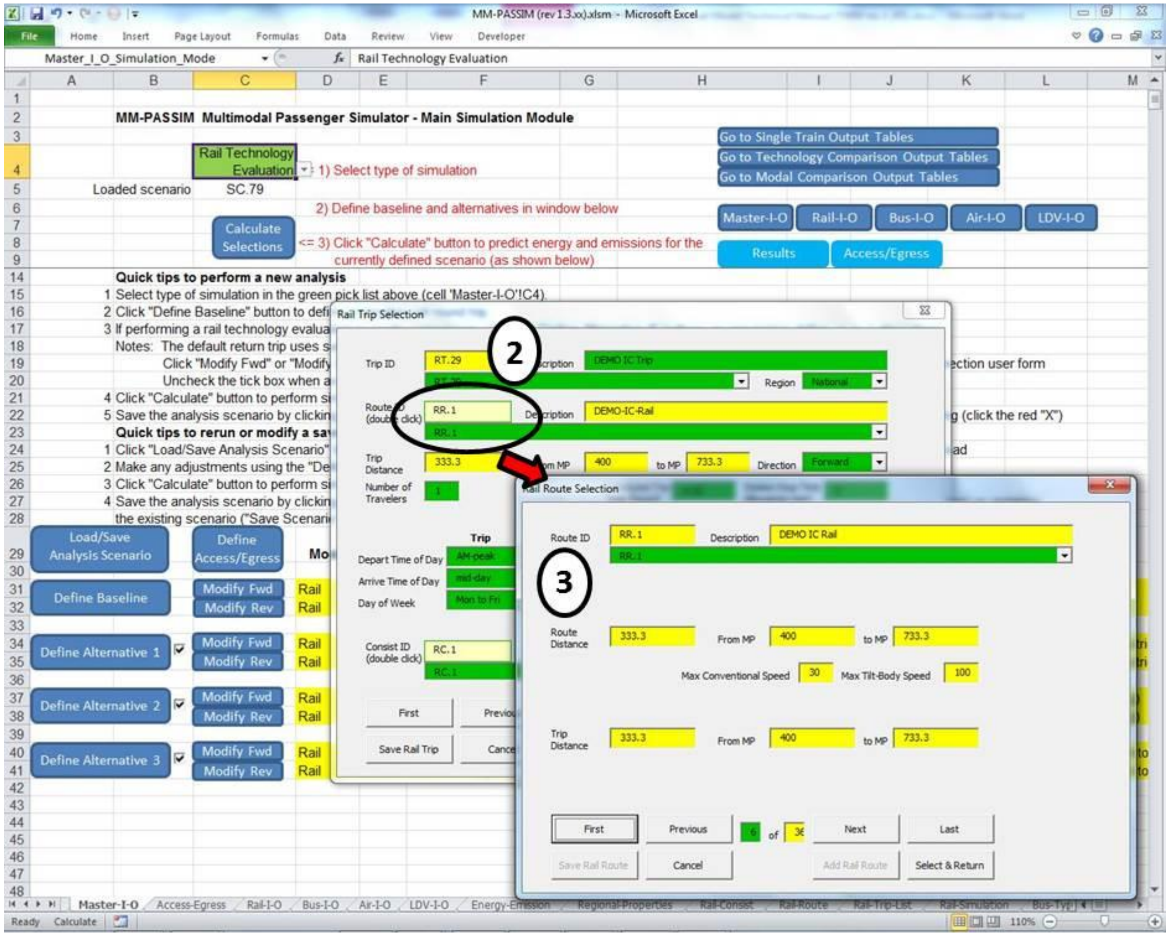
d) Double click on light yellow "Route ID" box (see highlight 2) to open "Rail Route Selection" form and make a route selection.
or
Select a route from the green "Route ID" drop-down list.

e) Double click on light yellow "Consist ID" box to open "Rail Consist Selection" form and make a consist selection
or
Select a consist from the green "Consist ID" drop-down list.

f) Make any changes to green fields (trip rimes, day of week, season, number of travelers, etc.).

g) Click on the gray "Save Rail Trip" button to save the modifications.

h) Click on the gray "Select & Return" button to return trip information back to "Master-I-O".



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Rail Technology Evaluation 1) Select type of simulation

Loaded scenario SC.79

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Quick tips to perform a new analysis

1 Select type of simulation in the green pick list above (cell 'Master-I-O'!C4).

2 Click "Define Baseline" button to defi

3 If performing a rail technology evalua

Notes: The default return trip uses s

Click "Modify Fwd" or "Modify

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4 Click "Calculate" button to perform si

5 Save the analysis scenario by clickin

Quick tips to rerun or modify a sa

1 Click "Load/Save Analysis Scenario"

2 Make any adjustments using the "De

3 Click "Calculate" button to perform si

4 Save the analysis scenario by clickin

the existing scenario ("Save Scenari

Rail Trip Selection:

Trip ID: RT.29 | Description: DEMO IC Trip | Region: National

Route ID (double click): RR.1 | Description: DEMO-IC-Rail

Trip Distance: 333.3 | From MP: 400 | to MP: 733.3 | Direction: Forward

Number of Travelers: 1

Depart Time of Day: AM-peak

Arrive Time of Day: mid-day

Day of Week: Mon to Fri

Consist ID (double click): RC.1

Rail Route Selection:

Route ID: RR.1 | Description: DEMO IC Rail

Route Distance: 333.3 | From MP: 400 | to MP: 733.3

Max Conventional Speed: 30 | Max Tilt-Body Speed: 100

Trip Distance: 333.3 | From MP: 400 | to MP: 733.3

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Figure A-19 Selecting a Rail Route

Usage Notes:

On “Rail Trip Selection” form:

a) Pick a rail route from the green “Route ID” drop-down list.

or

Double click on the light yellow “Route ID” box (see highlight 2) to open the “Rail Route Selection” form and make a route selection.

On the “Rail Route Selection” form:

b) Pick a rail route from the green “Route ID” drop-down list (see highlight 3).

or

Use gray navigation buttons to display desired rail route

c) Click gray “Select & Return” button to return to the “Rail Trip Selection” form.

The ‘Consist ID’ associated with a trip is displayed in the green-bordered light yellow field located just above the ‘First’ and ‘Previous’ navigation buttons of the ‘Rail Trip Selection’ form. A consist is selected by either using the ‘Rail Consist Selection’ pop up form which is activated by double clicking on the ‘Consist ID’ field (see Figure A-20) or selecting from the green drop-down list immediately below the yellow ‘Consist ID’ and ‘Description’ fields. If a user wishes to view or modify the rail consist data then they must double click on the ‘Consist ID’ field, otherwise choosing from the drop-down list simply selects the desired consist with the configuration as saved in the ‘Rail-Consist’ worksheet.

Double clicking on the ‘Consist ID’ field from the ‘Rail Trip Selection’ user form will display the ‘Rail Consist Selection’ pop up form. At the top of this form are yellow ‘Consist ID’ and ‘Description’ fields and a green consist drop-down list. The user accesses the desired ‘Consist ID’ by navigating through the available list of rail consists currently defined in the ‘Rail-Consist’ worksheet using the gray navigation buttons at the bottom of the form or alternatively selecting from the consist descriptions offered in the green drop-down list. The five yellow information fields displayed below the green consist drop-down list are not modifiable on the form. The five green drop-down lists positioned below the yellow information fields allow a user to configure the propulsion type and fuel(s), the method of hotel power generation and the method of energy recovery, if any, which may be assumed for the propulsion equipment. Propulsion type may be “onboard-fuel” (primarily diesel), “electric” or “dual-fuel” (both onboard-fuel and electric). The types of fuel presented in the primary and secondary fuel type drop-down lists are dependent on the propulsion type which has been selected. The method of hotel power provision is via engine power takeoff (PTO), a dedicated diesel generator or from grid power in the case of an electric power car. Energy recovery options include onboard storage, wayside storage, supplying electricity back to the electrical grid and adopting an optimal coasting driving strategy.

A user can add a new rail consist based upon an existing consist by first navigating through the list of existing rail consists until the one desired is displayed and then clicking on the gray ‘Add’ button. There are very few user modifiable consist parameters displayed on the ‘Rail Consist Selection’ form and the user will therefore need to adjust consist parameters directly in the appropriate area of the ‘Rail-Consist’ worksheet which is accessible to the user.

> **Note:** *Changes made to a displayed rail consist are not automatically saved and will be lost unless the gray ‘Save’ button is clicked prior to navigating away to another consist or clicking on the ‘Select & Return’ button to pass that selection back to the ‘Rail Trip Selection’ form.*

> **Caution:** *The relative position of consist parameters within the ‘Rail-Consist’ worksheet must not be altered except to manually insert or create a new consist which should be positioned relative to the last consist definition using a fixed 7 column offset. For example, the first consist definition begins in column I of the ‘Rail-Consist’ worksheet while the next begins in column P.*

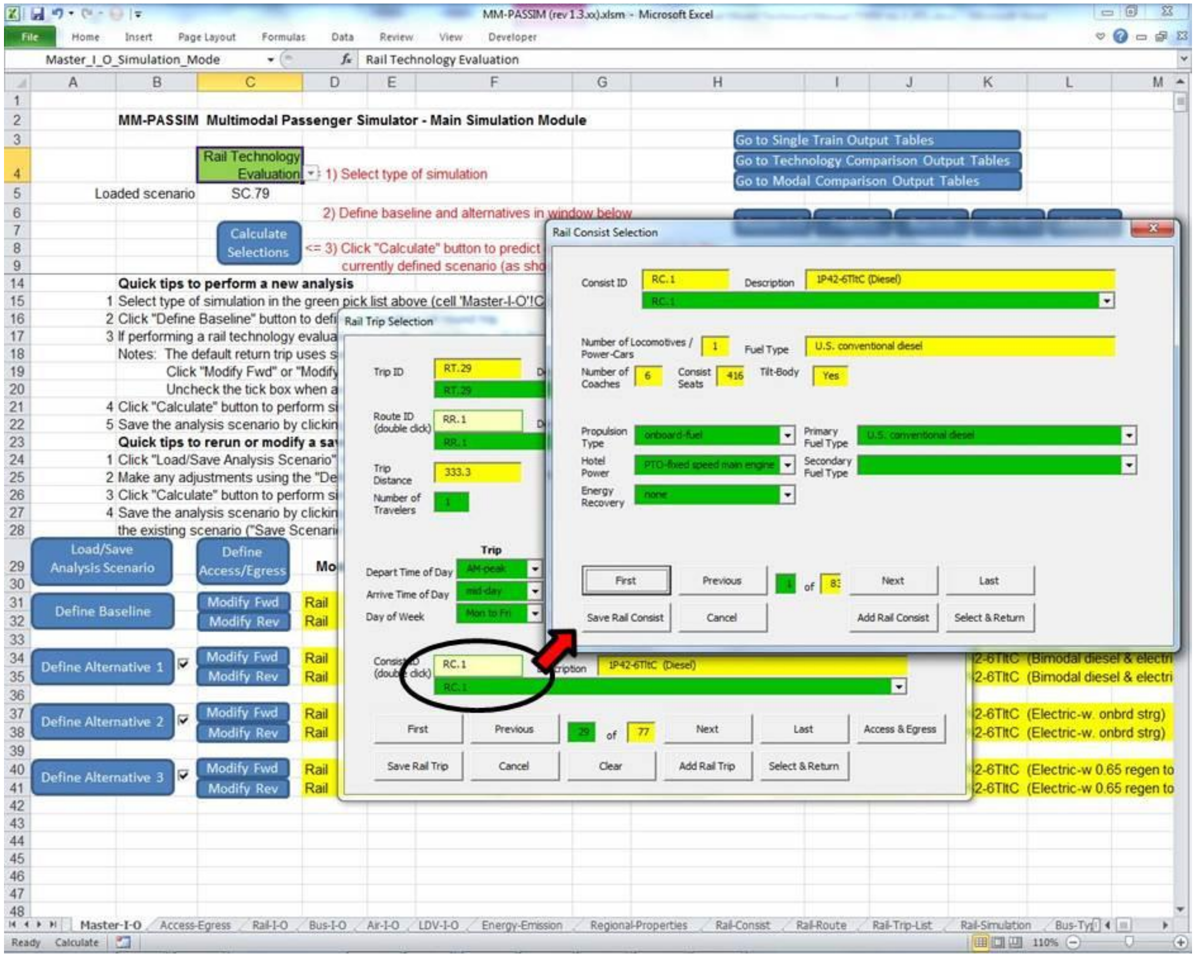
A new rail trip may be added by clicking the ‘Add’ button on the ‘Select Rail Trip’ menu. This creates a new ‘Trip ID’ while preserving the values in the other data fields. A user can clear all data fields by clicking on the ‘Clear’ button if they so desire, however this should not normally be required as the process of selecting a ‘Route ID’ and ‘Consist ID’ will result in the replacement of most of the data fields.

> **Note:** *Any changes made to the data fields on the 'Select Rail Trip' user form are not automatically saved and the user must explicitly save them by clicking the 'Save' button. Doing so will update the internally stored list of trip definitions (in the 'Rail-Trip' worksheet) but will not modify the trip definitions displayed in the rail trip definition area on the 'Master-I-O' sheet or the 'Rail-I-O' sheet. To do so, the user must click on the 'Select & Return' button which will write the trip definitions onto the 'Rail-I-O' worksheet. It is therefore possible to configure and run one-off simulated trips without modifying the trip list.*

The baseline round trip definition will automatically assign both the forward and return trips using the same consist and route selections, but the direction of the return trip is reversed from that of the forward trip and the return departure, arrival and day of week values are exchanged with the forward trip's departure, arrival and day of week values. In situations where this default return trip definition is not desired, the user can modify either the forward trip or the return trip individually by clicking on the blue "Modify Fwd" or "Modify Rev" buttons as required to access the 'Rail Trip Selection' form (see Figure A-21). A return trip does not have to be run in the reverse direction. For cases where a different route (as defined in the 'Rail-Route' worksheet) is selected for a return trip, the user must select the direction of travel which is consistent for travel from the destination back to the origin. The direction of travel is selected from the green drop-down list (see left pointing arrow highlight in Figure A-21).

> **Caution:** *A user should not directly modify any of the yellow highlighted fields associated with the trip selections listed on the 'Master-I-O' worksheet. This list is used by the VBA macros during the sequencing of the simulation steps and any invalid data or moved items may cause invalid predictions or program failure.*

The passenger's access to the rail mode departure station and their egress from the rail mode arrival station may both be characterized with up to five (5) access/egress legs each. This may be conveniently configured using the pop-up user form accessed by clicking the blue "Define Access/Egress" button on the 'Master-I-O' worksheet to activate the 'Trip Access and Egress Leg Selection' user form (see Figure A-22). Any currently defined access or egress legs for the selected rail trip will be displayed in the 'Trip Access and Egress Leg Selection' user form. All yellow fields on the form present information to the user about the rail trip to which the displayed access and egress legs apply while all green fields may be adjusted to meet the user's requirements in specifying the characteristics of those access and egress legs. For a single train simulation, the access and egress legs are specified separately for the forward and return trips and the user may switch between those trips by clicking the 'Next' and 'Previous' navigation buttons. For a technology comparison analysis, access and egress legs are defined separately for each rail trip involved. Therefore a complete comparison involving the baseline rail case and all three alternative rail round trips will require eight (8) sets of access/egress legs be specified. The green drop-down list located beneath the yellow 'Trip ID' field may be used to quickly select the desired trip from a list of descriptions without cycling through the sequence of applicable trips.



Master_I_O_Simulation_Mode | Rail Technology Evaluation

MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Rail Technology Evaluation 1) Select type of simulation

Loaded scenario SC.79

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict
currently defined scenario (as sho

Quick tips to perform a new analysis
1 Select type of simulation in the green pick list above (cell 'Master-I-O'!C
2 Click "Define Baseline" button to defi
3 If performing a rail technology evalua
Notes: The default return trip uses s
Click "Modify Fwd" or "Modify
Uncheck the tick box when a
4 Click "Calculate" button to perform si
5 Save the analysis scenario by clickin
Quick tips to rerun or modify a sa
1 Click "Load/Save Analysis Scenario"
2 Make any adjustments using the "De
3 Click "Calculate" button to perform si
4 Save the analysis scenario by clickin
the existing scenario ("Save Scenari

Rail Consist Selection

Consist ID: RC.1 | RC.1
Description: 1P42-6TltC (Diesel)
Number of Locomotives / Power-Cars: 1
Fuel Type: U.S. conventional diesel
Number of Coaches: 6
Consist Seats: 416
Tilt-Body: Yes
Propulsion Type: onboard-fuel
Primary Fuel Type: U.S. conventional diesel
Hotel Power: PTO-fixed speed main engine
Secondary Fuel Type:
Energy Recovery: none
1 of 8

Rail Trip Selection

Trip ID: RT.29 | RT.29
Route ID (double click): RR.1 | RR.1
Trip Distance: 333.3
Number of Travelers: 1
Trip
Depart Time of Day: AM-peak
Arrive Time of Day: mid-day
Day of Week: Mon to Fri
Consist ID (double click): RC.1 | RC.1
Description: 1P42-6TltC (Diesel)
29 of 77

2-6TltC (Bimodal diesel & electri
2-6TltC (Bimodal diesel & electri
2-6TltC (Electric-w. onbrd strg)
2-6TltC (Electric-w. onbrd strg)
2-6TltC (Electric-w 0.65 regen to
2-6TltC (Electric-w 0.65 regen to

Figure A-20 Selecting a Rail Consist

Usage Notes:

On “Rail Trip Selection” form:

a) Pick a rail consist from the green “Consist ID” drop-down list.

or

Double click on the light yellow “Consist ID” box to open the “Rail Consist Selection” form and make a consist selection.

On the “Rail Consist Selection” form:

b) Pick a rail consist from the green “Consist ID” drop-down list at the top.

or

Use gray navigation buttons to display desired consist

c) Click gray “Add” button if you wish to create a new consist by modifying the displayed consist.

d) Make any changes to propulsion type, fuel, hotel power and energy recovery by selecting from the green drop-down lists (middle of form).

e) Click gray “Save” button to save changes to the displayed consist.

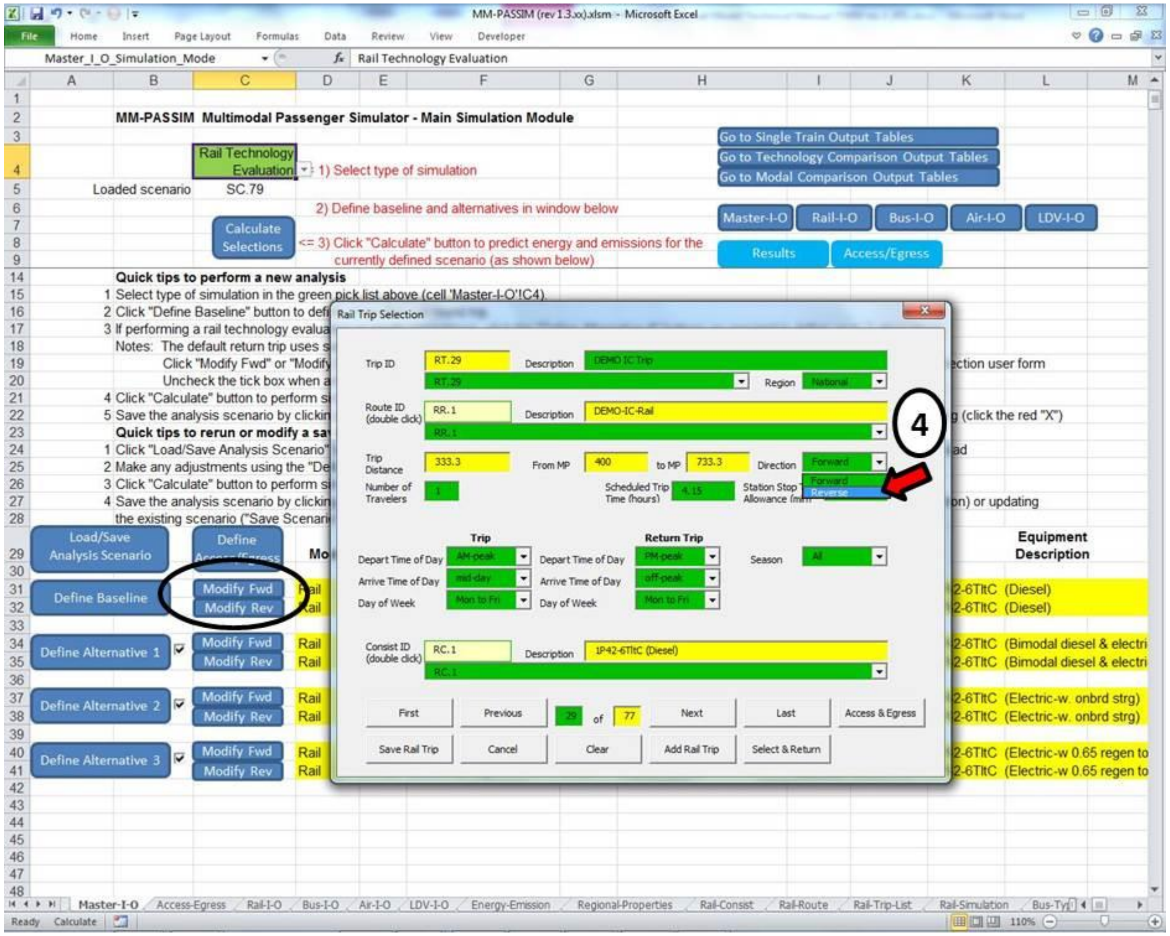
f) Click gray “Select & Return” button to return to the “Rail Trip Selection” form.

A user can also assign the access/egress legs for any rail trip by clicking the “Access & Egress” button on the right hand side of the “Rail Trip Selection” user form as depicted in Figure A-23. The access and egress legs currently defined for the displayed rail trip will be presented and the user may adjust all green fields accordingly. If all five legs are not required then any extra legs should be removed by selecting ‘none’ from the first position of the drop-down list for any leg not required and a macro will remove that data. The user can also scroll through the access and egress legs configured for any existing rail trips using the navigation buttons or by selecting from the green drop-down list immediately below the yellow ‘Trip ID’ field. This allows any existing access/egress configuration to be used as a template for the current trip. Clicking the “Select & Return” button will associate the currently displayed access & egress leg configurations with the rail trip being defined.

The ‘Trip Access and Egress Leg Selection’ user form provides yellow information fields indicating the ‘Trip ID’ and ‘Description’ on the top row and below that the transportation mode, region, day of week, departure time of day, arrival time of day, season of travel and finally the number of people assumed to be travelling together in one group. Please note that the number of travelers is specified in two places, in the yellow information field as just mentioned and also in a user modifiable green field which affects the intensity values used for the Auto/LDV based access and egress legs as specified on the ‘Regional-Properties’ worksheet. The number of travelers specified in the green field is the value used when evaluating access and egress leg intensities and should normally be the same as the yellow value stored with the main trip. However, in some Auto/LDV intercity trips where ride-sharing is involved it may be useful to independently assign the number of travelers in the main trip versus that assumed for access to a pickup point as well as egress from a drop-off point.

Access and egress legs are defined separately in the ‘Trip Access and Egress Leg Selection’ form. The region, city size and time of day may all be selected to best characterize the origin and destination of a trip. Clicking on the green ‘Region’ drop-down list permits selection of any region defined in the ‘Regional-Properties’ worksheet. A table of fuel and emissions intensity values for all access and egress modes is provided for each defined region presented in the drop-down list. The green ‘City Size’ and ‘Time of Day’ selections offer a limited number of choices to further tailor the access or egress modes. The choices of ‘City Size’ may be ‘Small Cities’, ‘Large Cities’, ‘Rural Municipality’ or ‘All Cities’ while the choices for ‘Time of Day’ include ‘Peak’, ‘Off-peak’ and ‘All’. Those values guide the VBA macro when choosing the most appropriate values from the table for a selected access/egress mode. The user is advised that the VBA macro expects every unique access/egress mode to be defined within the top portion of that table which would normally be associated with ‘All Cities’.

Each access and egress leg is selected by picking from the modes presented in the green drop-down lists. When a mode is selected, the user form automatically fills five of the remaining seven green user modifiable data fields with default values selected from the region’s data table. These default data include speed, fuel source, fuel intensity, energy intensity and GHG intensity. Although the inserted default data fields are yellow, the values may be adjusted to meet the user’s requirements. The user must manually provide data for the green fields specifying the distance to be traveled using that access/egress mode (in miles) and a dwell time (in minutes) for that leg. Once these access/egress data have been saved with a trip, they will appear green the next time they are loaded.



Master_I_O_Simulation_Mode — Rail Technology Evaluation

MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Rail Technology Evaluation — 1) Select type of simulation

Loaded scenario SC.79

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Quick tips to perform a new analysis

1 Select type of simulation in the green pick list above (cell 'Master-I-O'!C4).

Rail Trip Selection

Trip ID: RT.29 — Description: DEMO IC Trip — RT.29 — Region: National

Route ID (double click): RR.1 — Description: DEMO-IC-Rail — RR.1

Trip Distance: 333.3 — From MP: 400 — to MP: 733.3 — Direction: Forward (Forward / Reverse)

Number of Travelers: 1 — Scheduled Trip Time (hours): 4.15

Trip: Depart Time of Day: AM-peak — Arrive Time of Day: mid-day — Day of Week: Mon to Fri

Return Trip: Depart Time of Day: PM-peak — Arrive Time of Day: off-peak — Day of Week: Mon to Fri

Season: All

Consist ID (double click): RC.1 — Description: 1P42-6TltC (Diesel) — RC.1

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Figure A-21 Modifying a Return Rail Trip

Usage Notes:

On "Master-I-O" worksheet:

a) Click on either a blue "Modify Fwd" or "Modify Rev" button adjacent to a trip you wish to modify to open the "Rail Trip Selection" form – it will display the currently configured trip.

On the "Rail Trip Selection" form:

b) Pick a rail trip from the green "Trip ID" drop-down list at the top.

or

Use gray navigation buttons to display a desired trip.

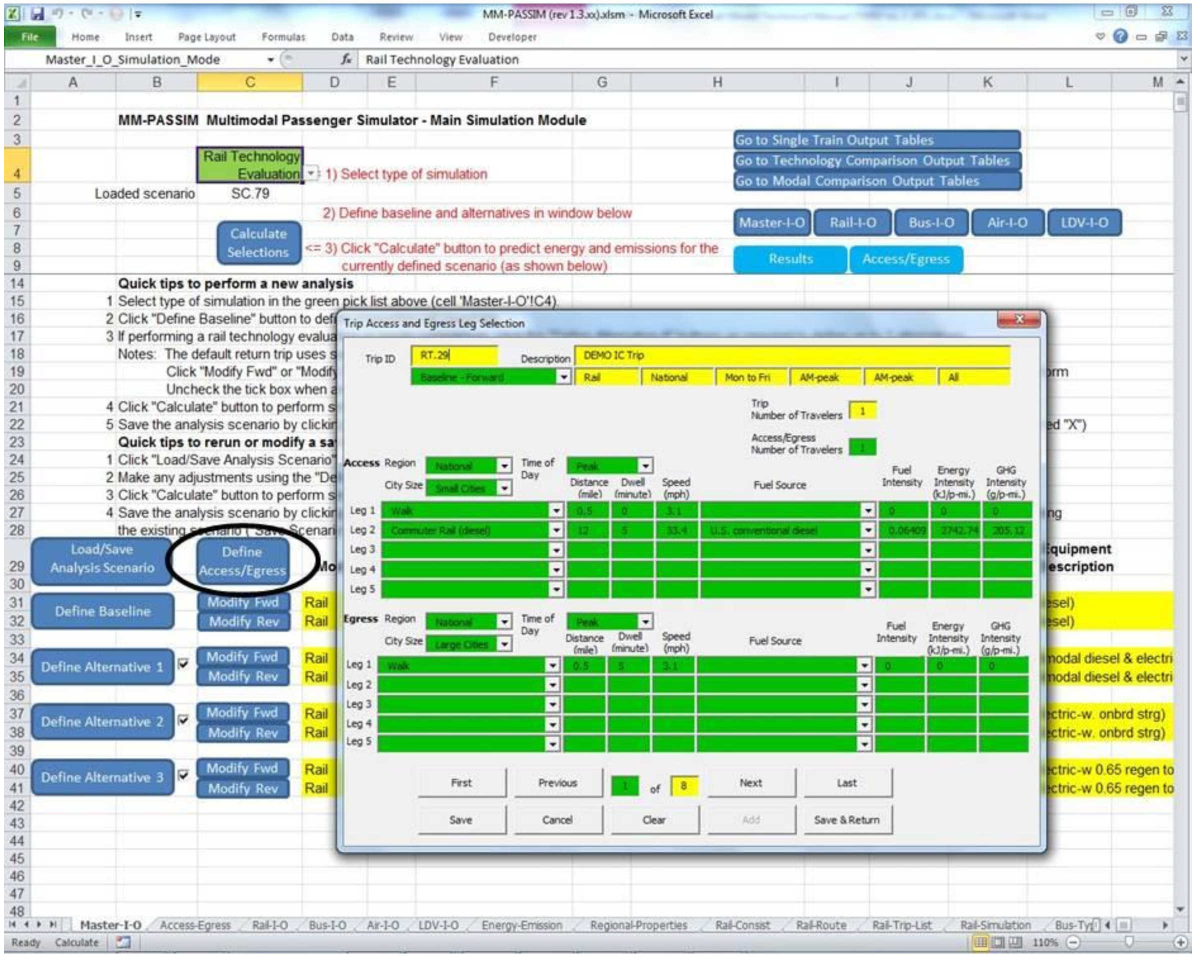
c) Use the Click gray "Add" button if you wish to create a new trip by modifying the displayed trip.

d) Click on gray arrow to the right side of green "Direction" drop-down list to modify direction of travel (see highlight 4).

e) Make any other required adjustments to the green fields in the middle of the form.

f) Click gray "Save" button to save changes to the displayed trip.

g) Click gray "Select & Return" button to return to the "Master-I-O" worksheet.



Rail Technology Evaluation 1) Select type of simulation

Loaded scenario SC.79

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Trip Access and Egress Leg Selection

Trip ID: RT.29 — Baseline - Forward

Description: DEMO IC Trip

Rail	National	Mon to Fri	AM-peak	AM-peak	All

Trip Number of Travelers: 1

Access/Egress Number of Travelers: 1

Access Region: National; City Size: Small Cities; Time of Day: Peak

	Mode	Distance (mile)	Dwell (minute)	Speed (mph)	Fuel Source	Fuel Intensity	Energy Intensity (kJ/p-mi.)	GHG Intensity (g/p-mi.)
Leg 1	Walk	0.5	0	3.1		0	0	0
Leg 2	Commuter Rail (diesel)	12	5	33.4	U.S. conventional diesel	0.06409	2742.74	205.12
Leg 3								
Leg 4								
Leg 5								

Egress Region: National; City Size: Large Cities; Time of Day: Peak

	Mode	Distance (mile)	Dwell (minute)	Speed (mph)	Fuel Source	Fuel Intensity	Energy Intensity (kJ/p-mi.)	GHG Intensity (g/p-mi.)
Leg 1	Walk	0.5	5	3.1		0	0	0
Leg 2								
Leg 3								
Leg 4								
Leg 5								

1 of 8

Figure A-22 Assigning Access & Egress Legs from 'Master-I-O' User Interface

To view and modify access/egress legs from the "Master-I-O" worksheet:

On the "Master-I-O" worksheet:

a) Click on the blue "Define Access/Egress" (see oval highlight) to open the "Trip Access and Egress Leg Selection" form.

On "Access and Egress Leg Selection Form:

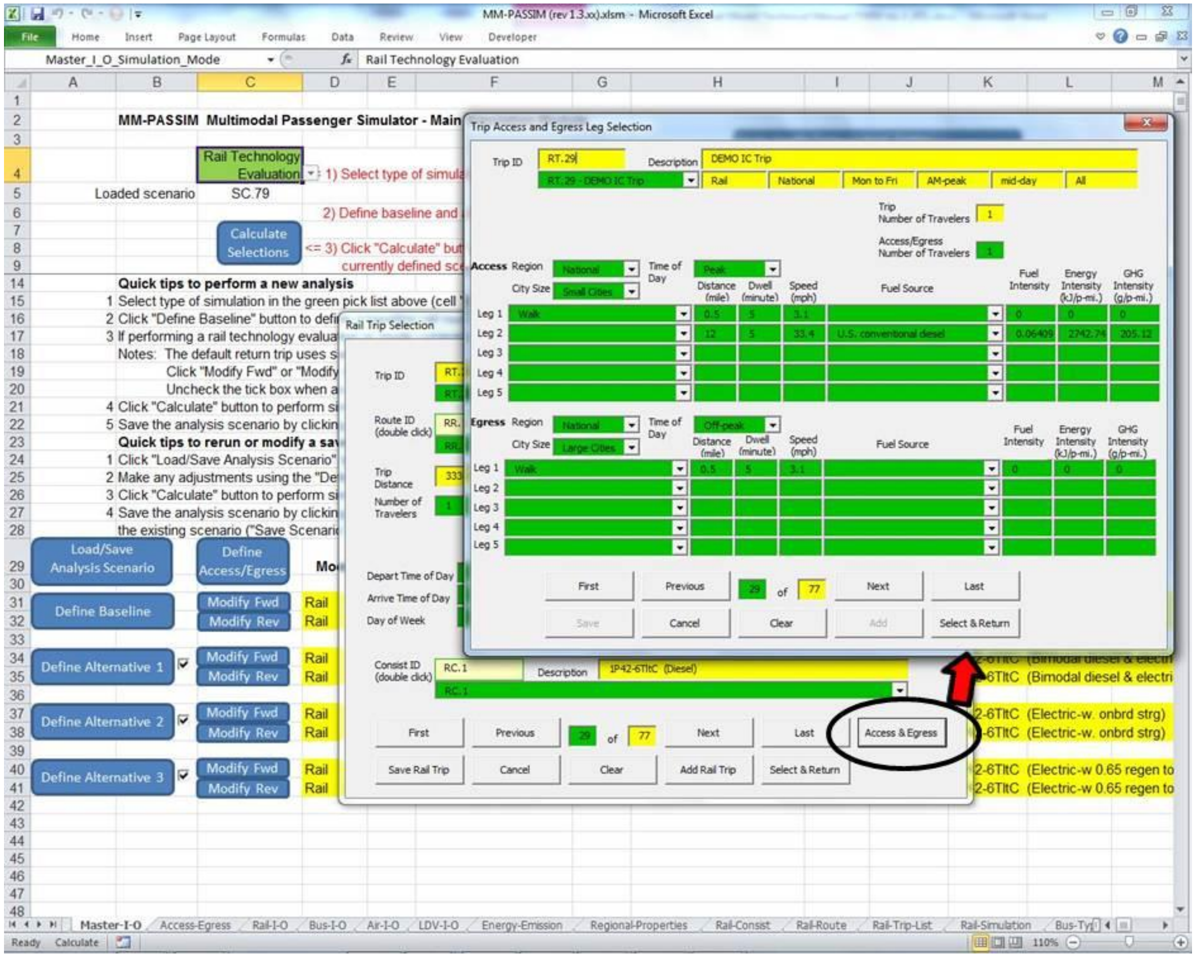
b) Select a trip from the green "Trip ID" drop-down list showing all trips currently configured on the "Master-I-O" worksheet.

or

Use the gray navigation buttons to display the access/egress legs for a trip.

c) Make any required adjustments in the green fields

d) Click on the gray "Select & Return" button



Master_I_O_Simulation_Mode — Rail Technology Evaluation

MM-PASSIM Multimodal Passenger Simulator - Main

Rail Technology Evaluation — 1) Select type of simula

Loaded scenario SC.79

2) Define baseline and

<= 3) Click "Calculate" but currently defined sc

Trip Access and Egress Leg Selection

Trip ID: RT.29 — Description: DEMO IC Trip

RT.29 - DEMO IC Trip | Rail | National | Mon to Fri | AM-peak | mid-day | All

Trip Number of Travelers: 1

Access/Egress Number of Travelers: 1

Access Region: National — City Size: Small Cities — Time of Day: Peak

		Distance (mile)	Dwell (minute)	Speed (mph)	Fuel Source	Fuel Intensity	Energy Intensity (kJ/p-mi.)	GHG Intensity (g/p-mi.)
Leg 1	Walk	0.5	5	3.1		0	0	0
Leg 2		12	5	33.4	U.S. conventional diesel	0.06409	2742.74	205.12
Leg 3								
Leg 4								
Leg 5								

Egress Region: National — City Size: Large Cities — Time of Day: Off-peak

		Distance (mile)	Dwell (minute)	Speed (mph)	Fuel Source	Fuel Intensity	Energy Intensity (kJ/p-mi.)	GHG Intensity (g/p-mi.)
Leg 1	Walk	0.5	5	3.1		0	0	0
Leg 2								
Leg 3								
Leg 4								
Leg 5								

29 of 77

Rail Trip Selection

Consist ID (double click): RC.1 — Description: 1P42-6TltC (Diesel)

29 of 77

Quick tips to perform a new analysis
1 Select type of simulation in the green pick list above (cell
2 Click "Define Baseline" button to defi
3 If performing a rail technology evalua
Notes: The default return trip uses s
Click "Modify Fwd" or "Modify
Uncheck the tick box when a
4 Click "Calculate" button to perform si
5 Save the analysis scenario by clickin
Quick tips to rerun or modify a sa
1 Click "Load/Save Analysis Scenario"
2 Make any adjustments using the "De
3 Click "Calculate" button to perform si
4 Save the analysis scenario by clickin
the existing scenario ("Save Scenari

2-6TltC (Bimodal diesel & electri
2-6TltC (Electric-w. onbrd strg)
2-6TltC (Electric-w 0.65 regen to

To view and modify access/egress legs from the “Rail Trip Selection” form:

On the “Rail Trip Selection” user form:

a) Click on the gray “Access & Egress” button (see oval highlight and arrow) to open the “Trip Access and Egress Leg Selection” form – the form will display the access & egress legs configured for the current trip.

On “Access and Egress Leg Selection Form:

b) Select any trip from the green “Trip ID” drop-down list

or

Use the gray navigation buttons to display the access/egress legs for any saved rail trip.

c) Make any required adjustments in the green fields

d) Click on the gray “Select & Return” button to pass the currently displayed access & egress leg configuration back and returns to the “Rail Trip Selection” user form.

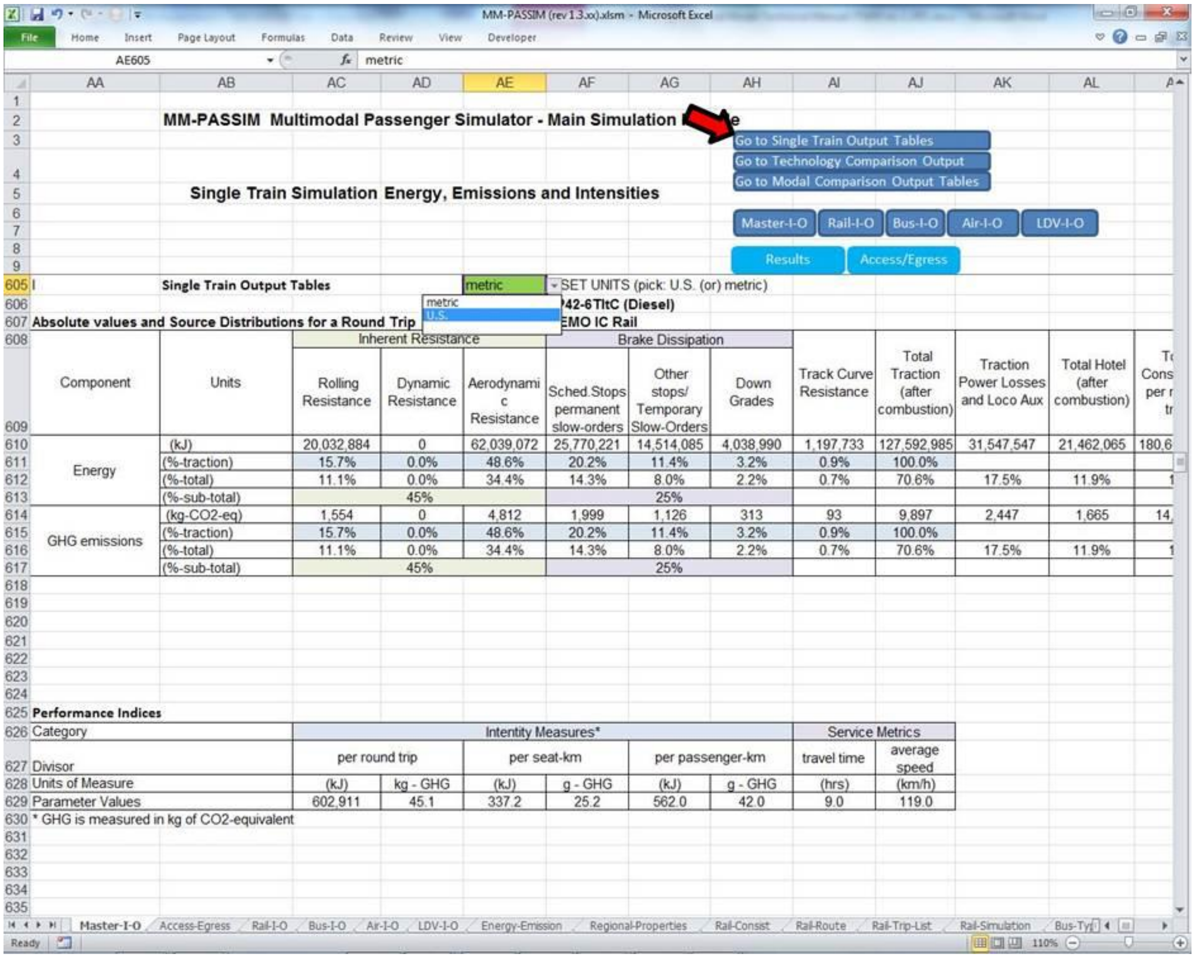
Figure A-23 Assigning Access & Egress Legs from Rail Trip Selection User Form

Caution: *The simulation dynamically calculates Auto/LDV access/egress mode intensities using the number of travelers as displayed in the pink cell in the on line 64 of the 'Regional-Properties' worksheet in the area associated with the currently selected region. That number is set to correspond with the number of travelers indicated in the green field when the 'Trip Access and Egress Leg Selection' user form loads. If the number of travelers is manually changed, then a user must also change the region selection to force the macro to update the number of travelers written to the 'Regional-Properties' worksheet.*

Advanced users may also manually adjust the access and egress leg specifications for a rail trip directly on the 'Rail-I-O' worksheet. Clicking on the blue "Rail-I-O Access/Egress" button in the upper left region of the 'Rail-I-O' worksheet will change the display focus to the appropriate area of the worksheet. The access legs are defined in the green fields of the left hand table while the egress legs are defined in the green fields of the table to the right (the user must scroll the screen to view it). Clicking one of the light blue buttons at the top of the screen will bring the associated access/egress tables into view. Clicking the blue "Rail-I-O" button will return to the main Rail Simulation Module user's interface. The currently configured rail mode simulations may then be executed directly from the 'Rail-I-O' worksheet by clicking the blue "Calculate Rail" button or the user can return to the main user interface on the 'Master-I-O' worksheet by clicking the blue "Master-I-O" button in the upper right area.

Clicking the blue "Calculate Selections" button at the upper left of the 'Master-I-O' display or the blue "Calculate Rail" button at the upper left of the 'Rail-I-O' display will trigger the VBA macros to perform the currently configured simulations. Executing an analysis from the 'Master-I-O' display will cause the display focus to switch to the simulation results summary table appropriate for the type of analysis being performed and the numbers will be updated as the simulation process proceeds. Executing from the 'Rail-I-O' worksheet does not automatically switch display focus and the results summary tables may be accessed by clicking the appropriate blue navigation button in the top right hand quadrant.

Simulation results are reported in the 'Master-I-O' worksheet in a location dedicated to the specific type of analysis being performed. As previously mentioned, the VBA macro automatically changes the focus of the worksheet window to the relevant data output area. Figure A-24 illustrates the tabular format of results provided after a single train simulation analysis. This output table may be configured to display results in either "metric" or "U.S." units according to a selection made from the green pulldown list at cell 'Master-I-O'!AE605. The highlighted arrow in the figure indicates a blue shortcut button located in the upper frozen pane of the 'Master-I-O' worksheet which may be clicked to jump directly to the single train simulation output area when it is not in view. Clicking on the blue 'Master-I-O' button will return window focus to the trip definition area on the 'Master-I-O' worksheet.



MM-PASSIM Multimodal Passenger Simulator - Main Simulation e

Single Train Simulation Energy, Emissions and Intensities

Single Train Output Tables metric SET UNITS (pick: U.S. (or) metric)

?42-6TltC (Diesel)

Absolute values and Source Distributions for a Round Trip EMO IC Rail

Component	Units	Inherent Resistance			Brake Dissipation								
		Rolling Resistance	Dynamic Resistance	Aerodynamic Resistance	Sched.Stops permanent slow-orders	Other stops/ Temporary Slow-Orders	Down Grades	Track Curve Resistance	Total Traction (after combustion)	Traction Power Losses and Loco Aux	Total Hotel (after combustion)	T Cons per r tr
Energy	(kJ)	20,032,884	0	62,039,072	25,770,221	14,514,085	4,038,990	1,197,733	127,592,985	31,547,547	21,462,065	180,6
	(%-traction)	15.7%	0.0%	48.6%	20.2%	11.4%	3.2%	0.9%	100.0%			
	(%-total)	11.1%	0.0%	34.4%	14.3%	8.0%	2.2%	0.7%	70.6%	17.5%	11.9%	1
	(%-sub-total)	45%			25%							
GHG emissions	(kg-CO2-eq)	1,554	0	4,812	1,999	1,126	313	93	9,897	2,447	1,665	14,
	(%-traction)	15.7%	0.0%	48.6%	20.2%	11.4%	3.2%	0.9%	100.0%			
	(%-total)	11.1%	0.0%	34.4%	14.3%	8.0%	2.2%	0.7%	70.6%	17.5%	11.9%	1
	(%-sub-total)	45%			25%							

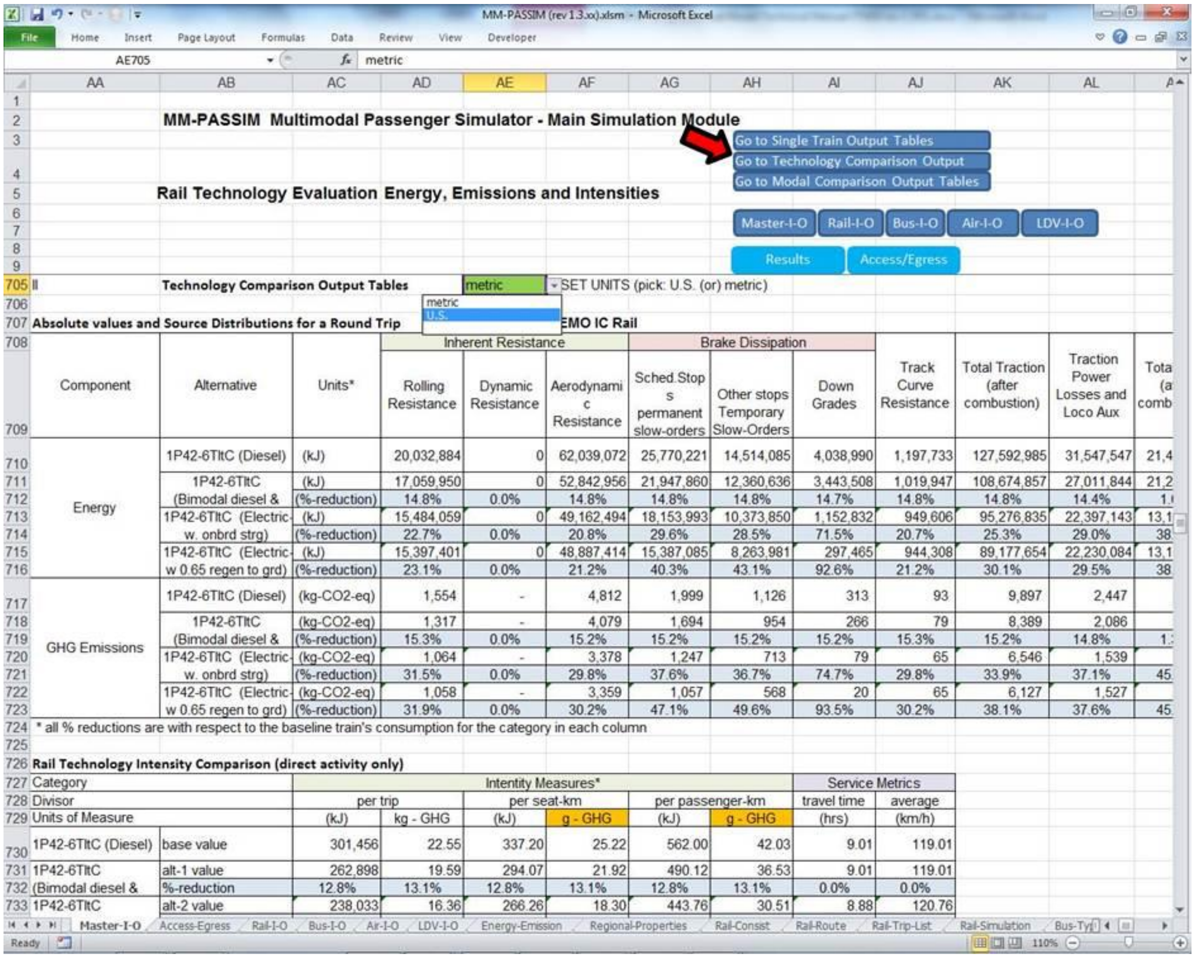
Performance Indices

Category	Intentity Measures*						Service Metrics	
Divisor	per round trip		per seat-km		per passenger-km		travel time	average speed
Units of Measure	(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Parameter Values	602,911	45.1	337.2	25.2	562.0	42.0	9.0	119.0

* GHG is measured in kg of CO2-equivalent

Figure A-24 Single Train Simulation Output Tables Area

Figure A-25 depicts the output tables provided for a technology comparison analysis. These tables may be configured to display results in either “metric” or “U.S.” units according to a selection made from the green pulldown list at cell ‘Master-I-O’!AE705. In these tables, the results of the technology alternatives are compared with those for the baseline rail trip. In cases where less than a full set of 3 alternatives are evaluated, the user should uncheck the check box located just to the right of the ‘Define Alternative #’ button on the trip definition area of the ‘Master-I-O’ worksheet (see Figure A-3 on page A-7) so that the unneeded analyses will not be performed.



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Rail Technology Evaluation Energy, Emissions and Intensities

Technology Comparison Output Tables metric SET UNITS (pick: U.S. (or) metric)

Absolute values and Source Distributions for a Round Trip **EMO IC Rail**

			Inherent Resistance			Brake Dissipation						
Component	Alternative	Units*	Rolling Resistance	Dynamic Resistance	Aerodynamic Resistance	Sched.Stops permanent slow-orders	Other stops Temporary Slow-Orders	Down Grades	Track Curve Resistance	Total Traction (after combustion)	Traction Power Losses and Loco Aux	Tota (a comb
Energy	1P42-6TltC (Diesel)	(kJ)	20,032,884	0	62,039,072	25,770,221	14,514,085	4,038,990	1,197,733	127,592,985	31,547,547	21,4
	1P42-6TltC (Bimodal diesel &	(kJ)	17,059,950	0	52,842,956	21,947,860	12,360,636	3,443,508	1,019,947	108,674,857	27,011,844	21,2
		(%-reduction)	14.8%	0.0%	14.8%	14.8%	14.8%	14.7%	14.8%	14.8%	14.4%	1.
	1P42-6TltC (Electric- w. onbrd strg)	(kJ)	15,484,059	0	49,162,494	18,153,993	10,373,850	1,152,832	949,606	95,276,835	22,397,143	13,1
		(%-reduction)	22.7%	0.0%	20.8%	29.6%	28.5%	71.5%	20.7%	25.3%	29.0%	38
	1P42-6TltC (Electric- w 0.65 regen to grd)	(kJ)	15,397,401	0	48,887,414	15,387,085	8,263,981	297,465	944,308	89,177,654	22,230,084	13,1
		(%-reduction)	23.1%	0.0%	21.2%	40.3%	43.1%	92.6%	21.2%	30.1%	29.5%	38
GHG Emissions	1P42-6TltC (Diesel)	(kg-CO2-eq)	1,554	-	4,812	1,999	1,126	313	93	9,897	2,447	
	1P42-6TltC (Bimodal diesel &	(kg-CO2-eq)	1,317	-	4,079	1,694	954	266	79	8,389	2,086	
		(%-reduction)	15.3%	0.0%	15.2%	15.2%	15.2%	15.2%	15.3%	15.2%	14.8%	1.
	1P42-6TltC (Electric- w. onbrd strg)	(kg-CO2-eq)	1,064	-	3,378	1,247	713	79	65	6,546	1,539	
		(%-reduction)	31.5%	0.0%	29.8%	37.6%	36.7%	74.7%	29.8%	33.9%	37.1%	45
	1P42-6TltC (Electric- w 0.65 regen to grd)	(kg-CO2-eq)	1,058	-	3,359	1,057	568	20	65	6,127	1,527	
		(%-reduction)	31.9%	0.0%	30.2%	47.1%	49.6%	93.5%	30.2%	38.1%	37.6%	45

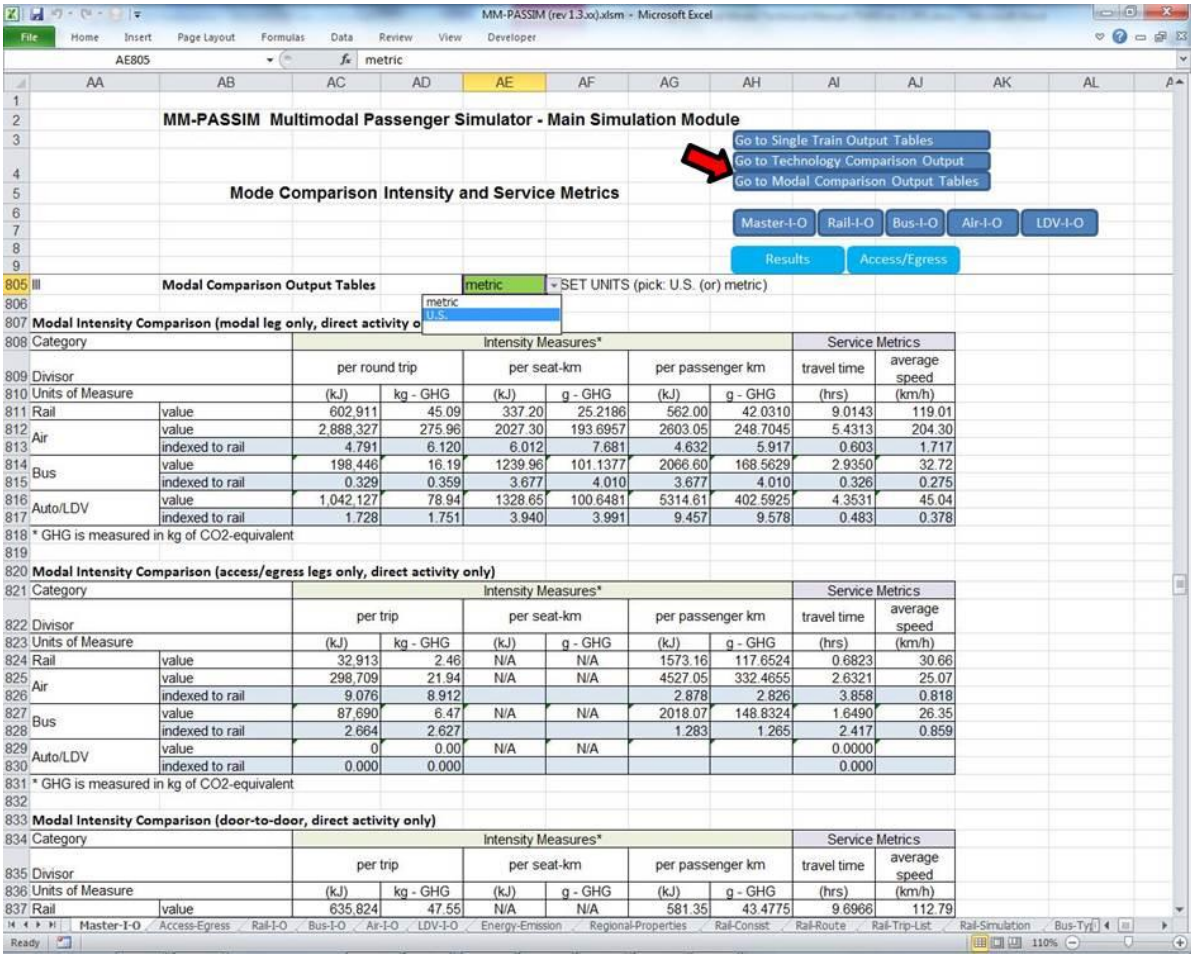
* all % reductions are with respect to the baseline train's consumption for the category in each column

Rail Technology Intensity Comparison (direct activity only)

Category		Intentity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger-km		travel time	average
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
1P42-6TltC (Diesel)	base value	301,456	22.55	337.20	25.22	562.00	42.03	9.01	119.01
1P42-6TltC	alt-1 value	262,898	19.59	294.07	21.92	490.12	36.53	9.01	119.01
(Bimodal diesel &	%-reduction	12.8%	13.1%	12.8%	13.1%	12.8%	13.1%	0.0%	0.0%
1P42-6TltC	alt-2 value	238,033	16.36	266.26	18.30	443.76	30.51	8.88	120.76

Figure A-25 Rail Technology Comparison Output Tables Area

Figure A-26 illustrates the output tables provided for a modal comparison analysis. You may select the unit system output by selecting from the green pulldown list at 'Master-I-O'!AE805. The rail related numbers on the top line always correspond with those calculated for the rail mode baseline trip. The modal comparison analysis organizes results into four tables. The first table presents a modal intensity comparison for the direct activity on the main modal leg of each mode simulated and includes energy and GHG emission intensities for a passenger round trip, per seat-distance and also per passenger-distance. Travel time and average speed for a round trip on the main modal leg are also shown. The intensity measures and service metrics for each non-rail mode are also indexed to the baseline rail mode case. The second output table presents a modal intensity comparison for the direct activity of the access/egress legs involved in the round trip for each selected transportation mode. We note that per seat-distance intensities are not calculated in this table, as indicated by "N/A" in the column, because the number of seats is not defined for all modes in in the access/egress source data. The third table calculates the intensities and service metrics for the door-to-door direct activity of the main trip's transportation mode and the access/egress legs. Finally, the fourth table presents the overall door-to-door intensities and service metrics including both direct activity as well as indirect well-to-pump consumption,



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison Intensity and Service Metrics

III **Modal Comparison Output Tables** metric SET UNITS (pick: U.S. (or) metric)

Modal Intensity Comparison (modal leg only, direct activity o

Category		Intensity Measures*						Service Metrics	
Divisor		per round trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	602,911	45.09	337.20	25.2186	562.00	42.0310	9.0143	119.01
Air	value	2,888,327	275.96	2027.30	193.6957	2603.05	248.7045	5.4313	204.30
	indexed to rail	4.791	6.120	6.012	7.681	4.632	5.917	0.603	1.717
Bus	value	198,446	16.19	1239.96	101.1377	2066.60	168.5629	2.9350	32.72
	indexed to rail	0.329	0.359	3.677	4.010	3.677	4.010	0.326	0.275
Auto/LDV	value	1,042,127	78.94	1328.65	100.6481	5314.61	402.5925	4.3531	45.04
	indexed to rail	1.728	1.751	3.940	3.991	9.457	9.578	0.483	0.378

* GHG is measured in kg of CO2-equivalent

Modal Intensity Comparison (access/egress legs only, direct activity only)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	32,913	2.46	N/A	N/A	1573.16	117.6524	0.6823	30.66
Air	value	298,709	21.94	N/A	N/A	4527.05	332.4655	2.6321	25.07
	indexed to rail	9.076	8.912			2.878	2.826	3.858	0.818
Bus	value	87,690	6.47	N/A	N/A	2018.07	148.8324	1.6490	26.35
	indexed to rail	2.664	2.627			1.283	1.265	2.417	0.859
Auto/LDV	value	0	0.00	N/A	N/A			0.0000	
	indexed to rail	0.000	0.000					0.000	

* GHG is measured in kg of CO2-equivalent

Modal Intensity Comparison (door-to-door, direct activity only)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	635,824	47.55	N/A	N/A	581.35	43.4775	9.6966	112.79

Figure A-26 ‘Master-I-O’ Modal Comparison Output Tables Area

A.5.2 Configuring and Running an Air Mode Comparison

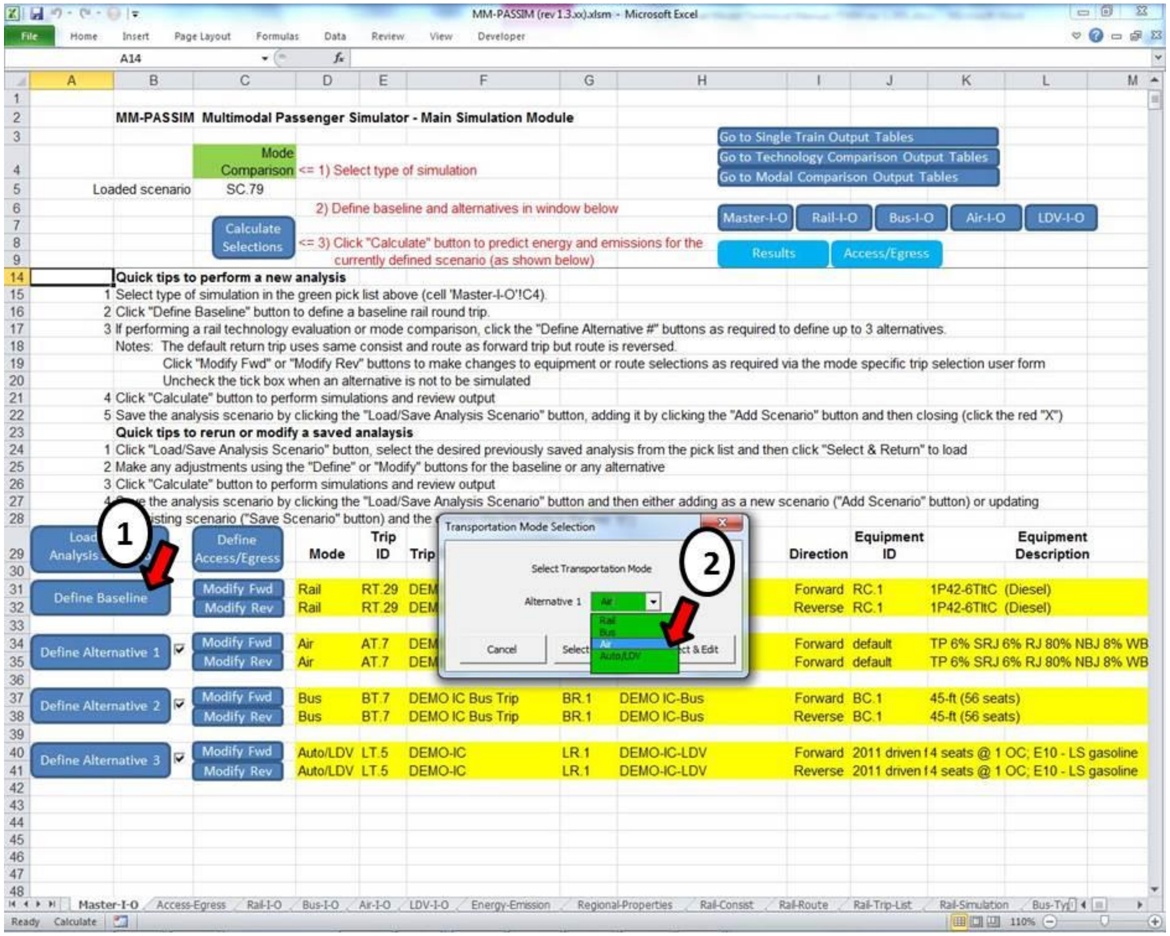
The Air-Simulation module is implemented using five (5) user accessible worksheets which together with the 'Master-I-O' worksheet provide for simulation configuration, user input and results output of air mode comparison analyses. These user accessible worksheets include the 'Air-I-O', 'Energy-Emission', 'Regional-Properties', 'Air-Trip-List' and 'Air-Default-Data' worksheets. While the 'Air-Trip-List' worksheet, which maintains the list of all configured air mode trips, is accessible to the user, it is typically maintained by the VBA macro code via the system of coordinated user forms. The 'Energy-Emission' worksheet specifies the energy and emissions characteristics of all fuel/energy sources used for all transportation modes and is therefore shared by all transportation mode sub-models. The Regional-Properties' worksheet is also used by all transportation modes. The 'Air-Default-Data' worksheet contains the default data referenced and used by the other air mode related worksheets. These data can be adjusted with care by a knowledgeable user.

The air mode simulation calculations are performed on the 'Air-Simulation' worksheet which should not normally be modified by a user. That worksheet predicts the energy use, GHG emissions produced and travel time associated with a forward direction air mode trip and a default return trip (assumed to be the mirror image of the forward trip). However, it is possible, and often desirable, to configure a two-way air mode trip as two successive one-way forward trips to achieve considerably more flexibility than if confined to a return trip defined as a simple mirror-image of the forward trip. That being the case, simulations of a two-way air trip may require two successive simulation sequences involving transfer of configuration data to the worksheet, recalculation of the worksheet and then transfer of results from the worksheet. That scenario is automatically set up and handled by the pop-up user forms and the VBA macros.

Defining an air mode simulation can be accomplished using the VBA macros and system of pop-up user forms available from the 'Master-I-O' worksheet when "Mode Comparison" has been selected in the green drop-down list at the top of the display or alternatively it may be configured directly from the 'Air-I-O' worksheet. Clicking any of the blue "Define Alternative #" buttons available on the left hand side of the 'Master-I-O' worksheet while the "'Mode Comparison" has been selected will prompt the user to choose a transportation mode for comparison. Selecting "Air" from the green drop-down list, as depicted in Figure A-27, and then clicking on the "Select & Edit" button will open the "Air Trip Selection" user form as shown in Figure A-28. Clicking on the "Select & Return" button will change the 'Master-I-O' trips to those defined on the 'Air-I-O' worksheet without displaying the "Air Trip Selection" user form. Table A-5 summarizes the steps required to configure an air trip.

Table A-5 Configuration Steps Required for an Air Trip

Define Air Case	Configuration Steps Required
Air Trip Selection Form	• Either select an existing Air trip from the 'Trip ID' drop-down list and click "Select and Return" or • Create a new Air trip by clicking "Add Air Trip" button • Enter a description of the Air trip • Pick the region • Set the number of travelers • Pick direction of travel • Pick the IATA code of the origin airport • Pick the departure airport activity period • Pick the IATA code of first intermediate airport stop (optional) • Pick the IATA code of second intermediate airport stop (optional) • Pick the IATA code of the destination airport • Pick the airport activity period for the default return trip • Set the fraction of multi-leg flights (multi + direct must equal 1) • Set the fraction of direct flights (multi + direct must equal 1) • Pick time of day for departure of outbound trip • Pick time of day for arrival of outbound trip • Pick day of week for outbound trip • Pick time of day for departure of return trip • Pick time of day for arrival of return trip • Pick day of week for return trip • Pick season of both outbound and return trips • Pick the aircraft data source (either default or user) • Pick the aircraft fuel type and only when user aircraft data is selected • Set/adjust the seat-km for each aircraft type over each leg of travel (note that each leg column must sum to 100%) • Set/adjust the load factor for each aircraft type (double click a green field to select the value from default data) • Set/adjust the landing and takeoff fuel for each aircraft type (double click a green field to select the value from default data) • Set/adjust the cruise fuel consumption for each aircraft type during peak activity period (double click a green field to select the value from default data) • Set/adjust the cruise fuel consumption for each aircraft type during off-peak activity period (double click a green field to select the value from default data) • Set/adjust the average cruise fuel consumption for each aircraft type (double click a green field to select the value from default data) • Assign access and egress legs by clicking the "Access & Egress" button • Save the new Air trip by clicking "Save Air Trip" button • Select the newly added Air trip by clicking "Select & Return" button



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison <= 1) Select type of simulation

Loaded scenario SC.79

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Quick tips to perform a new analysis

1 Select type of simulation in the green pick list above (cell 'Master-I-O'!C4).

2 Click "Define Baseline" button to define a baseline rail round trip.

3 If performing a rail technology evaluation or mode comparison, click the "Define Alternative #" buttons as required to define up to 3 alternatives.

Notes: The default return trip uses same consist and route as forward trip but route is reversed.

Click "Modify Fwd" or "Modify Rev" buttons to make changes to equipment or route selections as required via the mode specific trip selection user form

Uncheck the tick box when an alternative is not to be simulated

4 Click "Calculate" button to perform simulations and review output

5 Save the analysis scenario by clicking the "Load/Save Analysis Scenario" button, adding it by clicking the "Add Scenario" button and then closing (click the red "X")

Quick tips to rerun or modify a saved analaysis

1 Click "Load/Save Analysis Scenario" button, select the desired previously saved analysis from the pick list and then click "Select & Return" to load

2 Make any adjustments using the "Define" or "Modify" buttons for the baseline or any alternative

3 Click "Calculate" button to perform simulations and review output

4 ve the analysis scenario by clicking the "Load/Save Analysis Scenario" button and then either adding as a new scenario ("Add Scenario" button) or updating

isting scenario ("Save Scenario" button) and the

Mode	Trip ID	Trip			Direction	Equipment ID	Equipment Description
Rail	RT.29	DEM			Forward	RC.1	1P42-6TltC (Diesel)
Rail	RT.29	DEM			Reverse	RC.1	1P42-6TltC (Diesel)
Air	AT.7	DEM			Forward	default	TP 6% SRJ 6% RJ 80% NBJ 8% WB
Air	AT.7	DEM			Forward	default	TP 6% SRJ 6% RJ 80% NBJ 8% WB
Bus	BT.7	DEMO IC Bus Trip	BR.1	DEMO IC-Bus	Forward	BC.1	45-ft (56 seats)
Bus	BT.7	DEMO IC Bus Trip	BR.1	DEMO IC-Bus	Reverse	BC.1	45-ft (56 seats)
Auto/LDV	LT.5	DEMO-IC	LR.1	DEMO-IC-LDV	Forward	2011 driven f	4 seats @ 1 OC; E10 - LS gasoline
Auto/LDV	LT.5	DEMO-IC	LR.1	DEMO-IC-LDV	Reverse	2011 driven f	4 seats @ 1 OC; E10 - LS gasoline

Figure A-27 Selecting an Air Mode Round Trip

Selecting an Air Mode Trip

On the "Master-I-O" worksheet:

a) Click blue "Define Alternative #' button on left hand side of worksheet (see highlight 1).

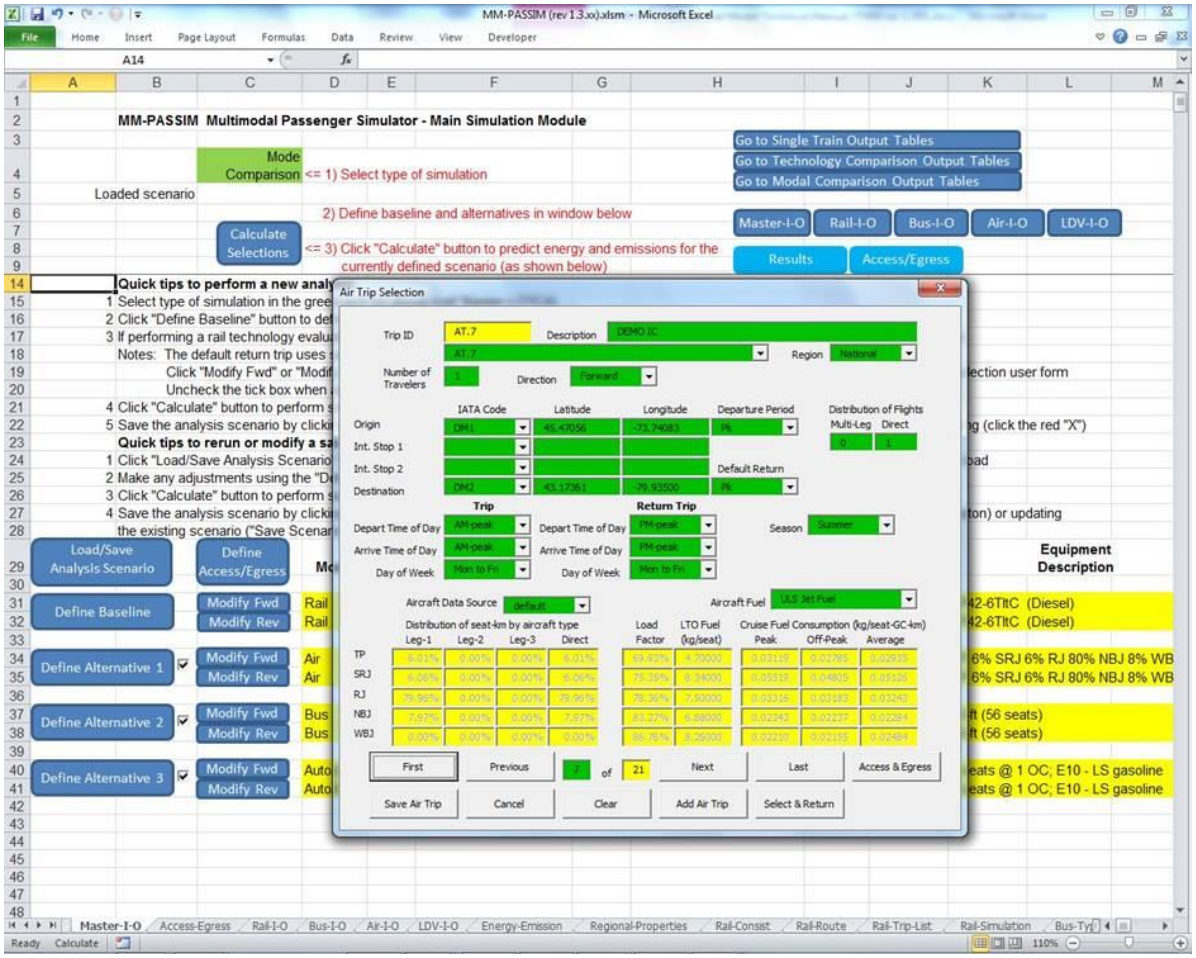
On "Transportation Mode Selection" form:

b) Click on gray arrow on right hand side of the green transportation mode drop-down list and then select the "Air" mode from the list (see highlight 2)

c) Click gray "Select & Edit" button at right to open the "Air Trip Selection" form.

or

Click gray "Select & Return" button in centre to use trip currently defined on the "Air-I-O" worksheet



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison <= 1) Select type of simulation

Loaded scenario

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Air Trip Selection

Trip ID: AT.7

Description: DEMO IC

AT.7

Region: National

Number of Travelers: 1

Direction: Forward

	IATA Code	Latitude	Longitude	Departure Period
Origin	DM1	45.47056	-73.74083	Pk
Int. Stop 1				
Int. Stop 2				
Destination	DM2	43.17361	-79.93500	Pk

Distribution of Flights: Multi-Leg 0, Direct 1

Default Return

	Trip		Return Trip
Depart Time of Day	AM-peak	Depart Time of Day	PM-peak
Arrive Time of Day	AM-peak	Arrive Time of Day	PM-peak
Day of Week	Mon to Fri	Day of Week	Mon to Fri

Season: Summer

Aircraft Data Source: default

Aircraft Fuel: ULS Jet Fuel

	Distribution of seat-km by aircraft type				Load	LTO Fuel	Cruise Fuel Consumption (kg/seat-GC-km)		
	Leg-1	Leg-2	Leg-3	Direct	Factor	(kg/seat)	Peak	Off-Peak	Average
TP	6.01%	0.00%	0.00%	6.01%	69.93%	4.70000	0.03119	0.02785	0.02935
SRJ	6.06%	0.00%	0.00%	6.06%	75.39%	8.34000	0.05519	0.04805	0.05126
RJ	79.96%	0.00%	0.00%	79.96%	78.36%	7.50000	0.03316	0.03183	0.03243
NBJ	7.97%	0.00%	0.00%	7.97%	83.27%	6.88000	0.02343	0.02237	0.02284
WBJ	0.00%	0.00%	0.00%	0.00%	86.76%	8.26000	0.02210	0.02155	0.02484

First | Previous | 7 of 21 | Next | Last | Access & Egress

Save Air Trip | Cancel | Clear | Add Air Trip | Select & Return

Figure A-28 Defining the Air Mode Round Trip

Usage Notes:

- Either select an existing Air trip from the green “Trip ID” drop-down list and click “Select and Return”

or

- Create a new Air trip by clicking the “Add Air Trip” button
- Enter description
- Pick direction of travel
- Pick IATA codes for all airports in trip
- Pick departure and arrival time of day and day of week (outbound & inbound)
- Pick Season
- Pick aircraft data source and fuel type
- Set/adjust aircraft data as required (double click yellow field to modify)
- Assign access/egress legs by clicking “Access & Egress” button
- Save the new Air trip by clicking “Save Air Trip” button
- Select the newly added Air Trip by clicking “Select & Return” button

An air trip is configured by adjusting the green fields on the ‘Air Trip Selection’ user form, shown in Figure A-28, to suit the desired scenario. The yellow “Trip ID” and green “Description” fields identify the currently displayed air trip. The gray navigation buttons at the bottom of the user form facilitate access to all previously defined air tips for review and potential use either as the desired trip or to serve as a template upon which to build a new trip. An existing air trip may also be selected from the green drop-down list located immediately below the “Trip ID” and “Description” information fields. The region, number of travelers and direction of travel are all set using green fields in the top portion of the user form. To define an air trip, the origin and destination cities and up to two optional intermediate stops are selected from the green drop-down list fields which choose from location data stored in the ‘Air-Default-Data’ worksheet. Airport latitude and longitude are automatically filled in when an airport code is selected. The user may add to that list of cities following the pre-defined tabular format (see cells ‘Air-Default-Data’!B4:G8) by inputting the IATA code, city name, latitude and longitude. The ‘Air-Simulation’ worksheet automatically calculates the great circle distance between cities from those coordinates during the simulation. The air trip may also be represented using a distribution of multi-leg and direct flights as defined by the green user input fields to the right of the trip leg definitions. The user also must define the flight departure and default return service period which can only have values of “Pk” for peak period or “OffPk” for anytime outside the peak air travel service period. The air trip departure and arrival times, day of week and season are defined for both the outbound and return air trips using the set of seven green drop-down lists in the area below the air trip definition area. Please note that these departure and arrival time periods refer to periods of city activity which differ from the air travel service period for use in the intensities of highway access/egress modes.

Specifying Aircraft Parameters

The aircraft parameters are specified in the lower portion of the ‘Air Trip Selection’ user form. The aircraft fuel type is set from the list available in the green drop-down list. The remaining primary simulation inputs are provided for five (5) broad aircraft categories which include turboprop (TP), small regional jet (SRJ), regional jet (RJ), narrow body jet (NBJ) and wide body jet (WBJ). The aircraft simulation parameters include a default distribution of seat-kilometers by aircraft category for a given trip length as well as passenger load factors, the landing and takeoff (LTO) fuel consumption and the cruise fuel consumption intensity for each aircraft category. Default values for these parameters are provided in the ‘Air-Default-Data’ worksheet and are automatically loaded into the fields of the “Air Trip Selection” user form when the green “Aircraft Data Source” on the left hand side is set to “default”. Changing the “Aircraft Data Source” field to “user” will toggle the fields from yellow to green and allow user modifications of any of the green data fields. The main modification expected by users is from the default distribution of aircraft used for that distance to a single selected aircraft type. However, all characteristics of each aircraft category can also be accessed and modified from the menu when displaying the “user” data. Double clicking on any green cell in the five columns on the right hand side (load factor, LTO fuel and cruise fuel consumptions) will toggle that cell’s view to display the default data in a yellow box. Double clicking the yellow box will toggle the view back to the user configured data.

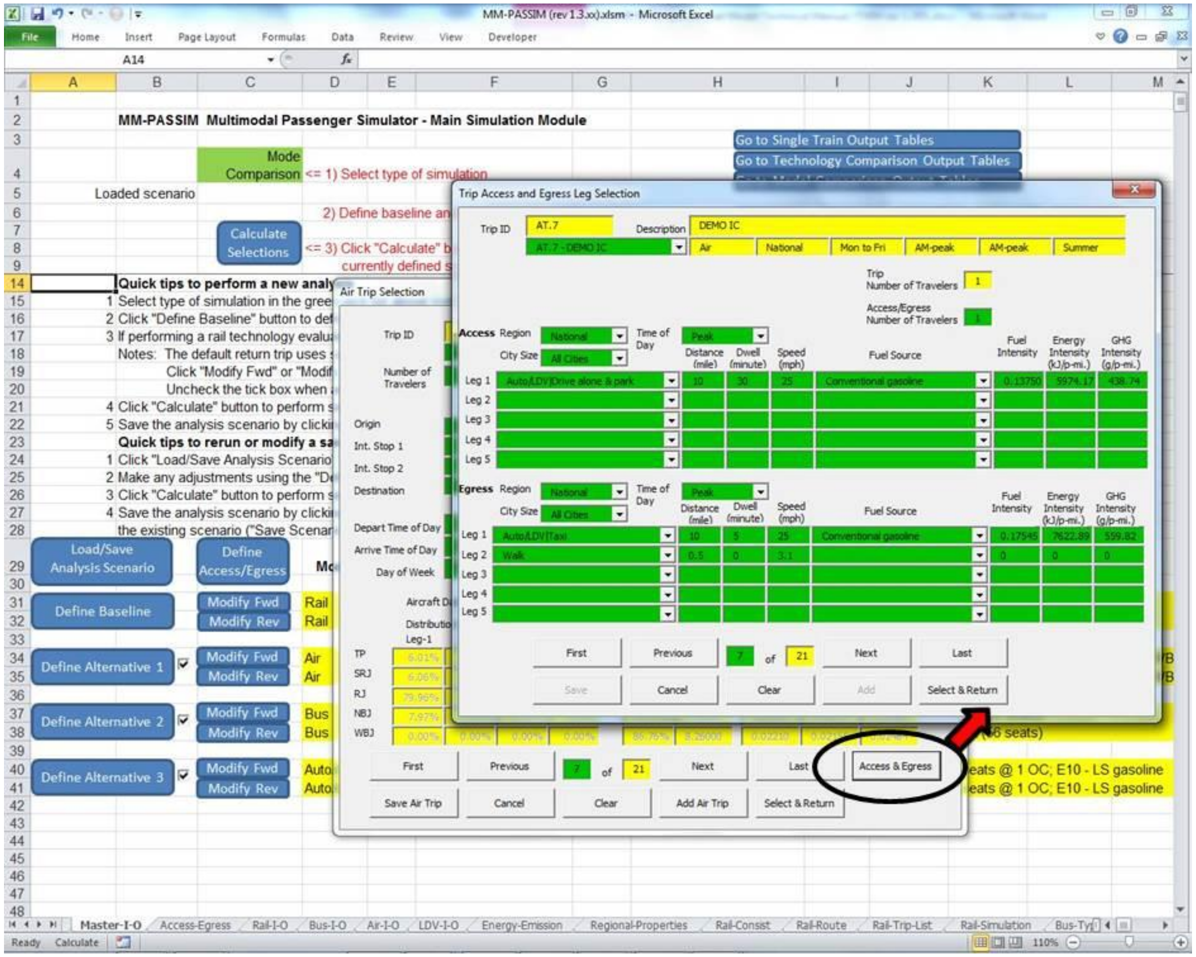
Defining Access & Egress

The method of passenger access and egress to and from an airport may be specified by clicking the “Access & Egress” button in the lower right hand quadrant to open the “Trip Access and Egress Leg Selection” user form (Figure A-29). The access and egress legs currently defined for the displayed air trip will be shown and the user may adjust all green fields accordingly. If a leg is not required then it should be removed by selecting “none” in the green drop-down list for that leg. The user can also scroll through the access and egress legs configured for any existing air trips using the navigation buttons. This allows any existing access/egress configuration to be used as a template for the current trip. Clicking the “Select & Return” button will associate the currently displayed access & egress leg configurations with the air trip being defined.

Access and egress legs are defined separately in the ‘Trip Access and Egress Leg Selection’ form. The region, city size and time of day may all be selected to best characterize the origin and destination of a trip. Clicking on the green ‘Region’ drop-down list permits selection of any region defined in the ‘Regional-Properties’ worksheet. A table of fuel and emissions intensity values for all access and egress modes is provided for each defined region presented in the drop-down list. The green ‘City Size’ and ‘Time of Day’ selections offer a limited number of choices to further tailor the access or egress modes. The choices of ‘City Size’ may be ‘Small Cities’, ‘Large Cities’, ‘Rural Municipality’ or ‘All Cities’ while the choices for ‘Time of Day’ include ‘Peak’, ‘Off-peak’ and ‘All’. Those values guide the VBA macro when choosing the most appropriate values from the table for a selected access/egress mode. The user is advised that the VBA macro expects every unique access/egress mode to be defined within the top portion of that table which would normally be associated with ‘All Cities’.

Access and egress leg are selected by picking from the modes presented in the green drop-down lists. When a mode is selected, the user form automatically fills five of the remaining seven green data fields with default values selected from the region’s data table. These default data include speed, fuel source, fuel intensity, energy intensity and GHG intensity. Although the inserted default data fields are yellow, the values may be adjusted to meet the user’s requirements. The user must manually provide data for the green fields specifying the distance to be traveled using that access/egress mode (in miles) and a dwell time (in minutes) for that leg. Once these access/egress data have been saved with a trip, they will appear green the next time they are loaded. The user is cautioned that the simulation dynamically calculates Auto/LDV access/egress mode intensities using the number of travelers as displayed in the pink cell in the on line 64 of the ‘Regional-Properties’ worksheet in the area associated with the currently selected region. That number is set to correspond with the number of travelers indicated in the green field when the ‘Trip Access and Egress Leg Selection’ user form loads. If the number of travelers is manually changed, then a user must also change the region selection to force the macro to update the number of travelers written to the ‘Regional-Properties’ worksheet.

Advanced users may also manually adjust the access and egress leg specifications for an air trip directly on the ‘Air-I-O’ worksheet by clicking on the blue “Air-I-O Access/Egress” button in the upper left region of the ‘Air-I-O’ worksheet to change the display focus to the appropriate area of the worksheet. The access legs are defined in the green fields of the left hand table while the egress legs are defined in the green fields of the table to the right (the user must scroll the screen to view it). Clicking the blue “Air-I-O” button will return to the main Air Simulation Module user’s interface. The currently configured air mode simulations may then be executed directly from the ‘Air-I-O’ worksheet by clicking the blue “Calculate Air” button or the user can return to the main user interface on the ‘Master-I-O’ worksheet by clicking the blue “Master-I-O” button in the upper right quadrant of the display.



Trip Access and Egress Leg Selection

Trip ID: AT.7 — Description: DEMO IC

AT.7 - DEMO IC | Air | National | Mon to Fri | AM-peak | AM-peak | Summer

Trip Number of Travelers: 1

Access/Egress Number of Travelers: 1

Access Region: National — City Size: All Cities — Time of Day: Peak

	Mode	Distance (mile)	Dwell (minute)	Speed (mph)	Fuel Source	Fuel Intensity	Energy Intensity (kJ/p-mi.)	GHG Intensity (g/p-mi.)
Leg 1	Auto/LDV|Drive alone & park	10	30	25	Conventional gasoline	0.13750	5974.17	438.74
Leg 2								
Leg 3								
Leg 4								
Leg 5								

Egress Region: National — City Size: All Cities — Time of Day: Peak

	Mode	Distance (mile)	Dwell (minute)	Speed (mph)	Fuel Source	Fuel Intensity	Energy Intensity (kJ/p-mi.)	GHG Intensity (g/p-mi.)
Leg 1	Auto/LDV|Taxi	10	5	25	Conventional gasoline	0.17545	7622.89	559.82
Leg 2	Walk	0.5	0	3.1		0	0	0
Leg 3								
Leg 4								
Leg 5								

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Figure A-29 Assigning Access & Egress Legs from Air Trip Selection User Form

To view and modify access/egress legs from the "Air Trip Selection" form:

On the "Air Trip Selection" user form:

a) Click on the gray "Access & Egress" button (see oval highlight and arrow) to open the "Trip Access and Egress Leg Selection" form – the form will display the access & egress legs configured for the current trip.

On "Access and Egress Leg Selection" Form:

b) Select any trip from the green "Trip ID" drop-down list

or

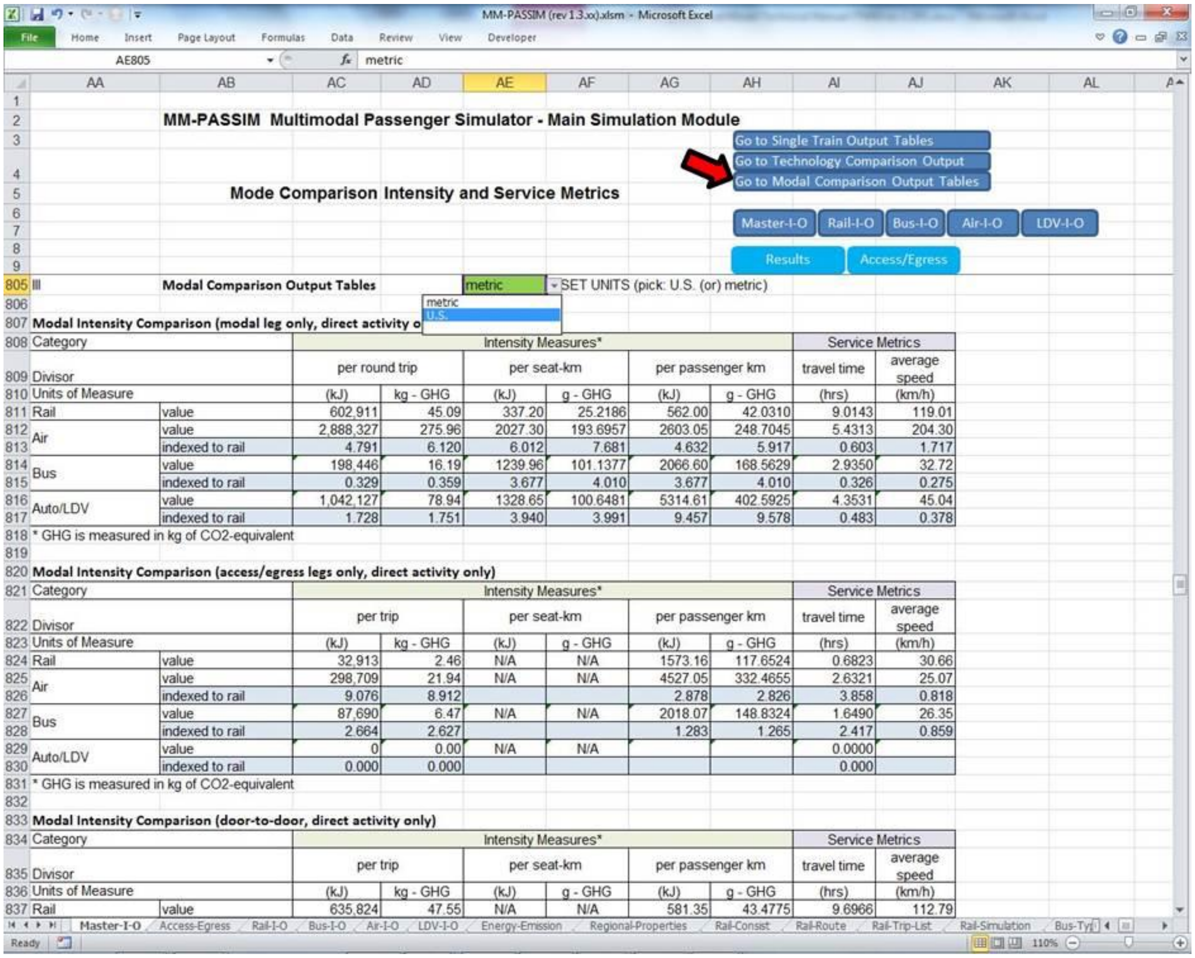
Use the gray navigation buttons to display the access/egress legs for any saved air trip.

c) Make any required adjustments in the green fields

d) Click on the gray "Select & Return" button to pass the currently displayed access & egress leg configuration back and returns to the "Air Trip Selection" user form.

Clicking the blue “Calculate Selections” button at the upper left of the ‘Master-I-O’ display or the blue “Calculate Air” button at the upper left of the ‘Air-I-O’ display will trigger the VBA macros to perform the currently configured simulations. Executing an analysis from the ‘Master-I-O’ display will cause the display focus to switch to the simulation results summary table appropriate for the type of analysis being performed and the numbers will be updated as the simulation process proceeds. Executing from the ‘Air-I-O’ worksheet does not automatically switch display focus and the results summary tables may be accessed by clicking the appropriate blue navigation button in the top right hand quadrant.

Simulation results are reported in the ‘Master-I-O’ worksheet in a location dedicated to the specific type of analysis being performed. As previously mentioned, the VBA macro automatically changes the focus of the worksheet window to the relevant data output area. Figure A-30 illustrates the tabular format of results provided after a mode comparison analysis is performed. The unit system displayed in these tables may be selected from the green pulldown list at ‘Master-I-O’!AE805. The highlighted arrow in the figure indicates a blue shortcut button located in the upper frozen pane which may be clicked to jump directly the mode comparison summary results table. Clicking on the blue ‘Master-I-O’ button will return window focus to the trip definition area on the ‘Master-I-O’ worksheet.



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison Intensity and Service Metrics

Modal Comparison Output Tables — metric — SET UNITS (pick: U.S. (or) metric)

Modal Intensity Comparison (modal leg only, direct activity o

Category		Intensity Measures*						Service Metrics	
Divisor		per round trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	602,911	45.09	337.20	25.2186	562.00	42.0310	9.0143	119.01
Air	value	2,888,327	275.96	2027.30	193.6957	2603.05	248.7045	5.4313	204.30
	indexed to rail	4.791	6.120	6.012	7.681	4.632	5.917	0.603	1.717
Bus	value	198,446	16.19	1239.96	101.1377	2066.60	168.5629	2.9350	32.72
	indexed to rail	0.329	0.359	3.677	4.010	3.677	4.010	0.326	0.275
Auto/LDV	value	1,042,127	78.94	1328.65	100.6481	5314.61	402.5925	4.3531	45.04
	indexed to rail	1.728	1.751	3.940	3.991	9.457	9.578	0.483	0.378

* GHG is measured in kg of CO2-equivalent

Modal Intensity Comparison (access/egress legs only, direct activity only)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	32,913	2.46	N/A	N/A	1573.16	117.6524	0.6823	30.66
Air	value	298,709	21.94	N/A	N/A	4527.05	332.4655	2.6321	25.07
	indexed to rail	9.076	8.912			2.878	2.826	3.858	0.818
Bus	value	87,690	6.47	N/A	N/A	2018.07	148.8324	1.6490	26.35
	indexed to rail	2.664	2.627			1.283	1.265	2.417	0.859
Auto/LDV	value	0	0.00	N/A	N/A			0.0000	
	indexed to rail	0.000	0.000					0.000	

* GHG is measured in kg of CO2-equivalent

Modal Intensity Comparison (door-to-door, direct activity only)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	635,824	47.55	N/A	N/A	581.35	43.4775	9.6966	112.79

Figure A-30 ‘Master-I-O’ Air Mode Comparison Output Tables Area

A modal comparison analysis organizes results into four tables. The rail related numbers on the first line of each table correspond with those calculated for the rail mode baseline trip. The first table presents a modal intensity comparison for the direct activity on the main modal leg of each mode simulated and includes energy and GHG emission intensities for a passenger round trip, per seat-distance and also per passenger-distance. Travel time and average speed for a round trip on the main modal leg are also shown. The intensity measures and service metrics for each non-rail mode are also indexed to the baseline rail mode case. The second output table presents a modal intensity comparison for the direct activity of the access/egress legs involved required for a round trip of each selected transportation mode. Seat-distance intensities are not calculated in this table, as indicated by “N/A” in the column, because the number of seats is not defined in the access/egress mode data. The third table calculates the intensities and service metrics for the door-to-door direct activity of the main trip’s transportation mode and the access/egress legs. Finally, the fourth table presents the overall door-to-door intensities and service metrics including both direct activity as well as indirect well-to-pump consumption,

A.5.3 Configuring and Running a Bus Mode Comparison

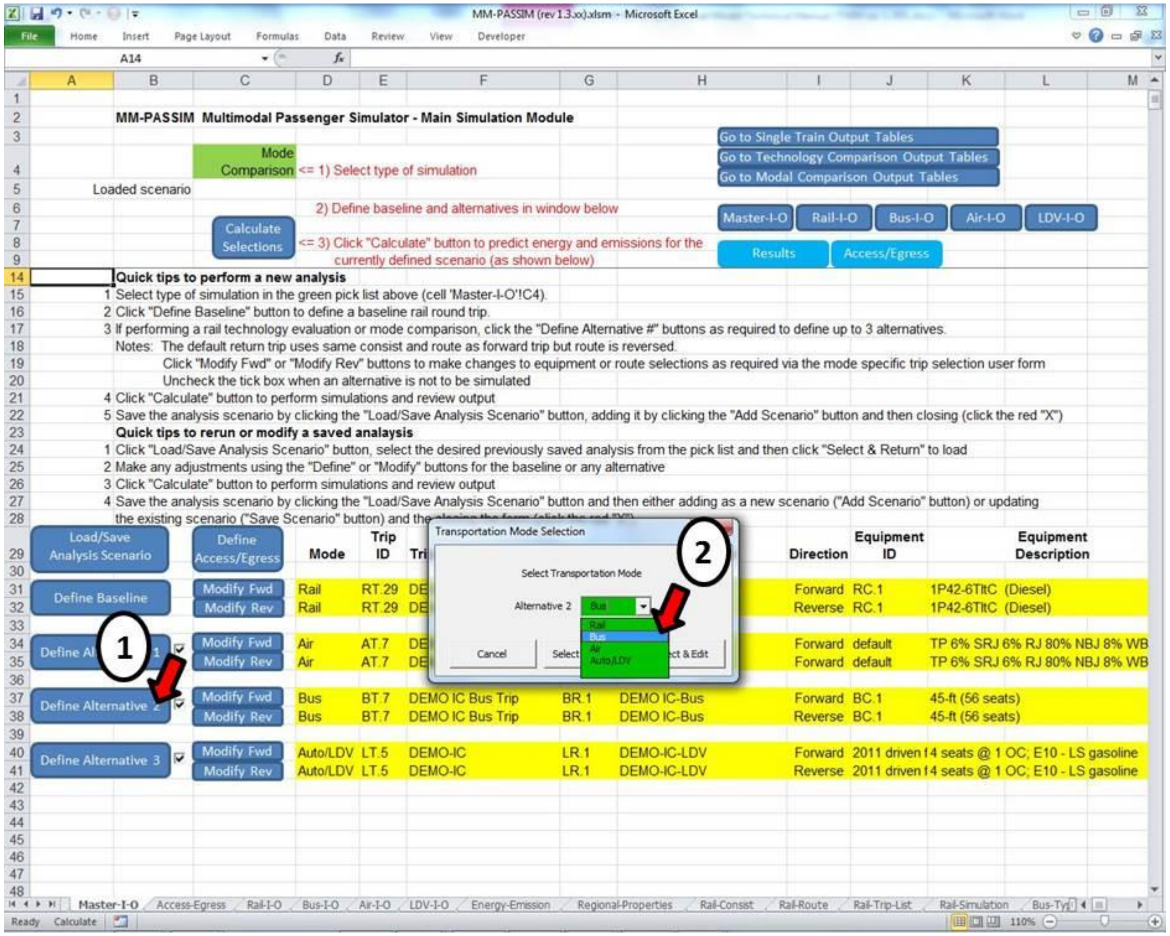
The Bus-Simulation module is implemented in eleven (11) worksheets which together with the ‘Master-I-O’ worksheet provide for simulation configuration, user input and results output of bus mode comparison analyses. The user accessible worksheets include the ‘Bus-I-O’, ‘Energy-Emission’, ‘Regional-Properties’, ‘Bus-Type’, ‘Bus-Route’, ‘Bus-Drive-Schedules’ and ‘Bus-Trip-List’ worksheets. The ‘Bus-Trip-List’ worksheet maintains the list of all configured bus mode trips and is typically maintained by the VBA macro code via the system of coordinated user forms although it may also be directly modified by an experienced user. The ‘Energy-Emission’ worksheet specifies the energy and emissions characteristics of all fuel/energy sources used for all transportation modes and is therefore shared by all transportation mode sub-models. The ‘Regional-Properties’ worksheet defines those parameters which may vary by geographical area. The ‘Bus-Type’, ‘Bus-Route’ and ‘Bus-Drive-Schedules’ worksheets contain most of the user configurable data for a bus mode simulation. The ‘Bus-Trip’, ‘Bus-Resist’, ‘Bus-Engine’ and ‘Bus-Simulation’ worksheets are all used internally to perform a bus mode simulation and should not normally be modified by a user.

A one-way bus mode trip is constructed by concatenating several specified lengths of bus operation. These are governed by pre-defined drive schedules representing driving in urban areas with varying speed limits and traffic densities. There is also a generally much longer segment of cruise in which the vehicle seeks to maintain a speed limit while ascending and descending grades. The ‘Bus-Simulation’ worksheet predicts the energy use, GHG emissions produced and travel time associated with any one individual portion of a bus mode trip at a time. VBA macros use the information on the ‘Bus-I-O’ worksheet to automatically manage the transfer of data to and from the ‘Bus-Simulation’ worksheet for successive portions which together comprise the total distance of a one-way trip.

Defining a bus mode simulation can be accomplished using the VBA macros and system of pop-up user forms available from the ‘Master-I-O’ worksheet when “Mode Comparison” has been selected in the green drop-down list at the top of the display or alternatively it may be configured directly from the ‘Bus-I-O’ worksheet. Clicking any of the blue “Define Alternative #” buttons available on the left hand side of the ‘Master-I-O’ worksheet while the “‘Mode Comparison” has been selected will prompt the user to choose a transportation mode for comparison. Selecting “Bus” from the green drop-down list, as depicted in Figure A-31, and then clicking on the “Select & Edit” button will open the “Bus Trip Selection” user form as shown in Figure A-32. Clicking on the “Select & Return” button directly selects the bus trip which is currently defined on the ‘Bus-I-O’ worksheet without opening the “Bus Trip Selection” user form. Table A-5 lists the steps required to configure a bus trip.

Table A-6 Configuration Steps Required for a Bus Trip

Define Bus Case	Configuration Steps Required
Bus Trip Selection Form	• Either select an existing Bus trip from the ‘Trip ID’ drop-down list and click “Select & Return” or • Create a new Bus trip by clicking “Add Bus Trip” button • Enter a description for the new trip • Pick a Bus route from the “Route ID” drop-down list • Set the scheduled trip time (in hours) • Set the average stop duration (in minutes) • Set the number of travelers • Pick direction of travel • Pick season for both outbound and return trips • Pick freeway drive schedule mix for Urban Area 1 (the origin) • Pick freeway drive schedule mix for Urban Area 2 (the destination) • Pick urban arterial drive schedule mix (for origin and destination) • Pick time of day for departure of outbound trip • Pick time of day for arrival of outbound trip • Pick day of week for outbound trip • Pick time of day for departure of return trip • Pick time of day for arrival of return trip • Pick day of week for return trip • Pick a bus type from the “Coach ID” drop-down list • Set the load factor (between 0 and 1) • Set number of passengers • Pick the bus fuel type • Assign access and egress legs by clicking the “Access & Egress” button • Save the new Bus trip by clicking “Save Bus Trip” button • Select the newly added Bus trip by clicking “Select & Return” button



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison <= 1) Select type of simulation

Loaded scenario

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Quick tips to perform a new analysis

1 Select type of simulation in the green pick list above (cell 'Master-I-O'!C4).
2 Click "Define Baseline" button to define a baseline rail round trip.
3 If performing a rail technology evaluation or mode comparison, click the "Define Alternative #" buttons as required to define up to 3 alternatives.
Notes: The default return trip uses same consist and route as forward trip but route is reversed.
Click "Modify Fwd" or "Modify Rev" buttons to make changes to equipment or route selections as required via the mode specific trip selection user form
Uncheck the tick box when an alternative is not to be simulated
4 Click "Calculate" button to perform simulations and review output
5 Save the analysis scenario by clicking the "Load/Save Analysis Scenario" button, adding it by clicking the "Add Scenario" button and then closing (click the red "X")

Quick tips to rerun or modify a saved analaysis

1 Click "Load/Save Analysis Scenario" button, select the desired previously saved analysis from the pick list and then click "Select & Return" to load
2 Make any adjustments using the "Define" or "Modify" buttons for the baseline or any alternative
3 Click "Calculate" button to perform simulations and review output
4 Save the analysis scenario by clicking the "Load/Save Analysis Scenario" button and then either adding as a new scenario ("Add Scenario" button) or updating the existing scenario ("Save Scenario" button) and the

Alternative 2 Bus

Mode	Trip ID	Tri			Direction	Equipment ID	Equipment Description
Rail	RT.29	DE			Forward	RC.1	1P42-6TItC (Diesel)
Rail	RT.29	DE			Reverse	RC.1	1P42-6TItC (Diesel)
Air	AT.7	DE			Forward	default	TP 6% SRJ 6% RJ 80% NBJ 8% WB
Air	AT.7	DE			Forward	default	TP 6% SRJ 6% RJ 80% NBJ 8% WB
Bus	BT.7	DEMO IC Bus Trip	BR.1	DEMO IC-Bus	Forward	BC.1	45-ft (56 seats)
Bus	BT.7	DEMO IC Bus Trip	BR.1	DEMO IC-Bus	Reverse	BC.1	45-ft (56 seats)
Auto/LDV	LT.5	DEMO-IC	LR.1	DEMO-IC-LDV	Forward	2011 driven I	4 seats @ 1 OC; E10 - LS gasoline
Auto/LDV	LT.5	DEMO-IC	LR.1	DEMO-IC-LDV	Reverse	2011 driven I	4 seats @ 1 OC; E10 - LS gasoline

Figure A-31 Selecting a Bus Mode Round Trip

To select a Bus mode trip:

On "Master-I-O" worksheet:

a) Click blue "Define Alternative #' button on left hand side of worksheet (see highlight 1).

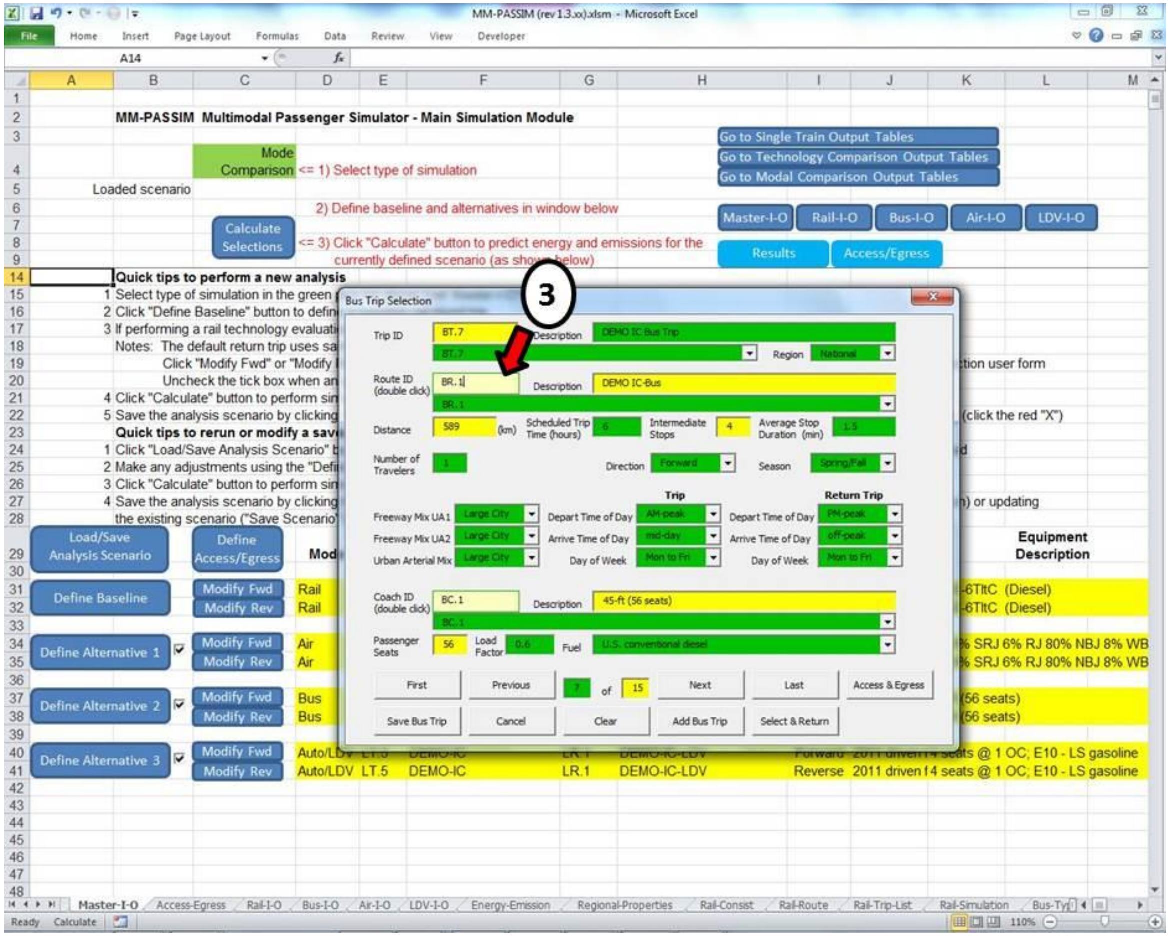
On "Transportation Mode Selection" form:

b) Click on gray arrow on right hand side of the green transportation mode drop-down list and then select the "Bus" mode from the list (see highlight 2)

c) Click gray "Select & Edit" button at right to open the "Bus Trip Selection" form.

or

Click gray "Select & Return" button in centre to use trip currently defined on the "Bus-I-O" worksheet



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison <= 1) Select type of simulation

Loaded scenario

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Bus Trip Selection

Trip ID: BT.7 — Description: DEMO IC Bus Trip — Region: National

Route ID (double click): BR.1 — Description: DEMO IC-Bus

Distance: 589 (km) — Scheduled Trip Time (hours): 6 — Intermediate Stops: 4 — Average Stop Duration (min): 1.5

Number of Travelers: 1 — Direction: Forward — Season: Spring/Fall

		Trip		Return Trip	
Freeway Mix UA1	Large City	Depart Time of Day	AM-peak	Depart Time of Day	PM-peak
Freeway Mix UA2	Large City	Arrive Time of Day	mid-day	Arrive Time of Day	off-peak
Urban Arterial Mix	Large City	Day of Week	Mon to Fri	Day of Week	Mon to Fri

Coach ID (double click): BC.1 — Description: 45-ft (56 seats)

Passenger Seats: 56 — Load Factor: 0.6 — Fuel: U.S. conventional diesel

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Figure A-32 Defining a Bus Mode Alternative Trip

Usage Notes:

On the "Bus Trip Selection" form:

a) Pick a bus trip from the green "Trip ID" drop-down list at the top.
or
Use the gray navigation buttons at the bottom to display a desired trip

b) Click gray "Add" button if you wish to create a new trip by modifying the currently displayed trip.

c) Double click on light yellow "Route ID" box (see highlight 3) to open the "Bus Route Selection" form and make a route selection.
or
Select a route from the green "Route ID" drop-down list.

d) Double click on light yellow "Coach ID" box to open the "Bus Type Selection" form and make a bus selection
or
Select a bus type from the green "Coach ID" drop-down list.

e) Make any changes to green fields (trip times, day of week, season, number of travelers, etc.).

f) Click on the gray "Save" button to save the modifications.

g) Click on the gray "Select & Return" button to return trip information back to "Master-I-O".

A bus trip is configured by adjusting the green fields in the ‘Bus Trip Selection’ form to the desired trip characteristics. The navigation buttons at the bottom of the form access all previously defined bus trips to use as the desired trip or as a template for a new trip. A trip may also be selected from the green drop-down list immediately below the yellow “Trip ID” field.

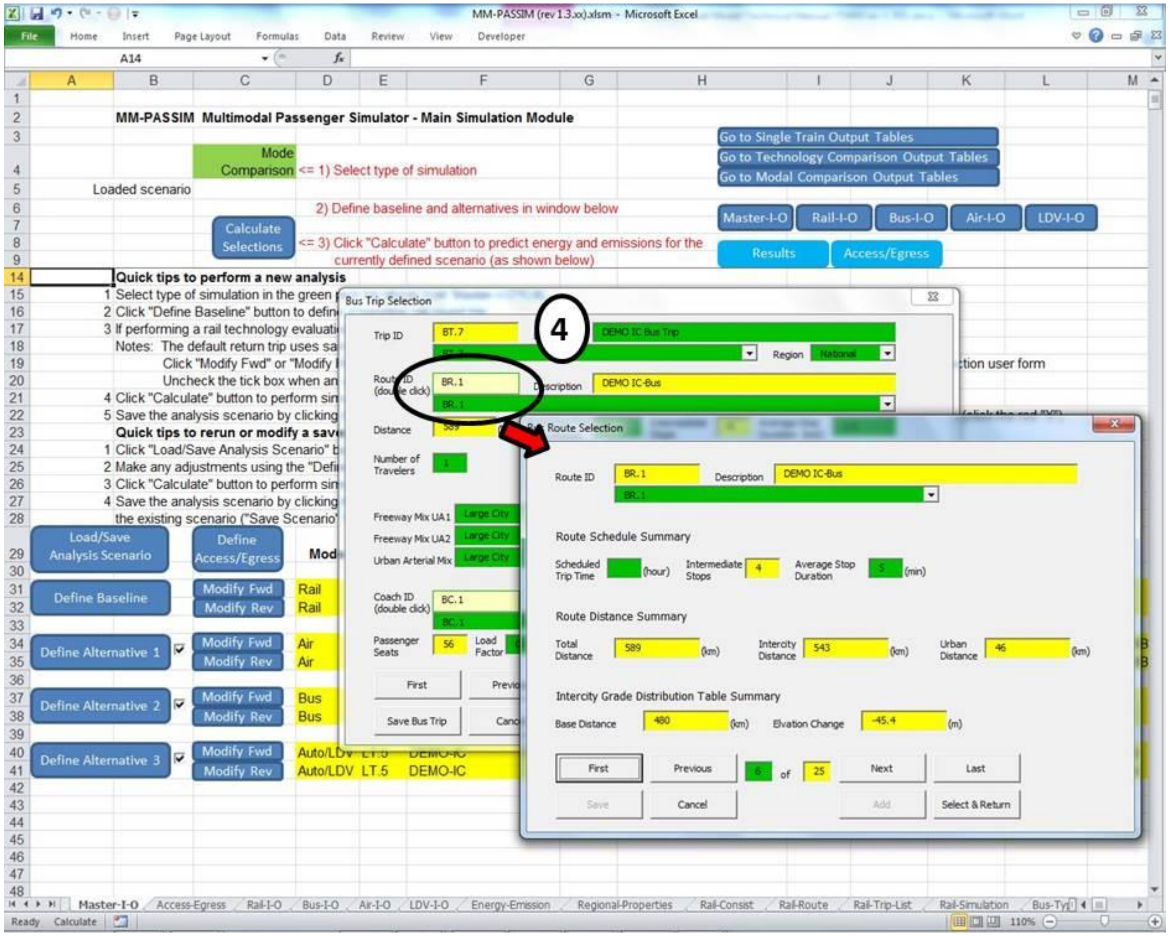
A bus trip combines a route specification with a bus type. A trip is identified by its unique ‘Trip ID’ (upper left yellow field) and a user modifiable ‘Description’ (upper right green field). The main trip leg is assumed to occur in a single geographic region, selected with the green “Region” drop-down list. The ‘Route ID’ associated with a trip is displayed in the light yellow field below the ‘Trip ID’ field (see highlight 3 in Figure A-32). Immediately right of the Route ID is the route “Description” field.

While complete specification of a bus route involves many parameters and is built on the ‘Bus-Route’ worksheet, a few are presented on the ‘Bus Trip Selection’ user form. These include the route distance and number of intermediate stops (in yellow cells which cannot be edited); the scheduled trip time (hours), average stop duration (minutes) and direction of travel which are in green fields and can be adjusted on this form.

The ‘Route ID’ is changed by double clicking inside the ‘Route ID’ field (see highlight 4 in Figure A-33) which will open the ‘Bus Route Selection’ pop up form. Navigation buttons at the bottom of this form allow the user to scroll through all the currently defined bus routes. Once the desired route is displayed, clicking on ‘Select & Return’ will select that ‘Route ID’ and return the user to the ‘Bus Trip Selection’ form. A route may also be selected from the green drop-down list immediately below the “Route ID” and “Description” fields.

Most parameters of a route specification defined in the ‘Bus-Route’ worksheet are not modifiable from the ‘Bus Route Selection’ user form. The ‘Route ID’, ‘Description’, number of intermediate stops and the distance fields are filled in by the VBA macro to offer sufficient information to the user to identify and confirm the route selection. The scheduled trip time (hour) and average stop duration (min) may be adjusted in the green fields on this form. The route distance summary breaks down the total distance traveled into intercity and urban segments. The overall length and net elevation change of the intercity grade distribution also indicated for information purposes. A user may expand the number of defined routes available for bus mode simulations by adding columns to the ‘Bus-Route’ worksheet following the pattern of previous entries.

Caution: *Routes added into the ‘Bus-Route’ worksheet must be offset by 12 columns to the right of the last defined route and the ‘Route ID’ should be unique and follow the indicated naming convention.*



Bus Trip Selection: Trip ID BT.7; DEMO IC Bus Trip; Region National; Route ID (double click) BR.1; Description DEMO IC-Bus; Distance 589; Number of Travelers 1; Freeway Mix UA1 Large City; Freeway Mix UA2 Large City; Urban Arterial Mix Large City; Coach ID (double click) BC.1; Passenger Seats 56; Load Factor

Bus Route Selection: Route ID BR.1; Description DEMO IC-Bus

Route Schedule Summary: Scheduled Trip Time (hour); Intermediate Stops 4; Average Stop Duration 5 (min)

Route Distance Summary: Total Distance 589 (km); Intercity Distance 543 (km); Urban Distance 46 (km)

Intercity Grade Distribution Table Summary: Base Distance 480 (km); Elvation Change -45.4 (m)

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Figure A-33 Selecting a Bus Route

Usage Notes:

On the “Bus Trip Selection” form:

a) Pick a bus route from the green “Route ID” drop-down list.

or

Double click on the light yellow “Route ID” box (see highlight 4) to open the “Bus Route Selection” form and make a route selection.

On the “Bus Route Selection” form:

b) Pick a bus route from the green “Route ID” drop-down list (at top).

or

Use gray navigation buttons to display desired bus route.

c) Adjust scheduled trip time (hours) and average stop duration (minutes) as required.

d) Click gray “Select & Return” button to return to the “Bus Trip Selection” form.

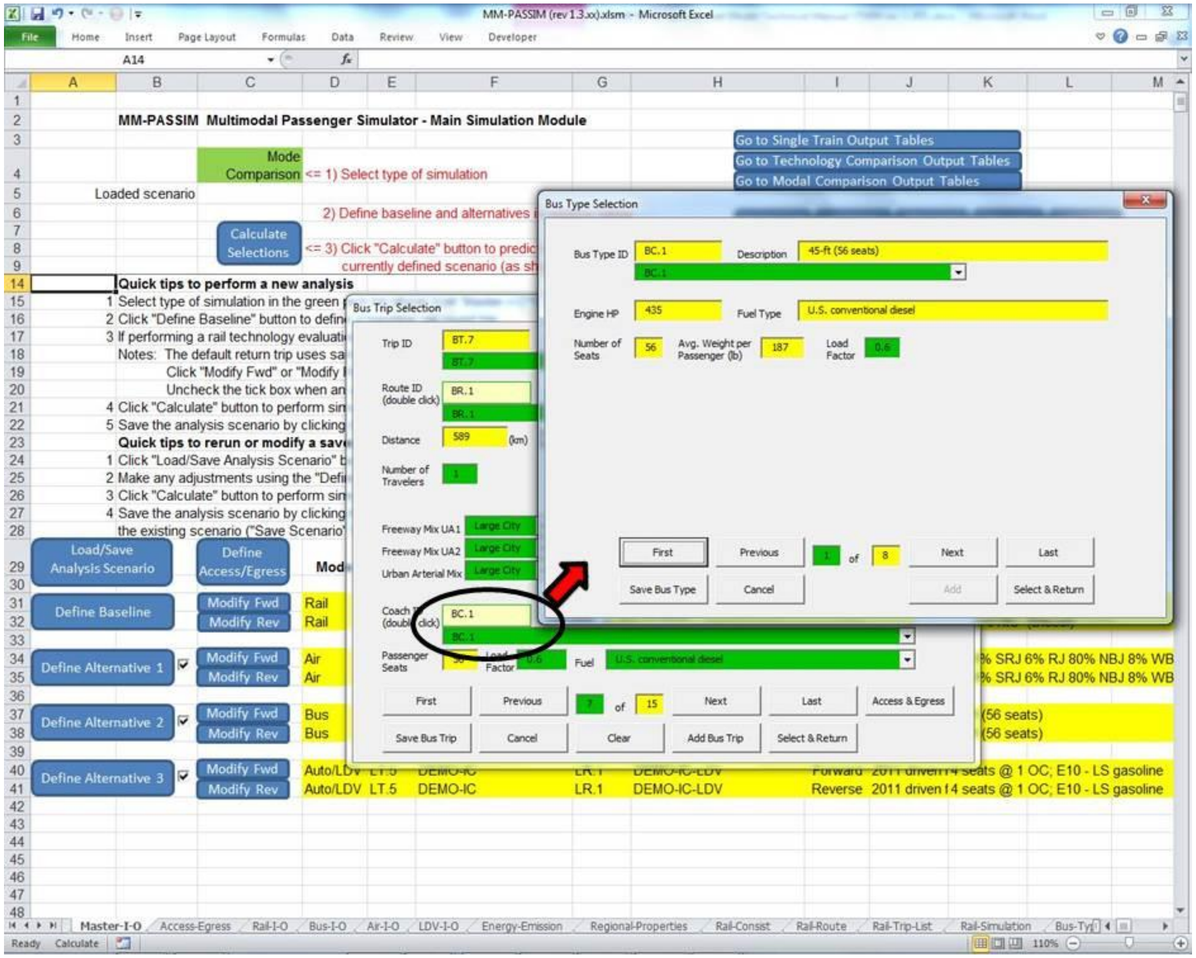
The central portion of the ‘Bus Trip Selection’ user form contains user adjustable green drop-down list fields which define general characteristics affecting the simulation of bus movements in the origin and destination urban centers. The three fields on the left hand side allow the user to select from three possible configurations of duty cycles used to represent the freeway mix assumed for travel within the origin and destination cities as well as a mix of urban arterial duty cycles to be used for both urban centers. The choices of “Small City”, “Large City” or “User Defined” refer to three data tables defined in the ‘Bus-Drive-Schedules’ worksheet. The “User Defined” table is provided to allow a user to customize the mix of duty cycles for their particular application without having to modify the defaults provided for small and large urban centers. Within these tables, a different mix of duty cycles is provided for 5 time periods which encompass the busy a.m. and p.m. peak periods, the lighter midday and off-peak (or shoulder) periods and finally a mix representing overnight travel. The user’s selections from the green ‘Depart Time of Day’ and ‘Arrive Time of Day’ drop-down lists provided for the forward and return trips on the ‘Bus Trip Selection’ user form determines the VBA macro’s choice of duty cycle mix to use. Additional green drop-down lists are provided to define the day of week for the forward and return trips as well as the season assumed for both trips.

The ‘Coach ID’ associated with a bus trip is displayed in the green-bordered light yellow field located in the lower portion of the ‘Bus Trip Selection’ user form. A coach is selected by either double clicking on the yellow ‘Coach ID’ field or by selecting it from the green drop-down list immediately below that information field. The yellow “Passenger Seats” and green “Load Factor” and “Fuel” fields provide a basic description of the currently selected coach. Only the load factor and fuel type may be adjusted directly on this form. If a coach is selected by double clicking on the ‘Coach ID’ field then the ‘Bus Type Selection’ pop up user form will be displayed (see Figure A-34). Using that form a user accesses the desired ‘Coach ID’ by navigating through the available list of defined bus coaches using the gray navigation buttons or alternatively by selecting it from the green drop-down list located below the yellow ‘Coach ID’ field. Clicking on the ‘Select & Return’ button will pass that selection back to the ‘Bus Trip Selection’ form. Please note that only the bus load factor may be modified on this form. All bus coach parameters are specified in the ‘Bus-Type’ worksheet which is accessible to the user.

> ***Caution:*** *The relative position of parameters within the ‘Bus-Type’ worksheet must not be altered except to create a new coach which should be positioned relative to the last coach definition using a fixed 7 column offset.*

A new bus trip may be added by clicking the ‘Add’ button on the ‘Select Bus Trip’ form. This creates a new ‘Trip ID’ while preserving the values in the other data fields. A user can clear all data fields by clicking on the ‘Clear’ button if they so desire, however this should not normally be required as the process of selecting a ‘Route ID’ and ‘Coach ID’ will result in the replacement of most of the data fields.

> ***Note:*** *Any changes made to the data fields on the ‘Select Bus Trip’ are not automatically saved and the user must explicitly save them by clicking the ‘Save’ button. Doing so will update the internally stored list of trip definitions (in the ‘Bus-Trip-List’ worksheet) but will not modify the trip definitions displayed in the bus trip definition area on the ‘Master-I-O’ sheet. To do so, the user must click on the ‘Select & Return’ button which will write the trip definitions on the ‘Master-I-O’ sheet. It is therefore possible to configure and run one-off simulated trips without modifying the trip list.*



Bus Trip Selection

Trip ID: BT.7

Route ID (double click): BR.1

Distance: 589 (km)

Number of Travelers: 1

Freeway Mix UA1: Large City

Freeway Mix UA2: Large City

Urban Arterial Mix: Large City

Coach ID (double click): BC.1

Fuel: U.S. conventional diesel

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Bus Type Selection

Bus Type ID: BC.1

Description: 45-ft (56 seats)

Engine HP: 435

Fuel Type: U.S. conventional diesel

Number of Seats: 56

Avg. Weight per Passenger (lb): 187

Load Factor: 0.6

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Figure A-34 Selecting a Bus Type

Usage Notes:

On the “Bus Trip Selection” form:

a) Pick a bus type from the green “Coach ID” drop-down list.

or

Double click on the light yellow “Coach ID” box (see oval highlight) to open the “Bus Type Selection” form and make a bus type selection.

On the “Bus Type Selection” form:

b) Pick a bus type from the green “Bus Type ID” drop-down list at the top.

or

Use gray navigation buttons to display the desired bus type.

c) Change the bus load factor (green input field) if required.

d) Click gray “Save Bus Type” button to save changes.

e) Click gray “Select & Return” button to return to the “Bus Trip Selection” form.

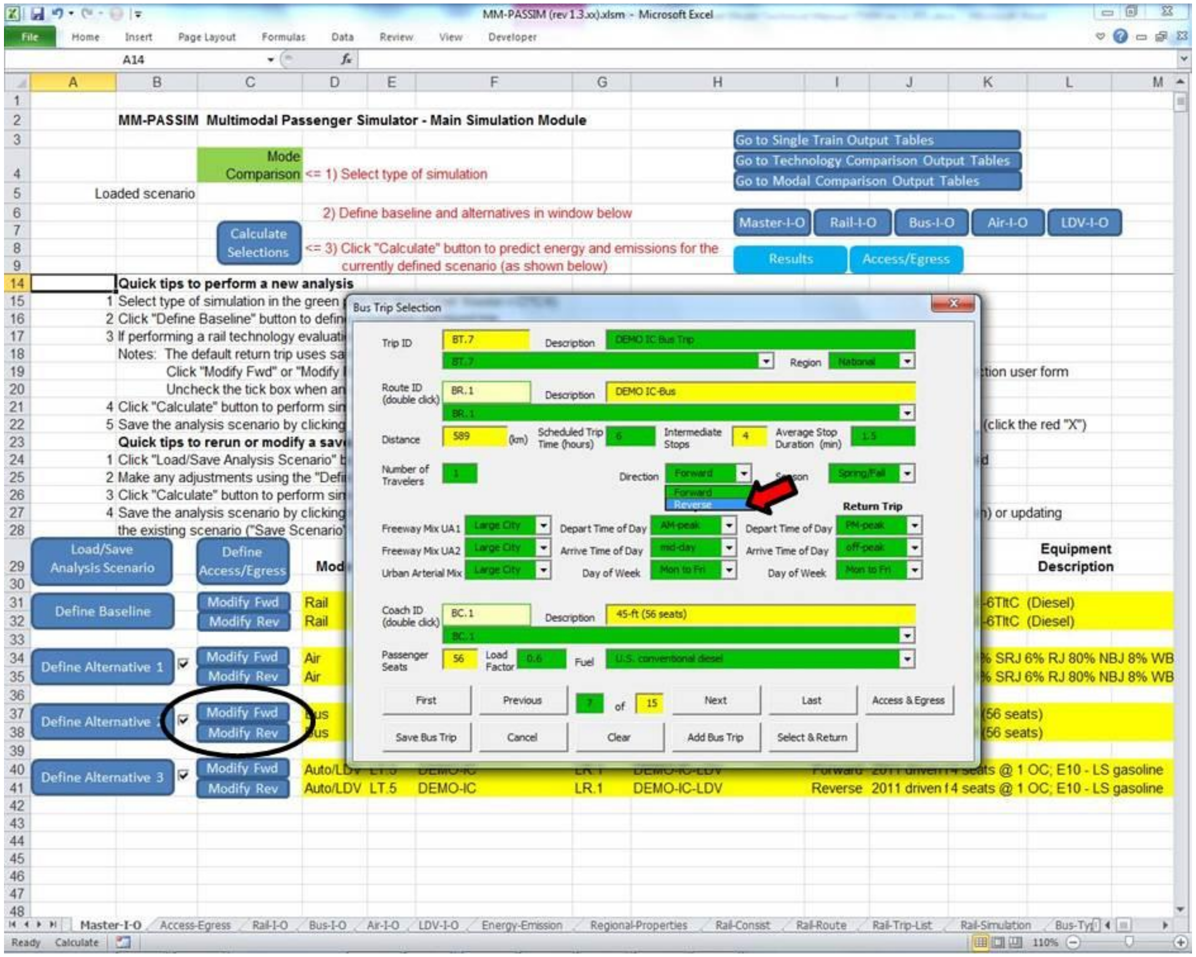
Defining a bus mode alternative will automatically assign both the forward and return trips using the same coach and route selections, but the direction of the return trip is reversed from that of the forward trip. In situations where this default return trip definition is not desired, the user can modify either the forward trip or the return trip individually by clicking on the blue “Modify Fwd” or “Modify Rev” buttons as required to access the ‘Bus Trip Selection’ form (see Figure A-35). It is not necessary that a return trip be run in the reverse direction should a different route be selected for the return trip which has been properly defined for the forward direction. In such a case, set the required direction in the drop-down list (see left pointing arrow highlight in Figure A-35).

Caution: *Users should not directly modify any of the yellow highlighted fields associated with the trip selections listed on the ‘Master-I-O’ worksheet. This list is used by the VBA macros during the sequencing of the simulation steps and any invalid data or moved items may cause invalid predictions or program failure.*

The passenger’s access to the bus mode departure station and their egress from the bus mode arrival station may both be characterized with up to five (5) access/egress legs each. This may be conveniently configured using the pop-up user forms accessed by clicking the blue “Define Access/Egress” button on the ‘Master-I-O’ worksheet to activate the “Trip Access and Egress Leg Selection” user form. Any currently defined access or egress legs for the selected bus trips can be displayed by using the navigation buttons and all green fields may be adjusted to meet the user’s requirements. Note that the access and egress legs are defined separately for each direction of a bus trip.

A user may also assign the access/egress legs for a bus trip by clicking the “Access & Egress” button on the right hand side of the “Bus Trip Selection” user form (Figure A-36). The access and egress legs currently defined for the displayed bus trip will be presented and the user may adjust all green fields accordingly. If all five legs are not required then the extra legs should be removed by selecting “none” from the left most green drop-down list for that leg. The user can also scroll through the access and egress legs configured for any existing bus trips using the navigation buttons. This allows any existing access/egress configuration to be used as a template for the current trip. Clicking the “Select & Return” button will associate the currently displayed access & egress leg configurations with the bus trip being defined.

Note: *Be sure to click the “Save Bus Trip” button on the ‘Bus Trip Selection’ menu after returning from the ‘Trip Access & Egress Leg Selection’ menu when any changes were made to the access/egress leg definitions.*



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison <= 1) Select type of simulation

Loaded scenario

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Quick tips to perform a new analysis
1 Select type of simulation in the green
2 Click "Define Baseline" button to defin
3 If performing a rail technology evaluati
Notes: The default return trip uses sa
Click "Modify Fwd" or "Modify
Uncheck the tick box when an
4 Click "Calculate" button to perform sin
5 Save the analysis scenario by clicking
Quick tips to rerun or modify a sav
1 Click "Load/Save Analysis Scenario" b
2 Make any adjustments using the "Defi
3 Click "Calculate" button to perform sin
4 Save the analysis scenario by clicking
the existing scenario ("Save Scenario")

tion user form
(click the red "X")
d
n) or updating

Trip ID: BT.7 Description: DEMO IC Bus Trip
BT.7 Region: National
Route ID (double click): BR.1 Description: DEMO IC-Bus
BR.1
Distance: 589 (km) Scheduled Trip Time (hours): 6 Intermediate Stops: 4 Average Stop Duration (min): 1.5
Number of Travelers: 1 Direction: Forward Season: Spring/Fall
Forward
Reverse

				Return Trip	
Freeway Mix UA1	Large City	Depart Time of Day	AM-peak	Depart Time of Day	PM-peak
Freeway Mix UA2	Large City	Arrive Time of Day	mid-day	Arrive Time of Day	off-peak
Urban Arterial Mix	Large City	Day of Week	Mon to Fri	Day of Week	Mon to Fri

Coach ID (double click): BC.1 Description: 45-ft (56 seats)
BC.1
Passenger Seats: 56 Load Factor: 0.6 Fuel: U.S. conventional diesel
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						Equipment Description
Mod						
☑	Rail					-6TltC (Diesel)
	Rail					-6TltC (Diesel)
☑	Air					% SRJ 6% RJ 80% NBJ 8% WB
	Air					% SRJ 6% RJ 80% NBJ 8% WB
☑	Bus					(56 seats)
	Bus					(56 seats)
☑	Auto/LDV	LT.5	DEMO-IC	LR.1	DEMO-IC-LDV	Forward 2011 driven f 4 seats @ 1 OC; E10 - LS gasoline
	Auto/LDV	LT.5	DEMO-IC	LR.1	DEMO-IC-LDV	Reverse 2011 driven f 4 seats @ 1 OC; E10 - LS gasoline

Figure A-35 Modifying a Return Bus Trip

Usage Notes:

On the "Master-I-O" worksheet:

a) Click on either a blue "Modify Fwd" or "Modify Rev" button adjacent to a trip you wish to modify to open the "Bus Trip Selection" form – it will display the currently configured trip.

On the "Bus Trip Selection" form:

b) Pick a rail trip from the green "Trip ID" drop-down list at the top.

or

Use gray navigation buttons to display a desired trip.

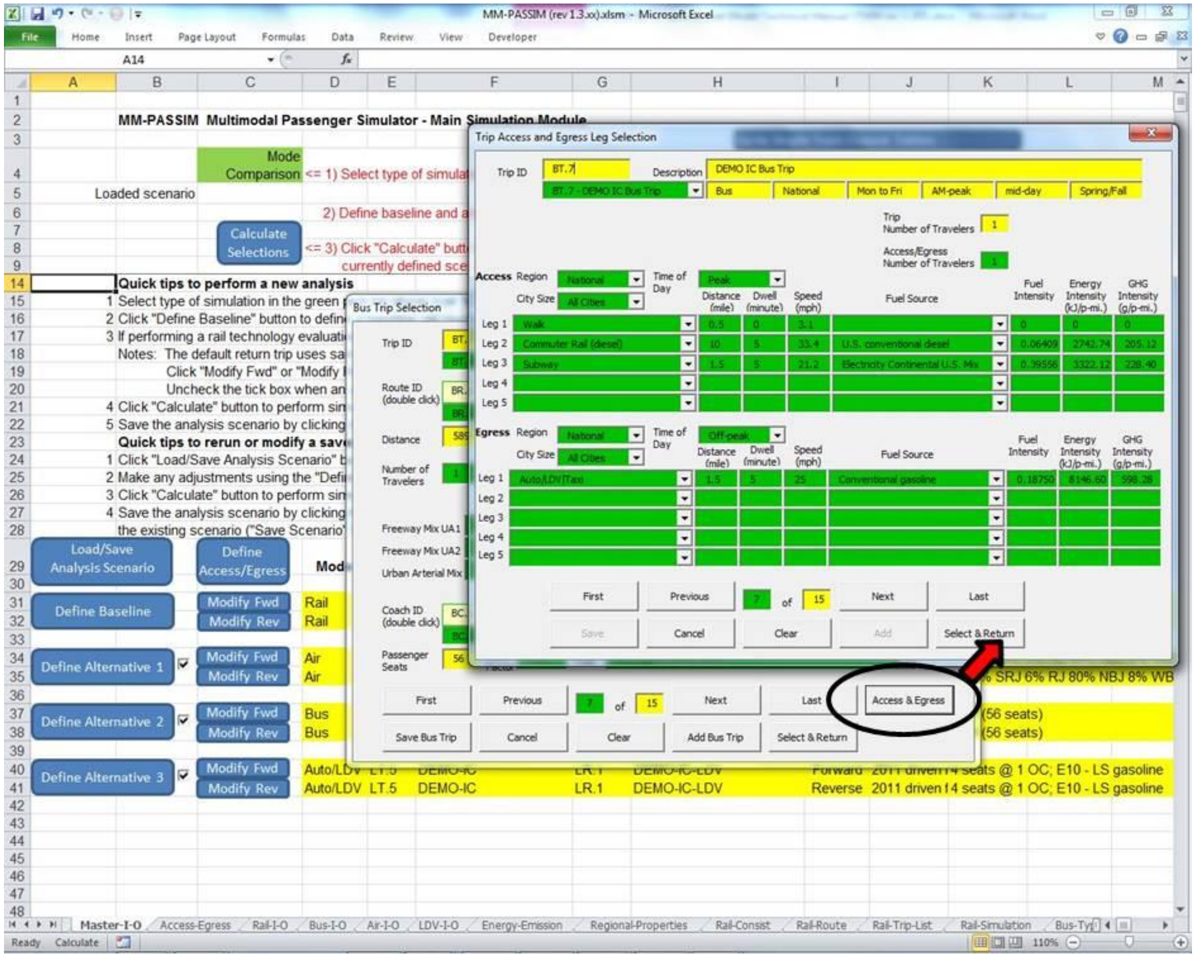
c) Use the Click gray "Add Bus Trip" button if you wish to create a new trip by modifying the displayed trip.

d) Click on the gray arrow on the right side of the green "Direction" drop-down list to modify direction of travel (see red arrow).

e) Make any other required adjustments to the green fields in the middle of the form.

f) Click gray "Save Bus Trip" button to save changes to the displayed trip.

g) Click gray "Select & Return" button to return to the "Master-I-O" worksheet.



Trip Access and Egress Leg Selection

Trip ID: BT.7
Description: DEMO IC Bus Trip
BT.7 - DEMO IC Bus Trip | Bus | National | Mon to Fri | AM-peak | mid-day | Spring/Fall

Trip Number of Travelers: 1
Access/Egress Number of Travelers: 1

Access Region: National; City Size: All Cities; Time of Day: Peak

		Distance (mile)	Dwell (minute)	Speed (mph)	Fuel Source	Fuel Intensity	Energy Intensity (kJ/p-mi.)	GHG Intensity (g/p-mi.)
Leg 1	Walk	0.5	0	3.1		0	0	0
Leg 2	Commuter Rail (diesel)	10	5	33.4	U.S. conventional diesel	0.06409	2742.74	205.12
Leg 3	Subway	1.5	5	21.2	Electricity Continental U.S. Mix	0.39556	3322.12	228.40
Leg 4								
Leg 5								

Egress Region: National; City Size: All Cities; Time of Day: Off-peak

		Distance (mile)	Dwell (minute)	Speed (mph)	Fuel Source	Fuel Intensity	Energy Intensity (kJ/p-mi.)	GHG Intensity (g/p-mi.)
Leg 1	Auto/LDV/Taxi	1.5	5	25	Conventional gasoline	0.18750	8146.60	598.28
Leg 2								
Leg 3								
Leg 4								
Leg 5								

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Figure A-36 Assigning Access & Egress Legs from Bus Trip Selection User Form

To view and modify access/egress legs from the "Bus Trip Selection" form:

On the "Bus Trip Selection" user form:

a) Click on the gray "Access & Egress" button (see oval highlight and arrow) to open the "Trip Access and Egress Leg Selection" form – the form will display the access & egress legs configured for the current trip.

On "Access and Egress Leg Selection Form:

b) Select any trip from the green "Trip ID" drop-down list

or

Use the gray navigation buttons to display the access/egress legs for any saved bus trip.

c) Make any required adjustments in the green fields

d) Click on the gray "Select & Return" button to pass the currently displayed access & egress leg configuration back and returns to the "Bus Trip Selection" user form.

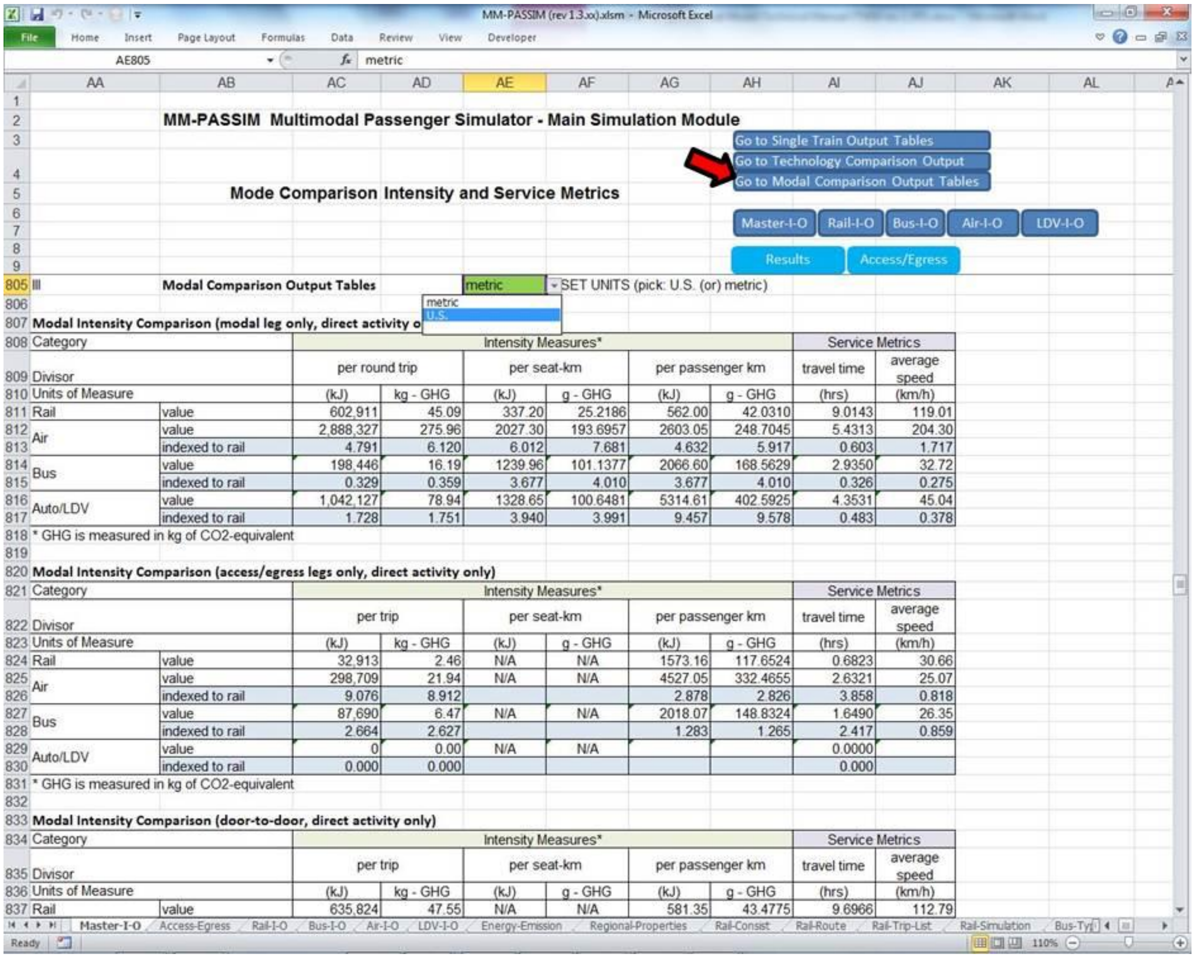
Access and egress legs are defined separately in the ‘Trip Access and Egress Leg Selection’ form. The region, city size and time of day may all be selected to best characterize the origin and destination of a trip. Clicking on the green ‘Region’ drop-down list permits selection of any region defined in the ‘Regional-Properties’ worksheet. A table of fuel and emissions intensity values for all access and egress modes is provided for each defined region presented in the drop-down list. The green ‘City Size’ and ‘Time of Day’ selections offer a limited number of choices to further tailor the access or egress modes. The choices of ‘City Size’ may be ‘Small Cities’, ‘Large Cities’, ‘Rural Municipality’ or ‘All Cities’ while the choices for ‘Time of Day’ include ‘Peak’, ‘Off-peak’ and ‘All’. Those values guide the VBA macro when choosing the most appropriate values from the table for a selected access/egress mode. The user is advised that the VBA macro expects every unique access/egress mode to be defined within the top portion of that table which would normally be associated with ‘All Cities’.

Each access and egress leg is selected by picking from the modes presented in the green drop-down lists. When a mode is selected, the user form automatically fills five of the remaining seven green user modifiable data fields with default values selected from the region’s data table. These default data include speed, fuel source, fuel intensity, energy intensity and GHG intensity. Although the inserted default data fields are yellow, the values may be adjusted to meet the user’s requirements. The user must manually provide data for the green fields specifying the distance to be traveled using that access/egress mode (in miles) and a dwell time (in minutes) for that leg. Once these access/egress data have been saved with a trip, they will appear green the next time they are loaded.

> ***Caution:*** *The simulation dynamically calculates Auto/LDV access/egress mode intensities using the number of travelers as displayed in the pink cell in the on line 64 of the ‘Regional-Properties’ worksheet in the area associated with the currently selected region. That number is set to correspond with the number of travelers indicated in the green field when the ‘Trip Access and Egress Leg Selection’ user form loads. If the number of travelers is manually changed, then a user must also change the region selection to force the macro to update the number of travelers written to the ‘Regional-Properties’ worksheet.*

Advanced users may also manually adjust the access and egress leg specifications for a bus trip directly on the ‘Bus-I-O’ worksheet. Clicking on the blue “Bus-I-O Access/Egress” button in the upper left region of the ‘Bus-I-O’ worksheet will change the display focus to the appropriate area of the worksheet. The access legs are defined in the green fields of the left hand table while the egress legs are defined in the green fields of the table to the right (the user must scroll the screen to view it). Clicking the blue “Bus-I-O” button will return to the main Bus Simulation Module user’s interface. The currently configured bus mode simulations may then be executed directly from the ‘Bus-I-O’ worksheet by clicking the blue “Calculate Bus” button or the user can return to the main user interface on the ‘Master-I-O’ worksheet by clicking the blue “Master-I-O” button in the upper right area.

Clicking the blue “Calculate Selections” button at the upper left of the ‘Master-I-O’ display or the blue “Calculate Bus” button at the upper left of the ‘Bus-I-O’ display will trigger the VBA macros to perform the currently configured simulations. Executing an analysis from the ‘Master-I-O’ display will cause the display focus to switch to the simulation results summary table appropriate for the type of analysis being performed and the numbers will be updated as the simulation process proceeds. Executing from the ‘Bus-I-O’ worksheet does not automatically switch display focus and the results summary tables may be accessed by clicking the appropriate blue navigation button in the top right hand quadrant. Simulation results for a bus mode comparison analysis are reported in a summary table on the ‘Master-I-O’ worksheet as depicted in Figure A-37. Select the desired system of output units from the green pulldown list at ‘Master-I-O’!AE805.



metric

MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison Intensity and Service Metrics

III **Modal Comparison Output Tables** metric SET UNITS (pick: U.S. (or) metric)

Modal Intensity Comparison (modal leg only, direct activity o

Category		Intensity Measures*						Service Metrics	
Divisor		per round trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	602,911	45.09	337.20	25.2186	562.00	42.0310	9.0143	119.01
Air	value	2,888,327	275.96	2027.30	193.6957	2603.05	248.7045	5.4313	204.30
	indexed to rail	4.791	6.120	6.012	7.681	4.632	5.917	0.603	1.717
Bus	value	198,446	16.19	1239.96	101.1377	2066.60	168.5629	2.9350	32.72
	indexed to rail	0.329	0.359	3.677	4.010	3.677	4.010	0.326	0.275
Auto/LDV	value	1,042,127	78.94	1328.65	100.6481	5314.61	402.5925	4.3531	45.04
	indexed to rail	1.728	1.751	3.940	3.991	9.457	9.578	0.483	0.378

* GHG is measured in kg of CO2-equivalent

Modal Intensity Comparison (access/egress legs only, direct activity only)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	32,913	2.46	N/A	N/A	1573.16	117.6524	0.6823	30.66
Air	value	298,709	21.94	N/A	N/A	4527.05	332.4655	2.6321	25.07
	indexed to rail	9.076	8.912			2.878	2.826	3.858	0.818
Bus	value	87,690	6.47	N/A	N/A	2018.07	148.8324	1.6490	26.35
	indexed to rail	2.664	2.627			1.283	1.265	2.417	0.859
Auto/LDV	value	0	0.00	N/A	N/A			0.0000	
	indexed to rail	0.000	0.000					0.000	

* GHG is measured in kg of CO2-equivalent

Modal Intensity Comparison (door-to-door, direct activity only)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	635,824	47.55	N/A	N/A	581.35	43.4775	9.6966	112.79

Figure A-37 ‘Master-I-O’ Bus Mode Comparison Output Tables Area

A modal comparison analysis organizes results into four tables. The rail related numbers on the first line of each table correspond with those calculated for the rail mode baseline trip. The first table presents a modal intensity comparison for the direct activity on the main modal leg of each mode simulated and includes energy and GHG emission intensities for a passenger round trip, per seat-distance and also per passenger-distance. Travel time and average speed for a round trip on the main modal leg are also shown. The intensity measures and service metrics for each non-rail mode are also indexed to the baseline rail mode case. The second output table presents a modal intensity comparison for the direct activity of the access/egress legs required for a round trip of each selected transportation mode. We note that per seat-distance intensities are not calculated in this table, as indicated by “N/A” in the column, because the number of seats is not defined in the access/egress mode data. The third table calculates the intensities and service metrics for the door-to-door direct activity of the main trip's transportation mode and the access/egress legs. Finally, the fourth table presents the overall door-to-door intensities and service metrics including both direct activity as well as indirect well-to-pump consumption.

A.5.4 Configuring and Running a Light Duty Vehicle (LDV) Mode Comparison

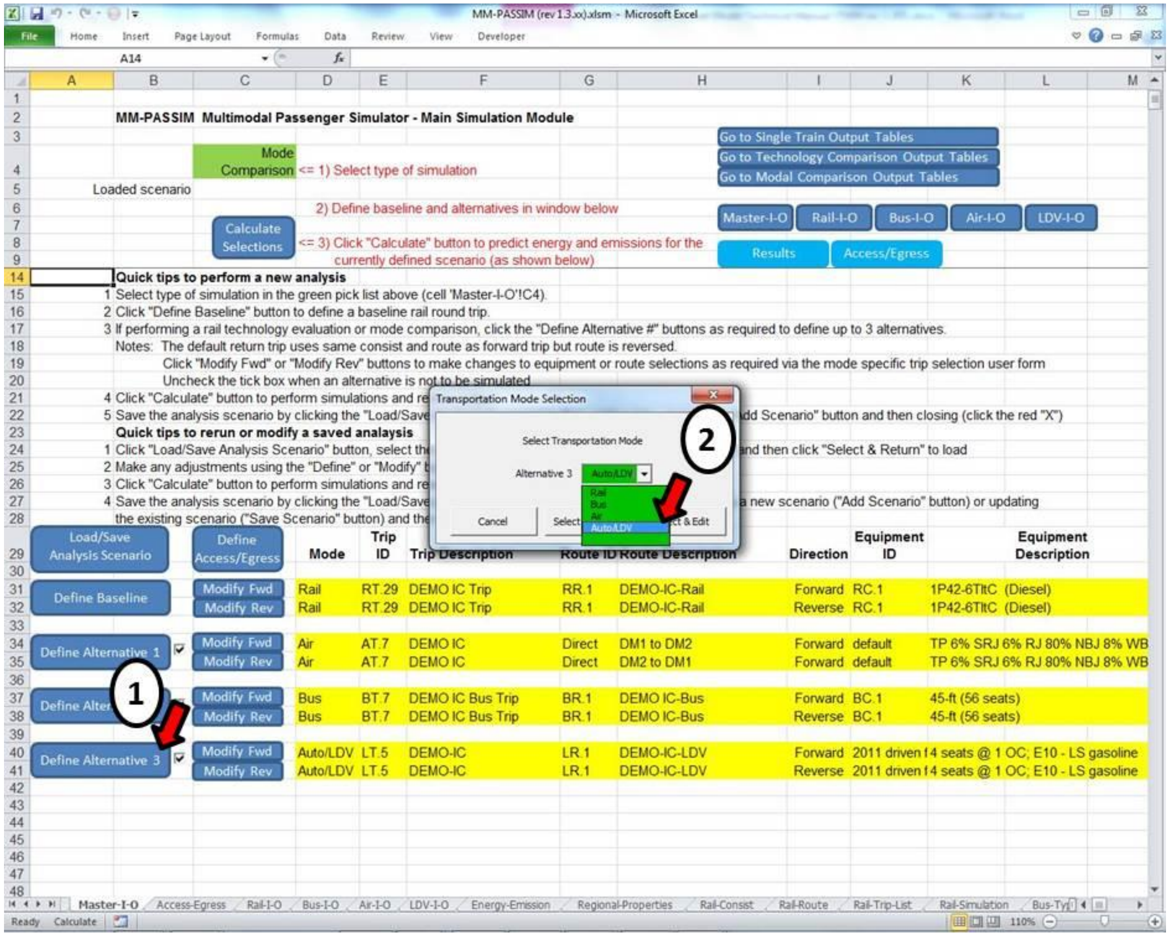
The LDV-Simulation module is implemented in eleven (11) worksheets which together with the 'Master-I-O' worksheet provide for simulation configuration, user input and results output of Auto/LDV mode comparison analyses. The user accessible worksheets include the 'LDV-I-O', 'Energy-Emission', 'Regional-Properties', 'LDV-Type', 'LDV-Route', 'LDV-Drive-Schedules' and 'LDV-Trip-List' worksheets. The 'LDV-Trip-List' worksheet maintains the list of all configured light duty vehicle mode trips and is typically maintained by the VBA macro code via the system of coordinated user forms although it may also be directly modified by an experienced user. The 'Energy-Emission' worksheet specifies the energy and emissions characteristics of all fuel/energy sources used for all transportation modes and is therefore shared by all transportation mode sub-models. The 'Regional-Properties' worksheet defines parameters which vary with geographical region under consideration and is also shared with the other transportation sub-models. The 'LDV-Type', 'LDV-Route' and 'LDV-Drive-Schedules' worksheets contain most of the user configurable data for an Auto/LDV mode simulation. The 'LDV-Trip', 'LDV-Resist', 'LDV-Engine' and 'LDV-Simulation' worksheets are all used internally to perform a light duty vehicle mode simulation and should not normally be modified by a user.

A one-way light duty vehicle mode trip is constructed by concatenating several specified lengths of light duty vehicle operation that are governed by pre-defined drive schedules. These drive schedules represent driving in urban areas with varying speed limits and traffic densities. There is also a generally much longer segment of cruise in which the vehicle seeks to maintain a speed limit while ascending and descending grades. The 'LDV-Simulation' worksheet predicts the energy use, GHG emissions produced and travel time associated with any one individual portion of a light duty vehicle mode. VBA macros use the information on the 'LDV-I-O' worksheet to automatically manage the transfer of data to and from the 'LDV-Simulation' worksheet for successive portions which together comprise the total distance of a one-way trip.

Defining a light duty vehicle mode simulation can be accomplished using the VBA macros and system of pop-up user forms available from the 'Master-I-O' worksheet when "Mode Comparison" has been selected in the green drop-down list at the top of the display. Alternatively it may be configured directly from the 'LDV-I-O' worksheet. Clicking any of the blue "Define Alternative #" buttons available on the left hand side of the 'Master-I-O' worksheet while the "'Mode Comparison" has been selected will prompt the user to choose a transportation mode for comparison. Selecting "Auto/LDV" from the green drop-down list, as depicted in Figure A-38, and then clicking on the "Select & Edit" button will open the "Auto/LDV Trip Selection" user form as shown in Figure A-39. Clicking on the "Select & Return" button will select the Auto/LDV mode without opening that user form and the simulation will be configured to use the trips currently defined in the 'LDV-I-O' worksheet. Table A-7 itemizes the steps required to configure an auto/LDV trip.

Table A-7 Configuration Steps Required for an Auto/LDV Trip

Define Auto/LDV Case	
Auto/LDV Trip Selection Form	• Either select an existing LDV trip from the 'Trip ID' drop-down list and click "Select & Return" or • Create a new Auto/LDV trip by clicking "Add LDV Trip" button • Enter a description for the new trip • Pick an Auto/LDV route from the "Route ID" drop-down list • Pick direction of travel • Pick season for both outbound and return trips • Set number of travelers • Pick freeway drive schedule mix for Urban Area 1 (the origin) • Pick freeway drive schedule mix for Urban Area 2 (the destination) • Pick urban arterial drive schedule mix (for origin and destination) • Pick time of day for departure of outbound trip • Pick time of day for arrival of outbound trip • Pick day of week for outbound trip • Pick time of day for departure of return trip • Pick time of day for arrival of return trip • Pick day of week for return trip • Pick an Auto/LDV type from the "Auto/LDV" drop-down list • Set number of passenger seats • Set number of passengers • Pick Auto/LDV fuel type • Assign access and egress legs by clicking the "Access & Egress" button • Save the new Auto/LDV trip by clicking "Save LDV Trip" button • Select the newly added Auto/LDV trip by clicking "Select & Return" button



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison <= 1) Select type of simulation

Loaded scenario

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Quick tips to perform a new analysis

1 Select type of simulation in the green pick list above (cell 'Master-I-O'!C4).
2 Click "Define Baseline" button to define a baseline rail round trip.
3 If performing a rail technology evaluation or mode comparison, click the "Define Alternative #" buttons as required to define up to 3 alternatives.
Notes: The default return trip uses same consist and route as forward trip but route is reversed.
Click "Modify Fwd" or "Modify Rev" buttons to make changes to equipment or route selections as required via the mode specific trip selection user form
Uncheck the tick box when an alternative is not to be simulated
4 Click "Calculate" button to perform simulations and re
5 Save the analysis scenario by clicking the "Load/Save … dd Scenario" button and then closing (click the red "X")

Quick tips to rerun or modify a saved analaysis

1 Click "Load/Save Analysis Scenario" button, select th … nd then click "Select & Return" to load
2 Make any adjustments using the "Define" or "Modify"
3 Click "Calculate" button to perform simulations and re
4 Save the analysis scenario by clicking the "Load/Save … a new scenario ("Add Scenario" button) or updating
the existing scenario ("Save Scenario" button) and the

Mode	Trip ID	Trip Description	Route ID	Route Description	Direction	Equipment ID	Equipment Description
Rail	RT.29	DEMO IC Trip	RR.1	DEMO-IC-Rail	Forward	RC.1	1P42-6TItC (Diesel)
Rail	RT.29	DEMO IC Trip	RR.1	DEMO-IC-Rail	Reverse	RC.1	1P42-6TItC (Diesel)
Air	AT.7	DEMO IC	Direct	DM1 to DM2	Forward	default	TP 6% SRJ 6% RJ 80% NBJ 8% WB
Air	AT.7	DEMO IC	Direct	DM2 to DM1	Forward	default	TP 6% SRJ 6% RJ 80% NBJ 8% WB
Bus	BT.7	DEMO IC Bus Trip	BR.1	DEMO IC-Bus	Forward	BC.1	45-ft (56 seats)
Bus	BT.7	DEMO IC Bus Trip	BR.1	DEMO IC-Bus	Reverse	BC.1	45-ft (56 seats)
Auto/LDV	LT.5	DEMO-IC	LR.1	DEMO-IC-LDV	Forward	2011 driven f	4 seats @ 1 OC; E10 - LS gasoline
Auto/LDV	LT.5	DEMO-IC	LR.1	DEMO-IC-LDV	Reverse	2011 driven f	4 seats @ 1 OC; E10 - LS gasoline

Figure A-38 Selecting an Auto/LDV Mode Round Trip

To select an Auto/LDV mode trip:

On “Master-I-O” worksheet:

a) Click blue “Define Alternative #’ button on left hand side of worksheet (see highlight 1).

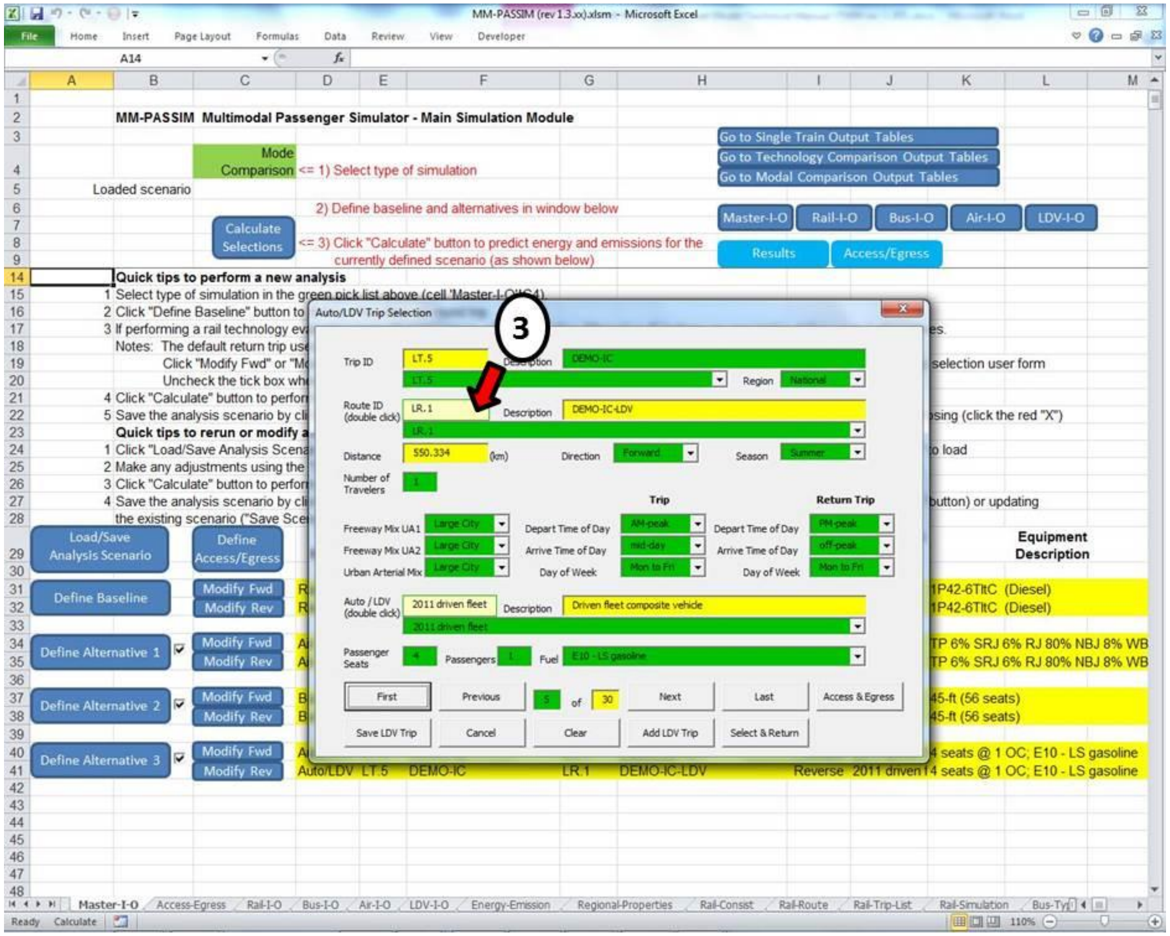
On “Transportation Mode Selection” form:

b) Click on gray arrow on right hand side of the green transportation mode drop-down list and then select the “Auto/LDV” mode from the list (see highlight 2)

c) Click gray “Select & Edit” button at right to open the “Auto/LDV Trip Selection” form.

or

Click gray “Select & Return” button in centre to use trip currently defined on the “LDV-I-O” worksheet



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison <= 1) Select type of simulation

Loaded scenario

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Quick tips to perform a new analysis

Auto/LDV Trip Selection

Trip ID: LT.5 — Description: DEMO-IC — LT.5 — Region: National

Route ID (double click): LR.1 — Description: DEMO-IC-LDV — LR.1

Distance: 550.334 (km) — Direction: Forward — Season: Summer

Number of Travelers: 1

		Trip		Return Trip	
Freeway Mix UA1	Large City	Depart Time of Day	AM-peak	Depart Time of Day	PM-peak
Freeway Mix UA2	Large City	Arrive Time of Day	mid-day	Arrive Time of Day	off-peak
Urban Arterial Mix	Large City	Day of Week	Mon to Fri	Day of Week	Mon to Fri

Auto / LDV (double click): 2011 driven fleet — Description: Driven fleet composite vehicle — 2011 driven fleet

Passenger Seats: 4 — Passengers: 1 — Fuel: E10 - LS gasoline

First | Previous | 5 of 30 | Next | Last | Access & Egress

Save LDV Trip | Cancel | Clear | Add LDV Trip | Select & Return

Auto/LDV LT.5 DEMO-IC LR.1 DEMO-IC-LDV Reverse 2011 driven 4 seats @ 1 OC; E10 - LS gasoline

Figure A-39 Defining an Auto/LDV Mode Alternative Trip

Usage Notes:

On the "Auto/LDV Trip Selection" form:

a) Pick an Auto/ LDV trip from the green "Trip ID" drop-down list at the top.

or

Use the gray navigation buttons at the bottom to display a desired trip

b) Click gray "Add LDV Trip" button if you wish to create a new trip by modifying the currently displayed trip.

c) Double click on light yellow "Route ID" box (see highlight 3) to open the "Auto/LDV Route Selection" form and make a route selection.

or

Select a route from the green "Route ID" drop-down list.

d) Double click on light yellow "Auto/LDV" box to open the "Auto/LDV Type Selection" form and make an Auto/LDV selection

or

Select an Auto/LDV type from the green "Auto/LDV" drop-down list.

e) Make any changes to green fields (trip times, day of week, season, number of travelers, etc.).

f) Click on the gray "Save LDV Trip" button to save the modifications.

g) Click on the gray "Select & Return" button to return trip information back to "Master-I-O".

A light duty vehicle trip is configured by adjusting the green fields to suit the desired scenario. The navigation buttons at the bottom of the user form allow access to all previously defined light duty vehicle tips for review and potential use either as the desired trip or to serve as a template upon which to build a new trip. A trip may also be directly selected from the green drop-down list located immediately below the yellow “Trip ID” and green “Description” fields.

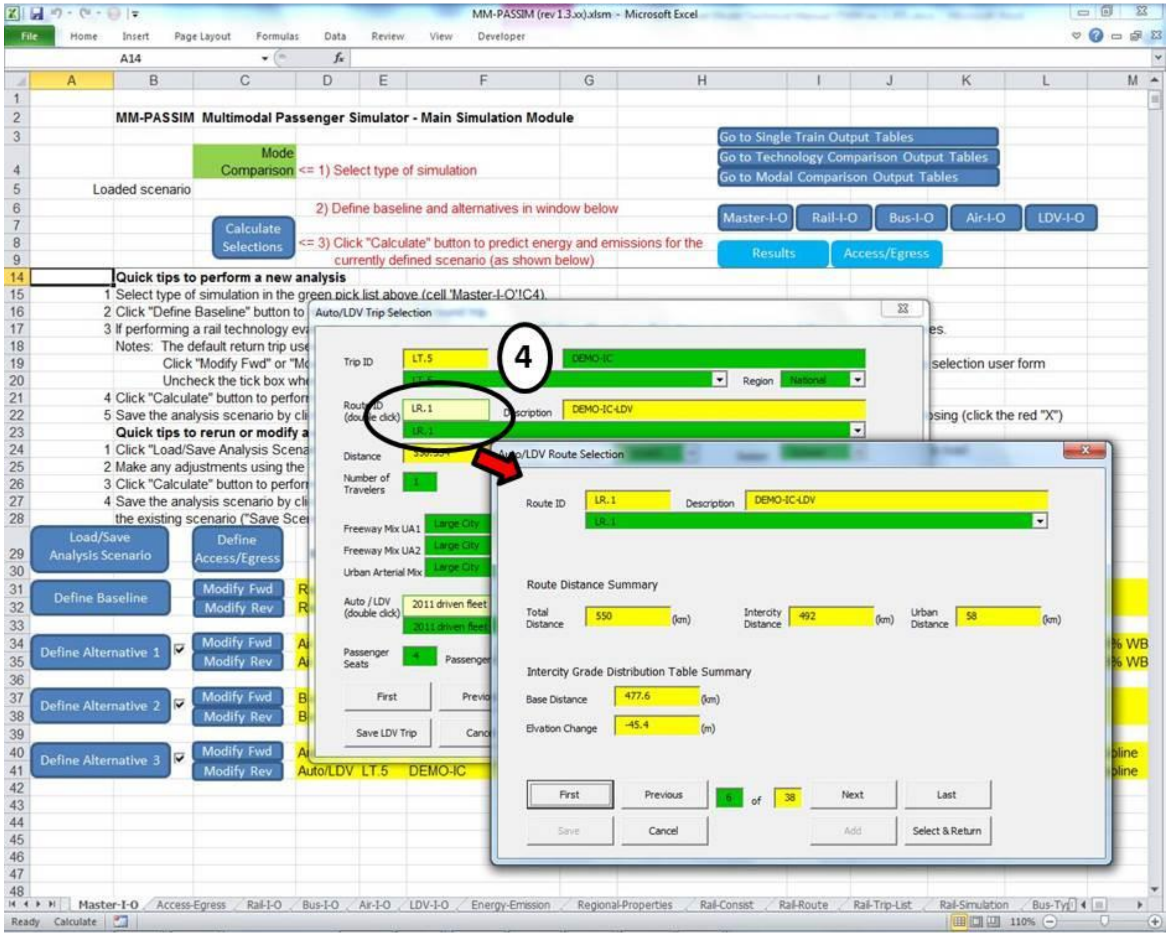
A light duty vehicle trip combines a route specification with a light duty vehicle type. The trip being displayed is identified by its unique “Trip ID” (upper left yellow field) and a user modifiable “Description” (upper right green field). The main trip leg is assumed to occur in a single geographic region which is specified in the green “Region” drop-down list. The “Route ID” associated with a trip is displayed in the green-bordered light yellow field located immediately below the “Trip ID” field (see highlight 3 in Figure A-39) and a description is provided in the yellow field immediately to its right. The light duty vehicle route distance is indicated in the yellow information field and can’t be modified from this form (it must be modified in the ‘LDV-Route’ worksheet, see Section A.7.13). A route to be used for a light duty vehicle trip may be changed either by selecting it from the green drop-down list or by using the ‘Auto/LDV Route Selection’ user form.

The yellow “Route ID” field is not directly modifiable by a user, but is changed using the ‘Auto/LDV Route Selection’ pop up user form which is accessed by double clicking the “Route ID” field (see highlight 4 in Figure A-40). The navigation buttons at the bottom of the form allow the user to scroll through all of the currently defined light duty vehicle routes and once the desired route is displayed, clicking on the ‘Select & Return’ will return the selected ‘Route ID’ back to the previous ‘Auto/LDV Trip Selection’ form. A route may also be directly selected from those presented in the green drop-down list positioned immediately below the “Route ID” and “Description” fields.

Most parameters of a route specification are defined in the ‘LDV-Route’ worksheet and are not modifiable from either user form. The yellow ‘Route ID’, ‘Description’ and ‘Distance’ fields are filled in by the VBA macro to offer sufficient information to the user to identify and confirm the route selection. The route distance summary breaks down the total distance to be traveled into intercity and urban segments. The length and net elevation change of the intercity grade distribution characterization for the route is also provided for information purposes. A user may expand the number of defined routes available for light duty vehicle mode simulations by adding columns to the ‘LDV-Route’ worksheet following the pattern of previous entries.

Caution: *Additional routes added to the ‘LDV-Route’ worksheet must be offset by 12 columns to the right of the last defined route and the ‘Route ID’ should be unique and follow the indicated naming convention.*

Selecting an Auto/LDV Route



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison <= 1) Select type of simulation

Loaded scenario

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Quick tips to perform a new analysis

1 Select type of simulation in the green pick list above (cell 'Master-I-O'!C4).

Auto/LDV Trip Selection

Trip ID: LT.5 — DEMO-IC

Region: National

Route ID (double click): LR.1

Description: DEMO-IC-LDV

Number of Travelers: 1

Freeway Mix UA1: Large City

Freeway Mix UA2: Large City

Urban Arterial Mix: Large City

Auto / LDV (double click): 2011 driven fleet

Passenger Seats: 4

Auto/LDV Route Selection

Route ID: LR.1

Description: DEMO-IC-LDV

Route Distance Summary

Total Distance: 550 (km)

Intercity Distance: 492 (km)

Urban Distance: 58 (km)

Intercity Grade Distribution Table Summary

Base Distance: 477.6 (km)

Elvation Change: -45.4 (m)

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Figure A-40 Selecting an Auto/LDV Route

On the "Auto/LDV Trip Selection" form:

a) Pick an Auto/LDV route from the green "Route ID" drop-down list.

or

Double click on the light yellow "Route ID" box (see highlight 4) to open the "Auto/LDV Route Selection" form and make a route selection.

On the "Bus Route Selection" form:

b) Pick a bus route from the green "Route ID" drop-down list (at top).

or

Use gray navigation buttons to display desired bus route.

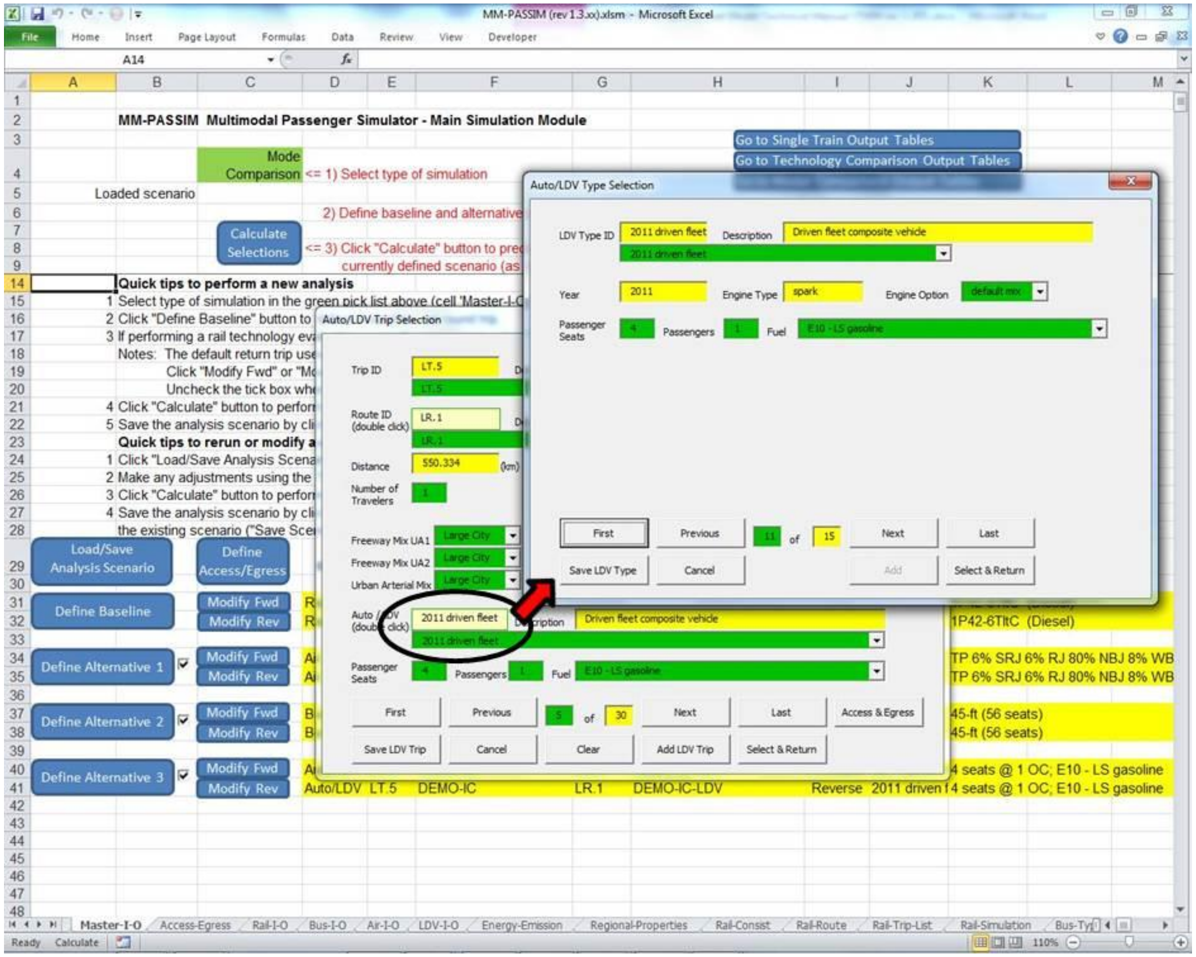
c) Click gray "Select & Return" button to return to the "Auto/LDV Trip Selection" form.

Note: There are no use configurable values on the "Auto/LDV Route Selection" form

The central portion of the ‘Auto/LDV Trip Selection’ user form presents many green user modifiable data fields. The “Direction” field specifies in which direction the light duty vehicle will operate through the defined route. The number of travelers should also be specified. Additionally, there are a number of user adjustable green drop-down list fields which define general characteristics affecting how light duty vehicle movements are simulated in the origin and destination urban areas. The three fields on the left hand side allow the user to select from three possible configurations of duty cycles used to represent the freeway mix assumed for travel within the origin and destination cities as well as a mix of urban arterial duty cycles to be used for both urban centers. The choices of “Small City”, “Large City” or “User Defined” refer to three data tables defined in the ‘LDV-Drive-Schedules’ worksheet. The “User Defined” table is provided to allow a user to customize the mix of duty cycles for their particular application without having to modify the defaults provided for small and large urban centers. Within these tables, a different mix of duty cycles is provided for 5 time periods which encompass the busy a.m. and p.m. peak periods, the lighter midday and off-peak (or shoulder) periods and finally a mix representing overnight travel. The user’s selections from the green ‘Depart Time of Day’ and ‘Arrive Time of Day’ drop-down lists provided for the forward and return trips on the ‘Bus Trip Selection’ user form determines the VBA macro’s choice of duty cycle mix to use. Additional green drop-down lists are provided to define the day of week for the forward and return trips as well as the season assumed for both trips.

The ‘Auto / LDV Type’ associated with a trip is displayed in the green-bordered light yellow field located in the lower portion of the ‘Auto/LDV Trip Selection’ form. A vehicle type is selected either by choosing it from the green drop-down list of all available light duty vehicles or by using the ‘Auto/LDV Type Selection’ pop-up form which is activated by double clicking on the ‘Auto / LDV Type’ field (see Figure A-41). When selecting from the drop-down list the green “Passenger Seats”, “Passengers” and “Fuel” fields will be updated according to the selected vehicle type and the user may change those parameters as required. If the ‘Auto / LDV Type’ was double clicked the user accesses the desired ‘Auto / LDV Type’ by navigating through the available list of defined vehicle types and then clicking on the ‘Select & Return’ button to pass that selection back to the ‘Auto/LDV Trip Selection’ user form. The vehicle can also be selected from the green drop-down list located below the yellow “LDV Type ID” and “Description” fields. Using the ‘Auto/LDV Type Selection’ user form provides a bit more information about the vehicle such as the year associated with the configuration data and the engine type. A user is also able to control whether the simulation assumes the simulated vehicle to be a hybrid, non-hybrid or a default mix of hybrid and non-hybrid vehicles by selecting from those options in the green ‘Engine Option’ field. Most light duty vehicle parameters are currently specified in the ‘LDV-Resist’ worksheet and some adjustments may be made with care. The ‘LDV-Type’ worksheet is used by the ‘Auto/LDV Type Selection’ user form and mainly contains pointers to data fields on the ‘LDV-Resist’ worksheet.

Caution: *Some parameters may be modified in the ‘LDV-Type’ worksheet but care must be taken to preserve the relative position of parameters (successive vehicle types must maintain a fixed 4 column offset from one another).*



Auto/LDV Trip Selection

Trip ID: LT.5

Route ID (double click): LR.1

Distance: 550.334 (km)

Number of Travelers: 1

Freeway Mix UA1: Large City

Freeway Mix UA2: Large City

Urban Arterial Mix: Large City

Auto/LDV (double click): 2011 driven fleet

Description: Driven fleet composite vehicle

Passenger Seats: 4 Passengers: 1 Fuel: E10 - LS gasoline

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Auto/LDV Type Selection

LDV Type ID: 2011 driven fleet

Description: Driven fleet composite vehicle

Year: 2011 Engine Type: spark Engine Option: default mix

Passenger Seats: 4 Passengers: 1 Fuel: E10 - LS gasoline

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Figure A-41 Selecting the Auto/LDV Type

On the "Auto/LDV Trip Selection" form:

a) Pick an Auto/LDV type from the green "Auto/LDV" drop-down list.

or

Double click on the light yellow "Auto/LDV" box (see oval highlight) to open the "Auto/LDV Type Selection" form and make an Auto/LDV type selection.

On the "Auto/LDV Type Selection" form:

b) Pick an Auto/LDV type from the green "LDV Type ID" drop-down list at the top.

or

Use gray navigation buttons to display the desired Auto/LDV type.

c) Change the green input fields as required (engine option, passenger seats, passengers and fuel type).

d) Click gray "Save LDV Type" button to save changes.

e) Click gray "Select & Return" button to return to the "Auto/LDV Trip Selection" form.

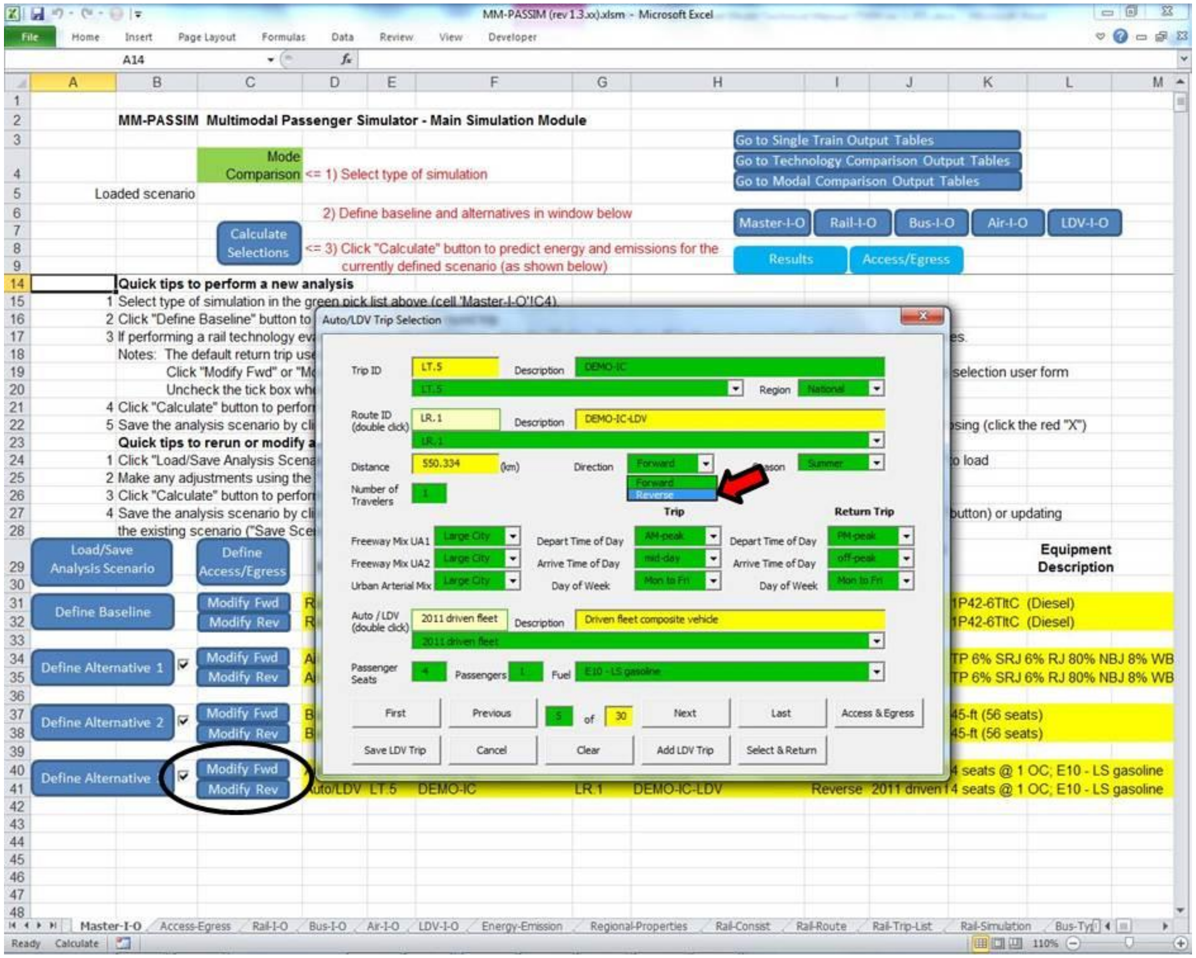
A new light duty vehicle trip may be added by clicking the ‘Add’ button on the ‘Select Auto/LDV Trip’ form. This creates a new ‘Trip ID’ while preserving the values in the other data fields. A user may clear all data fields by clicking on the ‘Clear’ button if they so desire, however this should not normally be required as the process of selecting a ‘Route ID’ and ‘Auto/LDV Type’ will result in the replacement of most of the data fields.

> ***Note:*** *Any changes made to the data fields on the ‘Select Auto/LDV Trip’ are not automatically saved and the user must explicitly save them by clicking the ‘Save’ button. Doing so will update the internally stored list of trip definitions (in the ‘LDV-Trip-List’ worksheet) but will not modify the trip definitions displayed in the Auto/LDV trip definition area on the ‘Master-I-O’ sheet. To do so, the user must click on the ‘Select & Return’ button which will write the trip definitions on the ‘Master-I-O’ sheet. It is therefore possible to configure and run one-off simulated trips without modifying the trip list.*

Defining an Auto/LDV mode alternative automatically assigns both the forward and return trips where the vehicle type and route selections are the same, but the direction of the return trip is reversed from that of the forward trip. In situations where this default return trip definition is not desired, the user can modify either the forward trip or the return trip individually by clicking on the blue “Modify Fwd” or “Modify Rev” buttons as required to access the ‘Auto/LDV Trip Selection’ form (see Figure A-42). It is not necessary that a return trip be run in the reverse direction should a different route be selected for the return trip which has already been defined for the forward direction. In such a case, set the required direction in the drop-down list (see left pointing arrow highlight in Figure A-42). The user should take note that the Auto/LDV simulation assigns a small portion of fuel use, energy consumption and emissions to vehicle startup and the return trip assigns smaller values since it is assumed that the engine has not fully cooled to ambient temperature. Therefore it may be more correct to use two forward trips when the return trip occurs on a subsequent day.

> ***Caution:*** *Users should not directly modify any of the yellow highlighted fields associated with the trip selections listed on the ‘Master-I-O’ worksheet. This list is used by the VBA macros during the sequencing of the simulation steps and any invalid data or moved items may cause invalid predictions or program failure.*

In general, passenger access to the departure location and egress from the arrival location of Auto/LDV trips may not be applicable since many light duty vehicle trips will be from door to door. However, there are cases such as car-pooling from road-side parking lots that may involve additional passenger access to the departure point and/or egress from the arrival location which may both be characterized with up to five (5) access/egress legs each. This may be conveniently configured using the pop-up user forms accessed by clicking the blue “Define Access/Egress” button on the ‘Master-I-O’ worksheet to activate the “Trip Access and Egress Leg Selection” user form. Any currently defined access or egress legs for the selected light duty vehicle trips can be displayed by using the navigation buttons and all green fields may be adjusted to meet the user’s requirements. Note that the access and egress legs are defined separately for each direction of an Auto/LDV trip.



MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison <= 1) Select type of simulation

Loaded scenario

2) Define baseline and alternatives in window below

<= 3) Click "Calculate" button to predict energy and emissions for the currently defined scenario (as shown below)

Auto/LDV Trip Selection

Trip ID: LT.5 Description: DEMO-IC

Region: National

Route ID (double click): LR.1 Description: DEMO-IC-LDV

Distance: 550.334 (km) Direction: Forward Season: Summer

Number of Travelers: 1

	Trip		Return Trip
Freeway Mix UA1: Large City	Depart Time of Day: AM-peak		Depart Time of Day: PM-peak
Freeway Mix UA2: Large City	Arrive Time of Day: mid-day		Arrive Time of Day: off-peak
Urban Arterial Mix: Large City	Day of Week: Mon to Fri		Day of Week: Mon to Fri

Auto / LDV (double click): 2011 driven fleet Description: Driven fleet composite vehicle

Passenger Seats: 4 Passengers: 1 Fuel: E10 - LS gasoline

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Figure A-42 Modifying a Return Auto/LDV Trip

On the "Master-I-O" worksheet:

a) Click on either a blue "Modify Fwd" or "Modify Rev" button adjacent to a trip you wish to modify to open the "Auto/LDV Trip Selection" form (see oval highlight) – it will display the currently configured trip.

On the "Auto/LDV Trip Selection" form:

b) Pick an Auto/LDV trip from the green "Trip ID" drop-down list at the top.

or

Use gray navigation buttons to display a desired trip.

c) Click the gray "Add LDV Trip" button if you wish to create a new trip by modifying the displayed trip.

d) Click on the gray arrow on the right side of the green "Direction" drop-down list to modify direction of travel (see red arrow).

e) Make any other required adjustments to the green fields in the middle of the form.

f) Click gray "Save LDV Trip" button to save changes to the displayed trip.

g) Click gray "Select & Return" button to return to the "Master-I-O" worksheet.

A user may also assign the access/egress legs for an Auto/LDV trip by clicking the “Access & Egress” button on the right hand side of the “Auto/LDV Trip Selection” user form (see Figure A-43). For personal vehicle use the access/egress legs will often be blank (i.e. the door to door trip is made in one vehicle); however, rental vehicles, carpool trips and destination urban access via commuter train are examples of LDV trips involving access or egress legs. The access and egress legs currently defined for the displayed light duty vehicle trip will be presented and the user may adjust all green fields accordingly. If a leg is not required then it should be removed by selecting “none” in the left most green drop-down list for the leg. The user can also scroll through the access and egress legs configured for any of the existing light duty vehicle trips using the navigation buttons. This allows any existing access/egress configuration to be used as a template for the current trip. Clicking the “Select & Return” button will associate the currently displayed access & egress leg configurations with the light duty vehicle trip being defined.

Access and egress legs are defined separately in the ‘Trip Access and Egress Leg Selection’ form. The region, city size and time of day may all be selected to best characterize the origin and destination of a trip. Clicking on the green ‘Region’ drop-down list permits selection of any region defined in the ‘Regional-Properties’ worksheet. A table of fuel and emissions intensity values for all access and egress modes is provided for each defined region presented in the drop-down list. The green ‘City Size’ and ‘Time of Day’ selections offer a limited number of choices to further tailor the access or egress modes. The choices of ‘City Size’ may be ‘Small Cities’, ‘Large Cities’, ‘Rural Municipality’ or ‘All Cities’ while the choices for ‘Time of Day’ include ‘Peak’, ‘Off-peak’ and ‘All’. Those values guide the VBA macro when choosing the most appropriate values from the table for a selected access/egress mode. The user is advised that the VBA macro expects every unique access/egress mode to be defined within the top portion of that table which would normally be associated with ‘All Cities’.

Each access and egress leg is selected by picking from the modes presented in the green drop-down lists. When a mode is selected, the user form automatically fills five of the remaining seven green user modifiable data fields with default values selected from the region’s data table. These default data include speed, fuel source, fuel intensity, energy intensity and GHG intensity. Although the inserted default data fields are yellow, the values may be adjusted to meet the user’s requirements. The user must manually provide data for the green fields specifying the distance to be traveled using that access/egress mode (in miles) and a dwell time (in minutes) for that leg. Once these access/egress data have been saved with a trip, they will appear green the next time they are loaded.

Caution: *The simulation dynamically calculates Auto/LDV access/egress mode intensities using the number of travelers as displayed in the pink cell in the on line 64 of the ‘Regional-Properties’ worksheet in the area associated with the currently selected region. That number is set to correspond with the number of travelers indicated in the green field when the ‘Trip Access and Egress Leg Selection’ user form loads. If the number of travelers is manually changed, then a user must also change the region selection to force the macro to update the number of travelers written to the ‘Regional-Properties’ worksheet.*

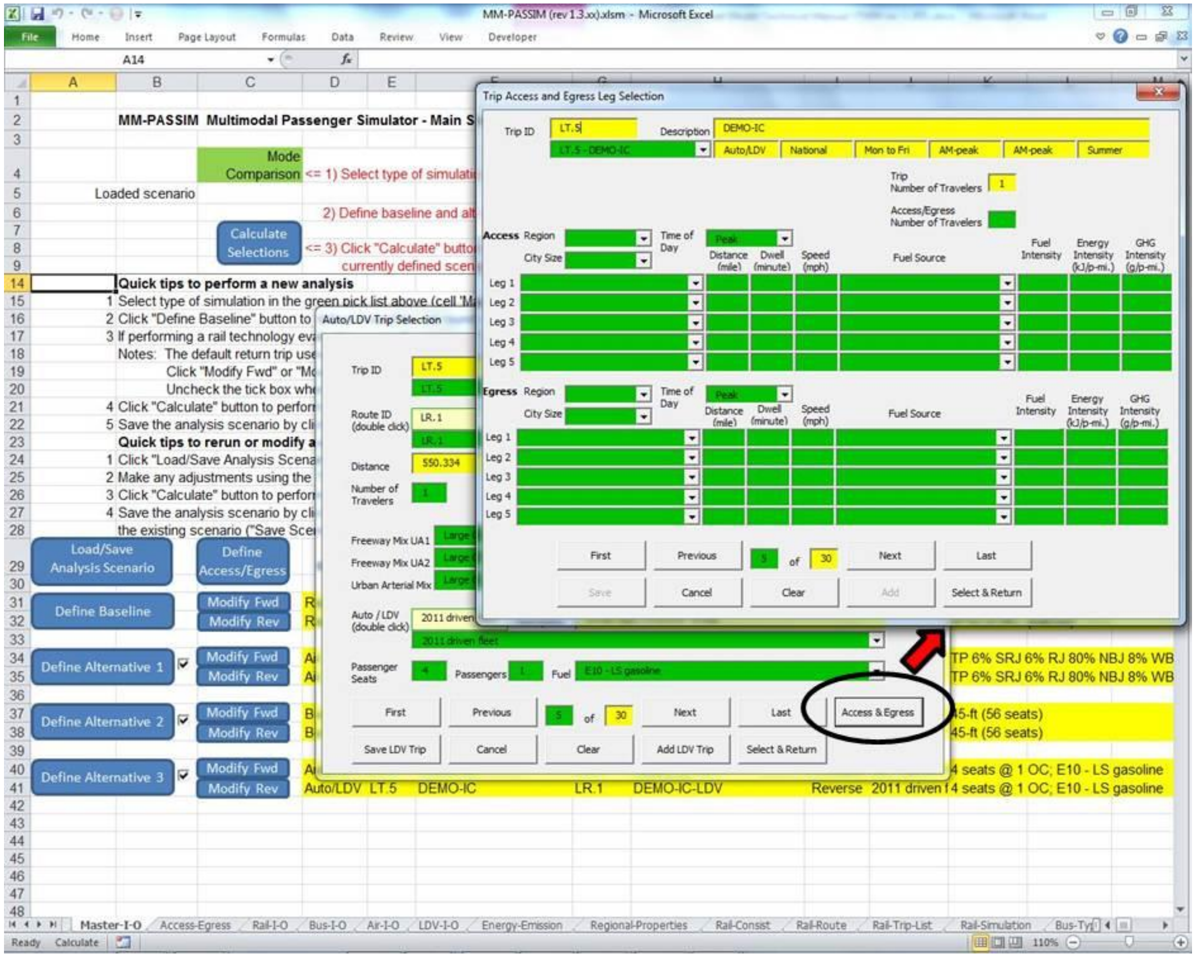


Figure A-43 Assigning Access & Egress Legs on Auto/LDV Trip Selection User Form

To view and modify access/egress legs from the "Auto/LDV Trip Selection" form:

On the "Auto/LDV Trip Selection" user form:

a) Click on the gray "Access & Egress" button (see oval highlight and arrow) to open the "Trip Access and Egress Leg Selection" form – the form will display the access & egress legs configured for the current trip.

On "Access and Egress Leg Selection Form:

b) Select any trip from the green "Trip ID" drop-down list

or

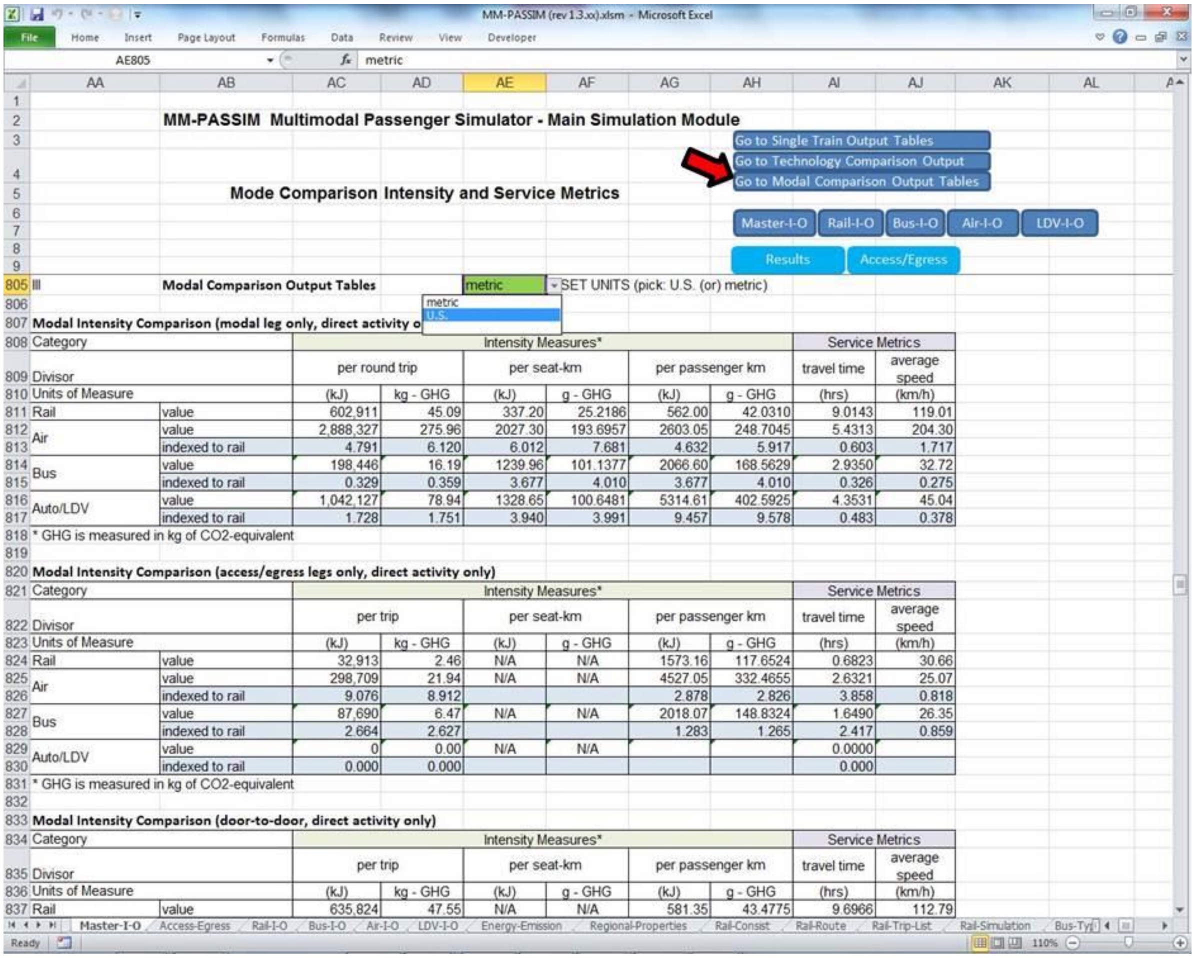
Use the gray navigation buttons to display the access/egress legs for any saved Auto/LDV trip.

c) Make any required adjustments in the green fields

d) Click on the gray "Select & Return" button to pass the currently displayed access & egress leg configuration back and returns to the "Auto/LDV Trip Selection" user form.

Advanced users may also manually adjust the access and egress leg specifications for a light duty vehicle trip directly on the ‘LDV-I-O’ worksheet. Clicking on the blue “LDV-I-O Access/Egress” button in the upper left region of the ‘LDV-I-O’ worksheet will change the display focus to the appropriate area of the worksheet. The access legs are defined in the green fields of the left hand table while the egress legs are defined in the green fields of the table to the right (the user must scroll the screen to view it). Clicking the blue “LDV-I-O” button will return to the main Auto/LDV Simulation Module user’s interface. The currently configured Auto/LDV mode simulations may then be executed directly from the ‘LDV-I-O’ worksheet by clicking the blue “Calculate LDV” button or the user can return to the main user interface on the ‘Master-I-O’ worksheet by clicking the blue “Master-I-O” button in the upper right area.

Clicking the blue “Calculate Selections” button at the upper left of the ‘Master-I-O’ display or the blue “Calculate LDV” button at the upper left of the ‘LDV-I-O’ display will trigger the VBA macros to perform the currently configured simulations. Executing an analysis from the ‘Master-I-O’ display will cause the display focus to switch to the simulation results summary table appropriate for the type of analysis being performed and the numbers will be updated as the simulation process proceeds. Executing from the ‘LDV-I-O’ worksheet does not automatically switch display focus and the results summary tables may be accessed by clicking the appropriate blue navigation button in the top right hand quadrant. Simulation results for a light duty vehicle mode comparison analysis are reported in a summary table on the ‘Master-I-O’ worksheet as depicted in Figure A-44. You may select either “metric” or “U.S.” units for display from the green pulldown list at Master-I-O’!AE805.



metric

MM-PASSIM Multimodal Passenger Simulator - Main Simulation Module

Mode Comparison Intensity and Service Metrics

III **Modal Comparison Output Tables** metric SET UNITS (pick: U.S. (or) metric)

Modal Intensity Comparison (modal leg only, direct activity o

Category		Intensity Measures*						Service Metrics	
Divisor		per round trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	602,911	45.09	337.20	25.2186	562.00	42.0310	9.0143	119.01
Air	value	2,888,327	275.96	2027.30	193.6957	2603.05	248.7045	5.4313	204.30
	indexed to rail	4.791	6.120	6.012	7.681	4.632	5.917	0.603	1.717
Bus	value	198,446	16.19	1239.96	101.1377	2066.60	168.5629	2.9350	32.72
	indexed to rail	0.329	0.359	3.677	4.010	3.677	4.010	0.326	0.275
Auto/LDV	value	1,042,127	78.94	1328.65	100.6481	5314.61	402.5925	4.3531	45.04
	indexed to rail	1.728	1.751	3.940	3.991	9.457	9.578	0.483	0.378

* GHG is measured in kg of CO2-equivalent

Modal Intensity Comparison (access/egress legs only, direct activity only)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	32,913	2.46	N/A	N/A	1573.16	117.6524	0.6823	30.66
Air	value	298,709	21.94	N/A	N/A	4527.05	332.4655	2.6321	25.07
	indexed to rail	9.076	8.912			2.878	2.826	3.858	0.818
Bus	value	87,690	6.47	N/A	N/A	2018.07	148.8324	1.6490	26.35
	indexed to rail	2.664	2.627			1.283	1.265	2.417	0.859
Auto/LDV	value	0	0.00	N/A	N/A			0.0000	
	indexed to rail	0.000	0.000					0.000	

* GHG is measured in kg of CO2-equivalent

Modal Intensity Comparison (door-to-door, direct activity only)

Category		Intensity Measures*						Service Metrics	
Divisor		per trip		per seat-km		per passenger km		travel time	average speed
Units of Measure		(kJ)	kg - GHG	(kJ)	g - GHG	(kJ)	g - GHG	(hrs)	(km/h)
Rail	value	635,824	47.55	N/A	N/A	581.35	43.4775	9.6966	112.79

Figure A-44 ‘Master-I-O’ Auto/LDV Mode Comparison Output Tables Area

A.6 Examples of Typical MMPASSIM Modeling Tasks

This section provides guidance for typical modeling tasks which a user will encounter while using the MMPASSIM model. These examples are supplementary to the more detailed descriptions of program functions and required data inputs which have been provided in the previous sections of this MMPASSIM user documentation.

A.6.1 Run Any Modal Simulation Using Existing Vehicles and Routes

Performing a modal simulation involving existing vehicles and routes is easily configured and run using MMPASSIM's system of built in menus.

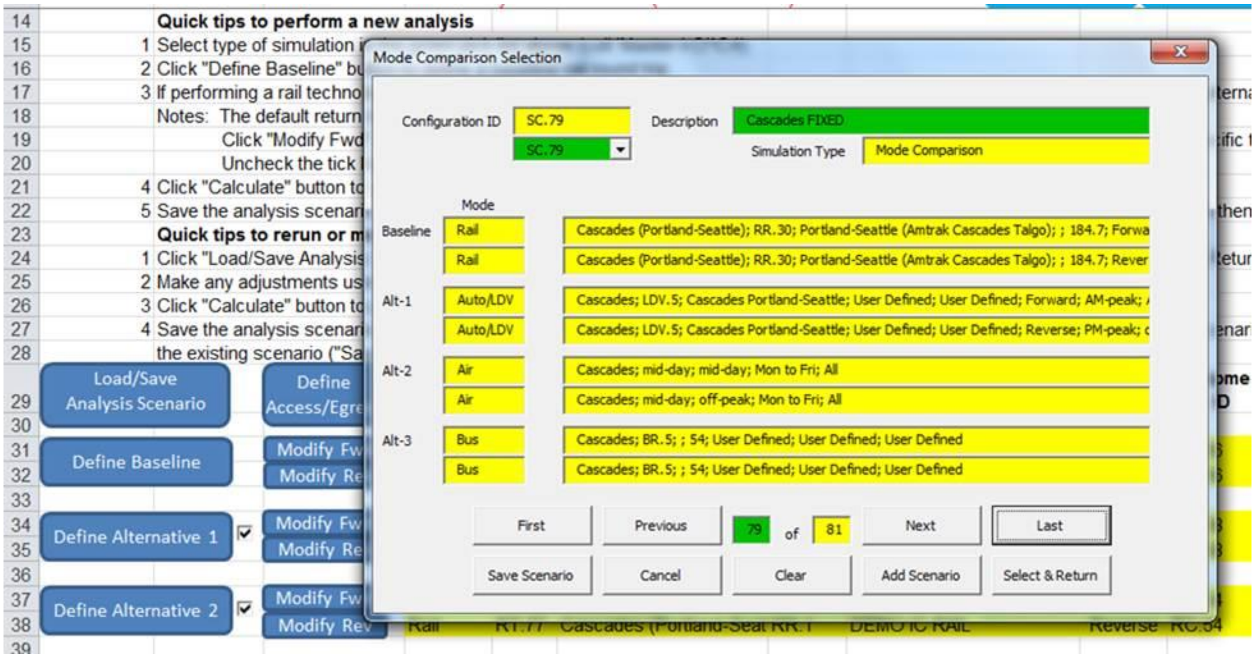
Start by opening the 'MMPASSIM' Microsoft Excel workbook and selecting "Enable Macros" in response to the Microsoft Excel Security Notice. Macros must be enabled since the MMPASSIM workbook makes extensive use of macros to perform its analyses. The workbook will open and the worksheet which was in view at the time when the MMPASSIM workbook was last saved will be displayed. If the displayed worksheet is not the 'Master-I-O' worksheet then please click on the 'Master-I-O' worksheet tab which can be found near the lower left corner of the window (click the "first sheet" tab scroll button which looks like "|<" to find the 'Master-I-O' tab if you don't see it). Then ensure that the main model interface is in view where the 'Master-I-O'!A1 cell is aligned in the top left corner of the visible area. You can easily jump to that starting point by clicking on the blue "Master-I-O" button displayed in the upper right hand quadrant of any of the "<modal>-I-O" worksheets or manually navigate to that view using standard Microsoft Excel procedures. Clicking on a blue "Master-I-O" button will ensure that the lower split window displays the set of blue analysis configuration buttons in the lower left quadrant and the summary of the currently configured trips to be analyzed will be highlighted in yellow in the bottom right area.

If you wish to reload a previously saved analysis scenario then click on the blue "Load/Save Analysis Scenario Button" (located over 'Master-I-O'!A29:B29) which will open the 'Mode Comparison Selection' form. That form, illustrated in Figure A-45, displays the analysis configuration corresponding to the saved analysis index listed in the 'Master-I-O'!C5 cell, or it will display the first saved analysis configuration if that cell is currently blank. You can search through and display a summary of saved configurations by picking directly from the green drop-down list located immediately beneath the yellow "Configuration ID" information field at the upper left of the form, scrolling through saved configurations using the navigation buttons at the bottom of the form or by directly entering a valid configuration index number in the green input field located to the right of the navigation button labeled "Previous". The yellow "Simulation Type" information field in the upper right quadrant indicates the type of analysis. The yellow information fields below that indicate the transportation mode and give a brief summary of the outbound and return trips as configured for the baseline and any alternative trips defined in the saved analysis configuration. If one or more alternative trips were not used in the saved analysis configuration then the corresponding yellow information fields will be blank. Clicking on the "Select & Return" button instructs a macro to load the indicated set of trips into the mode specific '<modal>-I-O' worksheets, sets up the 'Master-I-O' worksheet for the required analysis type and then returns focus to the 'Master-I-O' worksheet when the form exits. Clicking the blue "Calculate Selections" button will begin the analysis process and the worksheet focus will automatically move to the results output tables appropriate for the type of analysis performed.

If setting up a new simulation, first select the desired type of analysis from the green drop-down list located at ‘Master-I-O’!C4, then define the baseline trip and all required alternative trips via the menu system by clicking on the blue “Define Baseline” and the three “Define Alternative #” (where # is a “1”, “2” or “3”) buttons as required. The flowchart in Figure A-2 on page A-5 provides an overview of the simulation process for the three types of analyses which may be performed. Table A-2 on page A-32 itemizes the major configuration steps required. If one or more alternatives will not be included in the desired comparison then uncheck the tick box to remove it (the yellow information fields summarizing that trip will be cleared).

Single Train Simulation

A Single Train Simulation, as outlined in Figure A-4 on page A-10, requires only the baseline case be defined via the ‘Rail Trip Selection’ form. The configuration steps required are summarized in Table A-4 on page A-34. An existing rail trip may be selected by picking it from the green drop-down list found immediately below the yellow “Trip ID” information field. A different route may be chosen by selecting it from the green drop-down list positioned immediately below the light yellow “Route ID” information field. A different train consist may be chosen by selecting it from the list of all those currently defined in the green drop-down list positioned below the light yellow “Consist ID” information field. Further adjustments may be made to any of the green input fields on the form. Some require numerical input while others are selected from the values presented on the drop-down list. If changes have been made, the currently displayed trip may be saved under a new name by clicking on the “Add Rail Trip” button which automatically increments its “Trip ID”, then edit the green “Description” field as required and finally click on the “Save Rail Trip” button to store the new trip – please note that an added trip is not saved until the “Save Rail Trip” button has been clicked. Clicking the “Select & Return” button passes the current baseline rail trip configuration to the baseline trip definition area on the ‘Rail-I-O’ worksheet and returns focus to the ‘Master-I-O’ worksheet. Clicking the blue “Calculate Selections” button executes the Single Train Simulation and displays the Single Train output tables.



Configuration ID: SC.79
SC.79
Description: Cascades FIXED
Simulation Type: Mode Comparison

	Mode	
Baseline	Rail	Cascades (Portland-Seattle); RR.30; Portland-Seattle (Amtrak Cascades Talgo); ; 184.7; Forwa
	Rail	Cascades (Portland-Seattle); RR.30; Portland-Seattle (Amtrak Cascades Talgo); ; 184.7; Rever
Alt-1	Auto/LDV	Cascades; LDV.5; Cascades Portland-Seattle; User Defined; User Defined; Forward; AM-peak;
	Auto/LDV	Cascades; LDV.5; Cascades Portland-Seattle; User Defined; User Defined; Reverse; PM-peak;
Alt-2	Air	Cascades; mid-day; mid-day; Mon to Fri; All
	Air	Cascades; mid-day; off-peak; Mon to Fri; All
Alt-3	Bus	Cascades; BR.5; ; 54; User Defined; User Defined; User Defined
	Bus	Cascades; BR.5; ; 54; User Defined; User Defined; User Defined

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Figure A-45 Mode Comparison Selection Form

Rail Technology Evaluation

A Rail Technology Evaluation, as outlined in Figure A-5 on page A-11, requires definition of a baseline rail trip and up to three additional rail trips, all of which are defined using the 'Rail Trip Selection' form. The baseline rail trip is defined by clicking the blue "Define Baseline" button located at 'Master-I-O'!A29:B30 and then following the same procedure as outlined for defining the baseline rail trip for a Single Train Simulation (see Figure A-4 on page A-10 and Table A-4 on page A-34). Definition of each alternative rail trip is initiated by clicking on the corresponding "Define Alternative #" button on the 'Master-I-O' worksheet and again following the same process through the 'Rail Trip Selection' form to define the trip and then upon clicking the "Select & Return" button the trip definition is passed back to be stored on the 'Rail-I-O' worksheet. Once all trips are defined, clicking on the blue "Calculate Selections" button which overlays 'Master-I-O'!C7:C8 instructs a macro to start the Rail Technology Evaluation which will sequentially set up and execute each rail trip simulation and finish by displaying the Rail Technology Evaluation output tables for review.

Mode Comparison

A Mode Comparison requires definition of a baseline rail trip and up to three additional two-way trips for comparison which may include a single return bus trip, a single return LDV trip, a single return air trip and alternate return rail trips as required (where the term return trip refers to a complete two-way trip comprised of an outbound trip from the origin to destination and then an inbound trip from the outbound trip's destination back to its origin).

> ***Note:*** *Only one two-way trip for each non-rail transportation mode may be selected for analysis in a mode comparison but several two-way alternative rail trips can be specified if desired.*

Begin by selecting "Mode Comparison" from the drop-down list at 'Master-I-O'!C4 and then defining the baseline rail trip case by clicking the blue "Define Baseline" button and then selecting a rail trip, rail routes and rail consists as required from the 'Rail Trip Selection' user form. The procedure for selecting the baseline trip for a Mode Comparison is outlined in Figure A-6 on page A-13 (refer to the discussion on a *Single Train Simulation* above for more explanation).

Then, define up to three alternative mode two-way trips for comparison by:

a) clicking on a blue Define Alternative #" button, selecting the desired transportation mode from the green drop-down list presented and clicking the "Select & Edit" button (see Table A-3) making your desired selection of trip, route and equipment from the mode-specific trip selection form presented (see Table A-4 on page A-34, Table A-5 on page A-49, Table A-6 on page A-57 and Table A-7on page A-70).

b) clicking the "Select & Return" button to store the trip definition on the mode-specific '<modal>-I-O' worksheet and return you back to the 'Master-I-O' worksheet.

This procedure is outlined in Figure A-8 (page A-15) for bus mode trips, Figure A-9 (page A-16) for air mode trips and Figure A-10 (page A-17) for auto/light duty vehicle trips. Both the 'Bus Trip Selection' and 'Auto/LDV Trip Selection' user forms are similar to the 'Rail Trip Selection' in that they allow a user to select trips, routes and vehicles from green drop-down lists presenting all currently defined choices. The 'Air Trip Selection' user form allows users to select trips from a green drop-down list presenting all currently defined air-mode trips, but changes to route and equipment are configured on the form itself rather than by selecting from lists of stored routes and equipment types. If you will be including less than three alternatives in a comparison then you must uncheck the tick box to deactivate analysis for the alternatives which will not be used – the yellow information fields for that alternative will be cleared. Click on the blue "Calculate Selections" button at 'Master-I-O'!C7:C8 to instruct a macro to initiate the mode comparison and then display the Mode Comparison output tables for review.

A.6.2 Build a New Train from an Existing Base Train

The parameters used to represent the characteristics of a train consist in the MMPASSIM model are stored in the 'Rail-Consist' worksheet. The data is organized into sets of columns defining the values associated with a particular rail. These are located at intervals of seven (7) columns starting in column I for the first rail consist. The first column (A) in the worksheet contains color coded descriptions of the parameter(s) which are stored on that row. Columns B through H are hidden and contain a template of the rail consist input data which define named ranges used by the VBA macros to address data items in the 'Rail-Consist' worksheet and must not be deleted or modified. The first column of the data set describing the characteristics of the first train defined in the 'Rail-Consist' worksheet must be located in column I, the second data set begins at column P, the third data set begins at column W and so it continues onward in seven (7) column increments for all trains defined in the worksheet.

The process of building a new train based upon the characteristics of an existing train essentially involves appending a new copy of the columns of data which currently describe the base train to the right of the set of columns representing the last train already defined in the worksheet and then making any required changes to the user configurable green coloured fields. This can be quickly done manually by copying and pasting a block of columns but care must be taken to strictly maintain the seven (7) column interval between train consist data. The "Consist ID" in row 2 of the first column of a newly pasted data set must be edited so that it contains a unique character string since that string is used by the VBA macros to locate the data associated with a specific rail consist. If two identical IDs are used then the VBA macros will only ever locate the columns of data associated with the first instance when looking up the parameters associated with that train. The default "Consist ID" naming convention for trains is "RC.#" where # is an integer incrementing by 1 for each rail consist defined.

A new train can more be conveniently added into the 'Rail-Consist' data set using the "Add Rail Consist" button which is found on the 'Rail Consist Selection' form. This has the advantage of automatically assigning the next available "Consist ID" index, the macro will always properly align the appended columns at the start of the next 7 column interval and the macro provides some user guidance in presenting options for fuel, hotel power and energy recovery provisions compatible with the selected propulsion technology.

To access the 'Rail Consist Selection' form, click on the "Define Baseline" button which is located on both the 'Master-I-O' and the 'Rail-I-O' worksheets to open the 'Rail Trip Selection' form. Then, double clicking on the light yellow "Consist ID" field down towards the bottom left will open the 'Rail Consist Selection' form. Then navigate to display the desired base rail consist by either picking it from the green drop-down list located just below the yellow ‘Consist ID’ field or using the navigation buttons at the bottom of the form. Once the desired consist is displayed, clicking on the “Add Rail Consist” button will create a new “Consist ID” based on the index of the last consist currently defined in the ‘Rail-Consist’ worksheet and a copy of the columns defining the source rail consist is appended to the ‘Rail-Consist’ worksheet. Changes can then be made to the green “Propulsion Type”, “Primary Fuel”, “Secondary Fuel”, “Hotel Power” and “Energy Recovery” fields. The macro will provide a list of all available selections for a given field which are compatible with the current choice of “Propulsion Type”. For electric propulsion, please be sure to select an electricity generation mix appropriate for the region in which this train will be operating. Finally, clicking on the “Save Rail Consist” button will update the newly added rail consist definition to reflect any changes which have been made using any of the green drop-down lists.

> ***Note:*** *Exiting the ‘Rail Consist Selection’ form before clicking on the “Save Rail Consist” button will result in the newly added consist being a direct copy of the source consist but with a new “Consist ID” field.*

There are numerous user adjustable parameters associated with a rail consist, most of which can only be modified directly by editing the data contained in the green coloured cells of the ‘Rail-Consist’ worksheet. The description of the new train can be input in the green cell on row 3. The desired system of input units, either U.S. or metric, must be declared using the drop-down list on row 4 and all further user specified values must be input using the appropriate units as indicated on the worksheet. The number of locomotives and coaches, the number of powered and unpowered axles, physical parameters such as masses and rolling inertia and the train length are specified in the green fields on rows 5 through 20.

The train resistance coefficients are input in the green fields on rows 26 through 28. Transmission efficiencies may be set on rows 38 and 39. The five segment tractive effort curve, specifying the relationship between locomotive traction and speed, is defined in the green cells on rows 44 through 48. The fuel rate is specified by setting the series of parameters in the green fields on rows 52 through 60. The green flag value on row 63 determines whether or not dynamic braking will be used. The locomotive auxiliary power requirement is set on row 68. The auxiliary power diesel generator set fuel consumption is defined by the coefficients in the green cells on rows 70 and 71. The low speed tractive effort limit is specified on row 73 and the locomotive speed limit is specified on row 90. Please note that some of the pink cells are populated by the VBA macro according to the selections made on the ‘Rail Consist Selection’ user form while others, such as the seasonal adjustments on rows 29 through 32, are populated at the time an analysis is run based on data for the selected region.

> ***Note:*** *If a train consist was added manually by copying columns then the user should take care that the pink values on rows 40, 41, 65 through 67, 81 and 85 are set appropriately if the type of propulsion was manually changed. It is therefore recommended that changes in propulsion system selection, hotel power provisions and energy recover options be made through the ‘Rail Consist Selection’ user form.*

A.6.3 Build a New Train with a New Locomotive

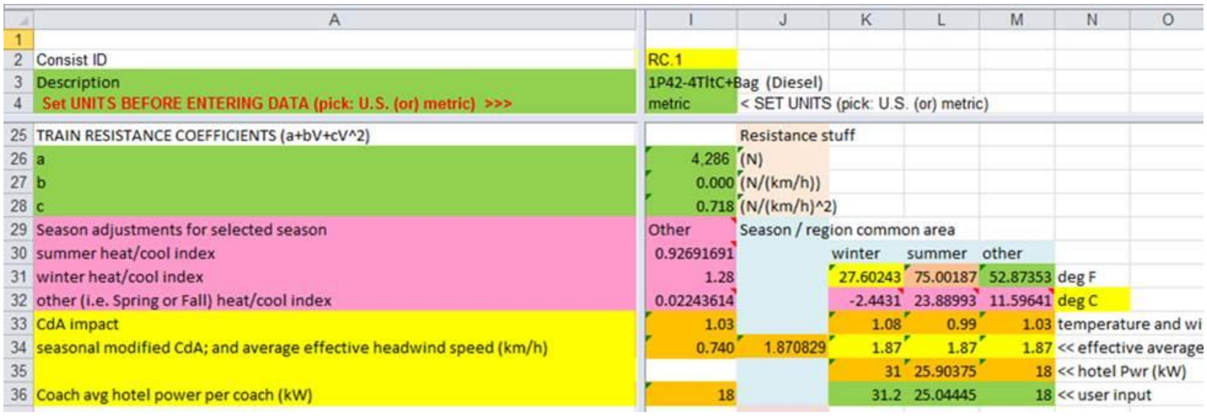
Building a new train with a new locomotive requires modification of data stored in the ‘Rail-Consist’ worksheet. This can be done by directly editing the locomotive-specific input fields in the set of seven (7) columns associated with an existing train, also termed a rail consist, or by creating a new train as a new consist by adding a new complete set of columnar data (7 columns in width) to the ‘Rail-Consist’ worksheet to the right of the last one currently defined and then modifying the locomotive data as required. If adding columns directly to the ‘Rail-Consist’ worksheet by copying and pasting, highlight a set of 7 complete columns by clicking the header of the first column of a source consist data set and then clicking the header of the 7th column to the right while pressing the shift key, then right click anywhere on the highlighted area and select “Copy” from the pop-up menu, then right click on the header of the 8th column to the right of the column declaring the last “Consist ID” (yellow cell on row 2) defined on the worksheet and select the “Paste (P)” icon (the first on the list) to paste the copy.

Caution: *Some cells in the columns defining rail consist data use formulae which necessitate pasting the cells contents rather than values. Also, you must edit the yellow “Consist ID” to provide it with a unique alphanumeric identifier (following along with the default naming scheme of “RC.#” where # is an integer number one greater than the consist to the left is recommended).*

You can also add a new rail consist based upon any previously defined consist using the ‘Rail Consist Selection’ user form by first displaying the desired existing consist and then clicking on the “Add Rail Consist” button to automatically create a copy with a new “Consist ID” and then clicking on the “Save Rail Consist” button to save it to the end of the list on the ‘Rail-Consist’ worksheet. The ‘Rail Consist Selection’ user form is accessed by double clicking the light yellow “Consist ID” information field on the ‘Rail Trip Selection’ user form.

By default, the window view of the ‘Rail-Consist’ worksheet is split to permit display of the input data descriptions provided in column A and the “Consist ID” (yellow cell on row 2), “Description” (green cell on row 3) and unit selections (green drop-down list on row 4) for the currently displayed columns while scrolling through and editing the data in the large window in the lower right of the display. Set the number of locomotives (or powered cars) in the green cell on row 5, the total number of powered axles on all locomotives in the green cell on row 7, the total weight carried on all powered axles in the green cell on row 10 and the mass-equivalent rotational inertia of each powered axle in the green cell on row 18. Note that all locomotives in a train are modeled using one set of physical characteristics in the input so in cases where different locomotive equipment are used in one train the values entered must represent the blend of locomotives in that train.

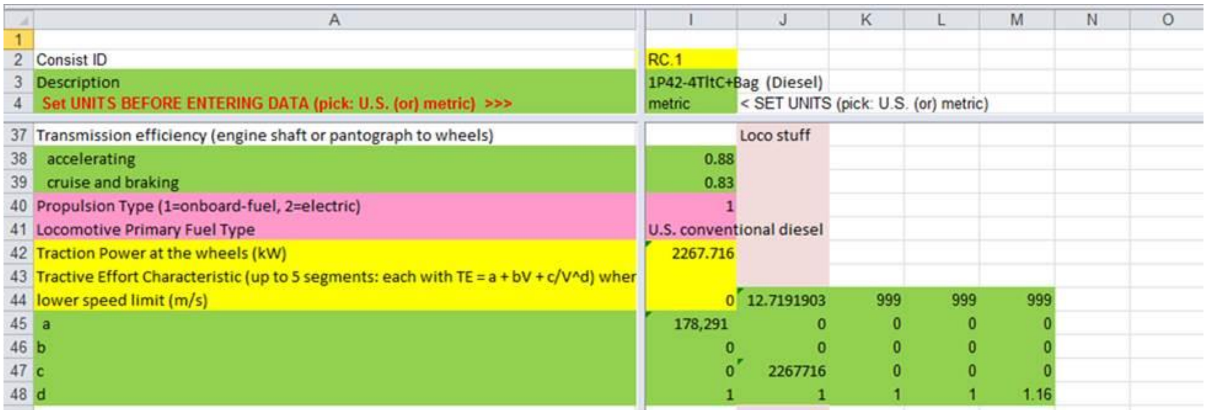
Train resistance is modeled using a quadratic equation which relates the train’s total resistive force to the speed of travel. The three coefficients are entered in the green cells on rows 26 through 28 (see Figure A-46) and must represent the total contribution to resistance of all vehicles in the train. Therefore, the magnitude of each coefficient should be changed appropriately as the number of vehicles included in the train changes. The first term is a constant related to the train’s resistance to rolling (row 26), the second coefficient represents a dynamic resistance term which is proportional to speed (row 27) while the third coefficient represents aerodynamic resistance which varies with the square of speed (row 28). Modifications of these coefficients to accommodate changes of locomotive equipment will require a reasonable estimate of the magnitude of individual contributions of locomotive and coach equipment to the total train resistance terms. Also, please note that the aerodynamic resistance term is automatically adjusted for the influence of headwind and ambient temperature and the modified value used by the simulation is shown in the orange cell on row 34. The adjustment depends on the season defined in the pink cell on row 29 to look up the appropriate seasonal data in the small table on rows 30 through 36. The contents of the pink cells in 'Rail-Consist' are loaded by the macro for a train at the time a rail simulation is performed based upon the user selected season for a rail trip.



	A	I	J	K	L	M	N	O
1								
2	Consist ID	RC.1						
3	Description	1P42-4TltC+Bag (Diesel)						
4	Set UNITS BEFORE ENTERING DATA (pick: U.S. (or) metric) >>>	metric	< SET UNITS (pick: U.S. (or) metric)					
25	TRAIN RESISTANCE COEFFICIENTS (a+bV+cV^2)		Resistance stuff					
26	a	4,286	(N)					
27	b	0.000	(N/(km/h))					
28	c	0.718	(N/(km/h)^2)					
29	Season adjustments for selected season	Other	Season / region common area					
30	summer heat/cool index	0.92691691		winter	summer	other		
31	winter heat/cool index	1.28		27.60243	75.00187	52.87353	deg F	
32	other (i.e. Spring or Fall) heat/cool index	0.02243614		-2.4431	23.88993	11.59641	deg C	
33	CdA impact	1.03		1.08	0.99	1.03	temperature and wi	
34	seasonal modified CdA; and average effective headwind speed (km/h)	0.740	1.870829	1.87	1.87	1.87	<< effective average	
35				31	25.90375	18	<< hotel Pwr (kW)	
36	Coach avg hotel power per coach (kW)	18		31.2	25.04445	18	<< user input	

Figure A-46 Train Resistance Coefficients in 'Rail-Consist' Worksheet

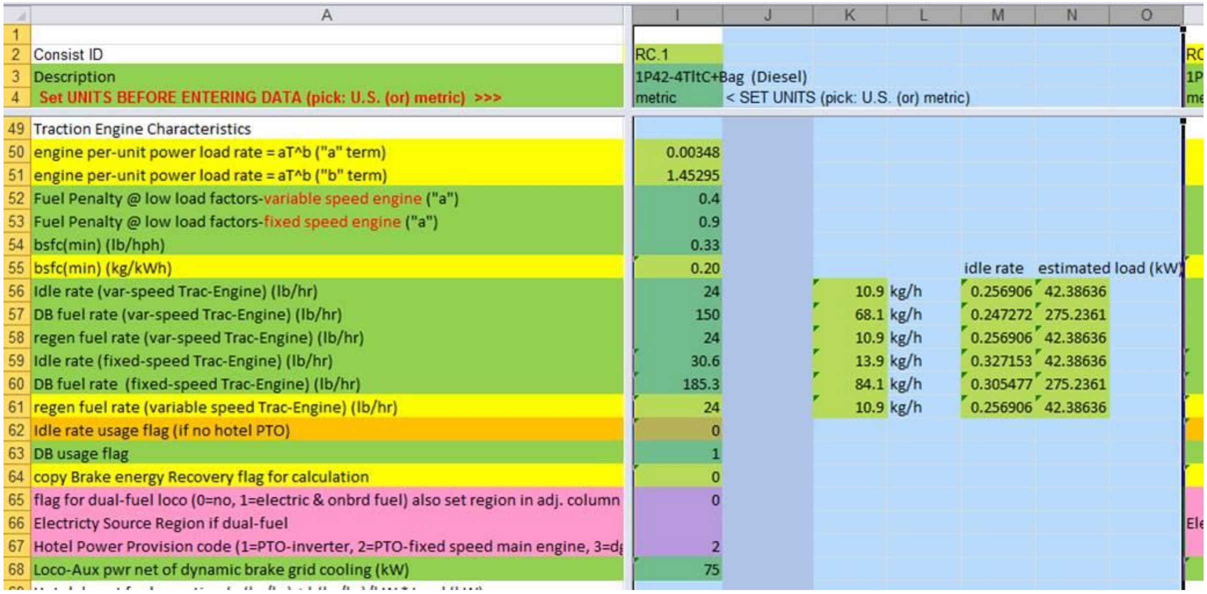
Transmission efficiencies and traction motor capabilities are defined on rows 37 through 48 as depicted in Figure A-47. The transmission efficiency when accelerating is input in the green cell on row 38 and when cruising and braking in the green cell on row 39. The traction characteristics of the locomotive are input as a multi-segment approximation of a tractive effort curve using the green fields of a 5-row by 5-column data table specified on rows 44 through 48. The first row identifies the lower speed (in m/s) associated with a maximum of 5 segments and a value of 999 should be entered if a segment is not used. Rows 45 through 48 hold sets of the four (4) coefficients used to define the tractive effort curve for each segment. The first term (a) is a constant, the second coefficient (b) defines a linear variation with speed, the third coefficient (c) represents an inverse variation with a power of speed defined by the fourth coefficient (d). Figure 3 on page 41 of Section 4.1.3.1 provides illustrations of a conventional diesel electric tractive effort curve represented using only 2 segments and a more complex VHSR electric power car tractive effort curve over 5 speed segments. There is also a low speed tractive effort limit applied to the traction characteristics which is specified on a per-powered-axle basis in the green cell on row 73.



	A	I	J	K	L	M	N	O
1								
2	Consist ID	RC.1						
3	Description	1P42-4TltC+Bag (Diesel)						
4	Set UNITS BEFORE ENTERING DATA (pick: U.S. (or) metric) >>>	metric	< SET UNITS (pick: U.S. (or) metric)					
37	Transmission efficiency (engine shaft or pantograph to wheels)		Loco stuff					
38	accelerating	0.88						
39	cruise and braking	0.83						
40	Propulsion Type (1=onboard-fuel, 2=electric)	1						
41	Locomotive Primary Fuel Type	U.S. conventional diesel						
42	Traction Power at the wheels (kW)	2267.716						
43	Tractive Effort Characteristic (up to 5 segments: each with TE = a + bV + c/V^d) wher							
44	lower speed limit (m/s)	0	12.7191903	999	999	999		
45	a	178,291	0	0	0	0		
46	b	0	0	0	0	0		
47	c	0	2267716	0	0	0		
48	d	1	1	1	1	1.16		

Figure A-47 Traction Motor Characteristics in 'Rail-Consist' Worksheet

Traction engine characteristics are defined on rows 49 through 68 as illustrated in Figure A-48. Coefficients defining the engine per-unit power load rate are declared in the yellow cells on rows 50 and 51. The green cells on rows 52 and 53 specify the fuel penalty at low load factors for variable and for fixed speed engines, respectively. The locomotive's brake specific fuel consumption is defined in the green cell on row 54. The green cells on rows 56 through 60 specify other fuel rates for the traction engine – rows 56 through 58 apply for variable-speed engines and 59 and 60 apply to fixed-speed engines. The green cell on row 63 indicates whether dynamic braking is to be used (a flag value of 1) or not. The locomotive auxiliary power requirement, excluding dynamic braking resistance grid cooling, is specified in the green cell on row 68 and should be adjusted for locomotive type. By default, this power requirement is calculated as 35 kW for electric locomotives and 75 kW for diesel-electric locomotives.



	A	I	J	K	L	M	N	O	
1									
2	Consist ID	RC.1							RC
3	Description	1P42-4TltC+Bag (Diesel)							1P
4	Set UNITS BEFORE ENTERING DATA (pick: U.S. (or) metric) >>>	metric	< SET UNITS (pick: U.S. (or) metric)						me
49	Traction Engine Characteristics								
50	engine per-unit power load rate = aT^b ("a" term)	0.00348							
51	engine per-unit power load rate = aT^b ("b" term)	1.45295							
52	Fuel Penalty @ low load factors-variable speed engine ("a")	0.4							
53	Fuel Penalty @ low load factors-fixed speed engine ("a")	0.9							
54	bsfc(min) (lb/hph)	0.33							
55	bsfc(min) (kg/kWh)	0.20				idle rate	estimated load (kW)		
56	Idle rate (var-speed Trac-Engine) (lb/hr)	24		10.9	kg/h	0.256906	42.38636		
57	DB fuel rate (var-speed Trac-Engine) (lb/hr)	150		68.1	kg/h	0.247272	275.2361		
58	regen fuel rate (var-speed Trac-Engine) (lb/hr)	24		10.9	kg/h	0.256906	42.38636		
59	Idle rate (fixed-speed Trac-Engine) (lb/hr)	30.6		13.9	kg/h	0.327153	42.38636		
60	DB fuel rate (fixed-speed Trac-Engine) (lb/hr)	185.3		84.1	kg/h	0.305477	275.2361		
61	regen fuel rate (variable speed Trac-Engine) (lb/hr)	24		10.9	kg/h	0.256906	42.38636		
62	Idle rate usage flag (if no hotel PTO)	0							
63	DB usage flag	1							
64	copy Brake energy Recovery flag for calculation	0							
65	flag for dual-fuel loco (0=no, 1=electric & onbrd fuel) also set region in adj. column	0							
66	Electricty Source Region if dual-fuel								Ele
67	Hotel Power Provision code (1=PTO-inverter, 2=PTO-fixed speed main engine, 3=d	2							
68	Loco-Aux pwr net of dynamic brake grid cooling (kW)	75							

Figure A-48 Traction Engine Characteristics in 'Rail-Consist' Worksheet

Particular care must be taken when specifying the ‘Rail-Consist’ data inputs which configure: the locomotive type, a dual-fuel locomotive, the fuel type(s) used, the method by which a locomotive generates hotel power and the type of brake energy recovery, if any, which may be used on the locomotive. This is because valid choices for some of these parameters depend upon the value of other parameters while others, such as fuel type selections, can only be from a defined list. It is preferable for users to make these selections using the ‘Rail Consist Selection’ form which will only present valid choices for each parameter value and a macro will automatically set the correct flags and values in the ‘Rail-Consist’ worksheet. These data inputs are coloured pink to signify that they can be set by a macro and also serves as a reminder to users to exercise caution when setting the values. The ‘Rail Consist Selection’ form is accessed by double clicking the light yellow “Consist ID” field on the ‘Rail Trip Selection’ user form.

> **Note:** *Always remember to click on the “Save Rail Consist” button to save any changes made to the data on the ‘Rail-Consist’ worksheet.*

A.6.4 Build a New Train with New Coaches

Building a new train with new passenger coaches requires modification of data stored in the ‘Rail-Consist’ worksheet. A new train, also termed a rail consist, can be easily added into the ‘Rail-Consist’ worksheet by clicking the “Add Rail Consist” button available on the ‘Rail Consist Selection’ user form. This will append a copy of the currently displayed rail consist to the next available set of columns in the ‘Rail-Consist’ worksheet and assign a unique “Consist ID”. You can scroll through all currently defined trains to select one which is similar to the train you wish to create. Alternatively, the set of seven (7) columns associated with an existing train can be manually copied to a new location to the right of set of columns defining the last “Consist ID” in the ‘Rail-Consist’ worksheet.

> **Note:** *If a train configuration is manually copied be sure to paste the cell contents rather than pasting cell values as some cells contain formulas. Also, the “Consist ID” in the yellow cell on row 2 must be given a unique alphanumeric identifier and the default “RC.#” format should be followed.*

Once a new consist is added, you must manually edit the green input fields in the set of seven (7) columns associated with the newly added train in the ‘Rail-Consist’ worksheet to adjust its parameters as necessary using the information in the following discussion and also in Section A.7.3 as a guide. By default, the window view of the ‘Rail-Consist’ worksheet is split to permit display of the input data descriptions provided in column A and the “Consist ID” (yellow cell on row 2), “Description” (green cell on row 3) and unit selections (green drop-down list on row 4) for the currently displayed columns while scrolling through and editing the data in the large window in the lower right of the display. Set the number of coaches in the green cell on row 4, the total number of unpowered axles (for all coaches) in the green cell on row 6 and the total number of axles in the train in the green cell on row 9.

For the purposes of a rail simulation, all coaches in a consist are considered to be the same (when coaches are different, the parameters input are for a “representative” coach). The total tare weight of all coaches is input in the green field on row 11, the average passenger weight (including luggage) is input in the green field on row 17, the total number of passenger seats in the consist is input in the green cell on row 12 and the passenger load factor is input in the green field on row 16. The mass-equivalent rotational inertia of each unpowered axle is input in the green cell on row 19. Note that the average seat pitch and common area inputs (rows 13 and 14) are unused. The total consist length, including all locomotives and coaches, is entered in the green input cell on row 20.

Train resistance is modeled using a quadratic equation which relates the train's total resistive force to the speed of travel (see Equation 5 on page 39 of Section 4.1.3.1). The three coefficients are entered in the green cells on rows 26 through 28 (see Figure A-46 on page A-89) and must represent the total contribution to resistance of all vehicles in the train. Therefore, the magnitude of each coefficient should be changed appropriately as the number of vehicles included in the train changes. The first term is a constant related to the train's resistance to rolling (row 26), the second coefficient represents a dynamic resistance term which is proportional to speed (row 27) while the third coefficient represents aerodynamic resistance which varies with the square of speed (row 28). Modifications of these coefficients to accommodate changing the type or number of coaches will require a reasonable estimate of the magnitude of individual contributions of locomotive and coach equipment to the total train resistance terms. Also, please note that the aerodynamic resistance term is automatically adjusted for the influence of headwind and ambient temperature and the modified value used by the simulation is shown in the orange cell on row 34. The adjustment depends on the season defined in the pink cell on row 29 to look up the appropriate seasonal data in the small table on rows 30 through 36. The contents of the pink cells in 'Rail-Consist' are loaded by the macro for a train at the time a rail simulation is performed based upon the user selected season for a rail trip.

It is also possible to build a simple rail consist using the 'Simple Rail Consist Selection' menu which is accessed by clicking on the blue "Save to 'Rail-Consist'" button on the 'Build-Simple-Rail-Trip' worksheet. This allows a user to build a train by selecting types and quantities of locomotives and coaches to be included. However, this utility only supports inclusion of a limited number of diesel-electric locomotives and only a few coach types. Please refer to the discussion previously provided in Section A.4.1 on page A-18 for more details.

A.6.5 Fit Train Performance to a Known Trip Schedule or Energy Efficiency

Rail schedules are developed on the basis of expected minimum run time performance of the train consist being operated plus an allowance for delays. The total scheduled trip time and the station sit/dwell times are specified via the trip data inputs on the Master-IO or Rail-IO sheets (the form is brought up via the 'define baseline' or 'define alternatives' blue buttons). Unscheduled delays are specified in the rail-route sheet (row 87 – row 96 for TSOs and row 98 – 100 for unscheduled stops.

The elapsed time information for a simulated rail trip is shown at Rail-Simulaiton!K4:K11. The simulated minimum run time, excluding dwell time at scheduled stops and any unscheduled stops or temporary slow orders is shown at K5. The total available slack in the schedule based on the user-specified values (in the rail-trip sheet) for scheduled trip time and dwell time at scheduled stops included is shown at K8.

If one is matching actual time and or energy performance data for a trip with known slow orders and unscheduled stops, the data inputs should be based on those data. If one is selecting values for average operating conditions, information on the operation's 'on-time-performance' is a useful guide. For example if on-time-performance is 95%, then the data input at row 100 for unscheduled stops could be set at 0.05 for the number of stops expected per trip and the average duration of that stop when incurred could be set to exceed the total available slack in the schedule (i.e. %-slack/100 X scheduled trip time X 60 min/hr); and the TSOs could be set such that part of the schedule slack is frequently used. Through an iterative process, the unscheduled delays can be set to provide reasonable operating values for the total average simulation run time (K9 of the simulation sheet) and available slack (K10 of the simulation sheet). As a guide, a 6% to 10% slack might exist prior to allocating unscheduled delays and 4% to 6% slack might remain on average after unscheduled delays are input to the route sheet. Worse on-time performance will require higher frequency and/or magnitude of unscheduled delays.

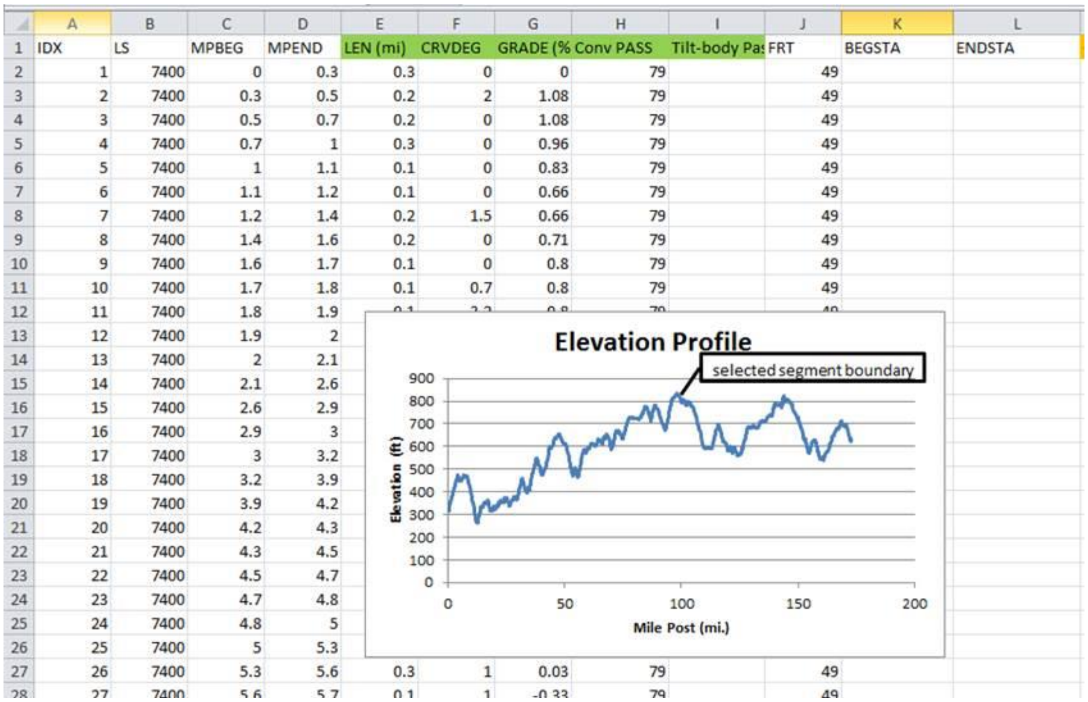
A.6.6 Build a New Track Profile

The columns of the ‘Rail-Route’ worksheet hold all data used by MMPASSIM to represent the physical characteristics of a rail route. The influence of vertical track profile is represented using a condensed Grade Distribution Table input in the green fields on rows 4 through 34 of that worksheet as illustrated in Figure A-49. This table requires the vertical track profile be characterized into a maximum of eight (8) segments, where the downward grades in each segment and in each direction of travel, are binned into six (6) severity ranges by percent-grade. The downward percent-grade ranges used are: 0.2% to 0.4%, 0.4% to 0.6%, 0.6% to 0.8%, 0.8% to 1.0%, 1.0% to 1.2% and finally anything greater than 1.2% downgrade. The table requires entries which specify both the actual average percent-grade for all of a segment’s track falling within each bin (rows 11 through 16 for the forward direction and rows 23 through 28 for the reverse direction) and the percentage of a segment’s track length with grades falling within each percent-grade bin (rows 17 through 22 for the forward direction and rows 29 through 34 for the reverse direction). The mile post (green fields on row 7) and elevation in feet (green fields on row 9) at the start and end location of each track segment must also be defined. The influence of horizontal alignment is assessed in the model using the average degrees of central angle per unit mile of track length (the sum of central angle for all curves divided by the total track length) and is input in the green field on row 4.

	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM
1													
2		RR.1	DEMO IC RAIL										
3													
4		Total CA of curvature		4026	12.078								
5		**Grade Distribution**			2	<< No. Grade Segments							
6		RGT.1	Grade Table 1										
7		(average grade and		MP	400	666	733.3						
8		proportion of total		Mile	0	266	333.3						
9		route distance by		Elev (ft)	60.4	261.9	273.7						
10		grade severity class)		Segment	1	2	3	4	5	6	7	8	
11		Forward Direction	Average %-Grade in Severity Range	-0.2	-0.29	-0.31							
12				-0.4	-0.48	-0.47							
13				-0.6	-0.69	-0.67							
14				-0.8	-0.92	-0.92							
15				-1	-1.05	-1.04							
16				-1.2	-1.24	0.00							
17			%-Distance of Severity Range	-0.2	10.7%	16.5%							
18				-0.4	7.6%	14.6%							
19				-0.6	4.9%	2.9%							
20				-0.8	2.5%	2.3%							
21				-1	1.9%	4.5%							
22				-1.2	0.0%	0.0%							
23		Reverse Direction	Average %-Grade in Severity Range	-0.2	-0.30	-0.32							
24				-0.4	-0.50	-0.47							
25				-0.6	-0.70	-0.68							
26				-0.8	-0.91	-0.94							
27				-1	-1.05	-1.08							
28				-1.2	-1.24	-1.33							
29			%-Distance of Severity Range	-0.2	9.8%	11.4%							
30				-0.4	6.0%	9.5%							
31				-0.6	4.6%	6.4%							
32				-0.8	3.8%	4.3%							
33				-1	1.9%	3.8%							
34				-1.2	0.3%	0.8%							
35													

Figure A-49 Example of a Grade Distribution Table in the 'Rail-Route' Worksheet

A track preprocessor is provided in a separate Microsoft Excel workbook to assist users through the process of converting track profile data as typically available in track charts into the condensed grade distribution table format required by MMPASSIM. Essentially this involves populating columns of the preprocessor's 'Track Data' worksheet (see Figure A-50) with the start (column C) and end (column D) milepost, grade (column G), degree of curvature (column F) and applicable speed limits (columns H and I) of the successive track sections comprising a subdivision and then segmenting the subdivision when obvious significant transitions in grade trends occur. The 'Readme' worksheet included in the track preprocessor workbook provides details on how to segment a track profile and create the condensed grade distribution table.



	A	B	C	D	E	F	G	H	I	J	K	L
1	IDX	LS	MPBEG	MPEND	LEN (mi)	CRVDEG	GRADE (%	Conv PASS	Tilt-body Pas	FRT	BEGSTA	ENDSTA
2	1	7400	0	0.3	0.3	0	0	79		49		
3	2	7400	0.3	0.5	0.2	2	1.08	79		49		
4	3	7400	0.5	0.7	0.2	0	1.08	79		49		
5	4	7400	0.7	1	0.3	0	0.96	79		49		
6	5	7400	1	1.1	0.1	0	0.83	79		49		
7	6	7400	1.1	1.2	0.1	0	0.66	79		49		
8	7	7400	1.2	1.4	0.2	1.5	0.66	79		49		
9	8	7400	1.4	1.6	0.2	0	0.71	79		49		
10	9	7400	1.6	1.7	0.1	0	0.8	79		49		
11	10	7400	1.7	1.8	0.1	0.7	0.8	79		49		
12	11	7400	1.8	1.9								
13	12	7400	1.9	2								
14	13	7400	2	2.1								
15	14	7400	2.1	2.6								
16	15	7400	2.6	2.9								
17	16	7400	2.9	3								
18	17	7400	3	3.2								
19	18	7400	3.2	3.9								
20	19	7400	3.9	4.2								
21	20	7400	4.2	4.3								
22	21	7400	4.3	4.5								
23	22	7400	4.5	4.7								
24	23	7400	4.7	4.8								
25	24	7400	4.8	5								
26	25	7400	5	5.3								
27	26	7400	5.3	5.6	0.3	1	0.03	79		49		
28	27	7400	5.6	5.7	0.1	1	-0.33	79		49		

Figure A-50 Example of Track Preprocessor’s Input Columns

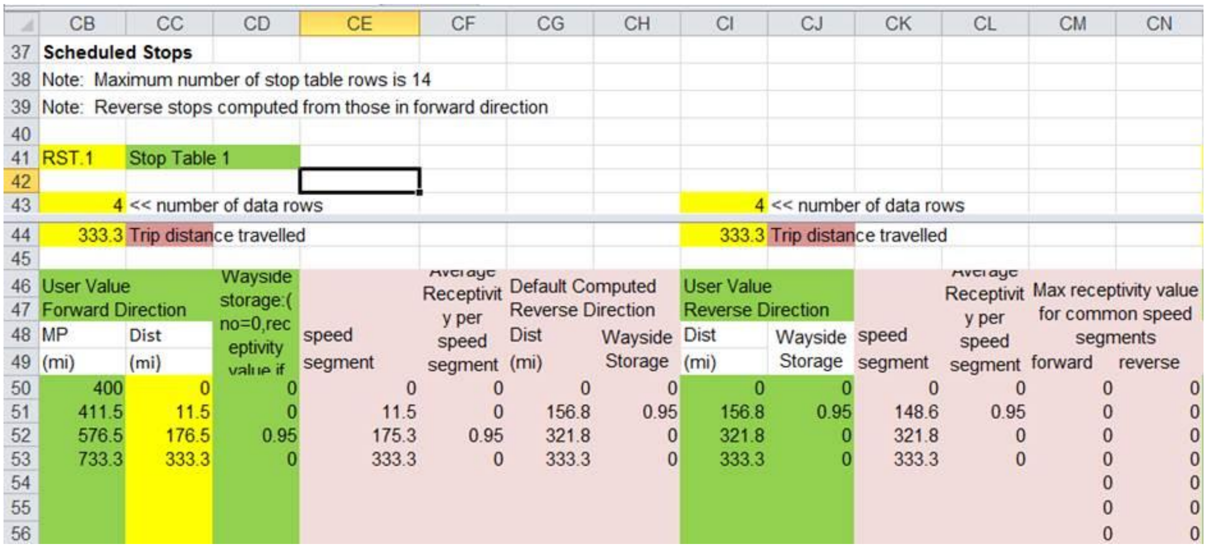
Once the grade distribution table is created (see Figure A-51), a user simply copies the grade segment boundaries from ‘Track Data’!AN112:AV112 in the preprocessor and pastes their ***values*** (using the paste special menu) into the target column on row 7 of the ‘Rail-Route’ worksheet and copies the balance of the grade distribution table from ‘Track Data’!AN113:AV138 in the preprocessor and again pastes their ***values*** (using the paste special menu) into the target columns on row 9 of the ‘Rail-Route’ worksheet. The first rail route’s grade table is inserted in column R of the ‘Rail-Route’ worksheet with tables for subsequent routes input in 13 column intervals (columns AE, AR, BE etc…). The track preprocessor also converts degree of curvature into degrees of central angle (column P) which can be summed and divided by the total subdivision length to derive the rail simulation’s required curvature input expressed in terms of degrees of central angle per mile of the total track length.

	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
112				MP	0	101	173						
113				Elev (ft)	315	805.88	627.84						
114				Segment	1	2	3	4	5	6	7	8	
115		Forward Direction	Average %-Grade in Severity Range	-0.2	-0.31	-0.35							
116				-0.4	-0.50	-0.49							
117				-0.6	-0.72	-0.71							
118				-0.8	-0.92	-0.75							
119				-1	-1.06	-0.80							
120				-1.2	-1.32	0.00							
121			%-Distance of Severity Range	-0.2	5%	10%							
122				-0.4	10%	9%							
123				-0.6	8%	15%							
124				-0.8	10%	5%							
125				-1	1%	0%							
126				-1.2	0.4%	0.0%							
127		Reverse Direction	Average %-Grade in Severity Range	-0.2	-0.29	-0.32							
128				-0.4	-0.53	-0.48							
129				-0.6	-0.68	-0.65							
130				-0.8	-0.91	-0.79							
131				-1	-1.05	-0.94							
132				-1.2	-1.35	0.00							
133			%-Distance of Severity Range	-0.2	9%	8%							
134				-0.4	9%	12%							
135				-0.6	8%	7%							
136				-0.8	17%	5%							
137				-1	4%	2%							
138				-1.2	0.3%	0.0%							
139													
140		% not effectively flat			82%	73%							

Figure A-51 Example of Track Preprocessor's Output Grade Distribution Table

Scheduled stops are input separately for the forward and reverse directions in the green fields of the Scheduled Stop Table located on rows 50 through 85 of the 'Rail-Route' worksheet (a sample is illustrated in Figure A-52 on page A-97). The first green column of input for a route (column CB in the example) declares the milepost of each stop to be made in the forward direction of travel. The second green input column (column CD in the example) declares the receptivity for wayside energy storage at the stop if available and should be set to zero where there is no wayside energy storage. Columns CC and CE through CH (in the example) contain automatically calculated values. For the reverse direction, stop locations are input in terms of miles from the start of the reverse trip (not milepost) in the third green input column (column CI in the example) and the receptivity of wayside storage, if any, in the fourth green input column (column CJ in the example). A maximum of 36 stops, including the origin and destination, may be specified for a route.

> **Note:** *The green fields associated with any unused records in the stop list must be cleared.*



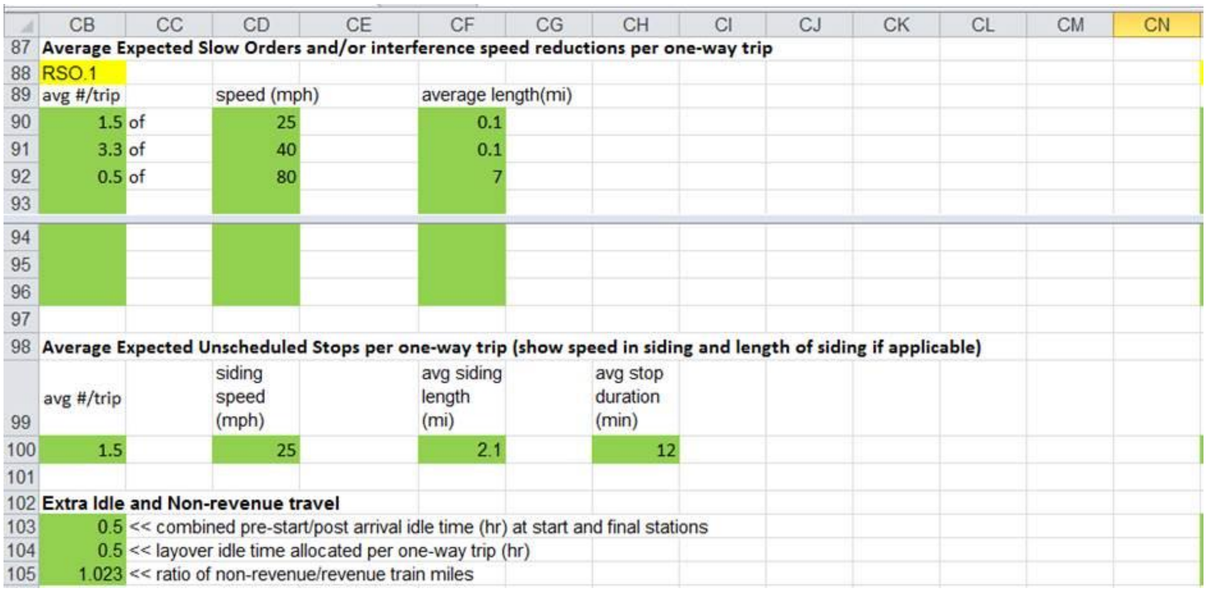
	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN
37	**Scheduled Stops**												
38	Note: Maximum number of stop table rows is 14												
39	Note: Reverse stops computed from those in forward direction												
40													
41	RST.1	Stop Table 1											
42													
43	4	<< number of data rows						4	<< number of data rows				
44	333.3	Trip distance travelled						333.3	Trip distance travelled				
45													
46	User Value		Wayside		Average	Default Computed		User Value			Average	Max receptivity value	
47	Forward Direction		storage:(		Receptivit	Reverse Direction		Reverse Direction			Receptivit	for common speed	
48	MP	Dist	no=0,rec eptivity	speed	y per speed	Dist	Wayside	Dist	Wayside	speed	y per speed	segments	
49	(mi)	(mi)	value if	segment	segment	(mi)	Storage	(mi)	Storage	segment	segment	forward	reverse
50	400	0	0	0	0	0	0	0	0	0	0	0	0
51	411.5	11.5	0	11.5	0	156.8	0.95	156.8	0.95	148.6	0.95	0	0
52	576.5	176.5	0.95	175.3	0.95	321.8	0	321.8	0	321.8	0	0	0
53	733.3	333.3	0	333.3	0	333.3	0	333.3	0	333.3	0	0	0
54												0	0
55												0	0
56												0	0

Figure A-52 Example of a Scheduled Stop Table in the 'Rail-Route' Worksheet

Slow orders and other speed reductions associated with train interference are input in the Slow Order Table using the green input fields on rows 90 through 96 of the ‘Rail-Route’ worksheet (see example in Figure A-53 on page A-98). Three columns of data are required to specify a speed reduction. The first identifies the average number of times which a speed reduction will be applied during a trip, the second data value declares the speed (in mph) to which travel will be limited while the third value specifies the average length of track (in miles) over which the speed reduction will apply. A maximum of seven (7) slow orders may be defined.

Note: *All green fields not in use for a route definition should be cleared.*

In addition to slow orders, a user may also characterize unscheduled stops which may occur over a one way trip using the four green input fields on row 100. The first value declares the average number of unscheduled stops per trip, the second input declares the siding speed limit (in mph), the third input declares the average siding length (in miles) and the fourth input specifies the average duration of an unscheduled stop (in minutes). These fields should be cleared when no unscheduled stops are anticipated. Extra idle time at the origin and destination stations, layover idle and additional non-revenue travel for a route are input in the green fields on rows 103 through 105.



	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN
87	**Average Expected Slow Orders and/or interference speed reductions per one-way trip**												
88	RSO.1												
89	avg #/trip		speed (mph)		average length(mi)								
90	1.5	of	25		0.1								
91	3.3	of	40		0.1								
92	0.5	of	80		7								
93													
94													
95													
96													
97													
98	**Average Expected Unscheduled Stops per one-way trip (show speed in siding and length of siding if applicable)**												
99	avg #/trip		siding speed (mph)		avg siding length (mi)		avg stop duration (min)						
100	1.5		25		2.1		12						
101													
102	**Extra Idle and Non-revenue travel**												
103	0.5	<< combined pre-start/post arrival idle time (hr) at start and final stations											
104	0.5	<< layover idle time allocated per one-way trip (hr)											
105	1.023	<< ratio of non-revenue/revenue train miles											

Figure A-53 Example of Slow Orders and Unscheduled Stops in the 'Rail-Route' Worksheet

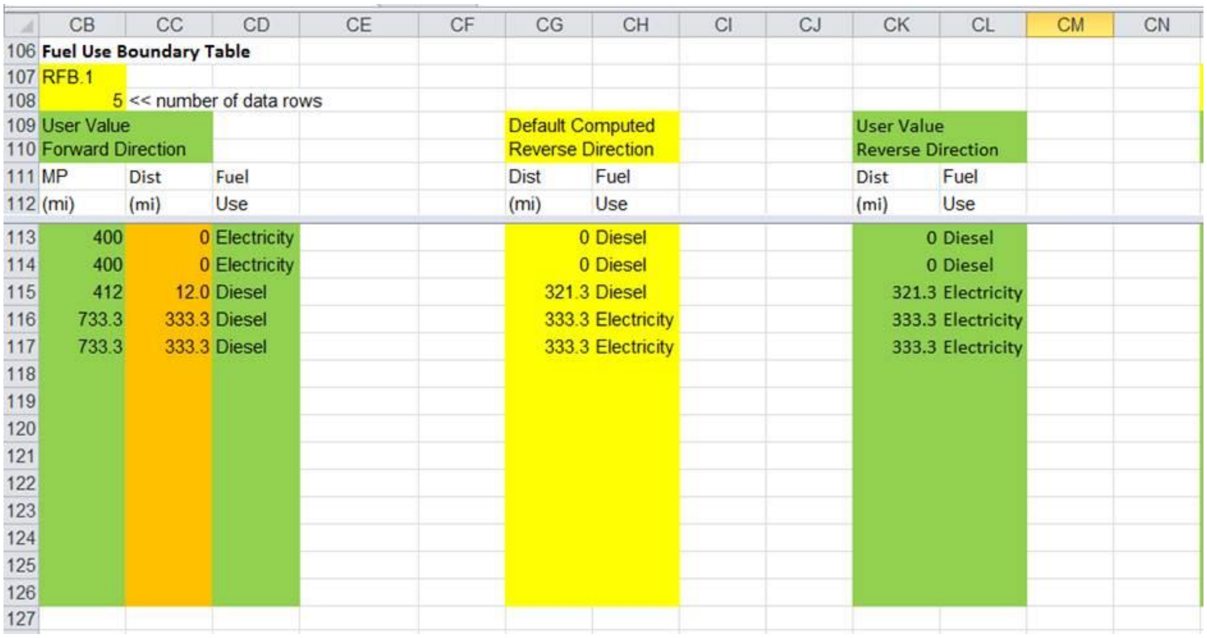
In situations where rail travel involves dual-fuel equipment used along combinations of electrified and non-electrified territories, a user must define where each fuel is to be used. This is specified in the Fuel Use Boundary table on rows 113 through 126 of the ‘Rail-Route’ worksheet. An example of this table is shown in Figure A-54. For each route there are four green input data columns and three columns which are automatically populated from user inputs (one orange and two yellow columns). The first green column of user input (column CB in the example) must declare the milepost of the boundary where a fuel type is to be changed.

> ***Note:*** *The starting location of the first boundary and the ending location of the last boundary must be repeated to support formula logic – therefore a maximum of 14 rows of input can declare up to 12 fuel use boundaries.*

The second green input column (CD in the example) identifies the fuel type, as either ‘Electricity’ or ‘Diesel’, which will be used starting at the indicated milepost until the next defined boundary is encountered. The keyword ‘Electricity’ is used by formula logic in the ‘Rail-Simulation’ worksheet to distinguish between pantograph electricity consumption and onboard fuel use – although there may be several onboard fuels defined in the ‘Energy-Emission’ worksheet for locomotive use, the ‘Diesel’ keyword should be used for all forms of onboard fuels. The third and fourth green input columns (CK and CL in the example) specify the location, in miles, of a fuel boundary from the start of a return trip and the keyword describing the fuel to be used beginning at that boundary.

> ***Note:*** *Although the yellow columns (CG and CH in the example) automatically calculate fuel use boundaries for the reverse direction based upon the*

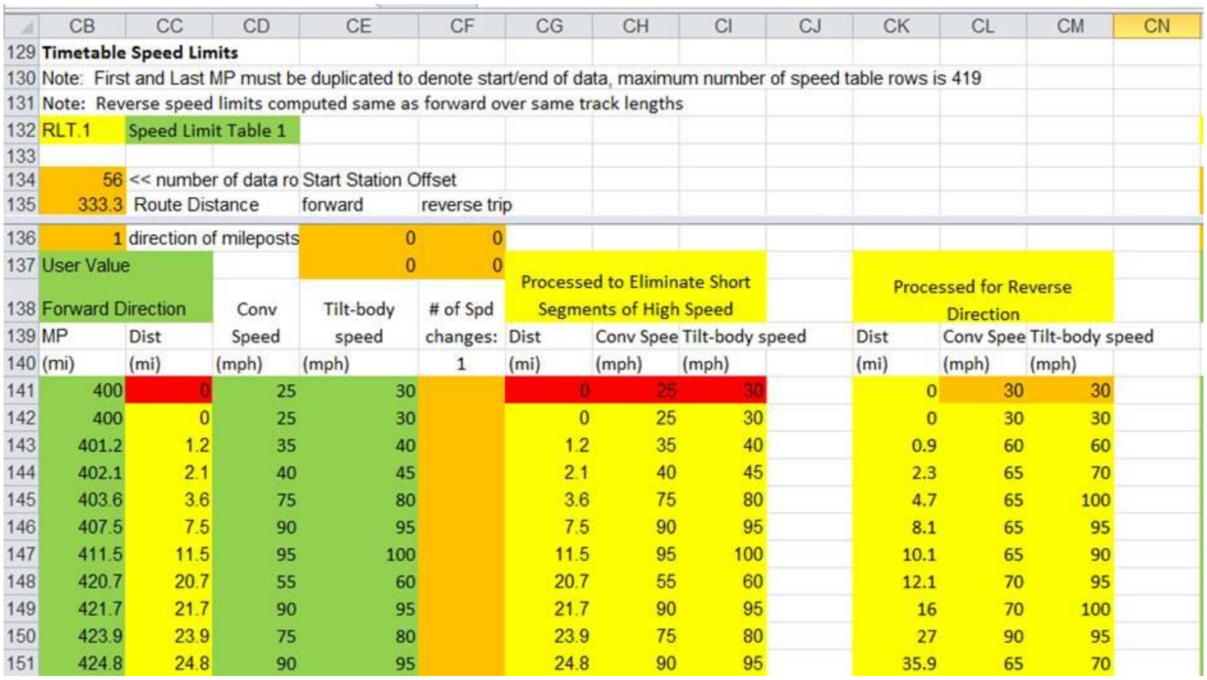
definitions entered for the forward direction, the user must still supply the reverse direction boundaries in the green input columns, either by highlighting the automatically generated columns and pasting by value (using paste special menu) definitions or entering them manually. This allows flexibility in defining reverse direction boundaries independent of the forward direction boundaries if required. All green user input fields on rows not required to define the current Fuel Use Boundary table must be cleared.



	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN
106	**Fuel Use Boundary Table**												
107	RFB.1												
108	5	<< number of data rows											
109	User Value					Default Computed				User Value			
110	Forward Direction					Reverse Direction				Reverse Direction			
111	MP	Dist	Fuel			Dist	Fuel			Dist	Fuel		
112	(mi)	(mi)	Use			(mi)	Use			(mi)	Use		
113	400	0	Electricity			0	Diesel			0	Diesel		
114	400	0	Electricity			0	Diesel			0	Diesel		
115	412	12.0	Diesel			321.3	Diesel			321.3	Electricity		
116	733.3	333.3	Diesel			333.3	Electricity			333.3	Electricity		
117	733.3	333.3	Diesel			333.3	Electricity			333.3	Electricity		
118													
119													
120													
121													
122													
123													
124													
125													
126													
127													

Figure A-54 Example of a Fuel Use Boundary Table in the 'Rail-Route' Worksheet

The final data table in a rail route definition specifies the location and speed limits to be observed for conventional and tilt-body passenger rail equipment. Figure A-55 illustrates the format of this table. The speed limit location and values in mph are specified in the three green user input columns (columns CB, CD and CE of the example) on rows 141 through 561 of the 'Rail-Route' worksheet. The first green input column defines the starting milepost of each speed limit encountered in the forward direction of travel. The second green input column defines the speed limit, in mph, to be observed for conventional passenger equipment while the third green input column declares the speed limit, again in mph, to be applied when tilt-body passenger equipment is used.

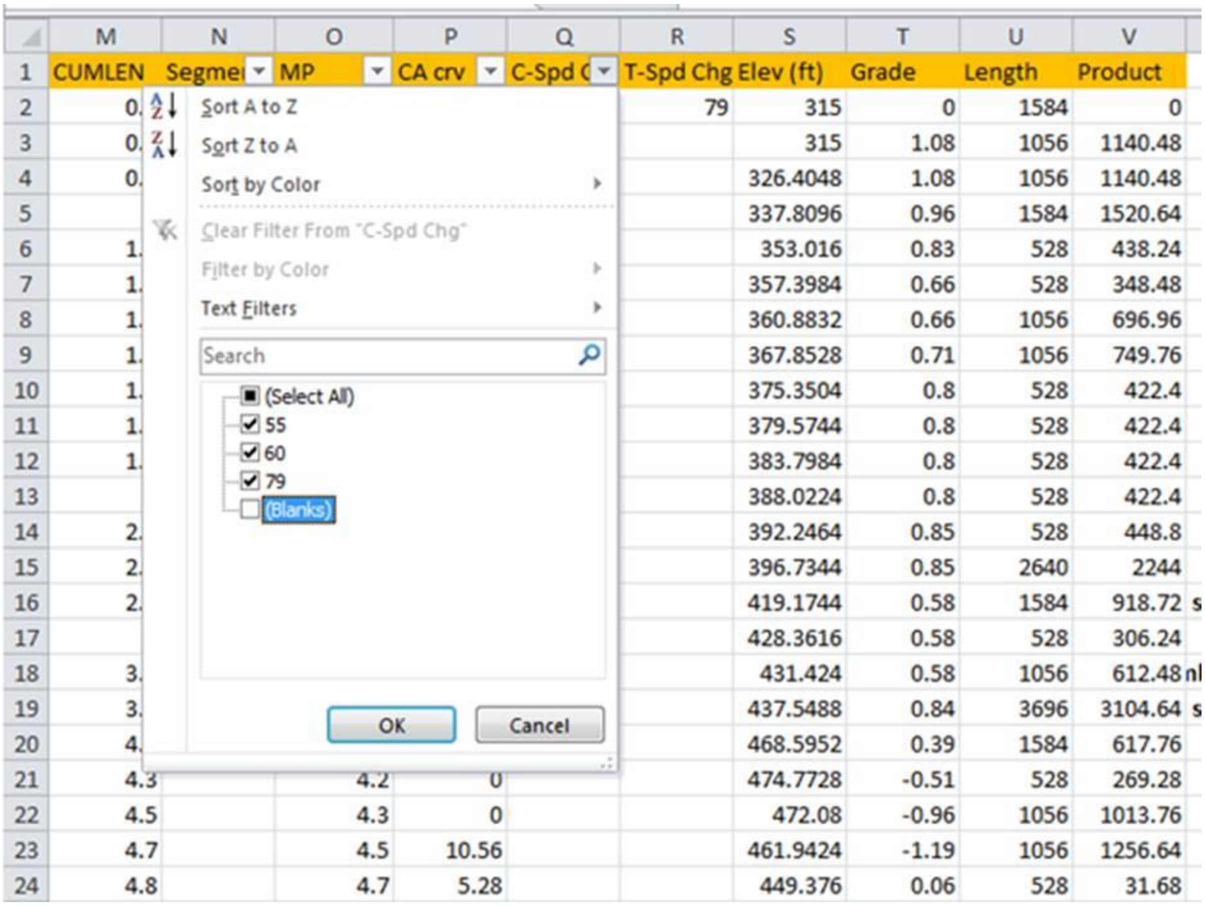


	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN
129	**Timetable Speed Limits**												
130	Note: First and Last MP must be duplicated to denote start/end of data, maximum number of speed table rows is 419												
131	Note: Reverse speed limits computed same as forward over same track lengths												
132	RLT.1	Speed Limit Table 1											
133													
134	56	<< number of data ro		Start Station Offset									
135	333.3	Route Distance		forward	reverse trip								
136	1	direction of mileposts		0	0								
137	User Value			0	0	Processed to Eliminate Short Segments of High Speed				Processed for Reverse Direction			
138	Forward Direction		Conv	Tilt-body	# of Spd								
139	MP	Dist	Speed	speed	changes:	Dist	Conv Spee	Tilt-body speed		Dist	Conv Spee	Tilt-body speed	
140	(mi)	(mi)	(mph)	(mph)	1	(mi)	(mph)	(mph)		(mi)	(mph)	(mph)	
141	400	0	25	30		0	25	30		0	30	30	
142	400	0	25	30		0	25	30		0	30	30	
143	401.2	1.2	35	40		1.2	35	40		0.9	60	60	
144	402.1	2.1	40	45		2.1	40	45		2.3	65	70	
145	403.6	3.6	75	80		3.6	75	80		4.7	65	100	
146	407.5	7.5	90	95		7.5	90	95		8.1	65	95	
147	411.5	11.5	95	100		11.5	95	100		10.1	65	90	
148	420.7	20.7	55	60		20.7	55	60		12.1	70	95	
149	421.7	21.7	90	95		21.7	90	95		16	70	100	
150	423.9	23.9	75	80		23.9	75	80		27	90	95	
151	424.8	24.8	90	95		24.8	90	95		35.9	65	70	

Figure A-55 Example of a Speed Limit Table in the 'Rail-Route' Worksheet

The track preprocessor may also be used to assist in extracting the table of speed limits from speed limit data as typically provided in columnar track chart data, This can be achieved using Excel's filtering capability on the preprocessor's two columns which identify changes in the conventional speed limit ('Track Data' column Q) and tilt-body speed limit ('Track Data' column R) for all non-blank values. This is done by clicking the gray down arrow in the orange "C-Spd Chg" header in cell 'Track-Data'!Q1, as shown in Figure A-56. This will open a filter menu where the check box corresponding with "(blanks)" should be cleared and then click the "OK" button to apply the filter. Once the speed change column is filtered, as depicted in Figure A-57, copy the mileposts from 'Track Data' column O, the conventional speed limits from 'Track Data' column Q and the tilt-body speed limits from 'Track Data' column R of the track preprocessor and paste their values (using the "Paste Special" menu) into the appropriate column in 'Rail-Route' worksheet.

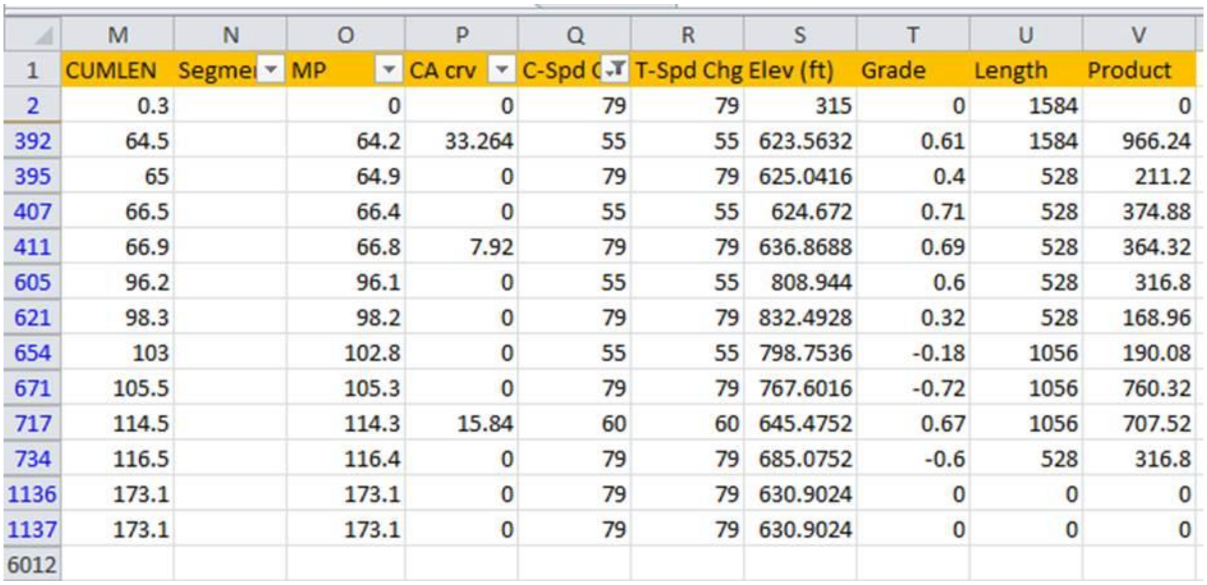
Note: *The first row of green user inputs and the last row of green user inputs specified in the Timetable Speed Limits table must be repeated to accommodate the formula logic used for automatic calculations. Therefore, a maximum of 419 speed limits may be assigned for any route. Also, all green user input fields should be cleared on any unused row in the table after pasting a column of data.*



■ (Select All)
☑ 55
☑ 60
☑ 79
☐ (Blanks)

	M	N	O	P	Q	R	S	T	U	V
1	CUMLEN	Segme	MP	CA crv	C-Spd C	T-Spd Chg	Elev (ft)	Grade	Length	Product
2	0.					79	315	0	1584	0
3	0.						315	1.08	1056	1140.48
4	0.						326.4048	1.08	1056	1140.48
5							337.8096	0.96	1584	1520.64
6	1.						353.016	0.83	528	438.24
7	1.						357.3984	0.66	528	348.48
8	1.						360.8832	0.66	1056	696.96
9	1.						367.8528	0.71	1056	749.76
10	1.						375.3504	0.8	528	422.4
11	1.						379.5744	0.8	528	422.4
12	1.						383.7984	0.8	528	422.4
13							388.0224	0.8	528	422.4
14	2.						392.2464	0.85	528	448.8
15	2.						396.7344	0.85	2640	2244
16	2.						419.1744	0.58	1584	918.72
17							428.3616	0.58	528	306.24
18	3.						431.424	0.58	1056	612.48
19	3.						437.5488	0.84	3696	3104.64
20	4.						468.5952	0.39	1584	617.76
21	4.3		4.2	0			474.7728	-0.51	528	269.28
22	4.5		4.3	0			472.08	-0.96	1056	1013.76
23	4.7		4.5	10.56			461.9424	-1.19	1056	1256.64
24	4.8		4.7	5.28			449.376	0.06	528	31.68

Figure A-56 Finding Speed Limit Changes Using Column Filter in Track Preprocessor



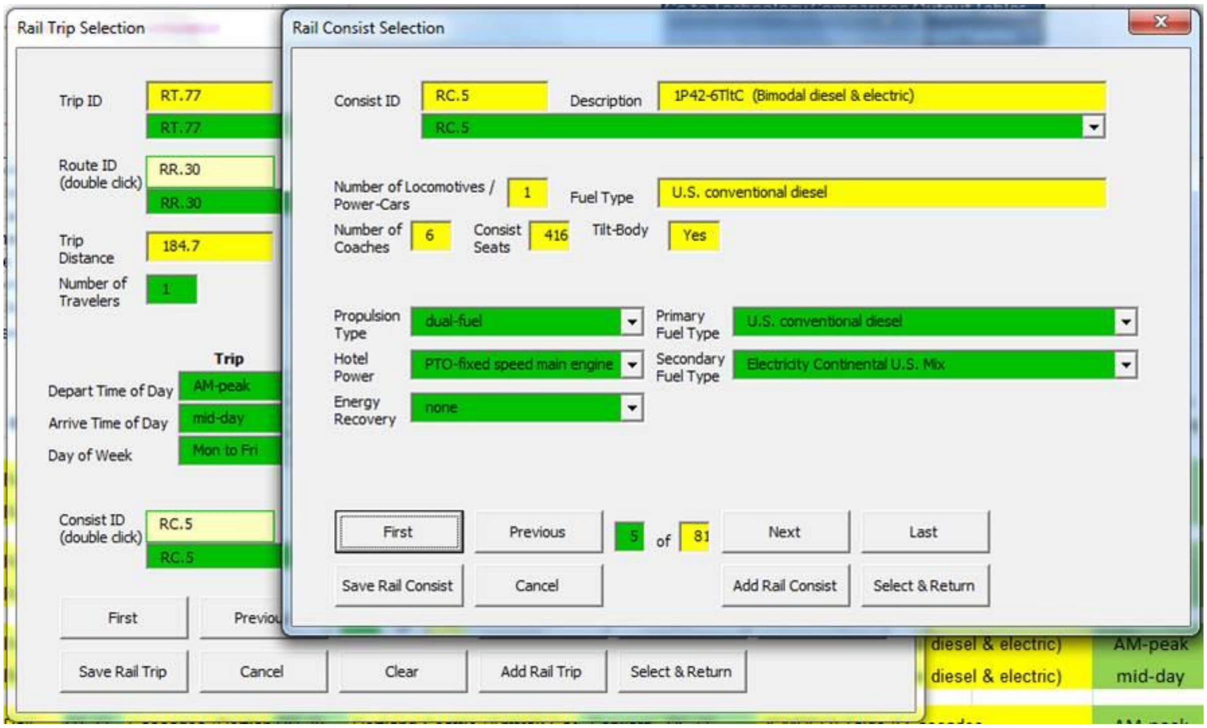
	M	N	O	P	Q	R	S	T	U	V
1	CUMLEN	Segme	MP	CA crv	C-Spd C	T-Spd Chg	Elev (ft)	Grade	Length	Product
2	0.3		0	0	79	79	315	0	1584	0
392	64.5		64.2	33.264	55	55	623.5632	0.61	1584	966.24
395	65		64.9	0	79	79	625.0416	0.4	528	211.2
407	66.5		66.4	0	55	55	624.672	0.71	528	374.88
411	66.9		66.8	7.92	79	79	636.8688	0.69	528	364.32
605	96.2		96.1	0	55	55	808.944	0.6	528	316.8
621	98.3		98.2	0	79	79	832.4928	0.32	528	168.96
654	103		102.8	0	55	55	798.7536	-0.18	1056	190.08
671	105.5		105.3	0	79	79	767.6016	-0.72	1056	760.32
717	114.5		114.3	15.84	60	60	645.4752	0.67	1056	707.52
734	116.5		116.4	0	79	79	685.0752	-0.6	528	316.8
1136	173.1		173.1	0	79	79	630.9024	0	0	0
1137	173.1		173.1	0	79	79	630.9024	0	0	0
6012										

Figure A-57 Column of Speed Limit Changes Once Filtered in Track Preprocessor

A.6.7 Train Technology Comparison by Modifying an Existing Train/Route

Performing train technology comparisons based upon modifications to the propulsion type, provision of hotel power and implementation of energy recovery capabilities of an existing train consist and route are straight forward using MMPASSIM's "Rail Technology Evaluation" analysis mode. These types of analyses may be set up and run from either the 'Master-I-O' or the 'Rail-I-O' worksheet by selecting "Rail Technology Evaluation" from the green drop-down list at cell C4 of either worksheet and then configuring a baseline trip and up to three other rail trips for comparison. Configure the trips by clicking the blue "Define Baseline" and "Define Alternative #" buttons as required to access the 'Rail Trip Selection' menu allowing configuration of each trip. The trips could all specify a common route but different consists, or the route can also be different if a particular technology alternative also requires route modifications.

The characteristics of locomotives, or power cars, in a train are characterized by parameters stored in the columns of the 'Rail-Consist' worksheet. The 'Rail Consist Selection' menu provides a convenient means to create new trains from existing definitions in the 'Rail-Consist' worksheet (using the "Add Rail Consist" button) and selecting key features and capabilities which are supported by the train data. The 'Rail Consist Selection' menu, depicted in Figure A-58, is accessed by double clicking the light yellow "Consist ID" located in the bottom right quadrant of a 'Rail Trip Selection' menu. Open the 'Rail Trip Selection' menu by clicking a blue "Define Baseline" or one of the "Define Alternative #" button associated with a rail trip definition on the 'Master-I-O' or the 'Rail-I-O' worksheets.



Rail Trip Selection

Trip ID: RT.77 / RT.77

Route ID (double click): RR.30 / RR.30

Trip Distance: 184.7

Number of Travelers: 1

Trip

Depart Time of Day: AM-peak

Arrive Time of Day: mid-day

Day of Week: Mon to Fri

Consist ID (double click): RC.5 / RC.5

Rail Consist Selection

Consist ID: RC.5 / RC.5

Description: 1P42-6TltC (Bimodal diesel & electric)

Number of Locomotives / Power-Cars: 1

Fuel Type: U.S. conventional diesel

Number of Coaches: 6

Consist Seats: 416

Tilt-Body: Yes

Propulsion Type: dual-fuel

Primary Fuel Type: U.S. conventional diesel

Hotel Power: PTO-fixed speed main engine

Secondary Fuel Type: Electricity Continental U.S. Mix

Energy Recovery: none

5 of 81

Figure A-58 Rail Consist Selection Menu

The ‘Rail Consist Selection’ menu presents five green drop-down lists which describe a locomotive’s basic characteristics. These are initially read from cells in the columns of the ‘Rail-Consist’ worksheet associated with the displayed “Consist ID”.

The green “Propulsion Type” drop-down list presents only three options:

- “onboard-fuel”
- “electric”
- “dual-fuel”.

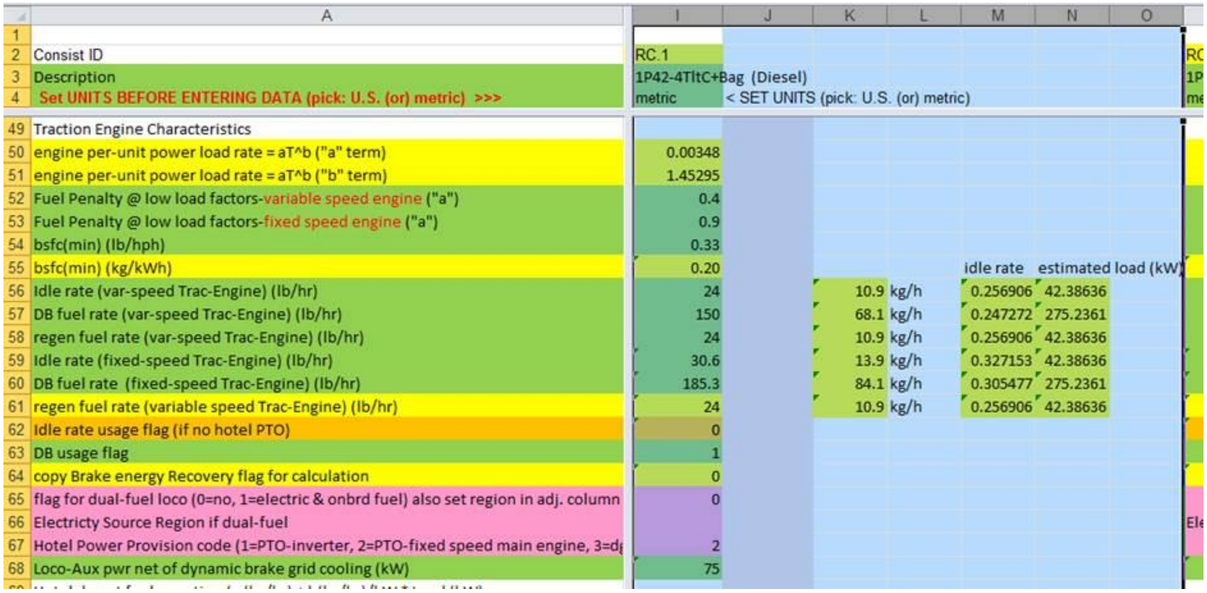
The selected “Propulsion Type” is represented in the pink cells on rows 40 and 65 of the column in ‘Rail-Consist’ associated with the displayed “Consist ID” (also stored in the yellow cell on row 2 of ‘Rail-Consist’). The pink cell on row 65 of ‘Rail-Consist’ is a dual-fuel locomotive flag which is set to “1” only when the “Propulsion Type” is selected to be “dual-fuel”, otherwise it is “0”. The pink cell on row 40 of ‘Rail-Consist’ is set to “2” when the “Propulsion Type” selection is “electric”, otherwise it is set to “1” indicating a “propulsion Type” of either “onboard-fuel” or “dual-fuel”.

The “Primary Fuel Type” and “Secondary Fuel Type” drop-down lists are coordinated with the current selection of “Propulsion Type” such that they only display valid fuel sources appropriate for a selected propulsion type. For locomotives using an onboard-fuel the list of options for the “Primary Fuel Type” are from the locomotive fuels table in ‘Energy-Emission’!E37:E45. For electric locomotives the “Primary Fuel Type” presents grid electricity sources from the regional mixes defined in ‘Energy-Emission’!E61:E77. The “Secondary Fuel Type” is only used to select the grid electricity when a “dual-fuel” locomotive has been selected. The “Primary Fuel Type” selection is stored in the pink cell on row 41 of ‘Rail-Consist’ while the “Secondary Fuel Type” is stored in the pink cell on row 66.

The green “Hotel Power” drop-down list presents the following 4 options:

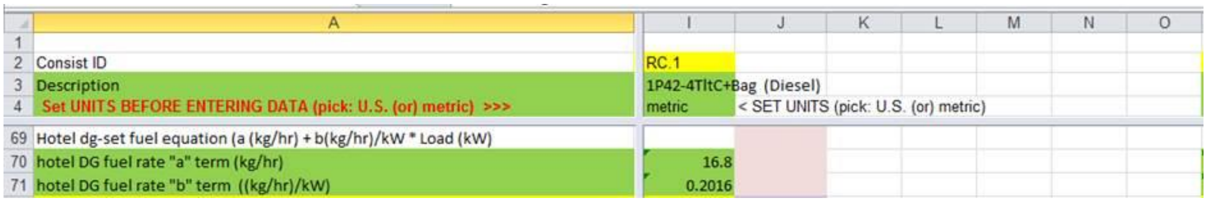
- “PTO-inverter”
- “PTO-fixed speed main engine”
- “Diesel genset”
- “Electric Loco”

The first three options are applicable to locomotives declared as using “onboard” and “dual-fuel” sources. The “Electric Loco” option should only be selected when a “Propulsion Type” of “electric” has been declared. The selection is stored in the pink cell on row 67 of ‘Rail-Consist’ as a flag value with “1” corresponding to “PTO-inverter”, “2” with “PTO-fixed speed main engine”, “3” with “Diesel genset” and “4” with “Electric Loco”. Choosing to take hotel power off of the main traction engine (one of the “PTO” options) affects both the power available for traction and the calculated fuel consumption. These impacts are calculated from the traction engine characterization defined on rows 49 through 68 of ‘Rail-Consist’ (Figure A-59). Using a diesel genset to provide hotel power will not reduce traction power and the fuel consumption is calculated by a fuel equation with coefficients defined in cells on rows 69 through 70 of ‘Rail-Consist’ (Figure A-60).



	A	I	J	K	L	M	N	O
1								
2	Consist ID	RC.1						
3	Description	1P42-4TltC+Bag (Diesel)						
4	Set UNITS BEFORE ENTERING DATA (pick: U.S. (or) metric) >>>	metric	< SET UNITS (pick: U.S. (or) metric)					
49	Traction Engine Characteristics							
50	engine per-unit power load rate = aT^b ("a" term)	0.00348						
51	engine per-unit power load rate = aT^b ("b" term)	1.45295						
52	Fuel Penalty @ low load factors-variable speed engine ("a")	0.4						
53	Fuel Penalty @ low load factors-fixed speed engine ("a")	0.9						
54	bsfc(min) (lb/hph)	0.33						
55	bsfc(min) (kg/kWh)	0.20				idle rate	estimated load (kW)	
56	Idle rate (var-speed Trac-Engine) (lb/hr)	24		10.9	kg/h	0.256906	42.38636	
57	DB fuel rate (var-speed Trac-Engine) (lb/hr)	150		68.1	kg/h	0.247272	275.2361	
58	regen fuel rate (var-speed Trac-Engine) (lb/hr)	24		10.9	kg/h	0.256906	42.38636	
59	Idle rate (fixed-speed Trac-Engine) (lb/hr)	30.6		13.9	kg/h	0.327153	42.38636	
60	DB fuel rate (fixed-speed Trac-Engine) (lb/hr)	185.3		84.1	kg/h	0.305477	275.2361	
61	regen fuel rate (variable speed Trac-Engine) (lb/hr)	24		10.9	kg/h	0.256906	42.38636	
62	Idle rate usage flag (if no hotel PTO)	0						
63	DB usage flag	1						
64	copy Brake energy Recovery flag for calculation	0						
65	flag for dual-fuel loco (0=no, 1=electric & onbrd fuel) also set region in adj. column	0						
66	Electricty Source Region if dual-fuel							
67	Hotel Power Provision code (1=PTO-inverter, 2=PTO-fixed speed main engine, 3=d	2						
68	Loco-Aux pwr net of dynamic brake grid cooling (kW)	75						

Figure A-59 Traction Engine Characteristics in 'Rail-Consist'



	A	I	J	K	L	M	N	O
1								
2	Consist ID	RC.1						
3	Description	1P42-4TltC+Bag (Diesel)						
4	Set UNITS BEFORE ENTERING DATA (pick: U.S. (or) metric) >>>	metric	< SET UNITS (pick: U.S. (or) metric)					
69	Hotel dg-set fuel equation (a (kg/hr) + b(kg/hr)/kW * Load (kW)							
70	hotel DG fuel rate "a" term (kg/hr)	16.8						
71	hotel DG fuel rate "b" term ((kg/hr)/kW)	0.2016						

Figure A-60 Diesel Genset Fuel Use Characteristics in 'Rail-Consist'

The green “Energy Recovery” drop-down list presents the following 5 options:

- “none”
- “onboard”
- “wayside”
- “electrical grid”
- “optimal coasting”

The selection of an “Energy Recovery” option is stored in the pink cell on row 85 of ‘Rail-Consist’ using a flag value where “0” corresponds with “none”, “1” with “onboard”, “2” with “wayside”, “3” with electrical grid and “4” with “optimal coasting” selections. When “none” is selected then the simulation uses the air brake system which may be assisted by dynamic braking when the flag in the green cell on row 63 of ‘Rail-Consist’ is set to “1”.

The “onboard” energy recovery option is applicable only where locomotives are equipped with electrical systems to store the energy generated during braking. This is characterized using the overall storage capacity in kW-hr and the power capacity at the wheels in Watts (specified in the yellow cells on rows 86 and 87 in 'Rail-Consist' worksheet) and may be used on any route.

The "wayside" energy recovery option can only be used with suitably equipped locomotives operating along routes which provide facilities to accept that wayside power at stop locations. The amount of energy recovered is assumed to only be limited by the locomotive's power regeneration capability specified in Watts in the yellow cell on row 89 of 'Rail-Consist'.

> ***Note:*** *Using "wayside" energy recovery also requires non-zero receptivity values be declared for all wayside storage sites in the appropriate columns of the Table of Scheduled Stops declared on rows 50 through 85 in the 'Rail-Route' worksheet.*

The "electrical grid" energy recovery option can be used with electrified propulsion systems and on the electrified portions of track traversed by a dual-fuel locomotive. Unlike the "wayside" option, the "electrical grid" option does not require specification of wayside receptivity as it is assumed that regeneration occurs during all braking and that it is returned to the grid for consumption by other users. However, like the "wayside" option, the energy recovery to the electrical grid during braking is limited by the locomotive's power regeneration capability as specified in the yellow cell on row 89 of 'Rail-Consist'.

The "optimal coasting" energy recovery option may be used with all propulsion system types. When used, the simulation allows coasting over a configurable proportion of schedule slack to reduce traction energy consumption. The yellow cell on row 88 of 'Rail-Consist' sets the proportion where slack and coast advice will be followed.

MMPASSIM also supports technology comparisons well beyond the suite of user-selectable propulsion types, fuels, hotel power provision and energy recovery options mentioned above. Typically a new train technology may be introduced into the model by creating a new train consist in the 'Rail-Consist' worksheet (by appending columns to the right) and then modifying the new train's characteristics specified in those new columns as influenced by the introduction of the new technology to the train. The characteristics you may wish to modify include:

- train physical properties (rows 5 through 20)
- tilt-body coach flag (uses higher speed limits) (set flag on row 15)
- train resistance coefficients (rows 25 through 28)
- transmission efficiency (rows 37 through 39)
- traction power and effort characteristics (rows 42 through 48)
- traction engine fuel consumption characteristics (rows 49 through 68)
- minimum brake specific fuel consumption (row 54)
- train braking characteristics (rows 72 through 80)

After adding a new train into the 'Rail-Consist' worksheet and making all desired data adjustments, the MMPASSIM macros will detect the new consist definition and make it available for selection from both the 'Rail Consist Selection' and the 'Rail Trip Selection' menus. Running a technology comparison using the newly included technology then requires defining a new trip which operates the newly created train over a route for comparison and then selecting it as one of the three alternatives in a rail technology comparison analysis.

A.6.8 Update the Light Duty Vehicle to a New MY Fleet

The ‘LDV-Resist’ worksheet contains a table at ‘LDV-Resist’!C29:AB48 which defines the default characteristics of light duty vehicles used by the ‘LDV-Simulation’ worksheet from which fuel consumption and emissions are calculated. Updating the light duty vehicle simulation with composite ‘sales weighted’ and ‘driven-fleet’ data for a model year beyond 2013 requires manual addition of data to that table. As depicted in Figure A-61, the first column (column C) of that table describes the parameter entered along one row while the next six columns (columns D through I) hold default values for each parameter associated with a particular class of light duty vehicle (as indicated in the yellow cells on row 31) for the base 2011 model year. The next three columns (columns J through L) provide default data calculated to represent composite vehicles used in ‘local’, ‘intercity’ and ‘taxi’ trips in the 2011 base year. The next two columns (columns M through N) provide parameter values which are calculated to represent a ‘sales weighted’ and a ‘driven fleet’ composite vehicle in the 2011 base year.

	C	D	E	F	G	H	I	J	K	L	M	N
27										Post 2011 Sales-weighted and Driven Fuel Economy (indexed to 2011 MY)	1.00	0.92
28										Derived Scale Factor (indexed to 2011 MY)	1	-0.079
29	Index	1	2	3	4	5	6	7	8	9	10	11
30	Year	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011
31	Name	small	mid/SW	MV/smSUV	Lg/mSUV/smF	PU-truck	LgSUV	Local	Intercity	Taxi	2011 sales w	2011 driven f
32	Description	Small automobile	Mid-size auto	Minivan or sn	Large auto or	Pickup truck	Large Sport Utili	Composite lc	Composite ir	Composite t	Sales weight	Driven fleet
33	engine (hp)	162.49	178.18	217.99	253.30	312.90	339.10	222.53	239.63	205.60	226.8	239.2
34	drivetrain loss reduction	-0.01	0.04	-0.01	0.05	-0.05	0.01	0.02	0.02	0.02	0.02	-0.02
35	tare (kg)	1516.73	1524.39	1850.60	1939.86	2512.39	2519.73	1828.13	1928.92	1729.04	1877.90	1951.63
36	spark or diesel	spark	spark	spark	spark	spark	spark	spark	spark	spark	spark	spark
37	kW/kW-100km/h	1.55	1.68	1.68	1.84	1.78	1.94	1.72	1.76	1.70	1.73	1.75
38	drive ratio	51.04	47.17	47.02	42.94	44.47	40.86	46.21	45.30	46.67	45.86	45.20
39	shift factor	1.00	0.92	0.92	0.84	0.87	0.80	0.91	0.89	0.91	0.90	0.89
40	a (N)	143.78	164.19	166.87	201.31	236.46	235.47	182.35	191.57	169.24	187.16	194.51
41	b (Nm^-1s)	2.44	2.32	3.30	4.24	6.25	6.27	3.61	4.01	3.00	3.83	3.98
42	c (Nm^-2s^2)	0.42	0.44	0.57	0.60	0.70	0.66	0.53	0.56	0.52	0.54	0.56
43	CdA (m^2)	0.703	0.724	0.953	0.992	1.166	1.101	0.876	0.923	0.865	0.900	0.936
44	%-Hybrid	8.00%	1.88%	0.40%	1.88%	0.40%	0.40%	3.86%	3.86%	10%	2.2%	1.3%
45	% non-hybrid CVTs	4.00%	9.99%	6.90%	9.99%	6.90%	6.90%	6.74%	6.74%	8.00%	7.8%	2.9%
46	Cold-Start Fuel Increment (kg)	0.095219497	0.096619828	0.118189719	0.116006847	0.14855653	0.139258018	0.11	0.12	0.11	0.11356175	0.1225
47	(N2O+CH4) CO2e increment (kg/kg)	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565	0.01839
48	(N2O+CH4) CO2e increment (kg/start)	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437	0.01589
49	passenger seats	4	4	5	5	3	7	4	4	3	4	4
50	passengers carried (default)	1	1	1	1	1	1	1	1	1	1	1
51	fuel	E10 - LS gasoline	E10 - LS gasoli	E10 - LS gasoli	E10 - LS gasoli	E10 - LS gasol	E10 - LS gasoline	E10 - LS gasol	E10 - LS gasol	E10 - LS gaso	E10 - LS gasol	E10 - LS gasol

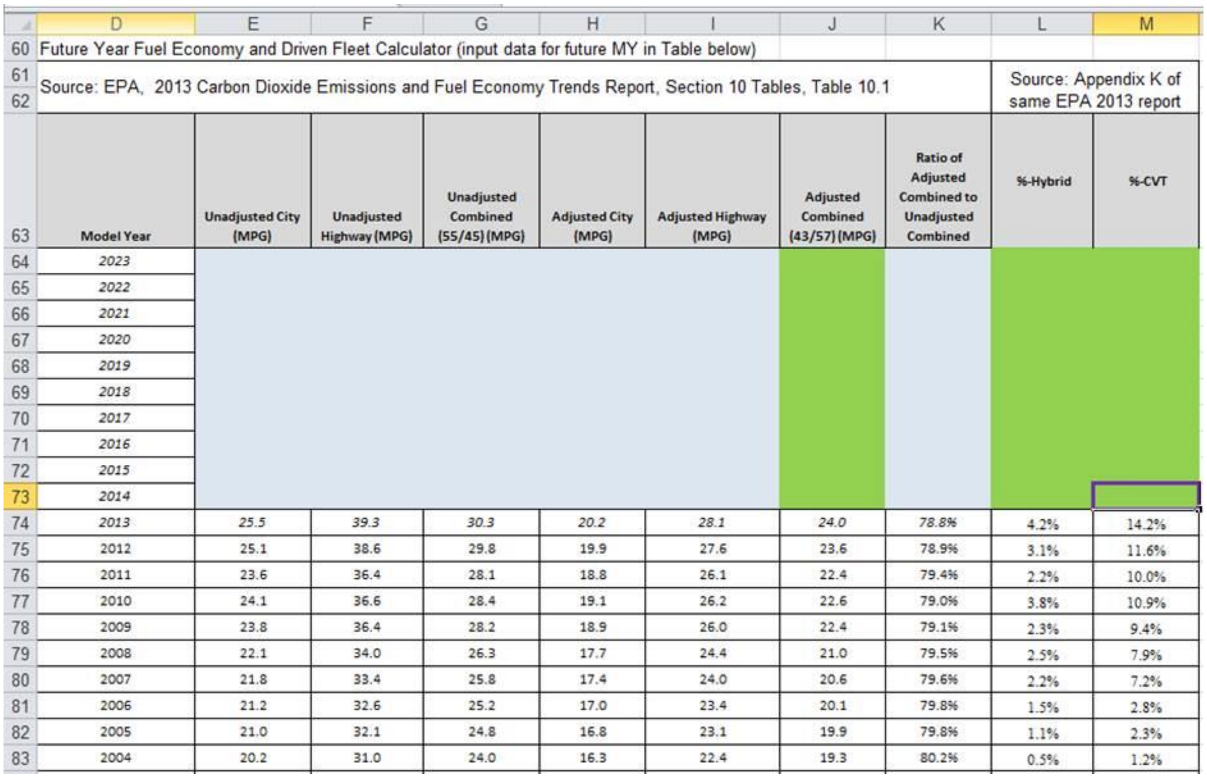
Figure A-61 Default 2011 Model Year Light Duty Vehicle Characteristics

The balance of the light duty vehicle characteristics table (columns O through AB), as illustrated in Figure A-62, provide parameters representing ‘sales weighted’ and ‘driven’ fleet composite vehicles for the year 2012 and later which are entered in sets of two columns for each year. Note that the post 2011 “sales weighted” and “drive” fleet composite vehicle parameters are calculated in each column from the 2011 base year values using a scale factor derived from estimates of each future year’s fuel economy relative to the 2011 base year. Pre-processed default composite values for the ‘sales weighted’ and ‘driven’ fleets for the years 2011, 2012 and 2013 are already provided in MMPASSIM. The future year scale factors are loaded in ‘LDV-Resist’!M27:AB28 from data generated in a preprocessor located further down on the ‘LDV-Resist’ worksheet.

	C	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
27	veighted and Driven Fuel Economy (indexed to 2011 MY)	1.05	0.94	1.07	0.95										
28	Derived Scale Factor (indexed to 2011 MY)	0.055	-0.065	0.070	-0.050										
29	Index	12	13	14	15	16	17	18	19	20	21	22	23	24	25
30	Year	2012	2012	2013	2013	2014	2014	2015	2015	2016	2016	2017	2017	2018	2018
31	Name	2012 sales	2012 drive	2013 sales	2013 drive	2014 sales	2014 drive	2015 sales	2015 drive	2016 sales	2016 drive	2017 sales	2017 drive	2018 sales	2018 drive
32	Description	Sales wei	Driven fle	Sales wei	Driven fle	Sales wei	Driven fle	Sales wei	Driven fle	Sales wei	Driven fle	Sales wei	Driven fle	Sales wei	Driven fle
33	engine (hp)	218.2	237.1	215.8	234.7										
34	drivetrain loss reduction	0.05	-0.01	0.06	0.00										
35	tare (kg)	1825.96	1939.04	1812.08	1925.01										
36	spark or diesel	spark	spark	spark	spark										
37	kW/kW-100km/h	1.71	1.75	1.70	1.74										
38	drive ratio	46.36	45.31	46.51	45.43										
39	shift factor	0.91	0.89	0.91	0.89										
40	a (N)	181.99	193.26	180.60	191.86										
41	b (Nm^-1s)	3.72	3.95	3.69	3.92										
42	c (Nm^-2s^2)	0.53	0.56	0.52	0.56										
43	CdA (m^2)	0.876	0.930	0.869	0.923										
44	%-Hybrid	3.1%	1.5%	4.2%	1.9%										
45	% non-hybrid CVTs	8.5%	3.6%	10.0%	4.4%										
46	Cold-Start Fuel Increment (kg)	0.1073	0.1210	0.1056	0.1193	0.1136	0.1136	0.1136	0.1136	0.1136	0.1136	0.1136	0.1136	0.1136	0.1136
47	(N2O+CH4) CO2e increment (kg/kg)	0.005654	0.015745	0.005654	0.013873	0.005654	0.012253	0.005654	0.010885	0.005654	0.009769	0.005654	0.008904	0.005654	0.008292
48	(N2O+CH4) CO2e increment (kg/start)	0.004368	0.013962	0.004368	0.012251	0.004368	0.010755	0.004368	0.009475	0.004368	0.008411	0.004368	0.007562	0.004368	0.006928
49	passenger seats	4	4	4	4										
50	passengers carried (default)	1	1	1	1										
51	fuel	E10 - LS ga	E10 - LS ga	E10 - LS ga	E10 - LS gasoline										

Figure A-62 Sales-Weighted and Driven-Fleet Light Duty Vehicle Characteristics

To add future year composite data for ‘sales-weighted’ and ‘driven’ fleets, the ‘LDV-Resist’ worksheet provides a preprocessor which determines appropriate scale factors from data which is published annually by the U.S. EPA and entered into the Fuel Economy Table at ‘LDV-Resist’!D61:M112. Figure A-63 illustrates the top portion of this table. The data in columns E to K came from Table 10.1 while the data in columns L and M came from Appendix A of the EPA’s 2013 Carbon Dioxide Emissions and Fuel Economy Trends report. Users can fill in the rows of the Fuel Economy Table for years 2014 to 2023 as data becomes available. The calculations performed in the orange cells at ‘LDV-Resist’!P64:T73 (see Figure A-64) determine the data used for both the sales-weighted composite vehicle (column P) and the driven-fleet composite vehicle (column Q) for the indicated year. The driven-fleet derivation for all future years applies the age distribution which existed in 2011 (in ‘LDV-Resist’!X64:X94 for the corresponding vehicle ages given in ‘LDV-Resist’!U64:U94) and presumes a 60% automobile and 40% light duty truck split (entered in ‘LDV-Resist’!V62:W62). If a different age distribution is desired for any given year then the desired distribution would need to be brought into a new location on the worksheet and the formula for that year modified to use the replacement data from that new data location.



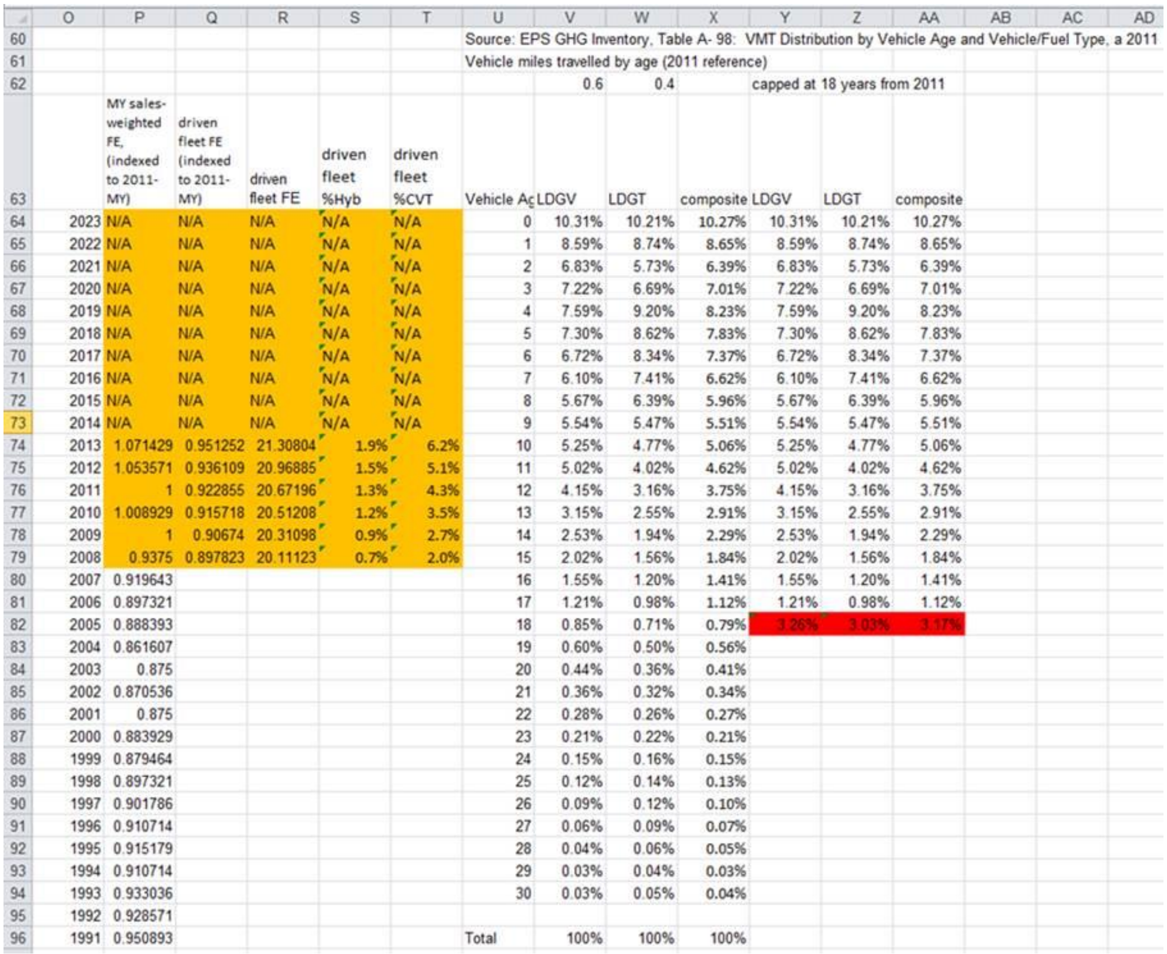
60 Future Year Fuel Economy and Driven Fleet Calculator (input data for future MY in Table below)

61–62 Source: EPA, 2013 Carbon Dioxide Emissions and Fuel Economy Trends Report, Section 10 Tables, Table 10.1

Source: Appendix K of same EPA 2013 report

	D	E	F	G	H	I	J	K	L	M
63	Model Year	Unadjusted City (MPG)	Unadjusted Highway (MPG)	Unadjusted Combined (55/45) (MPG)	Adjusted City (MPG)	Adjusted Highway (MPG)	Adjusted Combined (43/57) (MPG)	Ratio of Adjusted Combined to Unadjusted Combined	%-Hybrid	%-CVT
64	2023									
65	2022									
66	2021									
67	2020									
68	2019									
69	2018									
70	2017									
71	2016									
72	2015									
73	2014									
74	2013	25.5	39.3	30.3	20.2	28.1	24.0	78.8%	4.2%	14.2%
75	2012	25.1	38.6	29.8	19.9	27.6	23.6	78.9%	3.1%	11.6%
76	2011	23.6	36.4	28.1	18.8	26.1	22.4	79.4%	2.2%	10.0%
77	2010	24.1	36.6	28.4	19.1	26.2	22.6	79.0%	3.8%	10.9%
78	2009	23.8	36.4	28.2	18.9	26.0	22.4	79.1%	2.3%	9.4%
79	2008	22.1	34.0	26.3	17.7	24.4	21.0	79.5%	2.5%	7.9%
80	2007	21.8	33.4	25.8	17.4	24.0	20.6	79.6%	2.2%	7.2%
81	2006	21.2	32.6	25.2	17.0	23.4	20.1	79.8%	1.5%	2.8%
82	2005	21.0	32.1	24.8	16.8	23.1	19.9	79.8%	1.1%	2.3%
83	2004	20.2	31.0	24.0	16.3	22.4	19.3	80.2%	0.5%	1.2%

Figure A-63 ‘LDV-Resist’ Worksheet Fuel Economy Input Table



	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
60							Source: EPS GHG Inventory, Table A- 98: VMT Distribution by Vehicle Age and Vehicle/Fuel Type, a 2011									
61							Vehicle miles travelled by age (2011 reference)									
62								0.6	0.4		capped at 18 years from 2011					
63		MY sales-weighted FE, (indexed to 2011-MY)	driven fleet FE (indexed to 2011-MY)	driven fleet FE	driven fleet %Hyb	driven fleet %CVT	Vehicle Ag	LDGV	LDGT	composite	LDGV	LDGT	composite			
64	2023	N/A	N/A	N/A	N/A	N/A	0	10.31%	10.21%	10.27%	10.31%	10.21%	10.27%			
65	2022	N/A	N/A	N/A	N/A	N/A	1	8.59%	8.74%	8.65%	8.59%	8.74%	8.65%			
66	2021	N/A	N/A	N/A	N/A	N/A	2	6.83%	5.73%	6.39%	6.83%	5.73%	6.39%			
67	2020	N/A	N/A	N/A	N/A	N/A	3	7.22%	6.69%	7.01%	7.22%	6.69%	7.01%			
68	2019	N/A	N/A	N/A	N/A	N/A	4	7.59%	9.20%	8.23%	7.59%	9.20%	8.23%			
69	2018	N/A	N/A	N/A	N/A	N/A	5	7.30%	8.62%	7.83%	7.30%	8.62%	7.83%			
70	2017	N/A	N/A	N/A	N/A	N/A	6	6.72%	8.34%	7.37%	6.72%	8.34%	7.37%			
71	2016	N/A	N/A	N/A	N/A	N/A	7	6.10%	7.41%	6.62%	6.10%	7.41%	6.62%			
72	2015	N/A	N/A	N/A	N/A	N/A	8	5.67%	6.39%	5.96%	5.67%	6.39%	5.96%			
73	2014	N/A	N/A	N/A	N/A	N/A	9	5.54%	5.47%	5.51%	5.54%	5.47%	5.51%			
74	2013	1.071429	0.951252	21.30804	1.9%	6.2%	10	5.25%	4.77%	5.06%	5.25%	4.77%	5.06%			
75	2012	1.053571	0.936109	20.96885	1.5%	5.1%	11	5.02%	4.02%	4.62%	5.02%	4.02%	4.62%			
76	2011	1	0.922855	20.67196	1.3%	4.3%	12	4.15%	3.16%	3.75%	4.15%	3.16%	3.75%			
77	2010	1.008929	0.915718	20.51208	1.2%	3.5%	13	3.15%	2.55%	2.91%	3.15%	2.55%	2.91%			
78	2009	1	0.90674	20.31098	0.9%	2.7%	14	2.53%	1.94%	2.29%	2.53%	1.94%	2.29%			
79	2008	0.9375	0.897823	20.11123	0.7%	2.0%	15	2.02%	1.56%	1.84%	2.02%	1.56%	1.84%			
80	2007	0.919643					16	1.55%	1.20%	1.41%	1.55%	1.20%	1.41%			
81	2006	0.897321					17	1.21%	0.98%	1.12%	1.21%	0.98%	1.12%			
82	2005	0.888393					18	0.85%	0.71%	0.79%	3.26%	3.03%	3.17%			
83	2004	0.861607					19	0.60%	0.50%	0.56%						
84	2003	0.875					20	0.44%	0.36%	0.41%						
85	2002	0.870536					21	0.36%	0.32%	0.34%						
86	2001	0.875					22	0.28%	0.26%	0.27%						
87	2000	0.883929					23	0.21%	0.22%	0.21%						
88	1999	0.879464					24	0.15%	0.16%	0.15%						
89	1998	0.897321					25	0.12%	0.14%	0.13%						
90	1997	0.901786					26	0.09%	0.12%	0.10%						
91	1996	0.910714					27	0.06%	0.09%	0.07%						
92	1995	0.915179					28	0.04%	0.06%	0.05%						
93	1994	0.910714					29	0.03%	0.04%	0.03%						
94	1993	0.933036					30	0.03%	0.05%	0.04%						
95	1992	0.928571														
96	1991	0.950893					Total	100%	100%	100%						

Figure A-64 'LDV-Resist' Worksheet Vehicle Fuel Efficiency Calculation Block

Once data for future years has been added into the Fuel Economy Table, then the columns of composite ‘sales-weighted’ and ‘driven-fleet’ parameters (see Figure A-62) associated with that newly added year may be added by first copying the 2 columns of formulae calculating the ‘sales-weighted’ and ‘driven’ fleet values for a previously defined year from rows 27, 28 and rows 33 through 45 into the two columns associated with the new year being added. Given the year specified in row 30 and the fleet type (either “Sales weighted composite vehicle” or “Driven fleet composite vehicle”) specified in row 32, the formulae copied into rows 27 to 28 and 33 to 45 will provide the necessary characterization data to simulate the specified year’s composite vehicle.

A.6.9 Introduce a New Light Duty Vehicle

The ‘LDV-Resist’ worksheet contains a table at ‘LDV-Resist’!C29:AB48 which defines the default characteristics of all light duty vehicles available for simulation. The first six sets of parameters in this table represent default values applicable to different classes of 2011 model year light duty vehicles. The parameters are defined in the yellow columns D through I as depicted in Figure A-61 on page A-106. These default 2011 model year vehicles include:

- small automobile (Index 1)
- midsize automobile or station wagon (Index 2)
- minivan or small sport utility vehicle (Index 3)
- large auto or medium SUV or small pickup (Index 4)
- pickup truck (Index 5)
- large sport utility vehicle (Index 6)

In addition to these basic six vehicle types, there are also three sets of composite vehicle parameters provided to represent local trips (Index 7), intercity trips (Index 8) and taxi trips (Index 9). These three trip-type-specific composite vehicles are derived from the six default 2011 model year vehicles using the fleet distribution as specified in the yellow table at ‘LDV-Resist’!I19:L25. The rest of the columns in the vehicle definition table are used to provide vehicle parameters representative of ‘sales-weighted’ and ‘driven-fleet’ composite vehicles for the baseline 2011 model year and beyond.

While it is possible to modify and/or add to these light duty vehicle definitions, the user must take into careful consideration the many interdependencies which the fleet and future year composite vehicle parameters have with the set of six default 2011 vehicle types (the first six vehicles defined in the table). Modifying the parameters of any of the six default vehicle types will result in changes to the parameters of the fleet and future year vehicles from which they are derived. You can explore these data interdependencies using Microsoft Excel’s cell dependency tracing ability available in the Formula Auditing area of the Formula tab. Nevertheless, if a user wishes to update one or more of the first six fundamental vehicle types for use in simulating trips using a light duty vehicle for which they have detailed input data then they can freely do so provided they do not select any of the derived vehicle types (as those derived data will no longer be correct). This could be used, for example, to quickly input and simulate a new light duty vehicle type or to update one or more of the default vehicle types with characteristics of a particular model year.

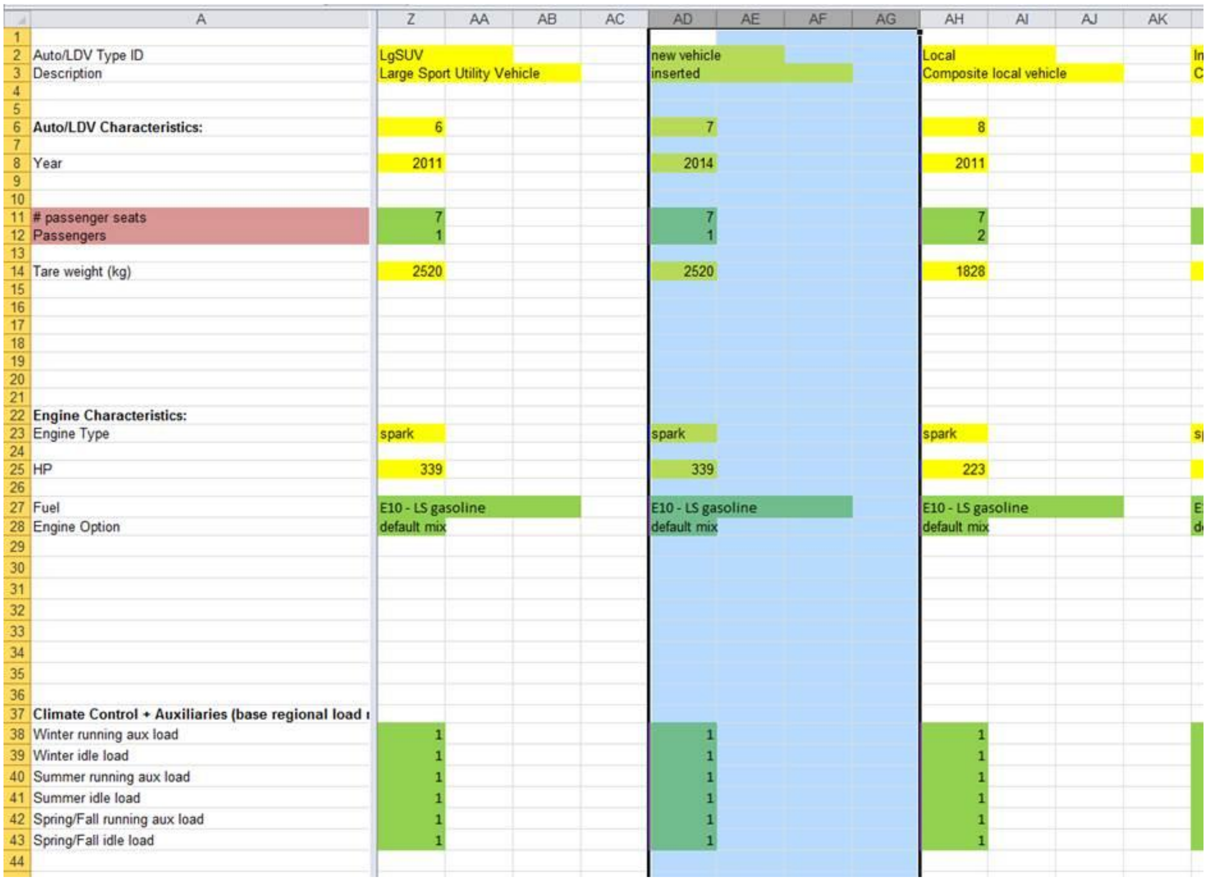
An alternate, but more complicated, procedure can be used to add new light duty vehicles into the model without disrupting the 2011 fleet and future-year ‘sales-weighted’ and ‘driven-fleet’ composite vehicles. This requires inserting columns into the table somewhere to the right of the last base 2011 vehicle type (column I) and to the left of the 2011 ‘sales-weighted’ composite vehicle (column M).

Caution: *This cannot be done by inserting a column into the entire sheet, but must be done by highlighting the cells in rows 27 through 51 in the column which is to be kept to the immediate right of the inserted column, then right clicking, selecting insert from the pop-up, selecting* *shift cells to the right and then clicking "OK". A good place to insert would be column J (highlight 'LDV-Resist'!J27:J51 in Figure A-65). After inserting the column, each inserted cell* ***must*** *be populated with data – the macros will fail to correctly find all vehicles in the list if blank cells are encountered before the end of the table. Pay particular attention to updating the "Index" values on row 29 so that they continue to increment by "1" in the added cell and each cell which follows to the right.*

	C	D	E	F	G	H	I	J	K	L	M	N
27											Post 2011 Sales-weighted and Driven Fuel Economy (indexed to 2011 MY)	1.00
28											Derived Scale Factor (indexed to 2011 MY)	1
29	Index	1	2	3	4	5	6	7	8	9	10	11
30	Year	2011	2011	2011	2011	2011	2011	2014	2011	2011	2011	2011
31	Name	small	mid/SW	MV/smSUV	Lg/mSUV/smF	PU-truck	LgSUV	new vehicle	Local	Intercity	Taxi	2011 sales w
32	Description	Small automobile	Mid-size auto	Minivan or sm	Large auto or	Pickup truck	Large Sport Utili	inserted	Composite lc	Composite i	Composite t	Sales weight
33	engine (hp)	162.49	178.18	217.99	253.30	312.90	339.10	339.10	222.53	239.63	205.60	226.8
34	drivetrain loss reduction	-0.01	0.04	-0.01	0.05	-0.05	0.01	0.01	0.02	0.02	0.02	0.02
35	tare (kg)	1516.73	1524.39	1850.60	1939.86	2512.39	2519.73	2519.73	1828.13	1928.92	1729.04	1877.90
36	spark or diesel	spark	spark	spark	spark	spark	spark	spark	spark	spark	spark	spark
37	kW/kW-100km/h	1.55	1.68	1.68	1.84	1.78	1.94	1.94	1.72	1.76	1.70	1.73
38	drive ratio	51.04	47.17	47.02	42.94	44.47	40.86	40.86	46.21	45.30	46.67	45.86
39	shift factor	1.00	0.92	0.92	0.84	0.87	0.80	0.80	0.91	0.89	0.91	0.90
40	a (N)	143.78	164.19	166.87	201.31	236.46	235.47	235.47	182.35	191.57	169.24	187.16
41	b (Nm^-1s)	2.44	2.32	3.30	4.24	6.25	6.27	6.27	3.61	4.01	3.00	3.83
42	c (Nm^-2s^2)	0.42	0.44	0.57	0.60	0.70	0.66	0.66	0.53	0.56	0.52	0.54
43	CdA (m^2)	0.703	0.724	0.953	0.992	1.166	1.101	1.101	0.876	0.923	0.865	0.900
44	%-Hybrid	8.00%	1.88%	0.40%	1.88%	0.40%	0.40%	0.40%	3.86%	3.86%	10%	2.2%
45	% non-hybrid CVTs	4.00%	9.99%	6.90%	9.99%	6.90%	6.90%	6.90%	6.74%	6.74%	8.00%	7.8%
46	Cold-Start Fuel Increment (kg)	0.095219497	0.096619828	0.118189719	0.116006847	0.14855653	0.139258018	0.13925802	0.11	0.12	0.11	0.11356175
47	(N2O+CH4) CO2e increment (kg/kg)	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565	0.00565
48	(N2O+CH4) CO2e increment (kg/start)	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437	0.00437
49	passenger seats	4	4	5	5	3	7	7	4	4	3	4
50	passengers carried (default)	1	1	1	1	1	1	1	1	1	1	1
51	fuel	E10 - LS gasoline	E10 - LS gasoli	E10 - LS gasoli	E10 - LS gasoli	E10 - LS gasol	E10 - LS gasoline	E10 - LS gaso	E10 - LS gasol	E10 - LS gaso	E10 - LS gasol	E10 - LS gasol

Figure A-65 Inserting New Vehicle into 'LDV-Resist' Vehicle Parameter Table

One last modification is required in the 'LDV-Type' worksheet. You must insert a set of 4 columns into the 'LDV-Type' worksheet at the same index location (yellow cell on row 6). For example, if a column was inserted at 'LDV-Resist'!J27:J51, which corresponds with an "Index" of 7 (the value in 'LDV-Resist'!J27), then columns must be inserted at AD through AJ which correspond with the 7th vehicle position index on the worksheet and then the data items need to be appropriately populated (see Figure A-66). If the column in 'LDV-Resist' is inserted correctly and fully populated with data and the columns in 'LDV-Type' are properly inserted, then the newly added vehicle will appear in the green "Auto / LDV" drop-down list displayed in the 'Auto/LDV Trip Selection' menu and also in the green "LDV Type ID" drop-down list displayed in the 'Auto/LDV Type Selection' menu. Any changes made to the user modifiable green fields on the 'Auto/LDV Type Selection' menu are stored on the 'LDV-Type' worksheet (hence the necessity of inserting the new columns into that worksheet).



	A	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	
1														
2	Auto/LDV Type ID	LgSUV				new vehicle				Local				In
3	Description	Large Sport Utility Vehicle				inserted				Composite local vehicle				C
4														
5														
6	**Auto/LDV Characteristics:**	6				7				8				
7														
8	Year	2011				2014				2011				
9														
10														
11	# passenger seats	7				7				7				
12	Passengers	1				1				2				
13														
14	Tare weight (kg)	2520				2520				1828				
15														
16														
17														
18														
19														
20														
21														
22	**Engine Characteristics:**													
23	Engine Type	spark				spark				spark				s
24														
25	HP	339				339				223				
26														
27	Fuel	E10 - LS gasoline				E10 - LS gasoline				E10 - LS gasoline				E
28	Engine Option	default mix				default mix				default mix				d
29														
30														
31														
32														
33														
34														
35														
36														
37	**Climate Control + Auxiliaries (base regional load**													
38	Winter running aux load	1				1				1				
39	Winter idle load	1				1				1				
40	Summer running aux load	1				1				1				
41	Summer idle load	1				1				1				
42	Spring/Fall running aux load	1				1				1				
43	Spring/Fall idle load	1				1				1				
44														

Figure A-66 Inserting New Vehicle into 'LDV-Type' Worksheet

A.6.10 Build a New Light Duty Vehicle or Bus Drive Schedule Allocation Matrix

The light duty vehicle and bus simulations (referred to collectively as “highway-mode” simulations) represent the total distances traveled on arterial roads and urban freeways in the origin and destination locations using time-of-day specific combinations of eight drive schedules representing the speed-time driving profile characteristics of travel over different road types with different average speeds. The available drive schedule combinations are configured in a matrix, as depicted in Figure A-67, which declares the percentages of the total travel distance within a region and during a time-of-day periods which are to be simulated using each of the eight drive schedules available.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1			Creep ~0.9 km/h	Urban LOS-F ~14 km/h	Urban City ~25 km/h	Urban Arterial ~40 km/h	Urban FW LOS-E ~75 km/h	Urban-FW LOS-A ~119 km/h	Urban-FW LOS-B/C ~105 km/h	FW-short US06 ~100 km/h		AVG km/h	Avg mph	time (hr/ 10-km)	delay (min/ 10-km)		
2	Arterial (O and D)	a.m. pk	3%	7%	25%	65%	0%	0%	0%	0%	100%	15.6	9.7	0.6	23.8		
3	User Defined	p.m. pk	3%	10%	12%	75%	0%	0%	0%	0%	100%	15.8	9.8	0.6	23.5		
4		midday	0%	0%	15%	85%	0%	0%	0%	0%	100%	37.7	23.4	0.3	1.4		
5		shoulders	0%	0%	5%	95%	0%	0%	0%	0%	100%	40.0	24.8	0.2	0.5		
6		overnight	0%	0%	0%	100%	0%	0%	0%	0%	100%	41.3	25.6	0.2	0.0	<< delay free trip	
7	Urb Freeway Urb-A(1)	a.m. pk	0%	0%	0%	8%	27%	0%	55%	10%	100%	84.9	52.7	0.1	1.8		
8	User Defined	p.m. pk	0%	0%	0%	6%	35%	0%	51%	9%	100%	84.8	52.6	0.1	1.8		
9		midday	0%	0%	0%	0%	16%	0%	72%	13%	100%	97.9	60.7	0.1	0.8		
10		shoulders	0%	0%	0%	0%	27%	0%	62%	11%	100%	93.9	58.2	0.1	1.1		
11		overnight	0%	0%	0%	0%	5%	80%	10%	5%	100%	113.0	70.0	0.1	0.0	<< delay free trip	
12	Urb Freeway Urb-A(2)	a.m. pk	0%	0%	0%	0%	0%	0%	85%	15%	100%	104.1	64.5	0.1	0.5		
13	User Defined	p.m. pk	0%	0%	0%	0%	6%	0%	80%	14%	100%	101.6	63.0	0.1	0.6		
14		midday	0%	0%	0%	0%	4%	0%	82%	14%	100%	102.4	63.5	0.1	0.5		
15		shoulders	0%	0%	0%	0%	0%	0%	85%	15%	100%	104.1	64.5	0.1	0.5		
16		overnight	0%	0%	0%	0%	5%	80%	10%	5%	100%	113.0	70.0	0.1	0.0	<< delay free trip	
17	Queue Delay		100%								100%						
18	Garage/Terminal property									100%	100%						
19	Intermediate LH urban				100%						100%						
20	Freeway LH Construction/weather delay (with one stop)						100%				100%						
21	Intermediate LH Toll-booth/border		100%								100%						

Figure A-67 Highway-Mode Drive Schedule Allocation Matrix

The same matrix format is used for bus simulations and for auto/LDV simulations but both are configured separately in cells C2:J21 in the 'Bus-Drive-Schedules' and the 'LDV-Drive-Schedules' worksheets respectively. The orange cells in the table at C2:J21 contain formulae which load data from other source tables based on the city-size identifiers loaded into the pink cells at A3, A8 and A13.

> ***Caution:*** *It is important that those orange cells not be over-written with any data since the pink city-size identifiers point those cell's to the contents of individual tables provided for a "**Small City**" at AC2:AJ21, for a "**Large City**" at AQ2:AX21 and for a "**User Defined**" city at BE2:BL21 (the city-size identifier must be one of those three quoted text strings). The pink city-size identifier cells are automatically loaded with the user-selected city-size identifiers for a highway-mode trip by an internal macro when setting up the highway-mode simulation to run.*

Highway-mode simulations use the same set of drive schedule combinations to represent travel along arterial roads in both the origin or destination locations (rows 2 through 6 in the '<modal>-Drive-Schedules' worksheet) while separate combinations are provided to represent freeway travel in the origin city (rows 7 through 11) and in the destination city (rows 12 through 16). For each of the three travel route categories (arterial, origin freeway and destination freeway) there are five time-of-day specific drive schedule combinations available which encompass "am peak", "pm peak", "midday", "shoulder" and "overnight" travel periods. The particular combination of drive schedules, in percent of travel length, that comprise a trip in each of these time-of-day periods is declared on a separate row thus constituting an allocation matrix. As previously indicated, the MMPASSIM model does offer different default characterizations for use in large cities and small cities as well as providing a facility for users to define and select their own set of user defined drive schedule combinations.

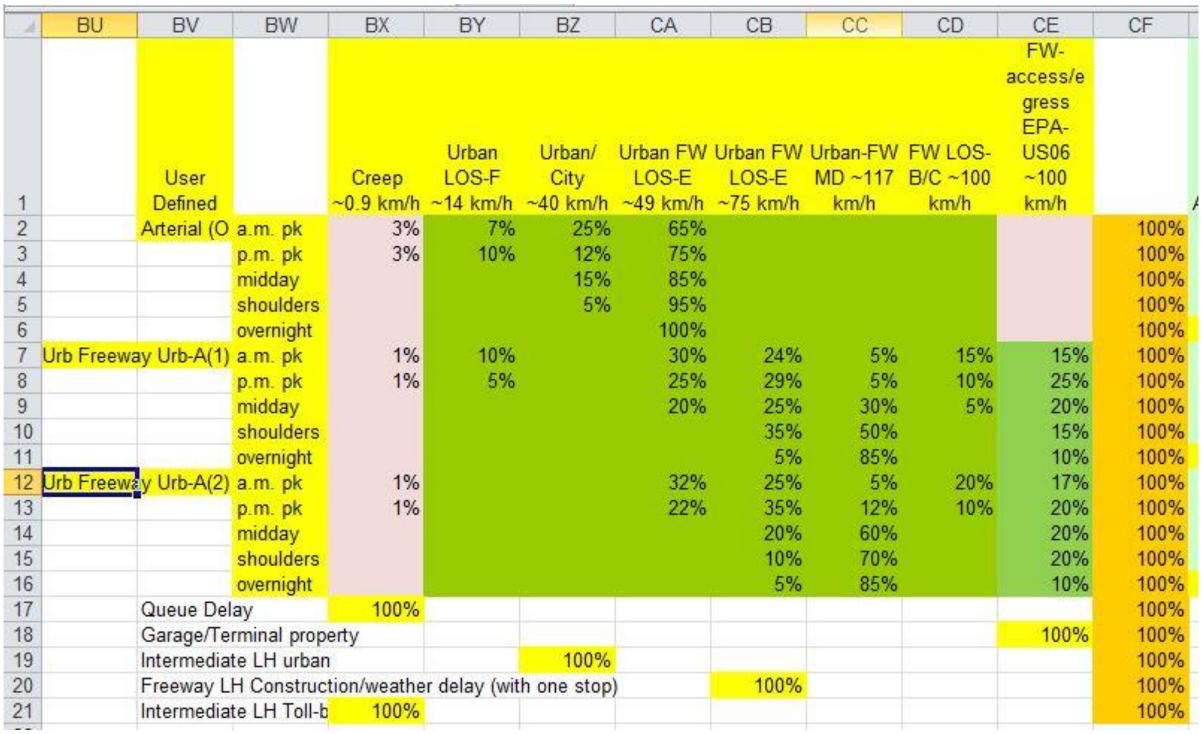
Customization of the drive schedule allocation matrix for a highway mode simulation is done by editing values in three data tables contained on the 'Bus-Drive-Schedules' and 'LDV-Drive-Schedules' worksheets (depending on the type of simulation). The data table locations and formats on both worksheets are identical. Default drive schedule allocations are provided to represent small and large cities and the model also offers a “User Defined” city type. The drive schedule allocations specified for all three of these city types may be freely modified by a user. Modifications to the “Small City” configuration are made to cells AC2:AJ21 and for the “Large City” configuration modify the cells in AQ2:AX21.

> **Note:** *Be aware that any modifications made to the “Small City”, “Large City” and “User Defined” drive schedule allocations are global in nature and will affect all subsequent simulations using that mode of travel.*

> **Note:** *Always ensure that the eight columns specifying the percentages for each drive schedule in each row of an allocation table sum to 100%.*

To modify the drive schedule allocation associated with “User Defined” cities for a highway mode, edit the percentage values in cells BX2:CE21 of the ‘<modal>-Drive-Schedules’ worksheet. Figure A-68 gives an example of a “User Defined” city allocation matrix.

> **Note:** *The descriptive text string in cell BV1 must always be “User Defined”.*



	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF
1		User Defined		Creep ~0.9 km/h	Urban LOS-F ~14 km/h	Urban/ City ~40 km/h	Urban FW LOS-E ~49 km/h	Urban FW LOS-E ~75 km/h	Urban-FW MD ~117 km/h	FW LOS-B/C ~100 km/h	FW-access/egress EPA-US06 ~100 km/h	
2		Arterial (O	a.m. pk	3%	7%	25%	65%					100%
3			p.m. pk	3%	10%	12%	75%					100%
4			midday			15%	85%					100%
5			shoulders			5%	95%					100%
6			overnight				100%					100%
7	Urb Freeway	Urb-A(1)	a.m. pk	1%	10%		30%	24%	5%	15%	15%	100%
8			p.m. pk	1%	5%		25%	29%	5%	10%	25%	100%
9			midday				20%	25%	30%	5%	20%	100%
10			shoulders					35%	50%		15%	100%
11			overnight					5%	85%		10%	100%
12	Urb Freeway	Urb-A(2)	a.m. pk	1%			32%	25%	5%	20%	17%	100%
13			p.m. pk	1%			22%	35%	12%	10%	20%	100%
14			midday					20%	60%		20%	100%
15			shoulders					10%	70%		20%	100%
16			overnight					5%	85%		10%	100%
17		Queue Delay		100%								100%
18		Garage/Terminal property									100%	100%
19		Intermediate LH urban				100%						100%
20		Freeway LH Construction/weather delay (with one stop)						100%				100%
21		Intermediate LH Toll-b		100%								100%

Figure A-68 User Defined Drive Schedule Allocation Matrix

You can also create drive schedule allocation matrices and associate them with particular cities which you may wish to reference in an MMPASSIM analysis. These allocation matrices follow the same format illustrated for the “User Defined” city type and are placed in the ‘<modal>-Drive-Schedules’ worksheet to the right of the “User Defined” allocation matrix in 19 column intervals. The first begins in column CQ, the next in column DJ and so on. Each city-specific drive schedule allocation matrix must be given a unique name which is placed in the cell 2 columns to the left and one row up with respect to the allocation matrix (cell CO1 for the first, cell DH1 for the next, etc.).

Note: *After adding one or more city-specific drive schedule allocation matrices you must click the blue "Update User Defined List" button located at cells AY1:BA1 to run a VBA macro which will register those new user defined city types and make them available on city size pulldown lists.*

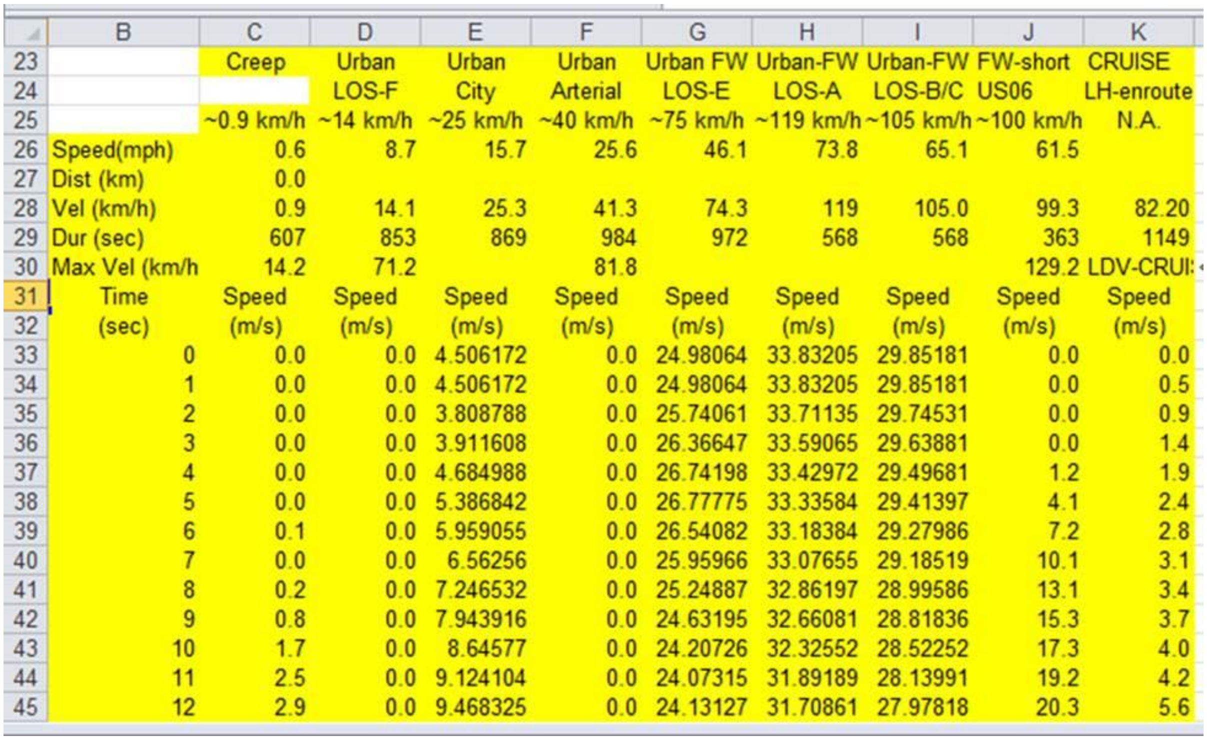
A.6.11 Fit Bus or LDV Performance to a Known Trip Schedule

As described in the previous section, highway congestion is accommodated in the model by selection of a range of drive schedules. A number of drive-schedule distributions were developed in the case study process. A new allocation matrix can be adjusted to fit knowledge of the route taken and the average travel time incurred. The allocation matrix (shown in Figure A-67) has a feedback calculator (green cells at the right of the data matrix) that indicates the average speed, total trip time and travel delay per 10-km (6 miles) of travel for the selected distribution in each row of the drive schedule matrix. In calibrating a trip to known travel times, one can shift proportions from higher-speed drive schedules to lower speed drive schedules to increase the travel time, and vice versa to decrease travel times, as appropriate for each row of the matrix (i.e. time of day and location). The matrix only applies to the congested portions of the trip – the rural freeway portion of an intercity trip is not included in the matrix or in the travel time calculations. If one is only interested in simulating an a.m. peak trip with a p.m. peak return, only those rows of the matrix need to be calibrated. The overnight trip is used as the congestion-free travel time and should be left congestion free in most cases.

A.6.12 Swap Out an Existing Light Duty Vehicle or Bus Drive Schedule

The drive schedules used in highway-mode simulations are stored in tables in the 'Bus-Drive-Schedules' and 'LDV-Drive-Schedules' worksheets. The tables are located in the yellow cells spanning B23:K1182 on either of those worksheets. As depicted in Figure A-69, the drive schedule table holds ten (10) columns. The first ten (10) lines of data (rows 23 through 32) provide headings and specify parameters related to the drive schedule in that column while the remaining 1150 rows list the vehicle speed profile to be followed in one second intervals. The first column of data (column B) indicates the elapsed time through a drive schedule and is shared by all drive schedules ***– it should not be changed***. The second column defines the characteristics of the first drive schedule available to a highway-mode simulation and the seven subsequent columns correspond with the second through eighth drive schedule used by highway-mode simulations.

Note: The last column (K) represents a special cruise drive schedule which is used internally and should not be modified.



	B	C	D	E	F	G	H	I	J	K
23		Creep	Urban	Urban	Urban	Urban FW	Urban-FW	Urban-FW	FW-short	CRUISE
24			LOS-F	City	Arterial	LOS-E	LOS-A	LOS-B/C	US06	LH-enroute
25		~0.9 km/h	~14 km/h	~25 km/h	~40 km/h	~75 km/h	~119 km/h	~105 km/h	~100 km/h	N.A.
26	Speed(mph)	0.6	8.7	15.7	25.6	46.1	73.8	65.1	61.5	
27	Dist (km)	0.0								
28	Vel (km/h)	0.9	14.1	25.3	41.3	74.3	119	105.0	99.3	82.20
29	Dur (sec)	607	853	869	984	972	568	568	363	1149
30	Max Vel (km/h	14.2	71.2		81.8				129.2	LDV-CRUI:
31	Time	Speed	Speed	Speed	Speed	Speed	Speed	Speed	Speed	Speed
32	(sec)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)
33	0	0.0	0.0	4.506172	0.0	24.98064	33.83205	29.85181	0.0	0.0
34	1	0.0	0.0	4.506172	0.0	24.98064	33.83205	29.85181	0.0	0.5
35	2	0.0	0.0	3.808788	0.0	25.74061	33.71135	29.74531	0.0	0.9
36	3	0.0	0.0	3.911608	0.0	26.36647	33.59065	29.63881	0.0	1.4
37	4	0.0	0.0	4.684988	0.0	26.74198	33.42972	29.49681	1.2	1.9
38	5	0.0	0.0	5.386842	0.0	26.77775	33.33584	29.41397	4.1	2.4
39	6	0.1	0.0	5.959055	0.0	26.54082	33.18384	29.27986	7.2	2.8
40	7	0.0	0.0	6.56256	0.0	25.95966	33.07655	29.18519	10.1	3.1
41	8	0.2	0.0	7.246532	0.0	25.24887	32.86197	28.99586	13.1	3.4
42	9	0.8	0.0	7.943916	0.0	24.63195	32.66081	28.81836	15.3	3.7
43	10	1.7	0.0	8.64577	0.0	24.20726	32.32552	28.52252	17.3	4.0
44	11	2.5	0.0	9.124104	0.0	24.07315	31.89189	28.13991	19.2	4.2
45	12	2.9	0.0	9.468325	0.0	24.13127	31.70861	27.97818	20.3	5.6

Figure A-69 Highway-Mode Drive Schedule Specification

The first three rows of each drive schedule column (rows 23 through 25) provide a brief description of the main characteristics of a drive schedule. The fourth row (row26) is a calculated cell indicating the average speed in mph over the drive schedule duration – it should not be necessary to change that cell when modifying a drive schedule. The fifth row (row 27) provides space to indicate the distance traveled in kilometers over a drive schedule but is not used by the model logic and may be left blank. The sixth row (row 28) specifies the average speed in km/h over the duration of a drive schedule and must be updated if changes are made to a drive schedule profile. The seventh row (row 29) specifies the number of seconds which the highway-mode simulation will use from the drive schedule profile. The eight (row 30) provides space to declare the maximum speed attained in drive schedule but is not used by the model logic and may be left blank. The ninth and tenth rows (rows 31 and 32) are simply headings to clarify the units required for the data entered in the remaining rows of a column.

Any of the speed profiles specified over rows 33 through 1182 of columns C through J in a drive schedule specification table may be changed if a user has more appropriate data for their analysis.

> **Note:** *The maximum drive schedule duration is limited to 1149 seconds and that cells in unused rows should be zeroed. Also, be sure to also set the average speed in km/h (row 28) and the drive schedule duration in seconds (row 29) appropriately.*

A.6.13 Modal Comparison Using Specific OD Address and Access/Egress Modes

The model allows up to five legs of the access and egress portions of a trip. The specification of these five legs can reflect a sequence used in making a single trip (e.g. from home to the commuter station or home to the airport). A number of access egress designations were developed in the case studies and are in the model for review. The Trip Access and Egress selection form is found in the Master-IO worksheet as well as the modal-IO worksheets. The process used to open the form is shown in Table A-8 while the process of selecting access legs for trips is shown in Table A-9.

Table A-8 Opening the Trip Access and Egress Selection Form

	Configuration Steps Required
Define Access/Egress Legs	• Either click “Define Access/Egress” button on ‘Master-I-O’ worksheet or • Click “Define Access/Egress” button on any ‘<modal>-I-O’ worksheet or • Click “Access/Egress” button on any modal Trip Selection form then • Refer to ‘Trip Access and Egress Selection Form’ (Table A-9)

Table A-9 Configuration Steps Required for Access and Egress for any Modal Trip

	Configuration Steps Required
Trip Access and Egress Selection Form	• Select a "Trip ID" from the drop-down list to load any access/egress legs from an existing trip (if desired) • Set the number of travelers assumed to be travelling together for all of the access and egress legs **For Access to Departure Location** • Pick the geographical region where access legs occur • Pick the city size associated with access leg travel • Pick the time of day for access leg travel • Pick the mode for each access leg (for a maximum of 5 legs, selecting none clears that access leg) • Set the distance (miles) for each access leg if different from preloaded value • Set the dwell time (minutes) for each access leg if different from preloaded value • Set the speed (mph) for each access leg if different from preloaded value (double click a green field to load the default for mode and region) • Pick the fuel source used for each access leg • Set the fuel intensity for each access leg (double click a green field to load the default for mode and region) • Set the energy intensity for each access leg (double click a green field to load the default for mode and region) • Set the GHG emission intensity for each access leg (double click a green field to load the default for mode and region) **For Egress from Arrival Location** • Pick the geographical region where egress legs occur • Pick the city size associated with egress leg travel • Pick the time of day for egress leg travel • Pick the mode for each egress leg (for a maximum of 5 legs, selecting none clears that egress leg) • Set the distance (miles) for each egress leg if different from preloaded value • Set the dwell time (minutes) for each egress leg if different from preloaded value • Set the speed (mph) for each egress leg if different from preloaded value (double click a green field to load the default for mode and region) • Pick the fuel source used for each egress leg • Set the fuel intensity for each egress leg (double click a green field to load the default for mode and region) • Set the energy intensity for each egress leg (double click a green field to load the default for mode and region) • Set the GHG emission intensity for each egress leg (double click a green field to load the default for mode and region) • Click "Select & Return" button to pass definitions to modal trip

A.6.14 Modal Comparison Using Survey Data for Distances and Access/Egress

The model allows up to five legs of the access and egress portions of a trip. The specification of these five legs can either reflect a sequence used in making a single trip (as described in the previous section) or as the proportions of modes used by travellers determined from a passenger survey. Surveys usually ask for the principal mode of access and the distance traveled. The distance traveled on each mode by the average user is the product of the proportion using the mode and the distance traveled by the mode. Interpretation of typical survey results into the distance traveled data-inputs for each of the five access modes is illustrated in Table A-10. The resulting simulation will reflect the results of a door-to-door trip for an average user of the principal mode being simulated rather than the results associated with a specific door-to-door trip.

Table A-10 Interpretation of Passenger Survey Data for Access Modes

Access Mode	Passenger Survey Findings		Model Inputs for Access Distance (mi)
	Average distance (mi)	Proportion using	
Walk/bike	0.75	10%	0.075
Drive and park	3.2	55%	1.76
Driven	1.8	15%	0.27
Taxi	6.2	3%	0.186
City bus	3.5	17%	0.595

A.7 Simulation Model Worksheet Data

A.7.1 Contents of the 'Energy-Emissions' Worksheet

The 'Energy-Emissions' worksheet defines the energy use and GHG emission factors for both upstream well-to-pump and direct consumption for the primary trip leg of all transportation modes considered by MMPASSIM. The data is organized into seven sets of tables.

The first table, "Global Warming Potential of Greenhouse Gases" (located at 'Energy-Emissions'!C5:D7), provides the standard global warming potential of CH_4 and N_2O in terms of their CO_2-equivalency.

The second table, "Fuel/Emission Factor Lookup Reference" (located at 'Energy-Emissions'!C18:Q22), is used internally and should not be modified.

The third set of tables, "Energy Use and Emission Factors for Rail Transportation" (located at 'Energy-Emissions'!C37:BF45) characterizes all on-board fuels available for rail mode simulations.

The fourth set of tables, "Energy Use and Emission Factors for Electrified Transportation Modes" (located at 'Energy-Emissions'!C61:BF77) characterizes the electricity available for transportation use by geographical region.

The fifth set of tables, "Energy Use and Emission Factors for Bus Transportation" (located at 'Energy-Emissions'!C126:BF129) characterizes on-board fuels available for bus mode simulations.

The sixth set of tables, "Energy Use and Emission Factors for Air Transportation" (located at 'Energy-Emissions'!C145:BI148) characterizes fuels available for air mode simulations.

The seventh set of tables, "Energy Use and Emission Factors for Auto/Light Duty Vehicle Transportation" (located at 'Energy-Emissions'!C164:BF174) characterizes all fuels available for auto & light duty vehicle mode simulations.

The aforementioned sets of tables defining fuel parameters, energy use and emission factors follow a consistent format across transportation modes.

> Column C defines the applicable transportation mode and column E describes the fuel (or energy in the case of electricity).
>
> Columns H through J define the energy content where column H (yellow) is the default energy content, column I (green) is the energy content used in simulations and column J defines the units (Btu/gal or Btu/kWh-generated).
>
> Columns L through N define the fuel density where column L (yellow) is the default fuel density, column M (green) is the fuel density used in simulations and column N defines the units (kg/gal).

Columns P through R define the upstream energy use factor where column P (yellow) is the default factor, column Q (green) is the energy use factor used by simulations and column R defines the units (Btu/mmBtu).

Columns T through V define the upstream CO_2 emission factors where column T (yellow) is the default emission factor, column U (green) is the emission factor used by simulations and column V defines the units (kg/gal or kg/kWh).

Columns X through Z define the upstream CH_4 emission factors where column X (yellow) is the default emission factor, column Y (green) is the emission factor used in simulations and column Z defines the units (g/gal or g/kWh).

Columns AB through AD define the upstream N_2O emission factors where column AB (yellow) is the default emission factor, column AC (green) is the emission factor used in simulations and column AD defines the units (g/gal or g/kWh).

Columns AF through AH define the upstream CO_2-equivalent emission factors where column AF (yellow) is the default emission factor, column AG (green) is the emission factor used in simulations and column AH defines the units (kg/kg-fuel for on-board fuels or kg/kWh-electricity).

Column AL repeats the definition of the applicable transportation mode and column AN describes the fuel (or energy in the case of electricity).

Column AQ through AT define the direct-consumption CO_2 emission factors where column AQ (yellow) is a default value calculated from carbon content, column AR (yellow) is the default emission factor, column AS (green) is the emission factor used in simulations and column AT defines the units (kg/gal or kg/kWh).

Columns AV through AX define the direct-consumption CH_4 emission factors where column AV (yellow) is the default emission factor, column AW (green) is the emission factor used in simulations and column AX defines the units (g/gal or g/kWh).

Columns AZ through BB define the direct-consumption N_2O emission factors where column AZ (yellow) is the default emission factor, column BB (green) is the emission factor used in simulations and column BC defines the units (g/gal or g/kWh).

Columns BD through BF define the direct-consumption CO_2-equivalent emission factors where column BD (yellow) is the default emission factor, column BE (green) is the emission factor used in simulations and column BF defines the units (kg/kg-fuel for on-board fuels or kg/kWh-electricity).

For the air transportation mode only, columns BH (yellow default) and BI (green values as used) define multipliers for direct CO_2 emissions while at cruising altitude.

A.7.2 Contents of the ‘Regional-Properties’ Worksheet

The ‘Regional-Properties’ worksheet defines factors which vary with geographical location, such as seasonal temperatures, traffic distributions, heating/cooling loads, urban congestion and energy and emission intensities for local urban area access and egress modes. The data for any one region are defined using a maximum of 17 columns and successive region data sets begin in 18 column increments from column D.

The first data element for a region is its unique “Region ID” defined in a yellow cell on row 2. A description field is immediately below that unique identifier.

The next group of data defines seasonal travel variations for a region. The duration, in months, of the “winter”, “summer” and combined “spring/fall” seasons must be specified by the user (green cells on row 10) from which the per unit seasonal distribution is calculated (yellow cells on row 11). Then, for each of these three season groupings, the per unit distribution of intercity travel (green cells on row 12) and commuter travel (green cells on row 13) must be defined.

The next group of data defines seasonal daytime temperature variations in terms of the daily average temperature (green cells on row 20) and also the percentage of time air conditioning is used in each season (green cells on row 22).

The next group of data characterizes the seasonal variation in use of climate control and vehicle auxiliaries. For buses, default auxiliary loads (in kW) are presented in the yellow cells on row 31 for winter season regular running and layover idle, summer season regular running and layover idle and finally for all operating modes in the combined spring and fall season. However, please note that the values used in simulations are read from the green cells on row 30. For automobiles and light duty vehicles, default auxiliary loads (in kW) are similarly defined in the yellow cells of row 37 for winter season running and idle, for summer season running and idle and for also for both running and idle during the combined spring and fall season. The actual values used in light duty vehicle simulations are read from the green cells on row 36. Finally, the default seasonal variation of rail consist climate control use is specified in terms of a heat/cool index for winter, summer and the combined spring and fall season in the yellow cells on row 42. The green values on row 41 are multiplied by the respective seasonal auxiliary loads provided in the ‘Rail-Consist’ worksheet to arrive at regionally adjusted auxiliary loads.

The next group of data (rows 48 to 51) defines congestion factors for peak and off-peak travel in large cities, small cities, rural municipalities and also provides a default for all cities. These factors are used as energy intensity multipliers for highway modes used in the access and egress legs of a trip. The base LDV fuel intensity on row 52 is used in conjunction with the pink “Number of Travelers” on row 64 to derive the direct fuel intensity of the auto/LDV modes used for access and egress.

The yellow cells on row 60 are used internally to locate selected data columns in the table of access/egress mode fuel and emission intensities and should not be modified.

The final data set provided in the ‘Regional-Properties’ worksheet is the table of access/egress mode fuel and emission intensities. This table defines the direct fuel intensity, the upstream and direct energy intensities and the upstream and direct CO_2-equivalent emission intensities for each access and egress mode available for use in a simulation of a particular region. These may vary with city size (large, small, rural or all) and time of day (peak or off-peak). Variations according to day of week and season are also supported. The user is advised that the VBA macro expects every unique access/egress mode available in a region to be defined within the top portion of that table and that those definitions would normally be associated with ‘All Cities’. Also, the green cells on row 61 should be manually adjusted to reflect the total number of unique access/egress modes defined in the top section of the table of access/egress modes for each region. It is not necessary for each region to have the same number of access/egress modes defined or to have the same detail in terms of city size and time of day variations. However, in order for the access/egress estimation to function reliably, a definition for each access/egress mode should exist for “All Cities”, for “All” time of day, for “All” day of week and for “All” season.

A.7.3 Contents of the 'Rail-Consist' Worksheet

The 'Rail-Consist' worksheet defines sets of parameters used by the rail simulation module. They are organized down the rows of the worksheet beginning in column "I" for the first defined consist and offset by 7 columns (i.e. column "P") for each additional consist defined on the worksheet. The following list identifies the data items required by the simulation. Many of the parameters are default values that can be used for most new train consists, while some are basic train-size and equipment related parameters that will change for new consists. In addition, some energy-recovery technology parameters at the bottom of the table are included even if not used in the simulation. They provide an indication of the effectiveness of using these technologies in the single-train base-run simulation. They can be copied as shown for most train consists, but should be checked and updated as appropriate if a specific simulation of a specific technology is being assessed in a technology comparison. The following table is color-coded to indicate which parameters are most often going to be required user inputs (green) and normally retained defaults (yellow) which will apply unless specific technologies are being simulated. Some values are brought in by the Macro (pink) depending on the region/season selected. Some calculated parameters (orange) follow from other inputs for convenience (as sort of a pre-processor for conventional trains). These calculations can be overridden with user inputs, as might be appropriate for integral HSR consists and/or DMU and EMU consists.

Item as Titled on the Worksheet List	**Notes on the Input Required**
Consist ID	Assigned by macro - must be unique
Description	An abbreviated description of the consist (e.g. 1P42-3C)
Input System of Units	Pick either "metric" or "U.S."
Number locos/power-cars	
Number of coaches/unpowered cars	DMUs and EMUs are included here.
number powered axles	
number unpowered axles	
Total Number of axles	May be calculated from previous two rows
Total Weight - all powered axles (kg) or (lb)	May be calculated from previous rows
Total Tare Wgt - all unpowered axles (kg) or (lb)	May be calculated from previous rows
Total Consist Seats	
Average Seat pitch (in)	Future use in a 'comfort index'.
Common area per consist (sq.ft)	Future use in a 'comfort index'.
Tilt-body Coaches (1=yes, 0=no)	If tilt body coaches are used, the simulation will choose the tilt-body speed column from the route speed table, otherwise it will choose the conventional speed column.
Passenger Load Factor (Route/Consist/Time-of-day)	This value must be the LF associated with the service being simulated.
Avg weight per passenger-with luggage (kg) or (lb)	
Mass-equivalent rotational inertia of Powered-axles (kg/axle) or (lb/axle)	Default can usually apply
Mass-equivalent rotational inertia of Unpowered-axles (kg/axle) or (lb/axle)	Default can usually apply

Consist Length Length (m) or (ft)	Over-writeable calculation from above data				
Consist Total Loaded Mass (kg) or (lb)	Calculated from above data				
Consist average mass-equivalent rotational inertia (kg/axle) or (lb/axle)	Calculated from above data				
Consist Length (m)	Calculated from above data				
Consist Length (mi)	Calculated from above data				
TRAIN RESISTANCE COEFFICIENTS (a+bV+cV^2)					
a (N) or (lb)					
b (N/(km/h)) or (lb/mph)					
c (N/(km/h)^2) or (lb/mph^2)					
Season adjustments for selected season	Macro loads: summer/winter/other				
Season adjustments for selected season	Loaded by macro				
Summer heat/cool index					
Winter heat/cool index					
other (i.e. Spring or Fall) heat/cool index					
CdA impact	Calculated number greater than or equal to 1.0.				
seasonal modified CdA	Calculated from above data				
Hotel Pwr (kW)	3 values: “Winter”, “Summer” and “Other” where pre-calculated values in the above row can be copied or modified.				
Coach avg hotel power per coach (kW)	Over-writeable calculation from above data				
Transmission efficiency (engine shaft or pantograph to wheels)					
Efficiency while accelerating					
Efficiency at cruise and braking					
Propulsion Type (1=onboard-fuel, 2=electric)	Set by macro				
Locomotive Primary Fuel Type	Set by macro				
Traction Power at the wheels (kW) or (hp)	A default calculation is used in some conventional consists and can be copied or over-written with known values.				
Tractive Effort Characteristic (up to 5 segments: each with TE = a + bV + c/V^d) where: **TE (kN) and V is (m/s) for “metric” units and** **TE (lb) and V is (mph) for “U.S.” units**	Up to 5 characterization regions can be defined using the coefficients in the equation at left in four 5 rows				
lower speed limit (m/s) or (mph)					
A					
B					
C					
D					
Traction Engine Characteristics					
engine per-unit power load rate = aT^b ("a" term)					
engine per-unit power load rate = aT^b ("b" term)					

Fuel Penalty @ low load factors-variable speed engine ("a")	
Fuel Penalty @ low load factors-fixed speed engine ("a")	
bsfc(min) (kg/kWh) or (lb/hph)	
bsfc(min) (kg/kWh)	Calculated from above
Idle rate (var-speed Trac-Engine) (kg/h) or (lb/hr)	
DB fuel rate (var-speed Trac-Engine) (kg/h) or (lb/hr)	DB is dynamic brake
regen fuel rate (var-speed Trac-Engine) (kg/h) or (lb/hr)	
Idle rate (fixed-speed Trac-Engine) (kg/h) or (lb/hr)	
DB fuel rate (fixed-speed Trac-Engine) (kg/h) or (lb/hr)	
regen fuel rate (variable speed Trac-Engine) (kg/h) or (lb/hr)	Same value as input 3-rows above (repeated for calculation purposes in the simulation sheet).
Idle rate usage flag (if no hotel PTO)	1 if no dynamic brakes and no hotel PTO, 0 otherwise
DB usage flag	1 if dynamic brakes used in braking, 0 if not
copy Brake energy Recovery flag for calculation	Automatically set
flag for dual-fuel loco (0=no, 1=electric & onbrd fuel) also set region in adj. column	If a dual fuel simulation is being run, this flag must be set to 1 and the route file must indicate the track segment boundary where electricity is used.
Electricity Source Region if dual-fuel	Set by macro via ‘Rail Consist Selection’ menu
Hotel Power Provision code **1=PTO-inverter** **2=PTO-fixed speed main engine** **3=dg-set** **4=electric-loco**	New consists should include this setting but the Macro brings in user specified values if they wish to change it on the Rail-IO forms. PTO is power takeoff from the main traction engine. An inverter permits a more efficient variable engine speed (Amtrak normal is 1). A dg-set is a separate diesel generator set for hotel power (many commuter locos use 3).
Loco-Aux pwr (kW)	Not coach hotel power, but locomotive auxiliary power (fans, air compressor, etc.)
Hotel dg-set fuel equation (a (kg/hr) + b(kg/hr)/kW * Load (kW)	
hotel DG fuel rate "a" term (kg/hr) or (lb/hr)	
hotel DG fuel rate "b" term ((kg/hr)/kW) or ((lb/hr)/kW)	
Brake Type logic (1=loco-only, 0=blended)	Can be set to one to get full potential of brake energy recovery (but a delay will be incurred due to the slower braking rate)

Low speed Tractive Effort Limit (N/pwr-axle) or (lb/pwr-axle)	
Low speed Tractive Effort Limit-all pwrd axles (N)	Calculated from above
Brake Rate (blended braking <=60 mph) (%-g)	Fraction of acceleration of gravity (also = force-fraction of total consist weight).
Maximum Friction Brake Rate (60 mph) (%-g)	Fraction of acceleration of gravity (also = force-fraction of total consist weight).
brake rate coeff (a) for speeds>60 mph	Coefficients for the quadratic equation (a+bV+cV^2) describing the normal blended brake rate for the consist (presumed to decrease with increasing speed)
brake rate coeff (b) for speeds>60 mph	
brake rate coeff (c) for speeds>60 mph	
Dynamic Brake power at wheels (Watts)	Maximum power at the wheels that can be utilized by the traction motors in dynamic or regenerative braking.
Brake Energy Recovery Usage Flag (1 if recovered, 0 if not)	1 if brake energy recovery is used, 0 if not
regen-energy acceptance ratio (by trains-or-grid)	Fraction value (<=1) applicable to the energy recovery system being simulated. For electric grid systems it is the %-time other trains are present and/or the network accepts regenerated energy into the grid; for optimal coasting it is the portion of time that train are ahead of schedule and drivers follow the coast advice; for wayside storage it is the percent time that the wayside device can accept power (i.e. is below its capacity threshold).
regen-energy cycle efficiency (for all types)	Charge and discharge cycle efficiency for the type of energy storage system being simulated.
Regen brake adhesion	Lesser of either torque or adhesion limit of low-speed regenerative braking (as a force-fraction of weight-on-powered axles)
Energy Recovery Type (1=onboard, 2=wayside, 3=elec-grid, 4=optimal coasting, 0=none)	Onboard and electric grid are used for all braking, wayside is used at scheduled stop locations as identified in the route file, optimal coasting is used at all scheduled stops based on the total slack-time available (presently input at B6 of the Rail-Simulation sheet).
Capacity of onboard storage when used (kW-hr)	
Onboard Storage Power capacity at wheels (Watts)	
portion with slack and coast advice followed	
Loco Regen Power limit to grid or wayside storage (Watts)	
Locomotive speed limit (km/h) or (mph)	

A.7.4 Contents of the ‘Rail-Route’ Worksheet

The ‘Rail-Route’ worksheet defines sets of tables used to characterize the route over which train operation will be evaluated. They are organized down the rows of the worksheet beginning in column “O” for the first defined consist and offset by 13 columns (i.e. column “AB” for next) for each additional consist defined on the worksheet. The following list identifies the data items required by the simulation.

Total CA (Central Angle) of curvature (calculated), CA per mile (user input) ______

Number of Grade Segments (user input) ______

Grade Distribution Table:MilePost											
Mile											
Elev (ft)											
Segment			1	2	3	4	5	6	7	8	Route
Forward Direction	Average %-Grade in Severity Range	-0.2									
		-0.4									
		-0.6									
		-0.8									
		-1									
		-1.2									
	%-Distance of Severity Range	-0.2									
		-0.4									
		-0.6									
		-0.8									
		-1									
		-1.2									
Reverse Direction	Average %-Grade in Severity Range	-0.2									
		-0.4									
		-0.6									
		-0.8									
		-1									
		-1.2									
	%-Distance of Severity Range	-0.2									
		-0.4									
		-0.6									
		-0.8									
		-1									
		-1.2									

Notes:

1) The MP mileage starts at zero and the grade data in each column is associated with the grades for the route segment between that MP heading on that column and the MP in the subsequent column. If only one grade classification is used there will be only one column of grade severity data under the MP = 0 column. The last segment column will be the end milepost and it will have only the elevation field filled as the gradient information past that

point is not relevant. The “Route” column is the total route average values and will be the same as column 1 if only one-segment is used to characterize the route.

2) The downgrades for the reverse direction are negative values of the upgrades in the forward direction.

A separate spreadsheet “route preprocessor” is provided to generate the data in the above grade severity Table if a user has detailed gradient and/or curvature profiles for a rail route of interest. The preprocessor uses Excel’s data-table formula to transform linear gradient data into the above formatted grade-severity Table. It also has a data column filter set to select speed limit changes along the route. The preprocessor includes a read-me sheet with a description of the steps required to process a file and there is a track file loaded as an example. However, users should have knowledge of the data table function and its application in order to effectively use the pre-processor.

Scheduled Stop Table (with example values)

4 << number of data rows

333.3 Trip distance traveled

User Value		Wayside storage: (0 or receptivity value if yes)		Default Computed			User Value	
Forward Direction				Reverse Direction			Reverse Direction	
MP (mi)	Dist (mi)			Dist (mi)	Wayside Storage		Dist (mi)	Wayside Storage
400	0	0		0	0		0	0
411.5	11.5	0		156.8	0.95		156.8	0.95
576.5	176.5	0.95		321.8	0		321.8	0
733.3	333.3	0		333.3	0		333.3	0

Notes:
The model accepts mileposts taken from a desired subdivision segment, but modifies the input MP to a zero mile beginning. It also uses the same MP locations in generating the stop file for the reverse trip. Thus, the distance traveled in the reverse direction corresponds to the station stop locations input for the forward direction. If the user wises to override this calculation, the distances from the origin of the reverse trip must be used in filling the ‘User-Value’ data columns. The ‘User Value’ data table must be filled with data as it is the data that is used in the simulation. A value copy of data from the ‘Default Computed’ table can be used if the default values are accepted.

Temporary Slow Order (TSO) data table (with example values)

avg #/trip		speed (mph)		average length(mi)
1.5	of	25		0.1
3.3	of	40		0.1
0.5	of	80		7

Notes:

Up to 7 different speeds can be selected and the associated probability or expected number of occurrences of that slow order being encountered in a one-way trip of the length input for the service being simulated is input at the first column of the table. The slow order speed (in mph) is input to the middle column and the average length of each occurrence of that slow order is input to the last column. Slow orders are applied in the simulation sheet with respect to the average cruise speed for all permanent speed limit segments of the route. Slow orders are not just maintenance based – they should include any diversions to second tracks necessitated by traffic interference. For example a diversion to a second track of equal speed rating to the main track, would be input as 2 slow orders equal to the speed limits of the cross-over switches taken and of length representative of the length of the crossovers. A diversion to a slower speed second track would increase the length of the slow order to include the length of the second track segment that is used.

Unscheduled Stop Table

avg #/trip		siding speed (mph)		avg siding length (mi)		avg stop duration (min)
0.5		25		2.1		12

Notes:

One row of data is required and provides the average/expected-number of occurrences of the passenger train being diverted to a siding or asked to stop on the mainline for any reason. The average speed in the sidings is input to the second column and the average length of the sidings is input to the third column. The last column is the average dwell time incurred for each unscheduled stop encountered. All inputs are with respect to a one-way trip over the simulated route segment.

Extra Idle and Non-revenue travel	
0.5	<< combined pre-start/post arrival idle time (hr) at start and final stations
0.5	<< layover idle time allocated per one-way trip (hr)
1.023	<< ratio of non-revenue/revenue train miles

Fuel Use Boundary Table for Dual Fuel Simulations (with example values)

User Value					Default Computed				User Value	
Forward Direction					Reverse Direction				Reverse Direction	
MP (mi)	Dist (mi)	Fuel Use			Dist (mi)	Fuel Use			Dist (mi)	Fuel Use
400	0	Electricity			0	Diesel			0	Diesel
400	0	Electricity			0	Diesel			0	Diesel
412	12.0	Diesel			321.3	Diesel			321.3	Electricity
733.3	333.3	Diesel			333.3	Electricity			333.3	Electricity
733.3	333.3	Diesel			333.3	Electricity			333.3	Electricity

Notes:
The fuel use indicated in the last column is applied from the mileage in the corresponding row up to the mileage in the subsequent row. As with the stop table, the user can override the calculated reverse trip locations and data must be copied into the User Value table even if default values are accepted. If a dual-fuel simulation is desired, the 'dual-fuel' flag must be set to "1" in the consist file that is selected for simulation.

Route Speed Table (with example data)

54	<< # of data rows			Start Station Offset						
333.3	Route Distance			forward	reverse trip					
1	direction of mileposts			0	0					
User Value				0	0					
Forward Direction					Processed to Eliminate Short Segments of High Speed			Processed for Reverse Direction		
MP (mi)	Dist (mi)	Conv Speed (mph)	Tilt-body speed (mph)	# of Spd changes 1	Dist (mi)	Conv Speed (mph)	Tilt-body speed (mph)	**Dist** (mi)	Conv Speed (mph)	Tilt-body speed (mph)
400	0	25	30		0	25	30	0	65	70
400	0	25	30		0	25	30	0	65	70
401.2	1.2	35	40		1.2	35	40	2.3	95	100
402.1	2.1	40	45		2.1	40	45	10.5	95	95
403.6	3.6	75	80		3.6	75	80	10.7	85	90

407.5	7.5	90	95		7.5	90	95	11.1	90	95
411.5	11.5	95	100		11.5	95	100	14.8	95	100
420.7	20.7	55	60		20.7	55	60	27	90	95
421.7	21.7	90	95		21.7	90	95	35.9	65	70
423.9	23.9	75	80		23.9	75	80	36.3	90	95
424.8	24.8	90	95		24.8	90	95	41.8	85	90
449.3	49.3	95	100		49.3	95	100	42.4	95	100
462.6	62.6	80	85		62.6	80	85	62	40	45
464.1	64.1	95	100		64.1	95	100	63	90	95
512	112	75	80		112	75	80	67.3	80	85
512.6	112.6	95	100		112.6	95	100	68.4	90	95
524	124	75	80		124	75	80	71.3	95	100
527	127	90	95		127	90	95	109.5	90	95
531.5	131.5	75	80		131.5	75	80	112.1	70	70
531.8	131.8	95	100		131.8	95	100	112.2	75	80
541.4	141.4	75	80		141.4	75	80	112.3	75	80
542.9	142.9	95	100		142.9	95	100	114.3	95	100
554.3	154.3	85	90		154.3	85	90	134.2	65	70
554.9	154.9	95	100		154.9	95	100	135.2	95	100
569.5	169.5	75	80		169.5	75	80	142.2	50	50
571.4	171.4	65	70		171.4	65	70	142.28	95	100
575.3	175.3	80	85		175.3	80	85	148.6	80	85
584.7	184.7	95	100		184.7	95	100	158	65	70
591.02	191.02	50	50		191.02	50	50	161.9	75	80
591.1	191.1	95	100		191.1	95	100	163.8	95	100
598.1	198.1	65	70		198.1	65	70	178.4	85	90
599.1	199.1	95	100		199.1	95	100	179	95	100
619	219	75	80		219	75	80	190.4	75	80
621	221	100	100	75	221	75	80	191.9	95	100
621.1	221.1	70	70		221.1	70	70	201.5	75	80

Notes:

1) The milepost column is changed to mileage distance from a zero mile start point.
2) The end point of the Speed Table must correspond with the final destination on the route and the last line of data must be duplicated to indicate the end of the dataset.
3) The data are reviewed for short high-speed segments in the middle three columns. For the input data shown, one speed change was made for an unrealistically short speed segment at MP 621. The increase in speed to 100 mph is applicable only to MP 621.1 a distance of 0.1 miles. For the simulation, the higher of the two adjacent speeds is adopted for that segment. Thus, the values of 75 mph for conventional trains and 80 mph for tilt-trains are shown in the calculated table. The last 3 columns are the calculated distances for a mirror image of the forward speed table.
4) If a different track/speed table is applicable to the reverse trip, the user must create a separate route for the reverse trip and identify it in the Master IO sheet when creating the simulation scenario.

A.7.5 Contents of the 'Rail-Trip-List' Worksheet

The 'Rail-Trip-List' worksheet is used by the VBA macro system to store rail trip definitions as they are developed by a user. Normally, the VBA macros should be used to add new trips and otherwise manage updating the contents of these fields in response to a user's selections on the 'Rail Trip Selection' user form. However, the list of defined rail trips may become large and a knowledgeable user may delete trips from the list manually. Care must be taken during this process such that the top of the list is maintained on row 25 and that there are no blank rows in between the top and bottom of the list (a blank row will be interpreted as the bottom of the list). Also, the columns should not shifted.

The following list identifies the data items used by the simulation.

Item as Titled on the Worksheet List	**Notes on the Data Value**
ID #	Assigned by the VBA macro. Normally "RT.#" where # is equivalent to (current row number - first row number +1). Each ID # should be unique.
Trip Description	A user's description of the trip, normally some combination of the consist description and the route description.
Region	Must be a valid region identified in 'Regional-Properties' worksheet
Route ID	Must be a valid identifier referencing a defined route in the 'Rail-Route' worksheet. Normally of the form "Route.#" where # is the index of the defined route in the route list.
Route Description	Should be the same as the description given in the 'Rail-Route' list.
Trip Length	Should be the same value as specified in the 'Rail-Route' list (specified in miles).
Start MP	Should be the same value as specified in the 'Rail-Route' list.
End MP	Should be the same value as specified in the 'Rail-Route' list.
Direction	Must be either "Forward" or "Reverse".
Departure Time of Day	Departure time of forward trip - must be "AM-peak", "PM-peak", "midday", "off-peak" or "overnight"
Arrival Time of Day	Arrival time of forward trip - must be "AM-peak", "PM-peak", "midday", "off-peak" or "overnight"
Departure Day of Week	Departure day of week of forward trip – must be "Mon to Fri", "Weekend" or "Daily"
Departure Season	Season of forward trip – must be "Winter", "Summer", "Spring/Fall" or "All"
Return Trip Departure Time of Day	Departure time of return trip - must be 'AM-peak', 'PM-peak', 'midday', 'off-peak' or 'overnight'
Return Trip Arrival Time of Day	Arrival time of return trip - must be "AM-peak", "PM-peak", "midday", "off-peak" or "overnight"
Return Trip Departure Day of Week	Departure day of week of return trip – must be "Mon to Fri", "Weekend" or "Daily"
Return Trip Departure Season	Season of return trip – must be "Winter", "Summer", "Spring/Fall" or "All" (assumed same as forward trip)
Consist ID	Must be a valid identifier referencing a defined consist in the 'Rail-Consist' worksheet. Normally of the form "RC.#" where # is the index of the defined consist in the consist list.

Consist Description	Should be the same as the description given in the 'Rail-Consist' list.
Number of Travelers	Number of people assumed to be traveling together
Scheduled Trip Time	Scheduled trip time (hours).
Station Stop Dwell Time	Allowance for all station stops (minutes).
Access/Egress Number of Travelers	Number of people assumed to be traveling together (same as for main leg)
Access Leg 1 - Mode	Access mode type
Access Leg 1 - Description	Access mode description
Access Leg 1 - Distance	Access mode distance (mile)
Access Leg 1 - Dwell	Access mode dwell time (minutes)
Access Leg 1 - Average Speed	Access mode average speed (mph)
Access Leg 1 - Fuel Source	Access mode fuel source (as defined in 'Regional-Properties' for this mode)
Access Leg 1 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 1 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 1 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 1 - Region	Access mode region
Access Leg 1 – City Size	Access mode city size
Access Leg 1 - Time of Day	Access mode time of day
Access Leg 1 - Day of Week	Access mode day of week
Access Leg 1 - Season	Access mode season
Access Leg 2 - Mode	Access mode type
Access Leg 2 - Description	Access mode description
Access Leg 2 - Distance	Access mode distance (mile)
Access Leg 2 - Dwell	Access mode dwell time (minutes)
Access Leg 2 - Average Speed	Access mode average speed (mph)
Access Leg 2 - Fuel Source	Access mode fuel source (as defined in 'Regional-Properties' for this mode)
Access Leg 2 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 2 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 2 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 2 - Region	Access mode region
Access Leg 2 – City Size	Access mode city size
Access Leg 2 - Time of Day	Access mode time of day
Access Leg 2 - Day of Week	Access mode day of week
Access Leg 2 - Season	Access mode season
Access Leg 3 - Mode	Access mode type
Access Leg 3 - Description	Access mode description
Access Leg 3 - Distance	Access mode distance (mile)

Access Leg 3 - Dwell	Access mode dwell time (minutes)
Access Leg 3 - Average Speed	Access mode average speed (mph)
Access Leg 3 - Fuel Source	Access mode fuel source (as defined in 'Regional-Properties' for this mode)
Access Leg 3 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 3 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 3 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 3 - Region	Access mode region
Access Leg 3 – City Size	Access mode city size
Access Leg 3 - Time of Day	Access mode time of day
Access Leg 3 - Day of Week	Access mode day of week
Access Leg 3 - Season	Access mode season
Access Leg 4 - Mode	Access mode type
Access Leg 4 - Description	Access mode description
Access Leg 4 - Distance	Access mode distance (mile)
Access Leg 4 - Dwell	Access mode dwell time (minutes)
Access Leg 4 - Average Speed	Access mode average speed (mph)
Access Leg 4 - Fuel Source	Access mode fuel source (as defined in 'Regional-Properties' for this mode)
Access Leg 4 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 4 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 4 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 4 - Region	Access mode region (for future use)
Access Leg 4 – City Size	Access mode city size
Access Leg 4 - Time of Day	Access mode time of day
Access Leg 4 - Day of Week	Access mode day of week
Access Leg 4 - Season	Access mode season
Access Leg 5 - Mode	Access mode type
Access Leg 5 - Description	Access mode description
Access Leg 5 - Distance	Access mode distance (mile)
Access Leg 5 - Dwell	Access mode dwell time (minutes)
Access Leg 5 - Average Speed	Access mode average speed (mph)
Access Leg 5 - Fuel Source	Access mode fuel source (as defined in 'Regional-Properties' for this mode)
Access Leg 5 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 5 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 5 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 5 - Region	Access mode region (for future use)
Access Leg 5 – City Size	Access mode city size
Access Leg 5 - Time of Day	Access mode time of day
Access Leg 5 - Day of Week	Access mode day of week

Access Leg 5 - Season	Access mode season
Egress Leg 1 - Mode	Egress mode type
Egress Leg 1 - Description	Egress mode description
Egress Leg 1 - Distance	Egress mode distance (mile)
Egress Leg 1 - Dwell	Egress mode dwell time (minutes)
Egress Leg 1 - Average Speed	Egress mode average speed (mph)
Egress Leg 1 - Fuel Source	Egress mode fuel source (as defined in 'Regional-Properties' for this mode)
Egress Leg 1 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 1 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 1 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 1 - Region	Egress mode region (for future use)
Egress Leg 1 – City Size	Egress mode city size
Egress Leg 1 - Time of Day	Egress mode time of day
Egress Leg 1 - Day of Week	Egress mode day of week
Egress Leg 1 - Season	Egress mode season
Egress Leg 2 - Mode	Egress mode type
Egress Leg 2 - Description	Egress mode description
Egress Leg 2 - Distance	Egress mode distance (mile)
Egress Leg 2 - Dwell	Egress mode dwell time (minutes)
Egress Leg 2 - Average Speed	Egress mode average speed (mph)
Egress Leg 2 - Fuel Source	Egress mode fuel source (as defined in 'Regional-Properties' for this mode)
Egress Leg 2 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 2 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 2 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 2 - Region	Egress mode region (for future use)
Egress Leg 2 – City Size	Egress mode city size
Egress Leg 2 - Time of Day	Egress mode time of day
Egress Leg 2 - Day of Week	Egress mode day of week
Egress Leg 2 - Season	Egress mode season
Egress Leg 3 - Mode	Egress mode type
Egress Leg 3 - Description	Egress mode description
Egress Leg 3 - Distance	Egress mode distance (mile)
Egress Leg 3 - Dwell	Egress mode dwell time (minutes)
Egress Leg 3 - Average Speed	Egress mode average speed (mph)
Egress Leg 3 - Fuel Source	Egress mode fuel source (as defined in 'Regional-Properties' for this mode)
Egress Leg 3 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 3 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)

Egress Leg 3 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 3 - Region	Egress mode region (for future use)
Egress Leg 3 – City Size	Egress mode city size
Egress Leg 3 - Time of Day	Egress mode time of day
Egress Leg 3 - Day of Week	Egress mode day of week
Egress Leg 3 - Season	Egress mode season
Egress Leg 4 - Mode	Egress mode type
Egress Leg 4 - Description	Egress mode description
Egress Leg 4 - Distance	Egress mode distance (mile)
Egress Leg 4 - Dwell	Egress mode dwell time (minutes)
Egress Leg 4 - Average Speed	Egress mode average speed (mph)
Egress Leg 4 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties’ for this mode)
Egress Leg 4 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 4 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 4 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 4 - Region	Egress mode region (for future use)
Egress Leg 4 – City Size	Egress mode city size
Egress Leg 4 - Time of Day	Egress mode time of day
Egress Leg 4 - Day of Week	Egress mode day of week
Egress Leg 4 - Season	Egress mode season
Egress Leg 5 - Mode	Egress mode type
Egress Leg 5 - Description	Egress mode description
Egress Leg 5 - Distance	Egress mode distance (mile)
Egress Leg 5 - Dwell	Egress mode dwell time (minutes)
Egress Leg 5 - Average Speed	Egress mode average speed (mph)
Egress Leg 5 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties’ for this mode)
Egress Leg 5 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 5 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 5 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 5 - Region	Egress mode region (for future use)
Egress Leg 5 – City Size	Egress mode city size
Egress Leg 5 - Time of Day	Egress mode time of day
Egress Leg 5 - Day of Week	Egress mode day of week
Egress Leg 5 - Season	Egress mode season

A.7.6 Contents of the ‘Air-Default-Data’ Worksheet

The ‘Air-Default-Data’ worksheet defines the default data used in air mode simulations. These include geographical locations of airports and aircraft simulation parameters for five (5) broad aircraft categories which include turboprop (TP), small regional jet (SRJ), regional jet (RJ), narrow body jet (NBJ) and wide body jet (WBJ). The default values for aircraft characteristics are circa 2011/12 and can be used in most simulations. Only a limited number of airport codes/co-ordinates are included at the bottom of the table and users can add more as needed.

The following list identifies the data items used by the simulation.

Item as Titled on the Worksheet List	**Notes on the Data Value**
	In columns C through E
Lower-dist(km)	(row 15) Lower boundary of great circle (GC) distance boundary in kilometers
Lower-dist(mi)	(row 16) Lower boundary of great circle (GC) distance boundary in statute miles
segment #	(row 17) Index of great circle distance segment
TP	(row 18) Row of % seat miles for turboprop aircraft in GC segment
SRJ	(row 19) Row of % seat miles for small regional jet aircraft in GC segment
RJ	(row 20) Row of % seat miles for regional jet aircraft in GC segment
NBJ	(row 21) Row of % seat miles for narrow body jet aircraft in GC segment
WBJ	(row 22) Row of % seat miles for wide body jet aircraft in GC segment
	In rows 18 through 22
LF	(col K) Column of passenger load factor by aircraft type
LTO Fuel (kg/seat)	(col L) Column of landing and takeoff fuel intensity by aircraft type
Cruise Fuel–peak (kg/seat-GC-km)	(col M) Column of peak cruise fuel consumption by aircraft type
Cruise Fuel–off peak (kg/seat-GC-km)	(col N) Column of off peak cruise fuel consumption by aircraft type
Cruise Fuel–average (kg/seat-GC-km)	(col O) Column of average cruise fuel consumption by aircraft type
	Beginning in row 31
IATA Code	(col C) The IATA designation for an airport.
City Name	(col D) Identifies the city served by the airport.
Latitude (degrees)	(col G) The airport’s latitude in decimal degrees.
Longitude (degrees)	(col H) The airport’s longitude in decimal degrees.

Note: Do not delete row 31. Cells ‘Air-Default-Data’!B31, ‘Air-Default-Data’!C31, ‘Air-Default-Data’!D21, ‘Air-Default-Data’!G31 and ‘Air-Default-Data’!H31 are named cells in Excel and deleting row 31 will result in those names being lost.

A.7.7 Contents of the ‘Air-Trip-List’ Worksheet

The ‘Air-Trip-List’ worksheet is used by the VBA macro system to store air trip definitions as they are developed by a user. Normally, the VBA macros should be used to add new trips and otherwise manage updating the contents of these fields in response to a user’s selections on the ‘Air Trip Selection’ user form. However, the list of defined air trips may become large and a knowledgeable user may delete trips from the list manually. Care must be taken during this process such that the top of the list is maintained on row 24 and that there are no blank rows in between the top and bottom of the list (a blank row will be interpreted as the bottom of the list). Also, the columns should not be shifted.

The following list identifies the data items used by the simulation.

Item as Titled on the Worksheet List	**Notes on the Data Value**
ID #	Assigned by the VBA macro. Normally “AT.#” where # is equivalent to (current row number - first row number +1). Each ID # should be unique.
Trip Description	A user’s description of the trip, normally some combination of the route description and aircraft description.
Region	As defined in ‘Regional-Properties’ worksheet
Fuel	As defined in ‘Energy-Emissions’ worksheet
Direction	Must be either “Forward” or “Reverse”.
Departure Time of Day	Must be “AM-peak”, “midday”, “PM-peak”, “off-peak” or “overnight”
Arrival Time of Day	Must be “AM-peak”, “midday”, “PM-peak”, “off-peak” or “overnight”
Departure Day of Week	Must be “Mon to Fri”, “Weekend” or “Daily”
Departure Season	Must be “Winter”, “Summer”, “Spring/Fall” or “All”
Return Trip Departure Time of Day	Must be “AM-peak”, “midday”, “PM-peak”, “off-peak” or “overnight”
Return Trip Arrival Time of Day	Must be “AM-peak”, “midday”, “PM-peak”, “off-peak” or “overnight”
Return Trip Departure Day of Week	Must be “Mon to Fri”, “Weekend” or “Daily”
Return Trip Departure Season	Must be “Winter”, “Summer”, “Spring/Fall” or “All”
Departure Service Period	Must be either “Pk” or “OffPk” – assigned by VBA macro
Return Service Period	Must be either “Pk” or “OffPk” – assigned by VBA macro
Number of Travelers	Number of people assumed to be traveling together
Origin IATA Code	IATA designation of origin airport
Origin Latitude	Latitude of origin airport
Origin Longitude	Longitude of origin airport
Intermediate Stop 1 IATA Code	IATA designation of intermediate stop 1
Intermediate Stop 1 Latitude	Latitude of intermediate stop 1
Intermediate Stop 1 Longitude	Longitude of intermediate stop 1
Intermediate Stop 2 IATA Code	IATA designation of intermediate stop 2

Intermediate Stop 2 Latitude	Latitude of intermediate stop 2
Intermediate Stop 2 Longitude	Longitude of intermediate stop 2
Destination IATA Code	IATA designation of destination airport
Destination Latitude	Latitude of destination airport
Destination Longitude	Longitude of destination airport
Multi-leg	% of total flights which are multi-leg
Direct	% of total flights which are direct
Aircraft data flag	Must be either “Default” or “User”
TP Leg 1 Distribution (seat-km)	% of total leg seat-km by TP aircraft
SRJ Leg 1 Distribution (seat-km)	% of total leg seat-km by SRJ aircraft
RJ Leg 1 Distribution (seat-km)	% of total leg seat-km by RJ aircraft
NBJ Leg 1 Distribution (seat-km)	% of total leg seat-km by NBJ aircraft
WBJ Leg 1 Distribution (seat-km)	% of total leg seat-km by WBJ aircraft
TP Leg 2 Distribution (seat-km)	% of total leg seat-km by TP aircraft
SRJ Leg 2 Distribution (seat-km)	% of total leg seat-km by SRJ aircraft
RJ Leg 2 Distribution (seat-km)	% of total leg seat-km by RJ aircraft
NBJ Leg 2 Distribution (seat-km)	% of total leg seat-km by NBJ aircraft
WBJ Leg 2 Distribution (seat-km)	% of total leg seat-km by WBJ aircraft
TP Leg 3 Distribution (seat-km)	% of total leg seat-km by TP aircraft
SRJ Leg 3 Distribution (seat-km)	% of total leg seat-km by SRJ aircraft
RJ Leg 3 Distribution (seat-km)	% of total leg seat-km by RJ aircraft
NBJ Leg 3 Distribution (seat-km)	% of total leg seat-km by NBJ aircraft
WBJ Leg 3 Distribution (seat-km)	% of total leg seat-km by WBJ aircraft
TP Direct Distribution (seat-km)	% of total direct seat-km by TP aircraft
SRJ Direct Distribution (seat-km)	% of total direct seat-km by SRJ aircraft
RJ Direct Distribution (seat-km)	% of total direct seat-km by RJ aircraft
NBJ Direct Distribution (seat-km)	% of total direct seat-km by NBJ aircraft
WBJ Direct Distribution (seat-km)	% of total direct seat-km by WBJ aircraft
TP Load Factor	% load factor of TP aircraft
SRJ Load Factor	% load factor of SRJ aircraft
RJ Load Factor	% load factor of RJ aircraft
NBJ Load Factor	% load factor of NBJ aircraft
WBJ Load Factor	% load factor of WBJ aircraft
TP LTO Fuel Consumption	Landing and takeoff fuel (kg/seat) of TP aircraft

SRJ LTO Fuel Consumption	Landing and takeoff fuel (kg/seat) of SRJ aircraft
RJ LTO Fuel Consumption	Landing and takeoff fuel (kg/seat) of RJ aircraft
NBJ LTO Fuel Consumption	Landing and takeoff fuel (kg/seat) of NBJ aircraft
WBJ LTO Fuel Consumption	Landing and takeoff fuel (kg/seat) of WBJ aircraft
TP Peak Cruise Fuel Consumption	Peak cruise fuel (kg/seat-GC-km) of TP aircraft
SRJ Peak Cruise Fuel Consumption	Peak cruise fuel (kg/seat-GC-km) of SRJ aircraft
RJ Peak Cruise Fuel Consumption	Peak cruise fuel (kg/seat-GC-km) of RJ aircraft
NBJ Peak Cruise Fuel Consumption	Peak cruise fuel (kg/seat-GC-km) of NBJ aircraft
WBJ Peak Cruise Fuel Consumption	Peak cruise fuel (kg/seat-GC-km) of WBJ aircraft
TP Off-Peak Cruise Fuel Consumption	Off-peak cruise fuel (kg/seat-GC-km) of TP aircraft
SRJ Off-Peak Cruise Fuel Consumption	Off-peak cruise fuel (kg/seat-GC-km) of SRJ aircraft
RJ Off-Peak Cruise Fuel Consumption	Off-peak cruise fuel (kg/seat-GC-km) of RJ aircraft
NBJ Off-Peak Cruise Fuel Consumption	Off-peak cruise fuel (kg/seat-GC-km) of NBJ aircraft
WBJ Off-Peak Cruise Fuel Consumption	Off-peak cruise fuel (kg/seat-GC-km) of WBJ aircraft
TP Average Cruise Fuel Consumption	Average cruise fuel (kg/seat-GC-km) of TP aircraft
SRJ Average Cruise Fuel Consumption	Average cruise fuel (kg/seat-GC-km) of SRJ aircraft
RJ Average Cruise Fuel Consumption	Average cruise fuel (kg/seat-GC-km) of RJ aircraft
NBJ Average Cruise Fuel Consumption	Average cruise fuel (kg/seat-GC-km) of NBJ aircraft
WBJ Average Cruise Fuel Consumption	Average cruise fuel (kg/seat-GC-km) of WBJ aircraft
Access/Egress Number of Travelers	Number of people assumed to be traveling together (same as main leg)
Access Leg 1 - Mode	Access mode type
Access Leg 1 - Description	Access mode description
Access Leg 1 - Distance	Access mode distance (mile)
Access Leg 1 - Dwell	Access mode dwell time (minutes)
Access Leg 1 - Average Speed	Access mode average speed (mph)
Access Leg 1 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties’ for this mode)
Access Leg 1 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 1 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 1 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 1 - Region	Access mode region

Access Leg 1 - City Size	Access mode city size
Access Leg 1 - Time of Day	Access mode time of day
Access Leg 1 - Day of Week	Access mode day of week
Access Leg 1 - Season	Access mode season
Access Leg 2 - Mode	Access mode type
Access Leg 2 - Description	Access mode description
Access Leg 2 - Distance	Access mode distance (mile)
Access Leg 2 - Dwell	Access mode dwell time (minutes)
Access Leg 2 - Average Speed	Access mode average speed (mph)
Access Leg 2 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties’ for this mode)
Access Leg 2 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 2 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 2 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 2 - Region	Access mode region
Access Leg 2 - City Size	Access mode city size
Access Leg 2 - Time of Day	Access mode time of day
Access Leg 2 - Day of Week	Access mode day of week
Access Leg 2 - Season	Access mode season
Access Leg 3 - Mode	Access mode type
Access Leg 3 - Description	Access mode description
Access Leg 3 - Distance	Access mode distance (mile)
Access Leg 3 - Dwell	Access mode dwell time (minutes)
Access Leg 3 - Average Speed	Access mode average speed (mph)
Access Leg 3 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties’ for this mode)
Access Leg 3 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 3 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 3 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 3 - Region	Access mode region
Access Leg 3 - City Size	Access mode city size
Access Leg 3 - Time of Day	Access mode time of day
Access Leg 3 - Day of Week	Access mode day of week
Access Leg 3 - Season	Access mode season
Access Leg 4 - Mode	Access mode type
Access Leg 4 - Description	Access mode description
Access Leg 4 - Distance	Access mode distance (mile)
Access Leg 4 - Dwell	Access mode dwell time (minutes)
Access Leg 4 - Average Speed	Access mode average speed (mph)
Access Leg 4 - Fuel Source	Access mode fuel source (as defined in ‘Regional-

	Properties' for this mode)
Access Leg 4 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 4 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 4 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 4 - Region	Access mode region
Access Leg 4 - City Size	Access mode city size
Access Leg 4 - Time of Day	Access mode time of day
Access Leg 4 - Day of Week	Access mode day of week
Access Leg 4 - Season	Access mode season
Access Leg 5 - Mode	Access mode type
Access Leg 5 - Description	Access mode description
Access Leg 5 - Distance	Access mode distance (mile)
Access Leg 5 - Dwell	Access mode dwell time (minutes)
Access Leg 5 - Average Speed	Access mode average speed (mph)
Access Leg 5 - Fuel Source	Access mode fuel source (as defined in 'Regional-Properties' for this mode)
Access Leg 5 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 5 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 5 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 5 - Region	Access mode region
Access Leg 5 - City Size	Access mode city size
Access Leg 5 - Time of Day	Access mode time of day
Access Leg 5 - Day of Week	Access mode day of week
Access Leg 5 - Season	Access mode season
Egress Leg 1 - Mode	Egress mode type
Egress Leg 1 - Description	Egress mode description
Egress Leg 1 - Distance	Egress mode distance (mile)
Egress Leg 1 - Dwell	Egress mode dwell time (minutes)
Egress Leg 1 - Average Speed	Egress mode average speed (mph)
Egress Leg 1 - Fuel Source	Egress mode fuel source (as defined in 'Regional-Properties' for this mode)
Egress Leg 1 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 1 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 1 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 1 - Region	Egress mode region
Egress Leg 1 - City Size	Egress mode city size
Egress Leg 1 - Time of Day	Egress mode time of day
Egress Leg 1 - Day of Week	Egress mode day of week
Egress Leg 1 - Season	Egress mode season
Egress Leg 2 - Mode	Egress mode type

Egress Leg 2 - Description	Egress mode description
Egress Leg 2 - Distance	Egress mode distance (mile)
Egress Leg 2 - Dwell	Egress mode dwell time (minutes)
Egress Leg 2 - Average Speed	Egress mode average speed (mph)
Egress Leg 2 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties’ for this mode)
Egress Leg 2 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 2 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 2 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 2 - Region	Egress mode region
Egress Leg 2 - City Size	Egress mode city size
Egress Leg 2 - Time of Day	Egress mode time of day
Egress Leg 2 - Day of Week	Egress mode day of week
Egress Leg 2 - Season	Egress mode season
Egress Leg 3 - Mode	Egress mode type
Egress Leg 3 - Description	Egress mode description
Egress Leg 3 - Distance	Egress mode distance (mile)
Egress Leg 3 - Dwell	Egress mode dwell time (minutes)
Egress Leg 3 - Average Speed	Egress mode average speed (mph)
Egress Leg 3 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties’ for this mode)
Egress Leg 3 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 3 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 3 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 3 - Region	Egress mode region
Egress Leg 3 - City Size	Egress mode city size
Egress Leg 3 - Time of Day	Egress mode time of day
Egress Leg 3 - Day of Week	Egress mode day of week
Egress Leg 3 - Season	Egress mode season
Egress Leg 4 - Mode	Egress mode type
Egress Leg 4 - Description	Egress mode description
Egress Leg 4 - Distance	Egress mode distance (mile)
Egress Leg 4 - Dwell	Egress mode dwell time (minutes)
Egress Leg 4 - Average Speed	Egress mode average speed (mph)
Egress Leg 4 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties’ for this mode)
Egress Leg 4 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 4 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 4 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 4 - Region	Egress mode region
Egress Leg 4 - City Size	Egress mode city size

Egress Leg 4 - Time of Day	Egress mode time of day
Egress Leg 4 - Day of Week	Egress mode day of week
Egress Leg 4 - Season	Egress mode season
Egress Leg 5 - Mode	Egress mode type
Egress Leg 5 - Description	Egress mode description
Egress Leg 5 - Distance	Egress mode distance (mile)
Egress Leg 5 - Dwell	Egress mode dwell time (minutes)
Egress Leg 5 - Average Speed	Egress mode average speed (mph)
Egress Leg 5 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties’ for this mode)
Egress Leg 5 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 5 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 5 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 5 - Region	Egress mode region
Egress Leg 5 - City Size	Egress mode city size
Egress Leg 5 - Time of Day	Egress mode time of day
Egress Leg 5 - Day of Week	Egress mode day of week
Egress Leg 5 - Season	Egress mode season

A.7.8 Contents of the 'Bus-Type' Worksheet

The 'Bus-Type' worksheet defines sets of parameters used by the bus simulation module. They are organized down the rows of the worksheet beginning in column "F" for the first defined bus type and offset by 4 columns (i.e. column "J") for each additional consist defined on the worksheet. The following list identifies the data items required by the simulation.

Item as Titled on the Worksheet List	**Notes on the Input Required**
Bus Type ID	Assigned by the VBA macro. Normally "BT.#" where # is equivalent to (current row number - first row number +1). Each ID # should be unique.
Description	User assigned description
Coach Characteristics:	
# axles	Total number of axles
Length (ft)	Bus length (ft)
tare wt (lb)	Bus tare weight (lb)
Gross Vehicle Weight Rating	GVWR (lb)
# seats	Number of passenger seats
Passenger Load Factor (Route/Consist/Time-of-day)	Load factor
Avg weight per passenger-with luggage (lb)	Passenger weight including luggage (lb)
gross wt (lb)	Gross vehicle weight (lb) (calculated)
Aerodynamic Drag Characteristics	
Total Cd	Total drag coefficient (dimensionless)
Frontal Area (m^2)	Frontal drag area (m^2)
Engine Characteristics:	
Engine Type	Information purposes only
Displacement (l)	Information purposes only
HP	Engine rated horsepower (hp)
Minimum BSFC (g/kWs)	Engine's minimum brake specific fuel consumption (g/kWs)
Fuel	Fuel type from those defined in 'Energy-Emission' worksheet
Hybrid Bus Only:	
Storage Energy Capacity (kWh)	
Storage Power Capacity (kW) target use (%)	(kW) first column, (%) in second column

Storage lower / upper limts (%)	(%) lower in first column, (%) upper in second column
storage losses coeff (charge / propel)	For charging in first column, for propulsion in second column
electro-mechanical transmission efficiency (either direction)	
Coach Climate Control + Auxiliaries	
Summer load multiplier	Multiplier for regional summer base load
Summer extended idle load multiplier	Multiplier for regional summer extended idle base load
Winter load multiplier	Multiplier for regional winter base load
Winter extended idle load multiplier	Multiplier for regional winter extended idle base load
Other (Spring&Fall) load multiplier	Multiplier for regional Spring/Fall base load

A.7.9 Contents of the ‘Bus-Route’ Worksheet

The ‘Bus-Route’ worksheet contains data used to characterize the route over which a bus will operate. For every defined route the data is organized into a number of tables, some of which span up to nine (9) columns. The data for the first defined route begins at address ‘Bus-Route’!N2 with each subsequent route definition offset from the previous one by twelve (12) columns.

The influence of grades along the route are accounted for by specifying the change in elevation (in meters) between the origin and destination at cell ‘Bus-Route’!Q72. Then, intercity grade distributions are provided which characterize grades into per unit distances of grade classes evaluated over the base distance (in km) as defined in cell ‘Bus-Route’!Q73. For descending grade forward direction these are given in table ‘Bus-Route’!N77:N104 while for ascending grade forward direction these are given in table ‘Bus-Route’!Q77:Q104.

The following list identifies the data items required by the simulation.

Item as Titled on the Worksheet List	**Notes on the Input Required**
Bus Route ID	Assigned by the VBA macro. Normally “BR.#” where # is a sequential integer value. Each ID # should be unique.
Description	User assigned description
Delay and Idle Times	
Intercity routine stops distribution	
Number of Toll booth stops in intercity-trip	Same for both directions of travel
Total queue delay at all toll-booth and traffic stand-still queuing stops (min)	Forward trip in first column, return trip in second column
Average number of intermediate wayside stops (normal)	Origin urban area in first column, inter-city highway in second column, destination urban area in third column
Average duration of each intermediate stop (min)	All areas
Origin/Destination Station Idle (hrs/one-way trip)	First column for origin, last column for destination
Scheduled Trip Time (hour)	
Layover Idle Time Allocated per one-way trip (by location)	
Layover Idle - winter (hr/trip)	First column for origin, second column for inter-city and last column for destination
Layover Idle - summer (hr/trip)	First column for origin, second column for inter-city and last column for destination
Layover Idle - spring/fall (hr/trip)	First column for origin, second column for inter-city and last column for destination

Drive schedule selection	
Rural congestion/weather delay distribution	
winter (slow) - Drive Schedule - 75km/h -LOS-E	First column is probability and second column is length (km)
non-winter (slow) - Drive Schedule - 75km/h -LOS-E	First column is probability and second column is length (km)
Urban time of Day Calculation	
Description	First two columns define time of day distribution for forward trip origin and destination, last two columns define time of day distribution for return trip origin and destination.
a.m. peak	
p.m. peak	
midday	
shoulders (calc as left over hrs)	
overnight	
TOTAL (error check)	
Urban Freeway and Arterial Distances	
Intercity avg total urban Freeway dist (forward trip / reverse trip)	First 2 columns for origin and destination city of forward trip, last two columns for origin and destination city of return trip (distances in km)
Total Intercity Urban arterial distance (forward trip / reverse trip)	First 2 columns for origin and destination city of forward trip, last two columns for origin and destination city of return trip (distances in km)
Intercity Speed Distribution	
Main inter-urban O-D route speed limits	First column distance (km) and last column posted speed (mph)
Distance at speed limit 1	
Distance at speed limit 2	
Distance at speed limit 3	
Distance at speed limit 4	
Intermediate urban bypass	
Intermediate urban Arterial	Distance (km) using “Arterial 40 km/h” drive schedule
Total One-Way Trip Distance (km)	Calculated
Actual cruise speed distribution for all but urban arterial	First column is % buses/route-km and last column is cruise speed (moh)
Actual cruise speed 1	
Actual cruise speed 2	
Actual cruise speed 3	
Actual cruise speed 4	
Actual cruise speed 5	

Actual cruise speed 6	
Forced speed reductions (from cruise speed to posted or forced lower traffic speed)	Number of reductions to lower speed (in mph)
Speed reduction 1	
Speed reduction 2	
Elevation change between forward trip Origin and Destination (m)	
Base Data Distance (km)	
Intercity Grade Distribution	
grade-class (percent)	First column is per unit distance in a grade class in descending grade forward direction, second column is per unit distance in a grade class in ascending grade forward direction
0.25 - 0.5	
0.5 - 0.75	
0.75 - 1	
1 - 1.25	
1.25 - 1.5	
1.5 - 1.75	
1.75 - 2	
2 - 2.25	
2.25 - 2.5	
2.5 - 2.75	
2.75 - 3	
3 - 3.25	
3.25 - 3.5	
3.5 - 3.75	
3.75 - 4	
4 - 4.25	
4.25 - 4.5	
4.5 - 4.75	
4.75 - 5	
5 - 5.25	
5.25 - 5.5	
5.5 - 5.75	
5.75 - 6	
6 - 6.25	
6.25 - 6.5	
6.5 - 6.75	
6.75 - 7	
>7	

A.7.10 Contents of the ‘Bus-Drive-Schedules’ Worksheet

The ‘Bus-Drive-Schedules’ worksheet defines the speed-time relationships used by the internal ‘Bus-Trip’ and ‘Bus-Simulation’ worksheets to simulate all movement of buses in urban areas (i.e. other than when cruising at high speed between urban centers). The orange table at ‘Bus-Drive_Schedules’!A2:J6 defines the drive schedule mix to be used on arterial roads in both the origin and destination cities during five (5) daily time periods defined as: a.m. peak, p.m. peak, midday, shoulder periods and overnight. This table draws from drive schedule distributions defined in one of three supporting tables associated with small cities (‘Bus-Drive-Schedules’!AA2:AJ6), large cities (‘Bus-Drive-Schedules’!AO2:AX6) or a user defined city distribution (‘Bus-Drive-Schedules’!BC2:BL6) depending on the table selector placed in the pink cell at ‘Bus-Drive-Schedules’!B3. The VBA macro automatically sets the table selector based upon the user’s trip configurations while performing a simulation. The orange table at ‘Bus-Drive-Schedules’!A7:J11 defines the drive schedule mix used on urban freeways around the origin city during the five (5) daily time periods and draws its data from tables at ‘Bus-Drive-Schedules’!AA7:AJ11 for small cities, ‘Bus-Drive-Schedules’!AO7:AX11 for large cities and ‘Bus-Drive-Schedules’!BC7:BL11 for a user defined city based on the table selector placed in the pink cell at ‘Bus-Drive-Schedules’!B8. Finally, the orange table at ‘Bus-Drive-Schedules’!A12:J16 defines the drive schedule mix used on urban freeways around the destination city during the five (5) daily time periods and draws its data from tables at ‘Bus-Drive-Schedules’!AA12:AJ16 for small cities, ‘Bus-Drive-Schedules’!AO12:AX16 for large cities and ‘Bus-Drive-Schedules’!BC12:BL16 for a user defined city based on the table selector placed in the pink cell at ‘Bus-Drive-Schedules’!B13.

A knowledgeable user may adjust the appropriate drive schedule mix to suit their analysis but must take care when doing so to ensure that the columns on each row of those tables sum to 100% so that travel at all times of the day are accounted for. Additional queue delays and operation under other specific extraordinary conditions and areas are assigned in ‘Bus-Drive-Schedules’!A17:J21.

The drive schedules are defined in the yellow table ‘Bus-Drive-Schedules’!B23:K5366. The first ten (10) rows of the table provide headings and summary characteristics for the drive schedules below. The drive schedules themselves specify the second-by-second speed target which the ‘Bus-Simulation’ worksheet will attempt to follow when assessing fuel consumption and emissions production. They are organized into yellow coloured columns starting at row 33 with column ‘B’ specifying the time in seconds and columns ‘C’ through ‘J’ defining the target speed in m/s.

A.7.11 Contents of the ‘Bus-Trip-List’ Worksheet

The ‘Bus-Trip-List’ worksheet is used by the VBA macro system to store bus trip definitions as they are developed by a user. Normally, the VBA macros should be used to add new trips and otherwise manage updating the contents of these fields in response to a user’s selections on the ‘Bus Trip Selection’ user form. However, the list of defined bus trips may become large and a knowledgeable user may delete trips from the list manually. Care must be taken during this process such that the top of the list is maintained on row 25 and that there are no blank rows in between the top and bottom of the list (a blank row will be interpreted as the bottom of the list). Also, the columns should not be shifted.

The following list identifies the data items used by the simulation.

Item as Titled on the Worksheet List	**Notes on the Data Value**
ID #	Assigned by the VBA macro. Normally “BT.#” where # is equivalent to (current row number - first row number +1). Each ID # should be unique.
Trip Description	A user’s description of the trip, normally some combination of the route description and bus type description.
Region	One of the region descriptors as defined in the ‘Regional-Properties’ worksheet
Route ID	Assigned by the VBA macro. Normally “BR.#” where # is equivalent to the route index in ‘Bus-Route’ worksheet.
Route Description	A user’s description of the route.
Trip Length	Length of trip in km
Urban Area1 Freeway Mix	For origin urban area, must be “Small City”, “Large City” or “User Defined”
Urban Area2 Freeway Mix	For destination urban area, must be “Small City”, “Large City” or “User Defined”
Urban Area Arterial Mix	For both origin and destination urban areas, must be “Small City”, “Large City” or “User Defined”
Direction	Must be either “Forward” or “Reverse”.
Departure Time of Day	For forward trip, must be “AM-peak”, “midday”, “PM-peak”, “off-peak”, “overnight” or “route default”
Arrival Time of Day	For forward trip, must be “AM-peak”, “midday”, “PM-peak”, “off-peak”, “overnight” or “route default”
Departure Day of Week	For forward trip, must be “Mon to Fri”, “Weekend” or “Daily”
Departure Season	For forward trip, must be “Winter”, “Summer”, “Spring/Fall” or “All”
Return Departure Time of Day	For return trip, must be “AM-peak”, “midday”, “PM-peak”, “off-peak”, “overnight” or “route default”
Return Arrival Time of Day	For return trip, must be “AM-peak”, “midday”, “PM-peak”, “off-peak”, “overnight” or “route default”
Return Departure Day of Week	For return trip, must be “Mon to Fri”, “Weekend” or “Daily”
Departure Season	For return trip, must be “Winter”, “Summer”, “Spring/Fall” or “All”
Coach ID	Assigned by the VBA macro. Normally “BC.#” where # is equivalent to the coach index in ‘Bus-Type’ worksheet.
Coach Description	A user’s description of coach type (in ‘Bus-Type’ worksheet)

Coach Fuel	A fuel descriptor defined in the bus fuel table of ‘Energy-Emissions’ worksheet
Passenger Seats	Number of passenger seats on the selected coach type
Passenger Load Factor	Must be 1 or less
Number of Travelers	Number of people assumed to be traveling together
Scheduled Trip Time (hours)	
Number of Intermediate Stops	
Station Stop Time Allowance (min)	
Access/Egress Number of Travelers	Number of people assumed to be traveling together for access/egress (normally the same as for primary trip)
Access Leg 1 - Mode	Access mode type
Access Leg 1 - Description	Access mode description
Access Leg 1 - Distance	Access mode distance (mile)
Access Leg 1 - Dwell	Access mode dwell time (minutes)
Access Leg 1 - Average Speed	Access mode average speed (mph)
Access Leg 1 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties” for access mode)
Access Leg 1 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 1 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 1 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 1 - Region	Access mode region
Access Leg 1 - City Size	Access mode city size
Access Leg 1 - Time of Day	Access mode time of day
Access Leg 1 - Day of Week	Access mode day of week
Access Leg 1 - Season	Access mode season
Access Leg 2 - Mode	Access mode type
Access Leg 2 - Description	Access mode description
Access Leg 2 - Distance	Access mode distance (mile)
Access Leg 2 - Dwell	Access mode dwell time (minutes)
Access Leg 2 - Average Speed	Access mode average speed (mph)
Access Leg 2 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties” for access mode)
Access Leg 2 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 2 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 2 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 2 - Region	Access mode region (for future use)
Access Leg 2 - City Size	Access mode city size
Access Leg 2 - Time of Day	Access mode time of day
Access Leg 2 - Day of Week	Access mode day of week
Access Leg 2 - Season	Access mode season

Access Leg 3 - Mode	Access mode type
Access Leg 3 - Description	Access mode description
Access Leg 3 - Distance	Access mode distance (mile)
Access Leg 3 - Dwell	Access mode dwell time (minutes)
Access Leg 3 - Average Speed	Access mode average speed (mph)
Access Leg 3 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties” for access mode)
Access Leg 3 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 3 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 3 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 3 - Region	Access mode region (for future use)
Access Leg 3 - City Size	Access mode city size
Access Leg 3 - Time of Day	Access mode time of day
Access Leg 3 - Day of Week	Access mode day of week
Access Leg 3 - Season	Access mode season
Access Leg 4 - Mode	Access mode type
Access Leg 4 - Description	Access mode description
Access Leg 4 - Distance	Access mode distance (mile)
Access Leg 4 - Dwell	Access mode dwell time (minutes)
Access Leg 4 - Average Speed	Access mode average speed (mph)
Access Leg 4 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties” for access mode)
Access Leg 4 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 4 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 4 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 4 - Region	Access mode region (for future use)
Access Leg 4 - City Size	Access mode city size
Access Leg 4 - Time of Day	Access mode time of day
Access Leg 4 - Day of Week	Access mode day of week
Access Leg 4 - Season	Access mode season
Access Leg 5 - Mode	Access mode type
Access Leg 5 - Description	Access mode description
Access Leg 5 - Distance	Access mode distance (mile)
Access Leg 5 - Dwell	Access mode dwell time (minutes)
Access Leg 5 - Average Speed	Access mode average speed (mph)
Access Leg 5 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties” for access mode)
Access Leg 5 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 5 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 5 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 5 - Region	Access mode region (for future use)

Access Leg 5 - City Size	Access mode city size
Access Leg 5 - Time of Day	Access mode time of day
Access Leg 5 - Day of Week	Access mode day of week
Access Leg 5 - Season	Access mode season
Egress Leg 1 - Mode	Egress mode type
Egress Leg 1 - Description	Egress mode description
Egress Leg 1 - Distance	Egress mode distance (mile)
Egress Leg 1 - Dwell	Egress mode dwell time (minutes)
Egress Leg 1 - Average Speed	Egress mode average speed (mph)
Egress Leg 1 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties” for egress mode)
Egress Leg 1 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 1 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 1 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 1 - Region	Egress mode region (for future use)
Egress Leg 1 - City Size	Egress mode city size
Egress Leg 1 - Time of Day	Egress mode time of day
Egress Leg 1 - Day of Week	Egress mode day of week
Egress Leg 1 - Season	Egress mode season
Egress Leg 2 - Mode	Egress mode type
Egress Leg 2 - Description	Egress mode description
Egress Leg 2 - Distance	Egress mode distance (mile)
Egress Leg 2 - Dwell	Egress mode dwell time (minutes)
Egress Leg 2 - Average Speed	Egress mode average speed (mph)
Egress Leg 2 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties” for egress mode)
Egress Leg 2 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 2 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 2 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 2 - Region	Egress mode region (for future use)
Egress Leg 2 - City Size	Egress mode city size
Egress Leg 2 - Time of Day	Egress mode time of day
Egress Leg 2 - Day of Week	Egress mode day of week
Egress Leg 2 - Season	Egress mode season
Egress Leg 3 - Mode	Egress mode type
Egress Leg 3 - Description	Egress mode description
Egress Leg 3 - Distance	Egress mode distance (mile)
Egress Leg 3 - Dwell	Egress mode dwell time (minutes)
Egress Leg 3 - Average Speed	Egress mode average speed (mph)
Egress Leg 3 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-

	Properties” for egress mode)
Egress Leg 3 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 3 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 3 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 3 - Region	Egress mode region (for future use)
Egress Leg 3 - City Size	Egress mode city size
Egress Leg 3 - Time of Day	Egress mode time of day
Egress Leg 3 - Day of Week	Egress mode day of week
Egress Leg 3 - Season	Egress mode season
Egress Leg 4 - Mode	Egress mode type
Egress Leg 4 - Description	Egress mode description
Egress Leg 4 - Distance	Egress mode distance (mile)
Egress Leg 4 - Dwell	Egress mode dwell time (minutes)
Egress Leg 4 - Average Speed	Egress mode average speed (mph)
Egress Leg 4 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties” for egress mode)
Egress Leg 4 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 4 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 4 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 4 - Region	Egress mode region (for future use)
Egress Leg 4 - City Size	Egress mode city size
Egress Leg 4 - Time of Day	Egress mode time of day
Egress Leg 4 - Day of Week	Egress mode day of week
Egress Leg 4 - Season	Egress mode season
Egress Leg 5 - Mode	Egress mode type
Egress Leg 5 - Description	Egress mode description
Egress Leg 5 - Distance	Egress mode distance (mile)
Egress Leg 5 - Dwell	Egress mode dwell time (minutes)
Egress Leg 5 - Average Speed	Egress mode average speed (mph)
Egress Leg 5 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties” for egress mode)
Egress Leg 5 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 5 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 5 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 5 - Region	Egress mode region (for future use)
Egress Leg 5 - City Size	Egress mode city size
Egress Leg 5 - Time of Day	Egress mode time of day
Egress Leg 5 - Day of Week	Egress mode day of week
Egress Leg 5 - Season	Egress mode season

A.7.12 Contents of the 'LDV-Type' Worksheet

The 'LDV-Type' worksheet is used by the 'Auto/LDV Type Selection' user form and contains pointers to data fields on the 'LDV-Resist' worksheet as most light duty vehicle default parameters used by the 'LDV-Simulation' worksheet are specified there. Yellow cells containing formulas should not be over-written with data values. The yellow cell at 'LDV-Type'!F6 (and at 4 column intervals to the right) identifies the index for the vehicle type in the default parameters table located at 'LDV-Resist'!C29:AB51. A knowledgeable user can make careful adjustments in the 'LDV-Resist' worksheet but data locations should not be changed.

The 'LDV-Type' worksheet contains a limited number of user modifiable parameters - notably the number of passenger seats per vehicle, the number of passengers carried, the fuel type and the user's selection of engine option. All of these may be adjusted on the 'Auto/LDV Type Selection' user form. The engine option can be either "Hybrid", "Non-hybrid" or "default mix", where the default mix is a combination of hybrid and conventional vehicles as defined in the 'LDV-Resist' data table. Data fields are also provided to adjust the regionally specified Auto/LDV climate control and auxiliary loads for a specific vehicle type. This adjustment is achieved by multiplying the running and idle auxiliary loads as specified for each season ("Winter", "Summer" and "Spring/Fall") in the 'Regional-Properties' table by the corresponding adjustment factors defined in the 'LDV-Type' column. Any changes made to the 'LDV-Type' worksheet must not alter the cell location of the first Auto/LDV type identifier at cell 'LDV-Type'!F2 and entries for successive vehicle types must maintain a fixed 4 column offset from the previous.

The following list identifies the data items in the 'LDV-Type' column for a vehicle.

Item as Titled on the Worksheet List	**Notes on the Input Required**
Auto/LDV Type ID	Assigned in the default data table located on the 'LDV-Resist' worksheet and used by reference
Description	Assigned in the default data table located on the 'LDV-Resist' worksheet and used by reference
Auto/LDV Characteristics:	Integer number index to a column of the default data table located on the 'LDV-Resist' worksheet
Year	Year associated with default data
# passenger seats	Total number of passenger seats in vehicle
Passengers	Number of passenger seats occupied
Tare weight (kg)	
Engine Characteristics:	
Engine Type	"spark" or "diesel"

HP	Engine horsepower
Fuel	As defined in ‘Energy-Emissions’ worksheet
Engine Option	“Hybrid”, “Non-hybrid” or “default mix”
Climate Control + Auxiliaries (base regional load multiplier)	
Winter running aux load	Multiplier for base regionally defined load
Winter idle load	Multiplier for base regionally defined load
Summer running aux load	Multiplier for base regionally defined load
Summer idle load	Multiplier for base regionally defined load
Spring/Fall running aux load	Multiplier for base regionally defined load
Spring/Fall idle load	Multiplier for base regionally defined load

A.7.13 Contents of the ‘LDV-Route’ Worksheet

The ‘LDV-Route’ worksheet contains data used to characterize the route over which a light duty vehicle will operate. For every defined route the data is organized into a number of tables, some of which span up to nine (9) columns. The data for the first defined route begins at address ‘LDV-Route’!N2 with each subsequent route definition offset from the previous one by twelve (12) columns.

The influence of grades along the route are accounted for by specifying the change in elevation (in meters) between the origin and destination at cell ‘LDV-Route’!Q72. Then, intercity grade distributions are provided which characterize grades into per unit distances of grade classes evaluated over the base distance (in km) as defined in cell ‘LDV-Route’!Q73. For descending grade forward direction these are given in table ‘LDV-Route’!N77:N104 while for ascending grade forward direction these are given in table ‘LDV-Route’!Q77:Q104.

The following list identifies the data items required by the simulation.

Item as Titled on the Worksheet List	**Notes on the Input Required**
Auto/LDV Route ID	Each ID must be unique. When assigned by the VBA macro these are of the form “LR.#” where # is a sequential integer value.
Description	User assigned description
Delay and Idle Times	
Intercity routine stops distribution	
Number of Toll booth stops in intercity-trip	Same for both directions of travel
Total queue delay at all toll-booth and traffic stand-still queuing stops (min)	First column for origin, last column for destination
Average number of intermediate wayside stops (normal)	All areas
Average cumulative duration of all intermediate stops (hr)	All areas
Origin/Destination Idle (hrs/one-way trip)	First column for forward trip, last column for return trip
% layover at location for all seasons	First column at destination, second column en route
Layover Idle Time Allocated per one-way trip (by location)	
Layover Idle - winter (hr/trip)	Inter-city layover hours per trip
Layover Idle - summer (hr/trip)	Inter-city layover hours per trip
Layover Idle - spring/fall (hr/trip)	Inter-city layover hours per trip
Drive schedule selection	
Rural Highway congestion/weather delay distribution	
winter (slow) - Drive Schedule - 75km/h -LOS-E	First column is probability and second column

	is length (km)
non-winter (slow) - Drive Schedule - 75km/h -LOS-E	First column is probability and second column is length (km)
Urban time of Day Calculation	
Description	First two columns define time of day distribution for forward trip origin and destination, last two columns define time of day distribution for return trip origin and destination.
a.m. peak	
p.m. peak	
midday	
shoulders (calc as left over hrs)	
overnight	
TOTAL (error check)	Each column should sum to 100%
Urban Freeway and Arterial Distances	
Intercity avg total urban Freeway dist (forward trip / reverse trip)	First 2 columns for origin and destination city of forward trip, last two columns for origin and destination city of return trip (distances in km)
Total Intercity Urban arterial distance (forward trip / reverse trip)	First 2 columns for origin and destination city of forward trip, last two columns for origin and destination city of return trip (distances in km)
Intercity Speed Distribution	
Main inter-urban O-D route speed limits	First column distance (km) and last column posted speed (mph)
Distance at speed limit 1	
Distance at speed limit 2	
Distance at speed limit 3	
Distance at speed limit 4	
Intermediate urban bypass	
Intermediate urban Arterial	Distance (km) using “Arterial 40 km/h” drive schedule
Total One-Way Trip Distance (Forward and Reverse)	Calculated. Forward trip in first column, return trip in last column
Actual cruise speed distribution for all but urban arterial	First column is % LDV/route-km and last column is cruise speed (mph)
Actual cruise speed 1	
Actual cruise speed 2	
Actual cruise speed 3	
Actual cruise speed 4	
Actual cruise speed 5	
Actual cruise speed 6	

Delta KE from forced speed reductions dissipated in brakes (from cruise speed to posted lower speed)	Number of reductions to lower speed in first column, lower speed (mph) in last column
Speed reduction 1	
Speed reduction 2	
Elevation change between forward trip Origin and Destination (m)	
Base Data Distance (km)	
Intercity Grade Distribution	
grade-class (percent)	First column is per unit distance in a grade class in descending grade forward direction, second column is per unit distance in a grade class in ascending grade forward direction
0.25 - 0.5	
0.5 - 0.75	
0.75 - 1	
1 - 1.25	
1.25 - 1.5	
1.5 - 1.75	
1.75 - 2	
2 - 2.25	
2.25 - 2.5	
2.5 - 2.75	
2.75 - 3	
3 - 3.25	
3.25 - 3.5	
3.5 - 3.75	
3.75 - 4	
4 - 4.25	
4.25 - 4.5	
4.5 - 4.75	
4.75 - 5	
5 - 5.25	
5.25 - 5.5	
5.5 - 5.75	
5.75 - 6	
6 - 6.25	
6.25 - 6.5	
6.5 - 6.75	
6.75 - 7	
>7	

A.7.14 Contents of the ‘LDV-Drive-Schedules’ Worksheet

The ‘LDV-Drive-Schedules’ worksheet defines the speed-time relationships used by the internal ‘LDV-Trip’ and ‘LDV-Simulation’ worksheets to simulate all movement of light duty vehicles in urban areas (i.e. other than when cruising at high speed between urban centers). The orange table at ‘LDV-Drive-Schedules’!A2:J6 defines the drive schedule mix to be used on arterial roads in both the origin and destination cities during five (5) daily time periods defined as: a.m. peak, p.m. peak, midday, shoulder periods and overnight. This table draws from drive schedule distributions in one of three supporting tables associated with small cities (‘LDV-Drive-Schedules’!AA2:AJ6), large cities (‘LDV-Drive-Schedules’!AO2:AX6) or a user defined city distribution (‘LDV-Drive_Schedules’!BC2:BL6) depending on the table selector placed in the pink cell at ‘LDV-Drive-Schedules’!B3. The VBA macro automatically sets the table selector based upon the user’s trip configurations while performing a simulation. The orange table at ‘LDV-Drive-Schedules’!A7:J11 defines the drive schedule mix used on urban freeways around the origin city during the five (5) daily time periods and draws its data from tables at ‘LDV-Drive-Schedules’!AA7:AJ11 for small cities, ‘LDV-Drive-Schedules’!AO7:AX11 for large cities and ‘LDV-Drive-Schedules’!BC7:BL11 for a user defined city based on the table selector placed in the pink cell at ‘LDV-Drive-Schedules’!B8. Finally, the orange table at ‘LDV-Drive-Schedules’!A12:J16 defines the drive schedule mix used on urban freeways around the destination city during the five (5) daily time periods and draws its data from tables at ‘LDV-Drive-Schedules’!AA12:AJ16 for small cities, ‘LDV-Drive-Schedules’!AO12:AX16 for large cities and ‘LDV-Drive-Schedules’!BC12:BL16 for a user defined city based on the table selector placed in the pink cell at ‘LDV-Drive-Schedules’!B13.

A knowledgeable user may adjust the appropriate drive schedule mix to suit their analysis but must take care when doing so to ensure that the columns on each row of those tables sum to 100% so that travel at all times of the day are accounted for. Additional queue delays and operation under other specific extraordinary conditions and areas are assigned in ‘LDV-Drive-Schedules’!A17:J21.

The drive schedules are defined in the yellow table ‘LDV-Drive-Schedules’!B23:K5366. The first ten (10) rows of the table provide headings and summary characteristics for the drive schedules below. The drive schedules themselves specify the second-by-second speed target which the ‘LDV-Simulation’ worksheet will attempt to follow when assessing fuel consumption and emissions production. They are organized into yellow coloured columns starting at row 33 with column ‘B’ specifying the time in seconds and columns ‘C’ through ‘J’ defining the target speed in m/s.

A.7.15 Contents of the ‘LDV-Trip-List’ Worksheet

The ‘LDV-Trip-List’ worksheet is used by the VBA macro system to store Auto/LDV trip definitions as they are developed by a user. Normally, the VBA macros should be used to add new trips and otherwise manage updating the contents of these fields in response to a user’s selections on the ‘Auto/LDV Trip Selection’ user form. However, the list of defined light duty vehicle trips may become large and a knowledgeable user may delete trips from the list manually. Care must be taken during this process such that the top of the list is maintained on row 25 and that there are no blank rows in between the top and bottom of the list (a blank row will be interpreted as the bottom of the list). Also, the columns should not be shifted.

The following list identifies the data items used by the simulation.

Item as Titled on the Worksheet List	**Notes on the Data Value**
ID #	Assigned by the VBA macro. Normally “LT.#” where # is equivalent to (current row number - first row number +1). Each ID # should be unique.
Trip Description	A user’s description of the trip, normally some combination of the route description and vehicle type description.
Region	A region identifier as defined in ‘Regional-Properties’ worksheet
Route ID	Assigned by the VBA macro. Normally “LR.#” where # is equivalent to the route index in ‘LDV-Route’ worksheet.
Route Description	A user’s description of the route.
Route Length	Route length (km)
Urban Area1 Freeway Mix	For origin urban area, must be “Small City”, “Large City” or “User Defined”
Urban Area2 Freeway Mix	For destination urban area, must be “Small City”, “Large City” or “User Defined”
Urban Area Arterial Mix	For both origin and destination urban areas, must be “Small City”, “Large City” or “User Defined”
Direction	Must be either “Forward” or “Reverse”.
Departure Time of Day	For forward trip, must be “AM-peak”, “midday”, “PM-peak” or “off-peak”
Arrival Time of Day	For forward trip, must be “AM-peak”, “midday”, “PM-peak” or “off-peak”
Departure Day of Week	For forward trip, must be “Mon to Fri”, “Weekend” or “Daily”
Departure Season	For forward trip, must be “Winter”, “Summer”, “Spring/Fall” or “All”
Return Departure Time of Day	For return trip, must be “AM-peak”, “midday”, “PM-peak” or “off-peak”
Return Arrival Time of Day	For return trip, must be “AM-peak”, “midday”, “PM-peak” or “off-peak”
Return Departure Day of Week	For return trip, must be “Mon to Fri”, “Weekend” or “Daily”
Return Departure Season	For return trip, must be “Winter”, “Summer”, “Spring/Fall” or “All”
Auto/LDV ID	Must be same as an Auto/LDV ID defined in ‘LDV-Type’ worksheet.
Auto/LDV Description	Description of auto/LDV type (as in ‘LDV-Type’ worksheet)

Auto/LDV Fuel	A valid Auto/LDV fuel type as defined in ‘Energy-Emission’ worksheet.
Auto/LDV Engine Option	Must be “Hybrid”, “Non-hybrid” or “default mix”
Passenger Seats	Number of passenger seats in vehicle
Passengers	Number of occupied passenger seats
Access/ Egress Number of Travelers	Number of people assumed to be traveling together
Access Leg 1 - Mode	Access mode type
Access Leg 1 - Description	Access mode description
Access Leg 1 - Distance	Access mode distance (mile)
Access Leg 1 - Dwell	Access mode dwell time (minutes)
Access Leg 1 - Average Speed	Access mode average speed (mph)
Access Leg 1 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties’ for this access mode)
Access Leg 1 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 1 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 1 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 1 - Region	Access mode region (for future use)
Access Leg 1 - City Size	Access mode city size
Access Leg 1 - Time of Day	Access mode time of day
Access Leg 1 - Day of Week	Access mode day of week
Access Leg 1 - Season	Access mode season
Access Leg 2 - Mode	Access mode type
Access Leg 2 - Description	Access mode description
Access Leg 2 - Distance	Access mode distance (mile)
Access Leg 2 - Dwell	Access mode dwell time (minutes)
Access Leg 2 - Average Speed	Access mode average speed (mph)
Access Leg 2 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties’ for this access mode)
Access Leg 2 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 2 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 2 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 2 - Region	Access mode region (for future use)
Access Leg 2 - City Size	Access mode city size
Access Leg 2 - Time of Day	Access mode time of day
Access Leg 2 - Day of Week	Access mode day of week
Access Leg 2 - Season	Access mode season
Access Leg 3 - Mode	Access mode type
Access Leg 3 - Description	Access mode description
Access Leg 3 - Distance	Access mode distance (mile)

Access Leg 3 - Dwell	Access mode dwell time (minutes)
Access Leg 3 - Average Speed	Access mode average speed (mph)
Access Leg 3 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties’ for this access mode)
Access Leg 3 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 3 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 3 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 3 - Region	Access mode region (for future use)
Access Leg 3 - City Size	Access mode city size
Access Leg 3 - Time of Day	Access mode time of day
Access Leg 3 - Day of Week	Access mode day of week
Access Leg 3 - Season	Access mode season
Access Leg 4 - Mode	Access mode type
Access Leg 4 - Description	Access mode description
Access Leg 4 - Distance	Access mode distance (mile)
Access Leg 4 - Dwell	Access mode dwell time (minutes)
Access Leg 4 - Average Speed	Access mode average speed (mph)
Access Leg 4 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties’ for this access mode)
Access Leg 4 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 4 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 4 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 4 - Region	Access mode region (for future use)
Access Leg 4 - City Size	Access mode city size
Access Leg 4 - Time of Day	Access mode time of day
Access Leg 4 - Day of Week	Access mode day of week
Access Leg 4 - Season	Access mode season
Access Leg 5 - Mode	Access mode type
Access Leg 5 - Description	Access mode description
Access Leg 5 - Distance	Access mode distance (mile)
Access Leg 5 - Dwell	Access mode dwell time (minutes)
Access Leg 5 - Average Speed	Access mode average speed (mph)
Access Leg 5 - Fuel Source	Access mode fuel source (as defined in ‘Regional-Properties’ for this access mode)
Access Leg 5 - Fuel Intensity	Access mode fuel intensity (kg/pass-mile)
Access Leg 5 - Energy Intensity	Access mode energy intensity (kJ/pass-mile)
Access Leg 5 - CO2e Intensity	Access mode CO2e emission intensity (g/pass-mi)
Access Leg 5 - Region	Access mode region (for future use)
Access Leg 5 - City Size	Access mode city size
Access Leg 5 - Time of Day	Access mode time of day
Access Leg 5 - Day of Week	Access mode day of week

Access Leg 5 - Season	Access mode season
Egress Leg 1 - Mode	Egress mode type
Egress Leg 1 - Description	Egress mode description
Egress Leg 1 - Distance	Egress mode distance (mile)
Egress Leg 1 - Dwell	Egress mode dwell time (minutes)
Egress Leg 1 - Average Speed	Egress mode average speed (mph)
Egress Leg 1 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties’ for this egress mode)
Egress Leg 1 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 1 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 1 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 1 - Region	Egress mode region (for future use)
Egress Leg 1 - City Size	Egress mode city size
Egress Leg 1 - Time of Day	Egress mode time of day
Egress Leg 1 - Day of Week	Egress mode day of week
Egress Leg 1 - Season	Egress mode season
Egress Leg 2 - Mode	Egress mode type
Egress Leg 2 - Description	Egress mode description
Egress Leg 2 - Distance	Egress mode distance (mile)
Egress Leg 2 - Dwell	Egress mode dwell time (minutes)
Egress Leg 2 - Average Speed	Egress mode average speed (mph)
Egress Leg 2 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties’ for this egress mode)
Egress Leg 2 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 2 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 2 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 2 - Region	Egress mode region (for future use)
Egress Leg 2 - City Size	Egress mode city size
Egress Leg 2 - Time of Day	Egress mode time of day
Egress Leg 2 - Day of Week	Egress mode day of week
Egress Leg 2 - Season	Egress mode season
Egress Leg 3 - Mode	Egress mode type
Egress Leg 3 - Description	Egress mode description
Egress Leg 3 - Distance	Egress mode distance (mile)
Egress Leg 3 - Dwell	Egress mode dwell time (minutes)
Egress Leg 3 - Average Speed	Egress mode average speed (mph)
Egress Leg 3 - Fuel Source	Egress mode fuel source (as defined in ‘Regional-Properties’ for this egress mode)
Egress Leg 3 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 3 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)

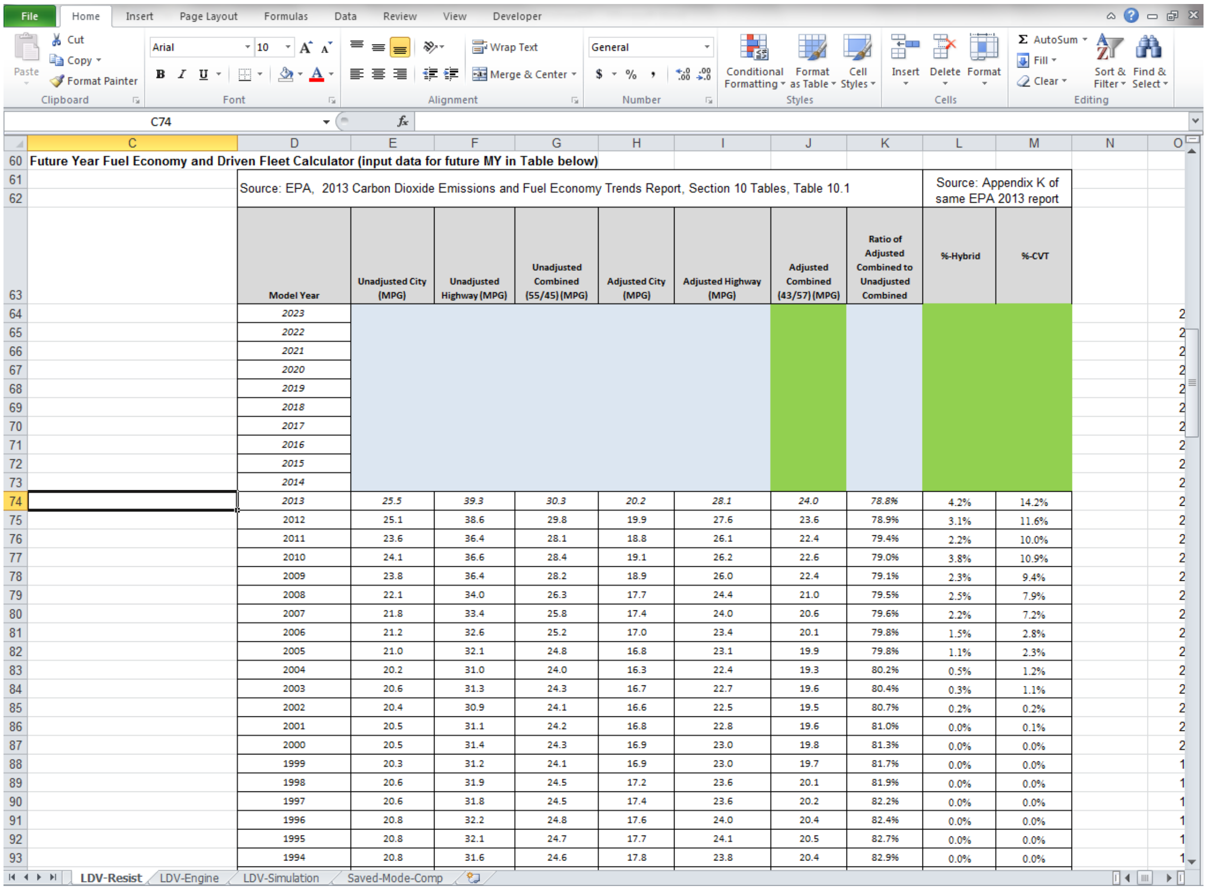
Egress Leg 3 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 3 - Region	Egress mode region (for future use)
Egress Leg 3 - City Size	Egress mode city size
Egress Leg 3 - Time of Day	Egress mode time of day
Egress Leg 3 - Day of Week	Egress mode day of week
Egress Leg 3 - Season	Egress mode season
Egress Leg 4 - Mode	Egress mode type
Egress Leg 4 - Description	Egress mode description
Egress Leg 4 - Distance	Egress mode distance (mile)
Egress Leg 4 - Dwell	Egress mode dwell time (minutes)
Egress Leg 4 - Average Speed	Egress mode average speed (mph)
Egress Leg 4 - Fuel Source	Egress mode fuel source (as defined in 'Regional-Properties' for this egress mode)
Egress Leg 4 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 4 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 4 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 4 - Region	Egress mode region (for future use)
Egress Leg 4 - City Size	Egress mode city size
Egress Leg 4 - Time of Day	Egress mode time of day
Egress Leg 4 - Day of Week	Egress mode day of week
Egress Leg 4 - Season	Egress mode season
Egress Leg 5 - Mode	Egress mode type
Egress Leg 5 - Description	Egress mode description
Egress Leg 5 - Distance	Egress mode distance (mile)
Egress Leg 5 - Dwell	Egress mode dwell time (minutes)
Egress Leg 5 - Average Speed	Egress mode average speed (mph)
Egress Leg 5 - Fuel Source	Egress mode fuel source (as defined in 'Regional-Properties' for this egress mode)
Egress Leg 5 - Fuel Intensity	Egress mode fuel intensity (kg/pass-mile)
Egress Leg 5 - Energy Intensity	Egress mode energy intensity (kJ/pass-mile)
Egress Leg 5 - CO2e Intensity	Egress mode CO2e emission intensity (g/pass-mi)
Egress Leg 5 - Region	Egress mode region (for future use)
Egress Leg 5 - City Size	Egress mode city size
Egress Leg 5 - Time of Day	Egress mode time of day
Egress Leg 5 - Day of Week	Egress mode day of week
Egress Leg 5 - Season	Egress mode season

A.7.16 The ‘LDV-Resist’ Worksheet Pre-processor

The LDV-Resist worksheet contains the pre-processed default values for a range of 2011 vehicle classes and composite values for the ‘sales-weighted’ and ‘driven’ fleets for the years 2011, 2012 and 2013.

The worksheet also includes a preprocessor to generate future year composite parameters for sales-weighted and driven fleets. The data shown in the Fuel Economy Table at D61:M112 (see Figure A-70) is populated with data that is published annually by the EPA in its Trends Report [EPA, 2013 Carbon Dioxide Emissions and Fuel Economy Trends Report]. The data in columns E to K came from Table 10.1 and the data in columns L and M came from Appendix K of the EPA’s 2013 report. Users can fill in the rows for years 2014 to 2023 as the data becomes available. The calculations performed at cells P64:T73 provide the data for the sales-weighted composite vehicle for the relevant year and the driven-fleet composite vehicle for the same year. The driven fleet is derived for the age distribution that existed in 2011 (cells X64:X94 for corresponding ages in U64:U94) and presumes a 60/40 split for autos/LDT. If a different age distribution is desired the formula for that year would have to be updated and the age distribution brought into a new location in the worksheet. When characterization data become available for a future year the appropriate row of the Fuel Economy Table can be populated with data.

Next, the formulae in cell ranges R27:R28 and R33 to R46 of the vehicle characteristics table can be separately copied into the appropriate year’s location to the right of the existing vehicle characterization data (See Figure A-71). Given the year specified in row 30 and the fleet type (“Sales weighted composite vehicle” or “Driven fleet composite vehicle”) specified in row 32, the formulae copied into rows 27 to 28 and 33 to 46 will provide the necessary characterization data to simulate the specified composite vehicle.



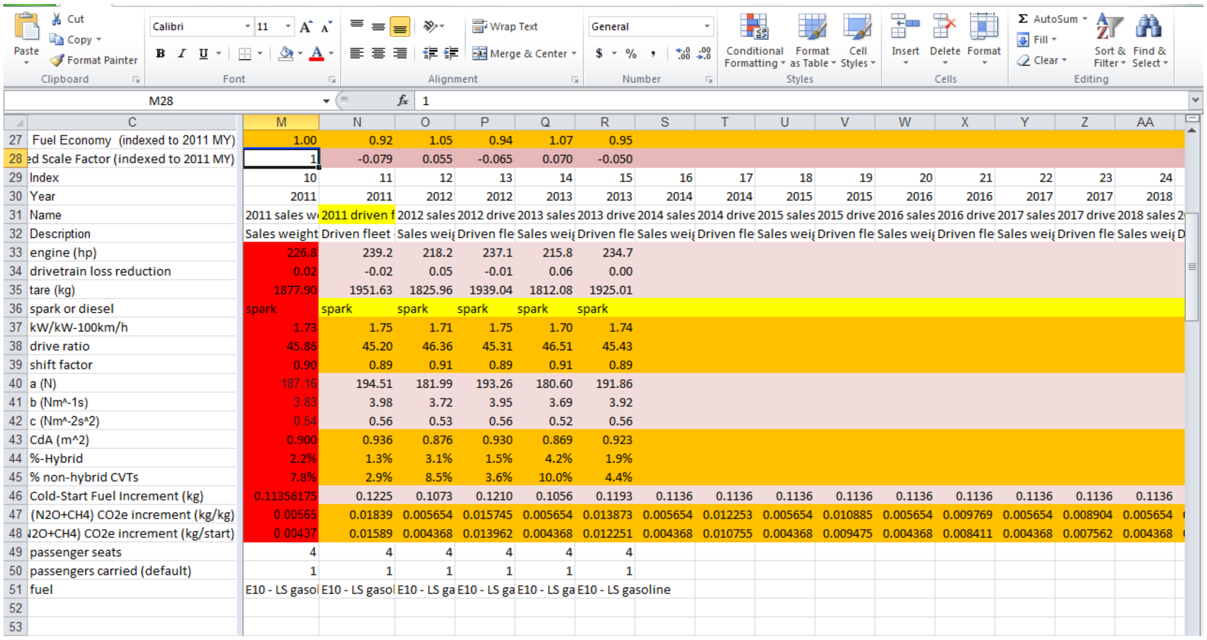
Future Year Fuel Economy and Driven Fleet Calculator (input data for future MY in Table below)

Source: EPA, 2013 Carbon Dioxide Emissions and Fuel Economy Trends Report, Section 10 Tables, Table 10.1

Source: Appendix K of same EPA 2013 report

Model Year	Unadjusted City (MPG)	Unadjusted Highway (MPG)	Unadjusted Combined (55/45) (MPG)	Adjusted City (MPG)	Adjusted Highway (MPG)	Adjusted Combined (43/57) (MPG)	Ratio of Adjusted Combined to Unadjusted Combined	%-Hybrid	%-CVT
2023									
2022									
2021									
2020									
2019									
2018									
2017									
2016									
2015									
2014									
2013	25.5	39.3	30.3	20.2	28.1	24.0	78.8%	4.2%	14.2%
2012	25.1	38.6	29.8	19.9	27.6	23.6	78.9%	3.1%	11.6%
2011	23.6	36.4	28.1	18.8	26.1	22.4	79.4%	2.2%	10.0%
2010	24.1	36.6	28.4	19.1	26.2	22.6	79.0%	3.8%	10.9%
2009	23.8	36.4	28.2	18.9	26.0	22.4	79.1%	2.3%	9.4%
2008	22.1	34.0	26.3	17.7	24.4	21.0	79.5%	2.5%	7.9%
2007	21.8	33.4	25.8	17.4	24.0	20.6	79.6%	2.2%	7.2%
2006	21.2	32.6	25.2	17.0	23.4	20.1	79.8%	1.5%	2.8%
2005	21.0	32.1	24.8	16.8	23.1	19.9	79.8%	1.1%	2.3%
2004	20.2	31.0	24.0	16.3	22.4	19.3	80.2%	0.5%	1.2%
2003	20.6	31.3	24.3	16.7	22.7	19.6	80.4%	0.3%	1.1%
2002	20.4	30.9	24.1	16.6	22.5	19.5	80.7%	0.2%	0.2%
2001	20.5	31.1	24.2	16.8	22.8	19.6	81.0%	0.0%	0.1%
2000	20.5	31.4	24.3	16.9	23.0	19.8	81.3%	0.0%	0.0%
1999	20.3	31.2	24.1	16.9	23.0	19.7	81.7%	0.0%	0.0%
1998	20.6	31.9	24.5	17.2	23.6	20.1	81.9%	0.0%	0.0%
1997	20.6	31.8	24.5	17.4	23.6	20.2	82.2%	0.0%	0.0%
1996	20.8	32.2	24.8	17.6	24.0	20.4	82.4%	0.0%	0.0%
1995	20.8	32.1	24.7	17.7	24.1	20.5	82.7%	0.0%	0.0%
1994	20.8	31.6	24.6	17.8	23.8	20.4	82.9%	0.0%	0.0%

Figure A-70 LDV-Resist Pre-processor Inputs for Future Years



	C	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
27	Fuel Economy (indexed to 2011 MY)	1.00	0.92	1.05	0.94	1.07	0.95									
28	ed Scale Factor (indexed to 2011 MY)	1	-0.079	0.055	-0.065	0.070	-0.050									
29	Index	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
30	Year	2011	2011	2012	2012	2013	2013	2014	2014	2015	2015	2016	2016	2017	2017	2018
31	Name	2011 sales w	2011 driven f	2012 sales	2012 drive	2013 sales	2013 drive	2014 sales	2014 drive	2015 sales	2015 drive	2016 sales	2016 drive	2017 sales	2017 drive	2018 sales
32	Description	Sales weight	Driven fleet	Sales weig	Driven fle	Sales weig	Driven fle	Sales weig	Driven fle	Sales weig	Driven fle	Sales weig	Driven fle	Sales weig	Driven fle	Sales weig
33	engine (hp)	226.8	239.2	218.2	237.1	215.8	234.7									
34	drivetrain loss reduction	0.02	-0.02	0.05	-0.01	0.06	0.00									
35	tare (kg)	1877.90	1951.63	1825.96	1939.04	1812.08	1925.01									
36	spark or diesel	spark	spark	spark	spark	spark	spark									
37	kW/kW-100km/h	1.73	1.75	1.71	1.75	1.70	1.74									
38	drive ratio	45.86	45.20	46.36	45.31	46.51	45.43									
39	shift factor	0.90	0.89	0.91	0.89	0.91	0.89									
40	a (N)	187.16	194.51	181.99	193.26	180.60	191.86									
41	b (Nm^-1s)	3.83	3.98	3.72	3.95	3.69	3.92									
42	c (Nm^-2s^2)	0.54	0.56	0.53	0.56	0.52	0.56									
43	CdA (m^2)	0.900	0.936	0.876	0.930	0.869	0.923									
44	%-Hybrid	2.2%	1.3%	3.1%	1.5%	4.2%	1.9%									
45	% non-hybrid CVTs	7.8%	2.9%	8.5%	3.6%	10.0%	4.4%									
46	Cold-Start Fuel Increment (kg)	0.11356175	0.1225	0.1073	0.1210	0.1056	0.1193	0.1136	0.1136	0.1136	0.1136	0.1136	0.1136	0.1136	0.1136	0.1136
47	(N2O+CH4) CO2e increment (kg/kg)	0.00565	0.01839	0.005654	0.015745	0.005654	0.013873	0.005654	0.012253	0.005654	0.010885	0.005654	0.009769	0.005654	0.008904	0.005654
48	N2O+CH4) CO2e increment (kg/start)	0.00437	0.01589	0.004368	0.013962	0.004368	0.012251	0.004368	0.010755	0.004368	0.009475	0.004368	0.008411	0.004368	0.007562	0.004368
49	passenger seats	4	4	4	4	4	4									
50	passengers carried (default)	1	1	1	1	1	1									
51	fuel	E10 - LS gasol	E10 - LS gasol	E10 - LS ga	E10 - LS ga	E10 - LS ga	E10 - LS gasoline									
52																
53																

Figure A-71 LDV-Resist Pre-processor Calculation Columns for Future Years

Appendix B

Terms, Abbreviations and Equation Variables

B.1 Terms

Balance speed	Speed at which a train’s tractive effort equals the sum of its up-grade and resistive force.
Breakeven grade	Speed at which a train’s downgrade force equals the resistive force.
Cruise segment	Portion of a trip taken at constant ‘cruise’ speed.
Cruise speed	Speed maintained on a long haul segment of a trip.
Consist	The locomotives and cars comprising a train.
Delay	Unscheduled events that add to a trips minimum travel time.
Dg-set	Diesel generator set used to generate hotel power.
Dynamic braking	Slowing a train by using traction motors to convert kinetic energy into electricity which is then dissipated as heat in resistance grids.
Hotel power	Electrical power provided for use by passenger compartments.
Regeneration	Conversion of kinetic energy into electrical energy during braking (usually back into the electricity grid or onboard storage rather than simply dissipated as heat as in dynamic braking).
Schedule slack	Time allowance built into a schedule in excess of the minimum run time to accommodate unscheduled delays.
Steps	Segments of track processed in one calculation row of the rail simulation sheet (segments are normally based on lengths of constant posted speed).
Tractive effort	The propulsive force generated at a powered axle’s wheel (mostly by electric traction motors).
Wayside	At the side of the tracks.

B.2 Abbreviations

ABA – American Bus Association
AC – Aircraft
AREMA – American Railway Engineering and Maintenance-of-Way Association
ATRI – American Transportation Research Institute
Bsfc – Brake specific fuel consumption
BTS – Bureau of Transportation Statistics
CN – Canadian National
CVT – Continuously variable transmission
CY – Calendar year
D – Destination
DEM – Digital elevation models
DMU – Diesel multiple unit
DOT – Department of Transportation
EMU – Electric multiple unit
FE – Fuel economy
FW – Freeway
GC – Great circle
GHG – Greenhouse gas
GHGeq – Greenhouse gas equivalent
HEP – Head-end power
HSR – High speed rail
ICAO – International Civil Aviation Organisation
IPCC – Intergovernmental Panel on Climate Change
IR – Inherent resistance
LDT – Light duty truck
LDV – Light duty vehicle
LOS – Level of service (a highway capacity metric)
LTO – Landing and takeoff
MBTA – Massachusetts Bay Transportation Authority
MY – Model year
NBJ – Narrow body jet
NCDC – National Climate Data Center
NTD – National Transit Database

O	– Origin
OD	– Origin-destination
pGCkm	– passenger great circle kilometer
PL	– Payload
RDC	– Rail diesel car
RF	– Radiative forcing
RJ	– Regional jet
sGCkm	– seat great circle kilometer
skm	– seat kilometer
SRJ	– Small regional jet
TE	– Tractive effort
TP	– Turboprop
TSO	– Temporary slow order
UDDS	– Urban Dynamometer Driving Schedule
VHSR	– Very high speed rail
Vkm	– vehicle kilometer
WBJ	– Wide body jet
WGI	– Working Group I

B.3 Equation Variables

a	Coefficient
A	Acceleration
A	Frontal area
b	Coefficient
Cd	Aerodynamic drag coefficient
Cra	Coefficient of rolling resistance & hysteresis
Crai	Tractive effort envelope coefficient
Crb	Coefficient of dynamic resistance
Crbi	Tractive effort envelope coefficient
Crc	Coefficient of aerodynamic resistance
Crci	Tractive effort envelope coefficient
Crdi	Tractive effort envelope coefficient
dt	Time step
Fh	Hotel power diesel generator set fuel consumption rate
g	Gravitational acceleration
Gbe	Breakeven down grade
Gmx	Maximum grade that can be climbed at cruise speed
IR	Inherent Resistance
Kr	Mass-equivalent rotational inertia of an axle
M	Mass
Na	Number of axles
P	Power
R	Ratio of cold-start/hot start fuel increment
SF	Scale factor for aerodynamic drag
t	Time
T	Temperature
TE	Tractive effort
TEi	Tractive effort
Ta	Ambient temperature
V	Speed
ρ	Density of air