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L'évolution de la planification du transport

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User Guide – SANDAG Travel Model in Emme

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1. Overview

This user guide documents the SANDAG travel demand model as implemented using the Emme modelling framework and components (traffic and transit assignments and aggregate demand modelling tools), integrated with disaggregate demand model components (CT-RAMP family of activity-based models). It also provides “how-to” instructions for master run model operation (see page 10) and the operation of the components implemented within the Emme framework.

This user guide has a companion report "Comparison and Validation - SANDAG Travel Model in Emme" which documents the comparison of the SANDAG travel model conversion to Emme against the previous implementation and the validation of the updated model.

Emme is a complete travel demand modelling system for urban, regional and national transportation forecasting. Emme offers a transport modelling application framework for leading computational performance and promotes true model transparency and offers an easy transition between interactive use and modern scripting using Python.

The Emme components of the SANDAG model are implemented as a set of discrete components in the Python scripting language, using Emme APIs, and Emme assignment, analysis, calculators and other modelling procedures. Each component is provided as a separate Emme Modeller tool which can be run independently with its own user interface and logging and reporting services. The entire model can be configured and executed using the *Master run* tool.

The tools are packaged and delivered as a Modeller toolbox within the Emme project. The main model components implemented in this framework are:

- Traffic assignment and skims
- Transit assignment and skims
- Truck demand model for heavy trucks within, into, out of and through San Diego
- Commercial vehicle model for other goods and services movements within San Diego
- An external-internal travel model covering non-resident travel into and out of San Diego made by non-Mexican residents (USA-SD)
- An external-external travel model covering travel through the San Diego region

In addition to the main components, there are also tools for select *element* type network analysis for traffic and transit, tools for reporting and data management.

Further information on disaggregate demand model components (for San Diego residents’ travel and other special market travel) can be found in other reports such as the Activity-Based Travel Model User’s Guide.

2. Model conversion summary

This section highlights the key changes in model implementation during the conversion to Emme. The main goal of the conversion project was to replace the previous traffic and transit assignments, aggregate demand model components, and other ancillary tools with equivalent Emme procedures. Most components were mapped to direct "drop-in" replacements with few model procedure changes.

Previous GISDK scripts files have been replaced by Emme Modeller tools implemented as Python scripts. There is a general mapping of previous files to new tools, however there are a couple of exceptions:

- Both `createhwynet.rsc` and `createtrnroutes.rsc` are replaced by the *Import network* tool

- The separate assignment and skim scripts (`hwyassign.rsc` / `hwyskim.rsc` and `trnassign.rsc` / `trnskim.rsc`) are replaced by single scripts which completes the assignment and generates the required skims for traffic and transit respectively
- The external-external model step is implemented as a separate tool
- Truck model steps have been broken out into separate generation and distribution steps with a Run truck model tool to execute the two procedures

The other significant change is the use of open matrix format (OMX) files for data exchange of skims and demand between the Emme network model, environment CT-RAMP and other Java-based procedures. Corresponding import from / export to OMX tools are in the SANDAG toolbox. The Java procedures and UEC definitions have also been updated to read / write the corresponding matrices from / to the new OMX files.

The traffic assignment now includes the turn penalties and prohibitions (turn bans) in all the model iterations. Previously, the turn details were only enabled for the final model iteration. The link lengths are now imported as specified in the source (trcov.e00) file, instead of being re-computed as in the previous model. There is a very small (average of 0.04%) discrepancy between the lengths which does result in a correspondingly very small difference in the calculated auto operating costs and assignment results. The generalized cost skims for the medium and heavy truck are calculated using the same values-of-time (VOTs) and operating cost as specified in the assignment. Previously they were calculated using the SOV tolls plus operating cost and VOT on the truck-accessible network. This is an important improvement as the skimmed values now correspond correctly with the assignment for the truck classes.

The transit network files which were previously generated in a binary format are now in CSV format. These include `trrt.csv`, `trlink.csv` and `trstop.csv`. A file `special_fares.txt` has been added to represent zonal fares using incremental boarding and in-vehicle costs.

One new key has been added to the `sandag_abm.properties` file: `skipInitialization`. If this key is True, the `Transit_database` and matrix initialization steps are skipped.

The transit network assignment model (transit path builder) is a more sophisticated algorithm than used previously in that it produces richer transit passenger routings through more paths (further discussed under *Transit assignment* on page 26). The transit impedances (generalized cost) are generally the same or shorter than those from previous versions. Note that the relative breakdown between different sub-components of travel impedance can be different (the amount of waiting time vs. walking time vs. time in-vehicle) even when the total generalized cost is quite similar. The same transit assignment parameters are used, with an increased transfer penalty (factor of 5), and additional fare representation implementation.

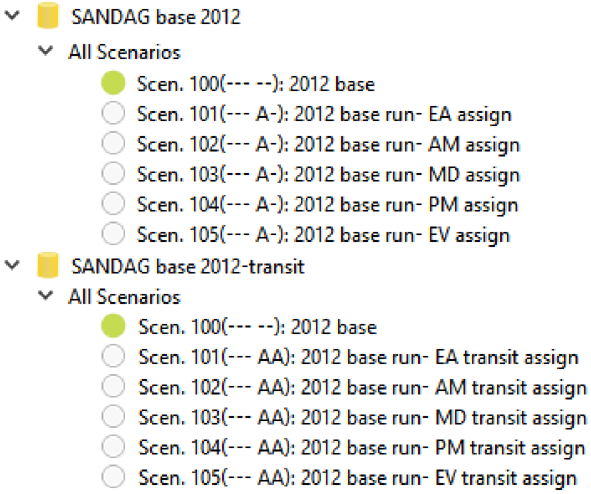
3. System design

The model is implemented using two frameworks: i) Assignments and aggregate demand model components implemented using Python and Emme, and ii) the CT-RAMP family of activity-based models in Java. The main interchange between these two frameworks are skim and demand matrices stored in OMX files. The model is operated and controlled from Emme using the *Master run* tool.

There are two different zone systems used in the Emme models: one for traffic and one for transit. The traffic assignment demand and skims are based on 4,996 Traffic Analysis Zones (TAZ) and the transit assignment demand and skims are based on 1,766 (for the base 2012 year) Transit Access Points (TAP). (The number and location of TAPs can change in different networks.) The zone systems and corresponding network and matrices are maintained in two distinct Emme databases.

The main Emme database (located under the `Database` directory) contains the combined traffic and transit networks, TAZ system, traffic demand and skim matrices as well as the traffic result scenarios. The second transit Emme database (located under the `Database_transit` directory) contains the TAP zone system with the transit demand, skim matrices and transit result scenarios (see Figure 1). Additional information on the file system setup is found in *Section 4* on page 7.

The first base scenario (*Scenario 100*) contains the imported data from the E00 (and associated) files with all inputs for all time periods. These files are generated from the TCOVED network manager. To contain the results for each of the five time period assignments, the base scenario is copied to five additional scenarios. The base database may contain an extra *Scenario 1: Empty scenario*, which is part of the template Emme project, but can be deleted after the model run.



SANDAG base 2012
All Scenarios
● Scen. 100(--- --): 2012 base
○ Scen. 101(--- A-): 2012 base run- EA assign
○ Scen. 102(--- A-): 2012 base run- AM assign
○ Scen. 103(--- A-): 2012 base run- MD assign
○ Scen. 104(--- A-): 2012 base run- PM assign
○ Scen. 105(--- A-): 2012 base run- EV assign
SANDAG base 2012-transit
All Scenarios
● Scen. 100(--- --): 2012 base
○ Scen. 101(--- AA): 2012 base run- EA transit assign
○ Scen. 102(--- AA): 2012 base run- AM transit assign
○ Scen. 103(--- AA): 2012 base run- MD transit assign
○ Scen. 104(--- AA): 2012 base run- PM transit assign
○ Scen. 105(--- AA): 2012 base run- EV transit assign

Figure 1 - Emme project setup with base (SANDAG base 2012) and transit (SANDAG base 2012-transit) databases and result scenarios after model run.

Model description

The SANDAG travel demand model imports network details from ArcInfo Interchange Files (`.E00`) (for the nodes and links), text (`.csv`) and data (`.dbf`) files (for the transit routes, turn restrictions and other network attributes). A base Emme scenario is created from the merged traffic and transit data, with attributes for all time periods. The main zone system corresponds to the TAZs (Traffic Analysis Zones) for the traffic assignment; while the TAPs (Transit Access Points) for the transit assignment are applied in a separate transit assignment database.

The traffic and transit networks include many attributes by time-of-day (see *Attribute name mappings* on page 42). The transit network includes parameters which vary by mode, route, or stop such as fares, transfer times and perceptions, wait time perceptions, as well as route-to-route-specific transfer wait times (see *Transit assignment* on page 26 for more details).

The bike and walk travel times and logsums are calculated from their route choice models implemented as Java procedures, or may be copied from pre-computed files to save runtime. Warm start demand for traffic (auto and truck) is imported and the initial traffic and transit assignments are run in Emme. The traffic demands are separated into eight auto classes plus six truck classes to represent SOV, HOV2, HOV3+, and light, medium and heavy trucks, further split into general purpose lanes only (GP) and toll, as well as HOV lanes for the HOV classes.

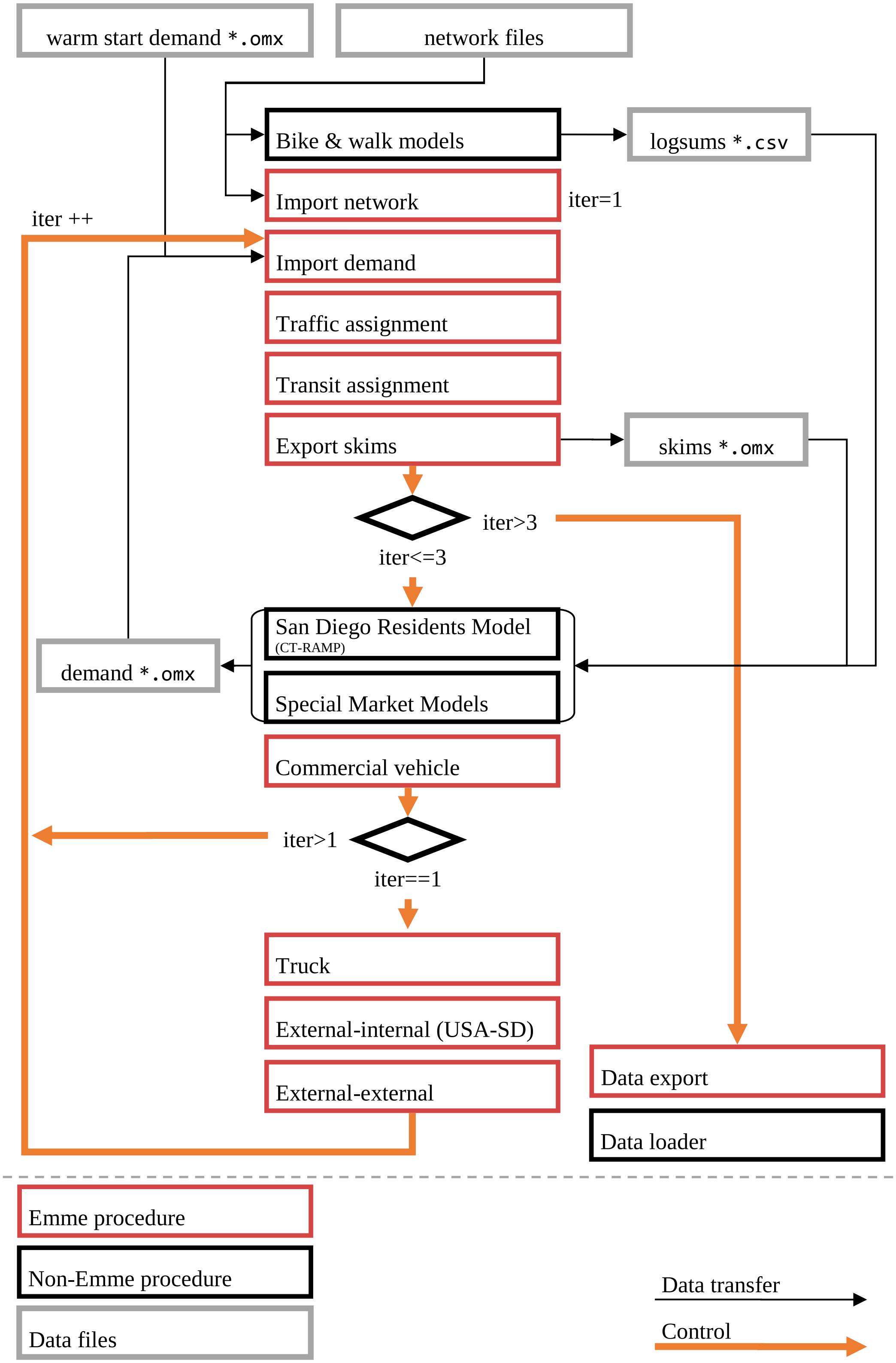


Figure 2 - System diagram of main model steps and data transfer between Emme and non-Emme procedures

The transit vehicles are input as background traffic flow in the traffic assignment, and the congested link travel times from the traffic assignment are used in the transit assignment for bus routes in mixed traffic. The transit assignments use two configurations of parameters: one for local bus-only demand and one for all modes (that is, including premium modes). The final assigned flows for transit includes 15 slices of demand by access mode (walk, PNR, KNR) and primary mode (local bus, express bus, BRT, LRT, commuter rail). Once the assignments finish, the traffic and transit skims are exported to OMX files.

Once the skims are complete, the CT-RAMP simulation models are initiated which import skims from these OMX files. For operational purposes, the models are separated into general travel by San Diego residents and a set of special market models which includes: trips to and from the San Diego airport; cross-border trips by Mexican residents; trips by visitors staying within San Diego; and special event trips. Upon completion, the zone-to-zone demands (TAZ for traffic, TAP for transit) are exported to OMX for each of the disaggregate demand models.

The aggregate commercial vehicle, truck, external-internal and external-external models are then run. Note only the first of these is run every iteration, while the final three are only run for the initial iteration (this is an adopted methodology to optimize runtime which was carried over from the previous implementation). These models operate directly on the Emme database, using the saved skims from the assignments and saving the demand matrices within the database. After the demand models are all completed, the demands from the disaggregate models are imported from OMX and summed up by mode and time-of-day, along with the commercial vehicle, external-internal and external-external auto demands for the next iteration of assignments and skims.

The demand model components are run for three iterations, with the traffic and transit assignments run four times. After the model run is completed, the assignment (network) results, skims and demands are exported to OMX and CSV files for later import into a database for reporting services.

4. Setup

A travel model scenario consists of both application and data files organized in a specific directory structure. A SANDAG travel model scenario contains 12 directories: `application`, `bin`, `conf`, `emme_project,` `input`, `input_truck`, `logFiles`, `output`, `sql`, `python`, `uec`, and `report` (see Figure 3).

- The `application` directory contains ABM model jar file `sandag_abm.jar` and third-party libraries.
- The `bin` directory contains command line batch files to run ABM from DOS, a batch file to set environmental variables, and the stand-alone executables like `psexec` and `pskill`.
- The `conf` directory contains the model configuration files, Java instructions and properties files, and the Java logging files.
- The `emme_project` directory contains the Emme-related data and settings, as well as the scripts to run the model, including highway, transit skims, and assignment, as well as commercial vehicle model, the external model, and the truck model.
- The `uec` directory contains the Utility Expression Calculator (UEC) files that specify the choice models.
- The `input` directory contains the input files required to run the specific scenario.
- The `input_truck` directory contains all truck model input files.
- The `logFiles` contains all logging files created during a model run, including logging from the client, logging for each computing node, and logging for specific ABM modules. These files will contain debugging information in case of an error; the same information is also logged in the Modeller Logbook.

- The `output` directory contains all ABM outputs, including both intermediate and final outputs, such as trip lists, trip tables by mode, highway, transit and bike assignment results, highway and transit skimming results, and EMFAC summaries.
- The `sql` directory contains all SQL scripts for creating ABM database structure and data loading. At the end of each model run, results in the output directory are loaded into a SQL database, which serves as the foundation for system performance summary and statistical analysis.
- The `python` directory contains all Python scripts for creating EMFAC2011 and EMFAC2014 input files.
- The `report` directory contains the network and matrix results at the end of the model run for processing by the data loader.

Prior to a model run, the `emme_project` directory is a template project with a pre-configured Emme database and project settings, but not yet populated with data. This template Emme project configured for use with the SANDAG model can be generated using the "`init_emme_project.py`" script found in the SANDAG github under `ABM\src\main\emme`. This script can be run from a command line with the Emme libraries installed under python. Use "`python init_emme_project.py -h`" or "`--help`" for usage instructions.

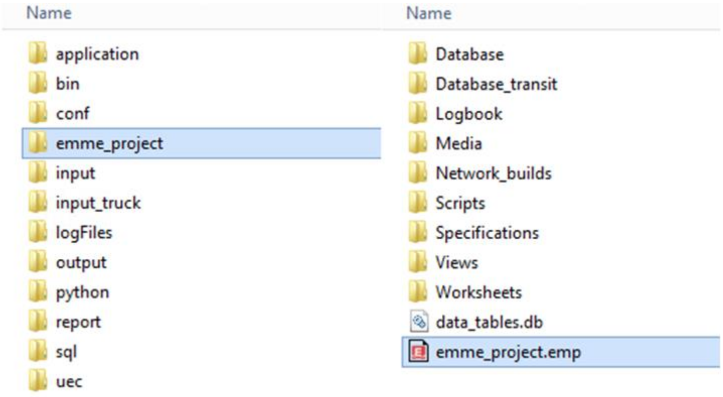


Figure 3 – ABM scenario directory structure

Below is a complete list of the Emme project directories and a description of their contents. Note that most of the content and structure is standard for an Emme project, except the `Database_transit` directory which is a custom for the SANDAG model.

- `Database`: contains the main Emme data (Emmebank, matrix files, network attribute and shape files) with both traffic and transit input data, and the traffic results and matrices.
- `Database_transit`: contains the transit results and matrix data (using the TAP zone system). Created during a model run (not present in template project).
- `Logbook`: contains the Modeller logbook and associated files.
- `Media`: contains image files, shapefiles and DBF files.
- `Network_builds`: contains the saved build files from the Network editor.
- `Scripts`: contains the `sandag_toolbox.mtbx` script and Emme Notebook scripts.
- `Specifications`: contains project specific tool specifications.
- `Views`: contains network views created with Emme.
- `Worksheets`: contains links to General worksheets and tables, plus any saved worksheets or tables. Custom worksheet files can be added here to be available in the Emme Desktop.
- `data_tables.db`: the data tables database.

- emme_project.emp: the main Emme project settings file. Open (double-click) to the launch the Emme Desktop with this project.

The sandag_toolbox.mtbx contains the Python scripts which implement the assignments, aggregate demand models, master run and other auxiliary model steps. The toolbox must be present under the emme_project/Scripts directory to run the model (this step is included in the "init_emme_project.py" script). A separate script which generates the toolbox file "build_toolbox.py" is found in the SANDAG github at ABM\src\main\emme\toolbox. Use "python build_toolbox.py -h" or "--help" for more.

The input directory contains the input files required to run the specific scenario, including a MGRA-based land use input file, synthetic population files, highway network files, transit network files, bike network files, network access files such as walk and bike time/logsums between MGRAs and TAZs, special market model input files, as well as warm start trip tables. More specifically, the input directory contains the following types of data (see Input Files section for details on each file):

- MGRA-based land use inputs
- PopSyn data
- Network: highway
- Network: transit
- Network: bike
- Network: auxiliary
- Intermediate: calculated accessibilities data and shadow pricing files
- Special market: Airport Model data
- Special market: Commercial Vehicle Model data
- Special market: Cross Border Model data
- Special market: External Model data
- Special market: Special Event Model data
- Special market: Visitor Model data
- Commercial Vehicle Model data
- Warm start trip tables from previous model runs

The uec files are used by the CT-RAMP UEC Java package to both locate input variables and specify utility equations that describe each discrete choice. The input variables and specifications are defined and stored in a Microsoft Excel workbook. The use of Excel enhances the flexibility and transparency of the model system -- utility coefficients, model structures, etc., can be edited via Excel (rather than via difficult to follow text files or source code). Each UEC workbook (i.e. Excel file) consists of at least two worksheets. One must be the UEC datasheet, which defines the input files used in the utility expressions, including zonal (vector) data and level-of-service "skims" (matrix data). The second, third, fourth, etc. page specifies one or more multinomial or nested logit models via a unique UEC utility sheet. The utility sheet consists of three sections, as follows:

1. The first section specifies the nesting structure of the logit model -- if omitted, a multinomial structure is assumed;
2. Next, variable names, or tokens, are defined for use in subsequent (moving down rows) utility equations; and,
3. The final section defines the utility terms, typically a variable and a coefficient for each of the logit model's alternatives.

The CT-RAMP Java code controls model flow, handles output files (e.g., trip tables, tour records), facilitates debugging, and allows for the UECs to access variables stored in memory (e.g., the results from upstream logit models). The UEC solve method returns an array of doubles dimensioned to the number of alternatives specified in the utility sheet. The array contains the sum-product of each of the formulas and coefficients for each alternative, which is the utility for each alternative. This array can then be used with a logit model object to first compute alternative probabilities and then simulate choices.

Emme comes with a distribution of Python 2.7 that is configured to work with the Emme APIs. If third-party Python libraries are required, the *Python path* (under Application Options) may be changed to use a different Python installation. The Emme libraries must also be installed in this Python installation using the **Install Modeller Package** button. For further details on configuring a custom installation see "Python path" in the Emme help.

5. Model operation and Master run tool

The following section serves as an overview of the *Master run* tool and quick start guide. For additional details on the model steps and other tools, see *Section 6: SANDAG Toolbox and Tools*.

The SANDAG travel demand model is executed via the *Master run* tool, which can be run from Emme Modeller. To access the Master run tool, start from a project configured as described under *Section 4: Setup*. Open Emme Desktop using the "`emme_project/emme_project.emp`" file, and open the Emme Modeller window, from the ■ icon in the toolbar, or from the menu under *Tools* -> *Modeller*. From the Modeller window, open the *SANDAG toolbox* in the left-hand pane, and double-click on the Master run tool as shown in Figure 4 (see also the *SANDAG toolbox* shown in Figure 8 on page 17).

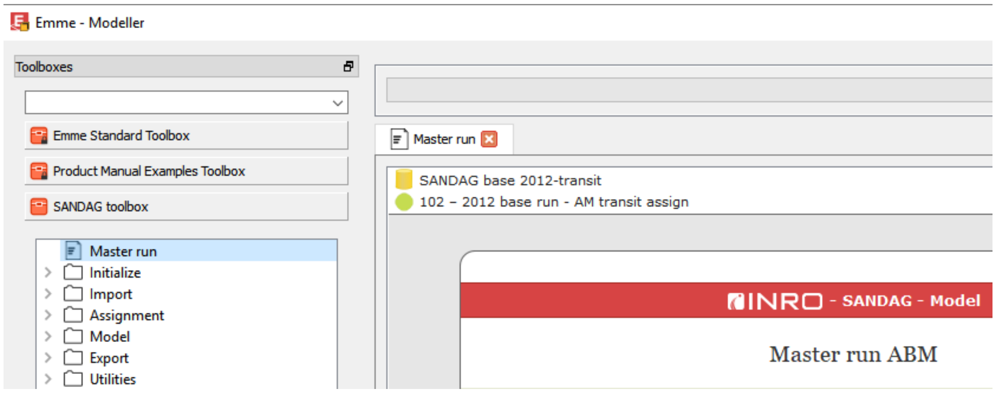


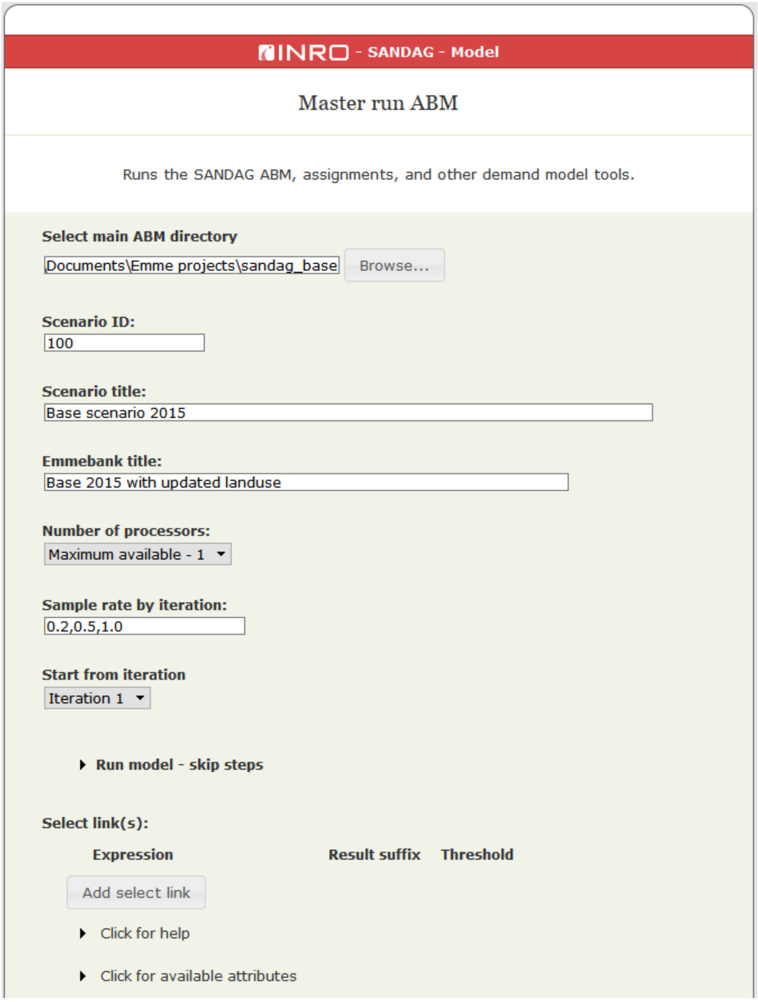
Figure 4 - The Modeller window and *Master run* tool

Master run tool

The *Master run* tool is the operates the SANDAG travel demand model. It operates all the model components as described in *Section 3: System design*. To operate the model, configure the inputs as described below, and click the **Run** button at the bottom of the tool page. For reference, the *Master run* tool UI is shown in Figure 5 (next page).

- *Main ABM directory*: directory which contains the ABM scenario data, including this project. The default is the parent directory of the current Emme project.
- *Scenario ID*: Scenario ID for the base imported network data. The result scenarios are indexed in the next five scenarios by time period.
- *Scenario title*: title to use for the scenario.
- *Emmebank title*: title to use for the Emmebank (Emme database)
- *Number of processors*: the number of processors to use for traffic and transit assignments and skims, aggregate demand models (where required) and other parallelized procedures in Emme. Default is *Max available – 1*.

- Properties (`conf/sandag_abm.properties`)
  - On opening the *Master run* tool the `sandag_abm.properties` file is read and the values cached and the inputs below are pre-set. When the Run button is clicked this file is written out with the values specified. Any manual changes to the file in-between opening the tool and clicking the Run button are overwritten.
    - *Sample rate by iteration*: three comma-separated values for the CT-RAMP sample rates for each iteration
    - *Start from iteration*: start iteration for the model run
    - *Skip steps*: optional checkboxes to skip model steps.
- *Select link*: add select link analyses for traffic. See the Select link analysis section under the *Traffic assignment* tool (page 23) for details on how to setup a select link analysis.



INRO - SANDAG - Model

Master run ABM

Runs the SANDAG ABM, assignments, and other demand model tools.

Select main ABM directory
Documents\Emme projects\sandag_base

Scenario ID:
100

Scenario title:
Base scenario 2015

Emmebank title:
Base 2015 with updated landuse

Number of processors:
Maximum available - 1

Sample rate by iteration:
0.2,0.5,1.0

Start from iteration
Iteration 1

Run model - skip steps

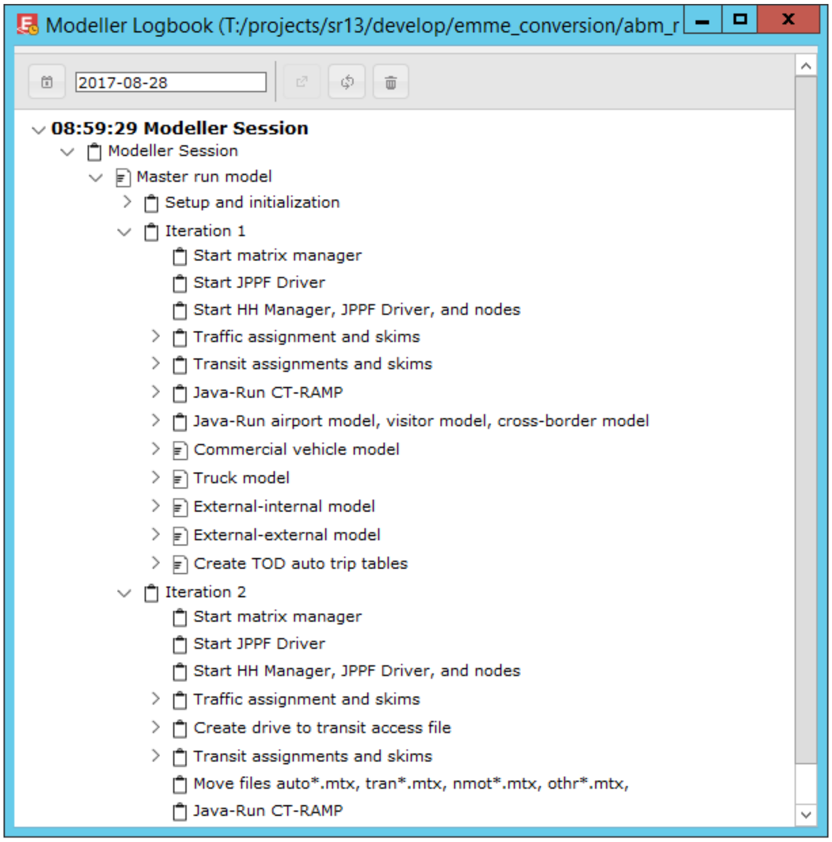
Select link(s):

Expression Result suffix Threshold

Figure 5 - *Master run* ABM tool user interface

As the model runs, a full runtime trace of the model steps, inputs and reports is recorded in the Modeller Logbook. As each step completes, it will record an entry in the Logbook along with reports and other results. The Logbook can be opened from the 🕒 icon in the upper right of the Modeller window. This icon can also be found in the toolbar in the Emme Desktop. If a Modeller tool is running, a window will pop-up over the Emme Desktop which includes a "**Show Logbook**" button (this window can be closed to use Desktop worksheets and tables while any tool is running). Click on the **Refresh** button to update the logbook view with the latest status.

The Logbook provides a real time, automated documentation of the model execution. The overall structure of the model is represented at the top level, with the occurrence, sequence and repetition of the steps involved in the model process. Nested Logbook entries may be collapsed or expanded to see detail. For the Emme assignment procedures, interactive charts are recorded. The statistical summaries of the impedance matrices are recorded for each time period (see Figure 7) following the assignment. These summary tables provide an easy way to check for skims with obvious outlier values.


Modeller Logbook (T:/projects/sr13/develop/emme_conversion/abm_r

2017-08-28

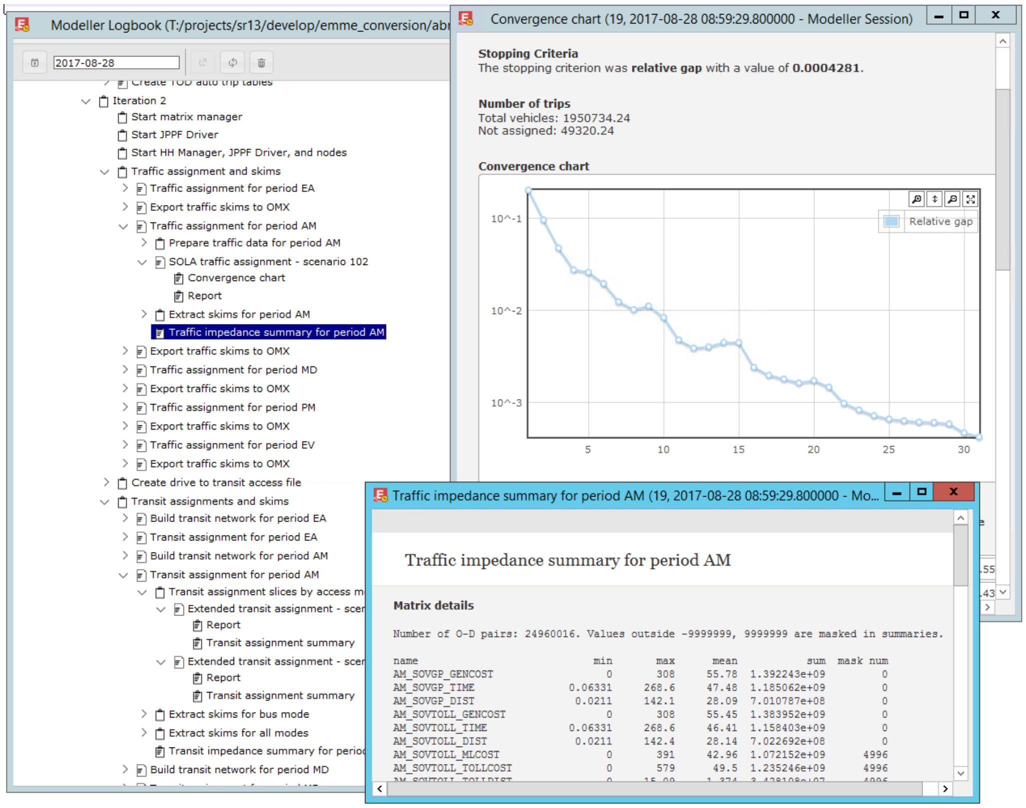
- 08:59:29 Modeller Session
  - Modeller Session
    - Master run model
      - Setup and initialization
      - Iteration 1
        - Start matrix manager
        - Start JPPF Driver
        - Start HH Manager, JPPF Driver, and nodes
        - Traffic assignment and skims
        - Transit assignments and skims
        - Java-Run CT-RAMP
        - Java-Run airport model, visitor model, cross-border model
        - Commercial vehicle model
        - Truck model
        - External-internal model
        - External-external model
        - Create TOD auto trip tables
      - Iteration 2
        - Start matrix manager
        - Start JPPF Driver
        - Start HH Manager, JPPF Driver, and nodes
        - Traffic assignment and skims
        - Create drive to transit access file
        - Transit assignments and skims
        - Move files auto*.mtx, tran*.mtx, nmot*.mtx, othr*.mtx,
        - Java-Run CT-RAMP

Figure 6 – Logbook output following a model.

For the Java CT-RAMP models the command-line (`stdout`) and error (`stderr`) output are captured and recorded as a report inside the Logbook.

Open a logbook entry to see additional details such as timestamps and input values. If there was an error during a model run the error message and Python traceback will be recorded here as well. For any entry created by a tool (look for the tool icon), the **Launch** button on the Modeller toolbar can be used to reload a snapshot of the tool to view and revise tool inputs and re-run. This includes the Master run and other custom SANDAG tools.

The traffic assignments can be distributed across multiple machines, as specified in the `server-config.csv` file under the `conf` directory. The midday and early AM periods will be run on the first remote machine, the PM peak and evening periods on the second remote machine and the AM peak assignment will run locally on the master machine. The flows for the traffic assignments are blended between the iterations using MSA.


Modeller Logbook (T:/projects/sr13/develop/emme_conversion/abr
2017-08-28
Create TOD auto trip tables
Iteration 2
Start matrix manager
Start JPPF Driver
Start HH Manager, JPPF Driver, and nodes
Traffic assignment and skims
Traffic assignment for period EA
Export traffic skims to OMX
Traffic assignment for period AM
Prepare traffic data for period AM
SOLA traffic assignment - scenario 102
Convergence chart
Report
Extract skims for period AM
Traffic impedance summary for period AM
Export traffic skims to OMX
Traffic assignment for period MD
Export traffic skims to OMX
Traffic assignment for period PM
Export traffic skims to OMX
Traffic assignment for period EV
Export traffic skims to OMX
Create drive to transit access file
Transit assignments and skims
Build transit network for period EA
Transit assignment for period EA
Build transit network for period AM
Transit assignment for period AM
Transit assignment slices by access m
Extended transit assignment - scen
Report
Transit assignment summary
Extended transit assignment - scen
Report
Transit assignment summary
Extract skims for bus mode
Extract skims for all modes
Transit impedance summary for period
Build transit network for period MD
Convergence chart (19, 2017-08-28 08:59:29.800000 - Modeller Session)
Convergence chart
10^-1
10^-2
10^-3
5
10
15
20
25
30
Relative gap
Traffic impedance summary for period AM (19, 2017-08-28 08:59:29.800000 - Mo...

Stopping Criteria
The stopping criterion was **relative gap** with a value of **0.0004281**.

Number of trips
Total vehicles: 1950734.24
Not assigned: 49320.24

Traffic impedance summary for period AM

Matrix details

```
Number of O-D pairs: 24960016. Values outside -9999999, 9999999 are masked in summaries.

name                          min       max      mean           sum  mask num
AM_SOVGP_GENCOST                0       308     55.78  1.392243e+09         0
AM_SOVGP_TIME             0.06331     268.6     47.48  1.185062e+09         0
AM_SOVGP_DIST              0.0211     142.1     28.09  7.010787e+08         0
AM_SOVTOLL_GENCOST              0       308     55.45  1.383952e+09         0
AM_SOVTOLL_TIME           0.06331     268.6     46.41  1.158403e+09         0
AM_SOVTOLL_DIST            0.0211     142.4     28.14  7.022692e+08         0
AM_SOVTOLL_MLCOST               0       391     42.96  1.072152e+09      4996
AM_SOVTOLL_TOLLCOST             0       579      49.5  1.235246e+09      4996
```

Figure 7 - Logbook and traffic impedance summaries and assignment convergence chart

Scripted operation

The Master run tool can be started via a Python interpreter with the Emme APIs (Modeller library) installed. It is easiest to run via the Emme Notebook where the connection to the Desktop is already made. The example code snippet below illustrates starting a single model run on the current project. The setup lines if running from the Emme Notebook are shown first, followed by the setup lines required if using an external Python environment.

```
import inro.modeller as _m
import os

# if running from within the Emme Notebook
modeller = _m.Modeller()
desktop = modeller.desktop

# if running from an external Python / command-line / IDE / etc.
import inro.emme.desktop.app as _app
desktop = _app.start_dedicated(True, "INRO",
   "<path/to>/emme_project/emme_project.emp")
modeller = _m.Modeller(desktop)


master_run = modeller.tool("sandag.master_run")
main_directory = \
   os.path.dirname(os.path.dirname(desktop.project_path()))
scenario_id = 100
scenario_title = "Base 2015 scenario"
emmebank_title = "Base 2015 with updated landuse"
num_processors = "MAX-1"
master_run(main_directory, scenario_id, scenario_title,
   emmebank_title, num_processors)
```

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Model runtime

Model runtime was benchmarked on Jayhawk (Machine details: Xeon E5-2690 v3 @ 2.60 GHz dual processor / 48 threads, 7200 rpm hard disk, 256GB RAM (server name jayhawk) with Emme project data accessed from a network drive. The base 2012 model run completed in 33hr25min, including intermediate data conversions from/to OMX and the export of results for the SQL Server data loader. Table 1 summarizes model runtime by iteration.

Model runtime improved slightly to 31hr48mn with Emme project data accessed on a local disk, but this result does not include the extra time required to offload the data to the remote drive. The Emme network and zonal aggregate demand model procedures represent 4hr5mn of the total model runtime as detailed in Table 2.

Table 1 - Summary of model runtime by model step.

Step	Runtime (hr:min)
Setup, initialization, and import network	0:13
Iteration 1 (20% sample rate)	5:56
Iteration 2 (50% sample rate)	9:56
Iteration 3 (100% sample rate)	15:00
Final assignments and data export	2:21
Total	33:25

Table 2 - Summary of model runtime by major model component.

Component	Runtime (hr:min)
Traffic assignments and skims	3:07
Transit assignments and skims	0:44
Aggregate demand models	0:12
CT-RAMP demand models	27:02
Emme export to / import from OMX	1:05
Data export for data loader	1:03

6. SANDAG Toolbox and Tools

The *SANDAG toolbox* contains all the model steps and auxiliary components, and can be distributed as a single file, `sandag_toolbox.mtbx` (see *Section 4* on page 7 for details on how to generate the toolbox file).

Each step is implemented as a Modeller tool in a single Python script. The toolbox interface (with the full list of tools) is pictured in Figure 8 on page 17. A detailed list of tools is found in Table 3 (following pages), along with the tool namespace (unique ID), file path in the SANDAG ABM github repository, and a brief description of each tool's purpose.. Each of the tools has its own user interface and may be run individually, though most tools will normally only be run as part of a full model run via the Master run tool.

The tools are implemented using standard Modeller API components. For an introduction to Modeller tool scripts see the *Modeller API Guide*, from the Emme start menu, or the Help menu in the Emme Desktop. For a detailed reference of available Emme APIs, including the Modeller API, see the *Emme API Reference*. Note that when making edits to script files the toolbox should be generated with the `link` option (see `build_sandag_toolbox.py` script on page 9), so that the tools can be *refreshed* with the latest script changes.

Operation of the tools is described in further detail in the following sections.

Table 3 - List of tools in SANDAG toolbox

Tool name	**Namespace** **File location under SANDAG ABM github /src/main/emme/** **Description**

Master run	`sandag.master_run`
	`toolbox/master_run.py`
	Main model run point and user interface. Executes all model steps including disaggregate models and other Java procedures. See Master run tool (page 10).

Initialize transit database	`sandag.initialize.initialize_transit_database`
	`toolbox/initialize/initialize_transit_database.py`
	Initializes Emme database for transit assignments under the `'Database_transit'` directory. Generates the TAP zone system based on the defined TAP nodes in the base scenario imported from the network files.

Initialize matrices	`sandag.initialize.initialize_matrices`
	`toolbox/initialize/initialize_matrices.py`
	Initializes the matrix IDs, names and descriptions in the Emme database. Note that this tool identifies all the matrices which are used.

Import network	`sandag.import.import_network`
	`toolbox/import/import_network.py`
	Imports the traffic and transit networks from the input network files.

Import seed demand	`sandag.import.import_seed_demand`
	`toolbox/import/import_seed_demand.py`
	Imports demand values from the specified OMX files (auto, truck and transit).

Import auto demand	`sandag.import.import_auto_demand`
	`toolbox/import/import_auto_demand.py`
	Imports the resident and special market demands stored in pre-defined OMX files and adds the CV, external-internal and external-external demand matrices stored inside the Emme database.

Import transit demand	`sandag.import.import_transit_demand`
	`toolbox/import/import_transit_demand.py`
	Imports the resident and special market demands stored in pre-defined OMX files.

Traffic assignment	`sandag.assignment.traffic_assignment`
	`toolbox/assignment/traffic_assignment.py`
	Assigns the 14 classes of traffic demand to the network for the specified time period and calculates the required skim matrices. Supports multiple simultaneous select link / zone analyses.

Build transit scenario	`sandag.assignment.build_transit_scenario`
	`toolbox/assignment/build_transit_scenario.py`
	Builds the transit network scenario for the specified period based on existing base (traffic + transit) scenario. Scenario data is copied from the base (traffic) database to the transit database (under the `Database_transit` directory).

Transit assignment	`sandag.assignment.transit_assignment`
	`toolbox/assignment/transit_assignment.py`
	Assigns the transit demand to the network for the specified period and calculates the required skim matrices.

Transit select analysis	`sandag.assignment.transit_select_analysis`
	`toolbox/assignment/transit_select_analysis.py`
	Runs the select link / node / line / … based on the results from the transit assignment. Used as a post-process tool following an assignment or full model run.

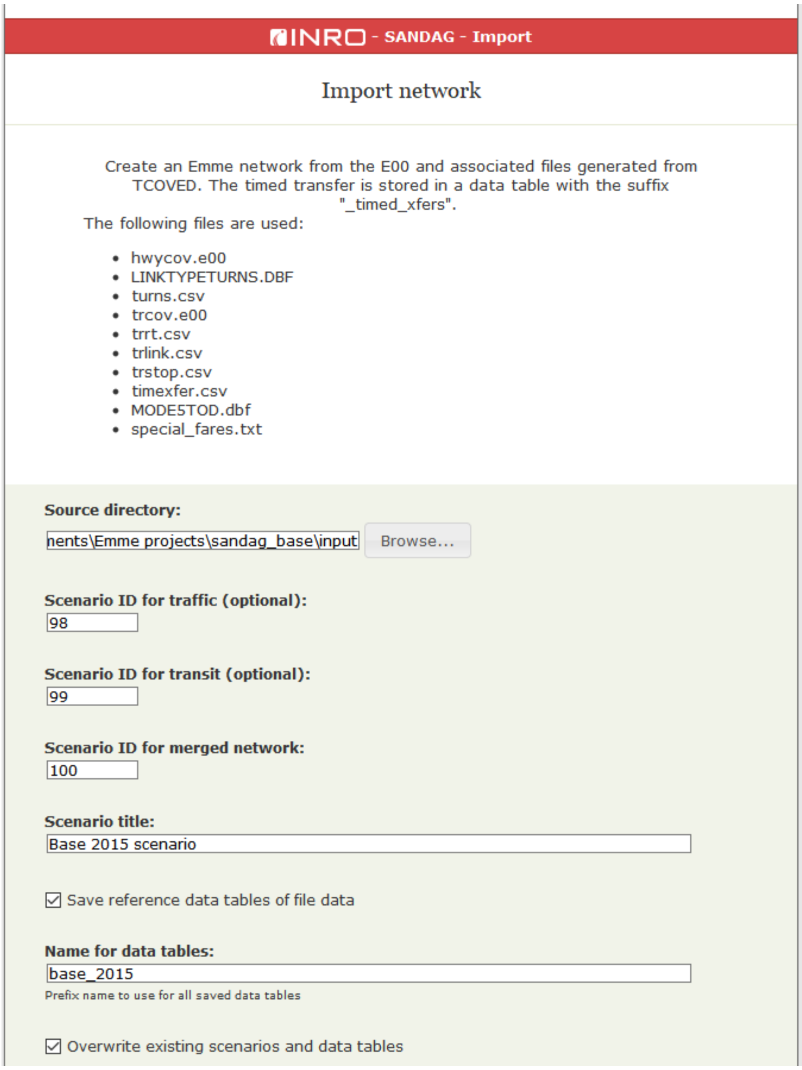
Run truck model	`sandag.model.truck.run_truck_model`
	`toolbox/model/truck/run_truck_model.py`
	Runs Truck model generation and distribution steps.

Truck Generation	sandag.model.truck.generation toolbox/model/truck/generation.py Generates standard truck trip and special (military) truck trips, regional truck trips, IE trips, EI trips and EE trips and balances truck trip totals.
Truck Distribution	sandag.model.truck.distribution toolbox/model/truck/distribution.py Distributes truck trips with congested skims and splits by time of day. Applies truck toll diversion model with free-flow toll and non-toll skims.
Run commercial vehicle model	sandag.model.commercial_vehicle.run_commercial_vehicle_model toolbox/model/commercial_vehicle/run_commercial_vehicle.py Runs Commercial Vehicle model generation, distribution, time of day and toll diversion steps.
Commercial Vehicle Generation	sandag.model.commercial_vehicle.generation toolbox/model/commercial_vehicle/generation.py Generates commercial vehicle productions and attractions based on mgra13_based_inputYYYY.csv.
Commercial Vehicle Distribution	sandag.model.commercial_vehicle.distribution toolbox/model/commercial_vehicle/distribution.py Distributes CV trips based on blended AM and MD travel times.
Commercial Vehicle Time of day	sandag.model.commercial_vehicle.time_of_day toolbox/model/commercial_vehicle/time_of_day.py Splits total CV demand by time of day.
Commercial Vehicle Toll diversion	sandag.model.commercial_vehicle.toll_diversion toolbox/model/commercial_vehicle/toll_diversion.py Splits CV demand into toll and non-toll (GP) matrices.
External-internal	sandag.model.external_internal toolbox/model/external_internal.py Runs the external-to-internal demand model from the USA to San Diego.
External-external	sandag.model.external_external toolbox/model/external_external.py Runs the external-to-external demand import (cross-regional trips, including Mexico to USA & USA to Mexico).
Export traffic skims	sandag.export.export_traffic_skims toolbox/export/export_traffic_skims.py Exports the traffic skim matrices to OMX files for use in the disaggregation demand model components.
Export transit skims	sandag.export.export_transit_skims toolbox/export/export_transit_skims.py Exports the transit skim matrices to OMX files for use in the disaggregation demand model components.
Export data loader network	sandag.export.export_data_loader_network toolbox/export/export_data_loader_network.py Exports the network results to text (CSV) files for subsequent loading by the Data Loader in the SQL database for reporting.
Export data loader matrices	sandag.export.export_data_loader_matrix toolbox/export/export_data_loader_matrices.py Exports the network results to OMX files for conversion to text (CSV) files by the Java DataExport for subsequent loading by the Data Loader in the SQL database for reporting.
Demand	sandag.utilities.demand toolbox/utilities/demand.py Common procedures used in the aggregate demand model tools.
General	sandag.utilities.general toolbox/utilities/general.py Common procedures used by multiple tools.
Properties	sandag.utilities.properties toolbox/utilities/properties.py Interface for editing the sandag_abm.properties file directly.

7. Import network

The *Import network* tool generates an Emme scenario from input network files. The following files are used:

- `hwycov.e00`: base nodes and links for traffic network with traffic attributes in ESRI input exchange format
- `linktypeturns.dbf`: fixed turn travel times by to/from link type (field `IFC`) pairs
- `turns.csv`: turn bans and fixed costs by link from/to ID (field `HWYCOV-ID`)
- `trcov.e00`: base nodes and links for transit network in ESRI input exchange format
- `trrt.csv`: transit routes and their attributes
- `trlink.csv`: itineraries for each route as sequence of link IDs (`TRCOV-ID` field)
- `trstop.csv`: transit stop attributes
- `timexfer.csv`: table of timed transfer pairs of lines
- `mode5tod.dbf`: global (per-mode) transit cost and perception attributes
- `special_fares.txt`: table listing special fares in terms of boarding and incremental in-vehicle costs. Used to represent the coaster zonal fare system. Can be in JSON or YAML format. If not available, a default 3-zone system with 2012 costs is used for the coaster routes.



Import network

Create an Emme network from the E00 and associated files generated from TCOVED. The timed transfer is stored in a data table with the suffix "_timed_xfers".

The following files are used:

- hwycov.e00
- LINKTYPETURNS.DBF
- turns.csv
- trcov.e00
- trrt.csv
- trlink.csv
- trstop.csv
- timexfer.csv
- MODE5TOD.dbf
- special_fares.txt

Source directory:
nents\Emme projects\sandag_base\input

Scenario ID for traffic (optional):
98

Scenario ID for transit (optional):
99

Scenario ID for merged network:
100

Scenario title:
Base 2015 scenario

☑ Save reference data tables of file data

Name for data tables:
base_2015
Prefix name to use for all saved data tables

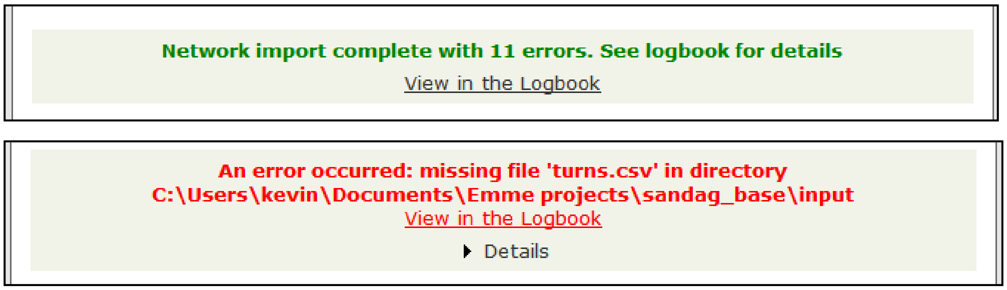
☑ Overwrite existing scenarios and data tables

Figure 8 - the user interface and inputs for the Import network tool

The user interface for the *Import network* tool provides the following inputs, as shown in Figure 8:

- *Source directory*: path to the location of the input network files
- *Scenario ID for traffic*: optional scenario to store the imported network from the traffic files only. Use to review traffic data in Emme Desktop separately from transit data.
- *Scenario ID for transit*: optional scenario to store the imported network from the transit files only. Use to review transit data in Emme Desktop separately from traffic data.
- *Scenario ID for merged network*: scenario to store the combined traffic and transit data from all network files (usual operation)
- *Save reference data tables of file data*: if checked, create a data table for each reference file for viewing in the Emme Desktop. Use to review input data alongside imported Emme Scenario. Note that the table containing the timed transfer information from timexter.csv is always created.
- *Name for data tables*: prefix to use to identify all data tables. Should be unique if importing multiple scenarios
- *Overwrite*: if checked, any existing data tables or scenarios with the same ID or name will be overwritten. If not checked and a corresponding scenario or data table already exists, an error will be raised.

The *Import network* tool generates a detailed report in the Logbook which provides runtime documentation of the import process. Details such as attribute mapping, and any warnings and errors are recorded. Warnings indicate discrepancies in the source network data that were resolved but should be reviewed. For example, a transit line may use a link which does not allow this mode. An error indicates that the network import did not complete for at least some data (for example, some turn prohibitions could not be matched to the base network). In this case, a green status message is shown in the tool page with the number of errors. Some errors (for example, missing files) will stop the process and display a pop-up with the error message as well as a red status message in the tool page and in the Logbook (see Figure 9 below).



Network import complete with 11 errors. See logbook for details

View in the Logbook

An error occurred: missing file 'turns.csv' in directory C:\Users\kevin\Documents\Emme projects\sandag_base\input

View in the Logbook

▸ Details

Figure 9 – The green tool page status message indicating minor errors, and the red halting error status message following runs of *Import network* tool.

The nodes and links (referred to as the base network in Emme help) for the traffic network is imported from `hwycov.e00`, with the nodes created first and the links connecting between them. The I-node (from node, field `AN`) and J-node (to node, field `BN`) are used to associate the nodes and links and uniquely identify the link in the Emme database. Only the ARC geometry and the AAT INFO table are used from the `.e00` files. See Table 10 on page 42 for a list of the attribute name mappings.

Separate forward and reverse links are generated from each ARC record in the `.e00` file. Reverse links are generated if the `IWAY` field value is 2 or 0 (two-way or not specified). The TAZs are identified from their connectors, links where the `IFC` field value is 10.

The prohibited turns by to- and from- link ID are read from turns.csv. The import process also supports fixed turn costs for individual turns (Emme additionally supports general algebraic turn penalty functions relating travel time / cost to turn flow). If the indicated link IDs do not make a valid turn (links not adjacent) an error is reported. General turn costs by link type (IFC field) pairs are set from linktypeturns.dbf. The nodes and links for transit are imported from trcov.e00 in the same way as the traffic nodes and links. Note that the correspondence between the HWYCOV-ID to TRCOV-ID values for the same physical links is important in order for the network merge to be correct. See Table 11, page 44 for a list of the attribute name mappings. The transit routes are imported from the trrt.csv, trlink.csv and trstop.csv files and matched to the transit base network. The transit line and stop / segment attributes (including per-line fares) are imported to Emme attributes (see Table 12 and Table 13 on page 45).

The mode-level attributes from mode5tod.dbf which vary by mode are copied to transit line attributes and used in the transit assignment specification. These are:

- WT_IVTPK: @vehicle_per_pk
- WT_IVTOP: @vehicle_per_op
- WT_FAREPK: @fare_per_pk
- WT_FAREOP: @fare_per_op
- XFERPENTM * WTXFERTM: @transfer_penalty
- DWELLTIME: set as the dwell time for transit segments with stops

The values for the perception factor on the auxiliary transit modes (WT_IVTPK and WT_IVTOP), and the waiting time perception factors (WT_FWTPK, WT_XWTPK, WT_FWTOP, and WT_XWTOP) are specified directly in the *Transit assignment* tool script (page 26).

The timed transfer information (route-to-route specific transfer times) from timexfer.csv is stored in a data table with the suffix "_timed_xfers". This table is used in the *Build transit assignment* tool to generate the time-period specific transit assignment scenario (see *Additional custom transit network adjustments* on page 28).

The special_fares.txt lists network-level incremental fares by boarding (line and/or stop) and in-vehicle segment. They specify additive fares based on the network elements encountered on a transit journey and are used to represent the Coaster (or other) zonal fare system. The input values are set on the network in the segment attributes "@coaster_fare_board" and "@coaster_fare_inveh". The lines are identified by their ID (route name) and the segments by the stop name. Both JSON and YAML format are supported. The following example special_fares.txt represents the Coaster zonal fare system for 2012 and shows the keywords and nesting (in YAML format):

```
boarding_cost:
   base:
       - {line: "398104", cost: 4.0}
       - {line: "398204", cost: 4.0}
   stop_increment:
       - {line: "398104", stop: "SORRENTO VALLEY", cost: 0.5}
       - {line: "398204", stop: "SORRENTO VALLEY", cost: 0.5}
in_vehicle_cost:
   - {line: "398104", from: "SOLANA BEACH", cost: 1.0}
   - {line: "398104", from: "SORRENTO VALLEY", cost: 0.5}
   - {line: "398204", from: "OLD TOWN", cost: 1.0}
   - {line: "398204", from: "SORRENTO VALLEY", cost: 0.5}
```

The transit network is merged onto the traffic base network using the @tcov_id link attributes (HWCOV-ID and TRCOV-ID). If the transit links do not match to a traffic link by ID, the process attempts to match by node ID (AN/BN fields), followed by the exact spatial location. If there is no existing traffic link (transit only links for rail lines, busways, TAP connectors or special walk links) new links and nodes are added. Links which do not have an ID (primarily the downtown walk links) are matched using the spatial location of the end nodes. Walk-only links are allowed to match to two traffic links to reduce incidents of overlapping links.

Mode definitions

A mode defines a group of vehicles or users which have access to the same parts of the network. Modes are used in both the traffic and transit assignments to define the available network for each class of demand. Each mode is uniquely identified by a single case-sensitive character. The modes which have access to a given link are listed on that link, and each link must allow at least one mode.

Table 4 - Mode definitions for traffic and transit network

Mode type	Mode	Description	Calculation
aux. auto	`s`	SOV	`IHOV == 1 && ITRUCK <= 4`
aux. auto	`h`	HOV2	`IHOV <= 2 && ITRUCK <= 4`
aux. auto	`i`	HOV3+	`IHOV <= 3 && ITRUCK <= 4`
aux. auto	`t`	TRKL (Light truck)	`IHOV == 1 && (ITRUCK <=3 || ITRUCK ==7)`
aux. auto	`m`	TRKM (Medium truck)	`IHOV == 1 && (ITRUCK <=2 || ITRUCK >= 6)`
aux. auto	`v`	TRKH (Heavy truck)	`IHOV == 1 && (ITRUCK ==1 || ITRUCK >= 5)`
aux. auto	`S`	SOV TOLL	`[ (IHOV == 1 || IHOV == 4) || (2 <= IHOV <=3 && ITOLL >0) ] && ITRUCK <= 4`
aux. auto	`H`	HOV2 TOLL	`[ (IHOV <= 2 || IHOV == 4) || (IHOV ==3 && ITOLL >0) ] && ITRUCK <= 4`
aux. auto	`I`	HOV3+ TOLL	`ITRUCK <= 4`
aux. auto	`T`	TRKL TOLL (Light truck toll)	`[ (IHOV == 1 || IHOV == 4) || (2 <= IHOV <=3 && ITOLL >0) ] && (ITRUCK <=3 || ITRUCK ==7)`
aux. auto	`M`	TRKM TOLL (Medium truck toll)	`[ (IHOV == 1 || IHOV == 4) || (2 <= IHOV <=3 && ITOLL >0) ] && (ITRUCK <=2 || ITRUCK >= 6)`
aux. auto	`V`	TRKV TOLL (Heavy truck toll)	`[ (IHOV == 1 || IHOV == 4) || (2 <= IHOV <=3 && ITOLL >0) ] && (ITRUCK ==1 || ITRUCK >= 5)`
transit	`b`	BUS	`MINMODE >= 6`
transit	`c`	CMR (Commuter rail)	`MINMODE == 4`
transit	`e`	EXP BUS (Express bus)	`MINMODE >= 6`
transit	`l`	LRT (Trolley, sprinter)	`MINMODE == 5`
transit	`p`	LTDEXP BUS (Limited express or premium bus)	`MINMODE >= 6`
transit	`r`	BRT RED	`MINMODE == 6`
transit	`y`	BRY YEL (yellow)	`MINMODE == 7`
aux. transit	`a`	ACCESS	`MINMODE == 3`
aux. transit	`w`	WALK	`MINMODE == 2`
aux. transit	`x`	TRANSFER	`MINMODE == 1`

Table 5 - Key mode fields from hwycov.e00 and trcov.e00

ARC field name in E00 files	Description
IHOV	Link operation type where: 1 = General purpose 2 = 2+ HOV (Managed lanes if lanes > 1) 3 = 3+ HOV (Managed lanes if lanes > 1) 4 = Toll lanes
ITRUCK	Truck restriction code (ITRUCK) where: 1 = All Vehicle Classes 2 = HHDT Excluded 3 = MHDT & HHDT Excluded 4 = LHDT & MHDT & HHDT Excluded (All Trucks Excluded) 5 = HHDT Only 6 = MHDT & HHDT Only 7 = LHDT & MHDT & HHDT Only (Truck Only)
MINMODE	Transit type where: 1 = special transfer walk links between certain nearby stops 2 = walk links in the downtown area 3 = the special TAP connectors 4 = Coaster Rail Line 5 = Light Rail Transit (LRT) Line 6 = Yellow Car Bus Rapid Transit (BRT) 7 = Red Car Bus Rapid Transit (BRT) 8 = Limited Express Bus 9 = Express Bus 10 = Local Bus

Modes are categorized by type in Emme:

- Auto: defines the complete traffic network
  - A dummy auto mode “d” is created to represent the entire accessible automobile network, even though no single other mode has comprehensive access.
- Auxiliary Auto: defines a subset of the auto network for use by a given class of traffic demand
- Transit: route-type modes (bus, train, etc.) with fixed itineraries and frequencies
- Auxiliary Transit: active modes used to access the transit routes (walk)

The traffic link mode definitions are calculated from two fields `IHOV` and `ITRUCK` while the transit link mode definitions are specified by the `MINMODE` field. The mode definitions and their calculations are listed in Table 4. For reference the definitions for the relevant input fields are listed in Table 5.

8. Traffic assignment

The traffic assignment for the SANDAG model is a 14-class assignment with generalized cost on links and BPR-type volume-delay functions which include capacities on links and at intersection approaches. The assignment is run using the fast-converging Second-Order Linear Approximation (SOLA) method in Emme to a relative gap of 5x10^{-4}. The per-link fixed costs include toll values and operating costs which vary by class of demand (see Table 6 for the complete list of classes). Assignment matrices and resulting network flows are always in PCE.

The *Traffic assignment* tool provides an interface to specify multiple select link type analyses (more on page 23), which can also be specified directly from the *Master run* tool. Additional path-based analyses are also supported by the *SOLA assignment* tool.

Table 6 - List of traffic demand classes and key class parameter values

Name	Mode	VOT ($0.01/min)	PCE	Cost attribute
SOVGP drive-alone non-toll	`s`	67	--	`@cost_operating`
SOVTOLL drive-alone toll	`S`	67	--	`@cost_auto`
HOV2GP shared-2 non-toll non-HOV	`s`	67	--	`@cost_operating`
HOV2HOV shared-2 non-toll HOV	`h`	67	--	`@cost_operating`
HOV2TOLL shared-2 toll and HOV	`H`	67	--	`@cost_hov`
HOV3GP shared 3+ non-toll non-HOV	`s`	67	--	`@cost_operating`
HOV3 HOV shared-3+ non-toll HOV	`i`	67	--	`@cost_operating`
HOV3TOLL shared-3+ toll HOV	`I`	67	--	`@cost_hov`
TRKLGP light truck non-toll	`t`	67	1.3	`@cost_operating`
TRKLTOLL light truck toll	`T`	67	1.3	`@cost_auto`
TRKMGP medium truck non-toll	`m`	68	1.5	`@cost_operating`
TRKMTOLL medium truck toll	`M`	68	1.5	`@cost_med_truck`
TRKHGP heavy truck non-toll	`v`	89	2.5	`@cost_operating`
TRKHTOLL heavy truck toll	`V`	89	2.5	`@cost_hvy_truck`

Volume-delay functions

The volume-delay functions are specified as open-ended algebraic expressions supporting standard functions. The VDF functions for SANDAG are a modified BPR of the form:

```
T0 * (1.0 + ALPHA1*((FLOW+PRELOAD)/CAPACITY)**BETA1)
+ CYCLE/2*(1-GC)**2 * (1.0 + ALPHA2*(FLOW+PRELOAD)/INT_CAPACITY)**BETA2)
```

- Where
  - T0 is the free-flow travel time along the link in minutes
  - ALPHA1, BETA1, ALPHA2 and BETA2 are BPR calibration terms
  - FLOW is the assigned flow from the traffic demand in PCEs
  - PRELOAD is the background volume from transit vehicles in PCEs
  - CAPACITY is the link mid-block capacity and INT_CAPACITY is the total intersection approach capacity in PCEs
  - CYCLE is the signal cycle length in minutes
  - GC is the green-to-cycle length for the link approach
- The attribute keyword for `FLOW` is `volau`
- The attribute for the background traffic `PRELOAD` is `volad`

  - This is calculated from the transit itineraries, their frequency, and the length of the period and is also stored in link data 2 (`ul2`)
- Per-link attributes:
  - `T0`: link data 1 (`ul1`)
  - `CAPACITY`: link data 2 (`ul3`)
  - `GC`: `@green_to_cycle`, which is cross-referenced by `el1`
  - `INT_CAPACITY`: `@capacity_inter`, which is cross-referenced by `el3`
- Global parameters (small subset of values for all links):
  - `CYCLE`, either 1.25, 1.5, 2.0 or 2.5
  - `ALPHA1`, always 0.8
  - `BETA1`, always 4
  - `ALPHA2`, either 6.0 or 4.5
  - `BETA2`, always 2

With the global parameters there are 6 total volume delay functions:

- `fd10` for freeways and links which do not end at an intersection
  ```
  ul1 * (1.0 + 0.8 * ((volau + volad) / ul3) **4)
  ```
- `fd20` for local collector and lower intersection and stop controlled approaches
  ```
  ul1 * (1.0 + 0.8 * ((volau + volad) / ul3) **4)
  + 1.25 / 2 * (1-el1) ** 2 * (1 + 4.5 * ((volau + volad) / el3) **2)
  ```
- `fd21` for collector intersection approaches
  ```
  ul1 * (1.0 + 0.8 * ((volau + volad) / ul3) **4)
  + 1.5 / 2 * (1-el1) ** 2 * (1.0 + 4.5 * ((volau + volad) / el3) **2)
  ```
- `fd22` for major arterial and major or prime arterial intersection approaches
  ```
  ul1 * (1.0 + 0.8 * ((volau + volad) / ul3) **4)
  + 2.0 / 2 * (1-el1) ** 2 * (1.0 + 4.5 * ((volau + volad) / el3) **2)
  ```
- `fd23` for primary arterial intersection approaches
  ```
  ul1 * (1.0 + 0.8 * ((volau + volad) / ul3) **4)
  + 2.5/ 2 * (1-el1) ** 2 * (1.0 + 4.5 * ((volau + volad) / el3) **2)
  ```
- `fd24` for metered ramps
  ```
  ul1 * (1.0 + 0.8 * ((volau + volad) / ul3) **4)
  + 2.5/ 2 * (1-el1) ** 2 * (1.0 + 6.0 * ((volau + volad) / el3) **2)
  ```

Traffic skims and results

The traffic skims are calculated by fixing the flows and running a second zero-iteration assignment, which computes the O-D skim values using path analyses. The total generalized cost, travel time, and distance are computed for all classes, as well as the toll cost, HOV facility distance, and managed lane distance for the applicable classes (see also matrix definitions on page 39). The fixed flows are the MSA averaged flows for iterations after the first global iteration.

Note that the assigned flows for trucks are in PCE values unless otherwise specified. This includes any select type results.

Traffic assignment tool

The *Traffic assignment* tool runs the traffic assignment and skims per period on the current primary scenario. The tool has the following inputs (see also Figure 10):

- *Period*: the time-of-day period, one of EA, AM, MD, PM, EV.
- *MSA iteration*: global iteration number. If greater than 1, existing flow values must be present and the resulting flows on links and turns will be the weighted average of this assignment and the existing values.
- *Relative gap*: minimum relative stopping criteria.
- *Max iterations*: maximum iterations stopping criteria.
- *Number of processors*: number of processors to use for the traffic assignments.

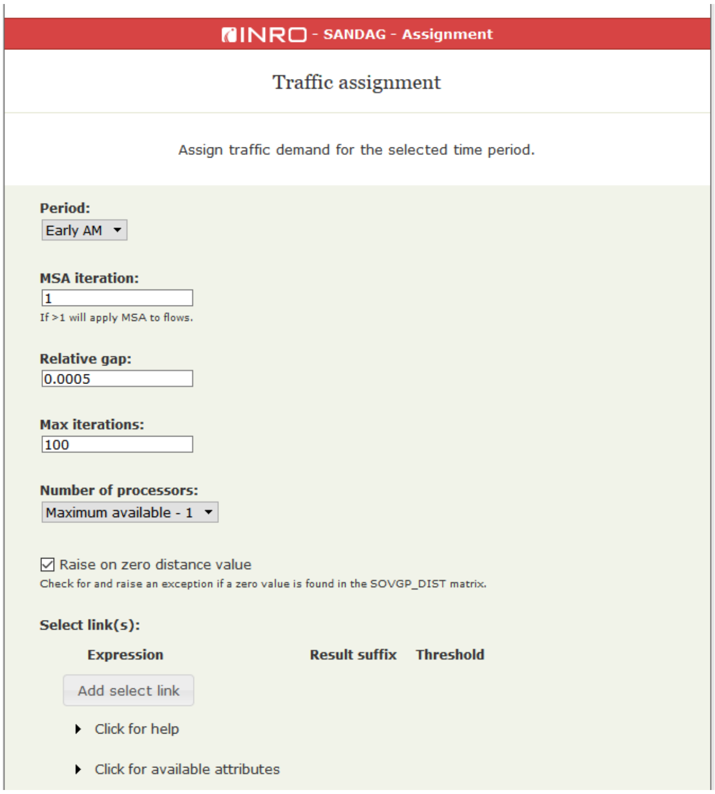
- *Raise on zero distance*: if checked, the distance skim for the SOVGP is checked for any zero values, which would indicate a disconnected zone, in which case an error is raised and the model run is halted.
- *Select link specification*: see *Traffic select link analysis* on the following page for details.

Distributed operation

When run from the *Master run* tool the 5 time-of-day traffic assignments can be distributed across multiple machines. The specification of the distributed operation is done in the conf/server-config.csv file. The configuration for multiple machines is listed in rows referenced by the name of the current machine, with the following columns used (additional columns may be used by CT-RAMP):

- ServerName: Name of the main machine which is running the model
- SNODE: Is single node? Must be “yes” or “no”
- NODE1: Name of the first distributed node
- NODE2: Name of the second distributed node
- THREADN1: Number of threads to use on the first node
- THREADN2: Number of threads to use on the second node

When run in distributed mode (`SNODE="no"`) two additional Emme databases are created under Database_remote1, with the PM and MD data, and Database_remote2, with the AM data. The EA and EV periods are run on the main machine. Remote processes are started on the two remote nodes and after they have completed the results are copied back to the main database. The PsExec utilitiy is used to start the remote runs via `emme_python.bat` which configures the environment and `remote_run_traffic.py` which coordinates the input settings for each of the time period assignments.



Traffic assignment

Assign traffic demand for the selected time period.

Period:
Early AM

MSA iteration:
1
If >1 will apply MSA to flows.

Relative gap:
0.0005

Max iterations:
100

Number of processors:
Maximum available - 1

☑ Raise on zero distance value
Check for and raise an exception if a zero value is found in the SOVGP_DIST matrix.

Select link(s):

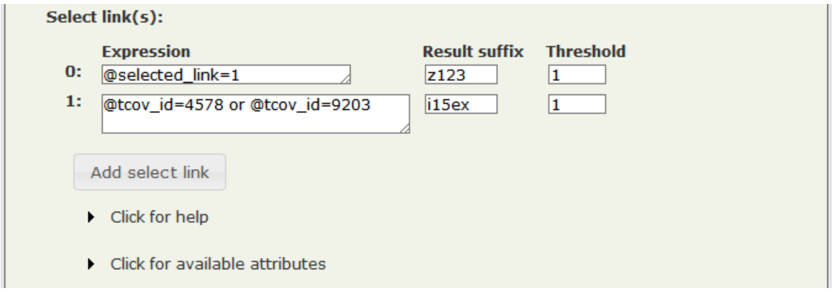
Expression	Result suffix	Threshold

Figure 10 - SANDAG *Traffic assignment* tool user interface

Traffic select link analysis

The *Traffic assignment* tool also provides an interface to specify multiple simultaneous select link analyses. Select zone analyses can be completed by performing select link analyses on the incoming / outgoing connectors as appropriate (see the example below). Analyses may be added to the tool page and each requires three inputs to be specified (see also Figure 11):

- *Expression*: an Emme selection expression to identify the link(s) of interest.
- *Result suffix*: the suffix to use in the naming of per-class result attributes and matrices, up to 6 characters. Should be unique (existing attributes / matrices will be overwritten).
- *Threshold*: the minimum number of links which must be encountered for the path selection. The default value of 1 indicates an "any" link selection.



Select link(s):

	Expression	Result suffix	Threshold
0:	@selected_link=1	z123	1
1:	@tcov_id=4578 or @tcov_id=9203	i15ex	1

Figure 11 - user interface for select link analysis in *Traffic assignment* tool

The selection expression identifies the selected links with non-zero (True) values. Any standard or extra attribute can be used. The expression syntax is one (or more) selection criteria of the form `attribute=value` or `attribute=min,max`. Multiple criteria may be combined with '`and`' ('`&`'), '`or`' ('`|`'), and '`xor`' ('`^`'). Use '`not`' ('`!`') in front of a criterion to negate it.

Links may be identified by any combination of attributes, Emme or TCOVED ID ("`@tcov_id`"). For example, if two links X and Y are required, the syntax is "`@tcov_id=X or` "`@tcov_id=Y`". A common workflow is to create an extra attribute (e.g. "`@selected_link`") initialized to 0 and "tag" the selected link(s) using the Network Editor or Calculator by changing the value to 1. The simple selection expression "`@selected_link=1`" is used to reference those links.

Result link and turn flows will be saved in extra attributes "`@sel_TP_NAME_SUFFIX`", where `TP` is the period, `NAME` is the class name, and `SUFFIX` is the specified result suffix. The selected O-D demand will be saved in "`SELDEM_TP_NAME_SUFFIX`".

The threshold can be used to change the selection type. The most common use case is a selection on any one of several links, in which case the minimum threshold of "1" can be used. To specify an all type of selection, the number of required links must be known. For example, if there are two selected links the threshold is set to "2" to see paths which use both links.

To identify the connectors for a select zone analysis, the links can be identified by the zone IDs (in addition to the link ID, or a tag attribute). To identify all outgoing connectors for a particular zone use "`i=ZONEID`". To identify all incoming connectors use "`j=ZONEID`", and to identify both (for demand between a particular pair of zones) use "`i=ZONEID or j=ZONEID`" and a threshold of "2".

9. Transit assignment

The transit assignment uses a headway-based approach, where the average headway between vehicle arrivals for each transit line is known, but not exact schedules. Passengers and vehicles arrive at stops randomly and passengers choose their travel itineraries considering the expected average waiting time (usually half the combined headways of the attractive lines).

The Emme *Extended transit assignment* is based on the concept of optimal strategy but extended to support a number of behavioral variants. The optimal strategy is a set of rules which define sequence(s) of walking links, boarding and alighting stops which produces the minimum expected travel time (generalized cost) to a destination. At each boarding point the strategy may include multiple possible attractive transit lines with different itineraries. A transit strategy will often be a tree of options, not just a single path. A line is considered attractive if it reduces the total expected travel time by its inclusion. The demand is assigned to the attractive lines in proportion to their relative frequencies.

The shortest "travel time" is a generalized cost formulation, including perception factors (or weights) on the different travel time components, along with fares, and other costs / perception biases such as transfer penalties which can vary over the network and transit journey. For more details on the transit assignment see the *Algorithm* section for the *Extended transit assignment* in the Emme Help.

The model has three access modes to transit (walk, park-and-ride (PNR), and kiss-and-ride (KNR)) and five main modes (local bus, express / premium bus, bus rapid transit (BRT), light rail transit (LRT), and commuter rail), for 15 total demand classes. These classes are assigned by slices, one at a time, to produce the total transit passenger flows on the network.

While there are 15 slices of demand, there are only two classes of skims: Local bus only, and all modes (access to the premium services). The assignment specification and skims do not vary by access mode and are the same for the four main modes which are considered premium modes: express bus, BRT, LRT and commuter rail. The access mode does not change the assignment parameters or skims.

Travel time components

The in-vehicle travel times for vehicles in mixed traffic is based on the results of the traffic assignment, which is referenced by the attribute "`timau`". For vehicles with dedicated lanes / facilities, the travel times are imported by period from `trcov.e00 as` "`@time_link_ea`", "`@time_link_am`", "`@time_link_md`", "`@time_link_pm`", or "`@time_link_ev`". The perception of in-vehicle travel time is imported from `mode5tod.dbf` and can vary by mode and time-of-day. The perception factors are stored in transit line attributes "`@vehicle_per_pk`" and "`@vehicle_per_op`". The time / cost perception factors (PF) and penalties are as follows:

- Walk: PF of 1.8 for peak and 1.6 for off-peak
- Initial wait: PF of 1.5 for peak and 1.6 for off-peak
- Transfer wait: PF of 3.0 for peak and 2.5 for off-peak

Table 7 - costs and perception factors which vary by mode

Mode	In-vehicle perception factor	Transfer penalty (minutes)	Fare perception factor	
			Peak	Off-peak
Commuter rail	1.0	0.05	0.63	0.52
LRT	1.0	0.50	0.65	0.54
Regional BRT	1.0	0.50	0.46	0.23
Premium bus	1.0	5.00	0.46	0.23
Express	1.5	5.00	0.60	0.51
Local bus	1.5	5.00	0.67	0.58

Representing fares

The fares for most routes are paid per-boarding, except for free transfers between trolley lines, and the Coaster commuter rail which has a zonal fare system. However, the day passes ($5) and regional day passes ($12) provide effective maximum fares which in most cases works out to a small increment over the single boarding fare. To set the maximum trip fare we assume there is a second transit trip and therefore this maximum fare is half the price of a day pass, or $2.50 for regular services (local buses, trolley, express bus and BRT), and $6 for premium services. Monthly passes are not represented.

To represent the fares *Journey levels* are used to keep track of the sequence of boardings by mode. Journey levels allow the generalized costs experienced by passengers to vary depending upon the particular sequence of transit modes that they board. The boarding cost is specified as a line extra attribute, and each boarding of a mode can change the boarding costs for subsequent boardings (which use a different extra attribute). For full details on Journey levels see the *Extended transit assignment* in the Emme Help.

A fare extra attribute is calculated for each state (relevant sequence of boardings), to represent the subsequent incremental boarding fares for each line. The local bus assignment case is relatively simple and there are three levels (states):

- Not boarded yet: pay the full boarding fare for this line, usually $1.75 or $2.25
- Boarded bus once: pay the incremental fare up to half a day pass, $0.75 or $0.25
- Boarded bus twice, have a day pass: all subsequent boardings are free

The base fares are stored in the line extra attribute "`@fare`", copied from the `trrt.csv` file in the Import Network tool. The incremental fares are calculated as "`2.50 - @fare`" for each line (for those with fares > $1.00) and stored in "`@xfer_from_bus`". This represents the incremental fare for the separate NCTD ($1.75 boarding fare) and MTS ($2.25 boarding fare) geographic areas well. There is a very small area of overlap between the two service areas at the University of California San Diego where the represented fare will be off by $0.25 for passengers connecting between the two areas. There are also a small number of community services which are free (five lines) or have fares of $1.00 (two lines). The incremental fares when transferring from other bus lines to these lines is correctly represented (`@xfer_from_bus=0` for free lines and 0.25 for $1.00 lines); however, the calculated fare when boarding other lines after these community lines will be low (`@fare` on community lines + `@xfer_from_bus` on the regular line). A straightforward improvement to this representation would be to code each group of lines with the same fare as a separate mode so that the transfer fare could be calculated.

Table 8 - Journey level table for bus mode only assignments.

Level		Fare attribute	Next journey level
#	Name		
0	base	@fare	1
1	boarded_bus	@xfer_from_bus	2
2	day_pass	0	2

The fare representation for the all modes setup requires additional levels with the premium bus services, the Coaster zonal fare, and the regional day pass:

- Not boarded yet: pay the full boarding fare for this line
- Boarded bus once: pay the incremental fare up to half a day pass, $0.75 or $0.25, for local bus, LRT, BRT, or express bus; pay $4, the increment fare to the regional day pass

- Have a day pass (boarded bus twice, or LRT / BRT / express bus once): all subsequent boardings of these four modes are free; if boarding a premium bus service or Coaster pay $3.50, the increment up to a regional day pass
- Boarded premium bus once: pay the incremental fare of $1, from the premium fare ($5) to the regional day pass ($6)
- Boarded coaster: pay the incremental fare of $1.25 from the average Coaster fare ($4.75, range $4 to $5.50) to the regional day pass ($6)

There are additional cost attributes to represent the Coaster zonal fare when it is the first boarding. If other modes have already been used before boarding the Coaster line, the fare becomes the regional day pass level so there is no further incremental cost. The zonal fare is represented as an initial boarding cost at stations and the incremental in-vehicle cost at zone boundary crossings. These costs are stored in the segment attributes "`@coaster_fare_board`" and "`@coaster_fare_inveh`" (see `special_fares` under *Import network* on page 19 for how this is specified).

There are four bus lines in the base year coded as having the premium mode but take an express bus fare ($2.50) and should be covered by the day pass instead of the regional day pass (route 870 variants). Strategies which include this route and other premium services may underestimate the fare, while strategies which include this route and other non-premium services (local bus, LRT…) may overestimate the fare. When skimming the fare cost, the maximum allowed fare is half the regional day pass.

Table 9 - Journey level table for all modes assignments.

Level		Fare attribute	Next journey level			
#	Name		Local bus	LRT, express bus, BRT	Premium bus	Coaster
0	base	`@fare`	1	2	3	4
1	boarded_bus	`@xfer_from_bus`	2	2	5	5
2	day_pass	`@xfer_from_day`	2	2	5	5
3	boarded_premium	`@xfer_from_premium`	5	5	5	5
4	boarded_coaster	`@xfer_from_coaster`	5	5	5	5
5	regional_pass	`0`	5	5	5	5

Additional custom transit network adjustments

The following additional network preparation steps are implemented in *the Build transit network* tool (see page 30).

Timed-transfer

Timed-transfer connections between pairs of lines are specified by a data table which is imported from `timexfer.csv` by the *Import network* tool (page 17). This data table specifies timed transfer pairs as the alighting line, the boarding line and the fixed waiting time when transferring. All transfers have a single walk link between the alighting and boarding stops.

To represent this, extra stops are added to both lines with a duplicate walk link which connects the new stops (see Figure 12). The new stops are alighting only for the alighting line and boarding only for the boarding line, and the duplicate walk link is one-way only. The walk time (along with other attributes) is copied from the parallel source link. For the boarding stop, a segment-specific headway is used for the boarding lines which is set as 2 times the specified wait. Finally, the incoming segments for the new stops are zero-cost segments for all lines. If there are multiple connections from or to the same line at the same stop they are grouped together to simplify the representation.

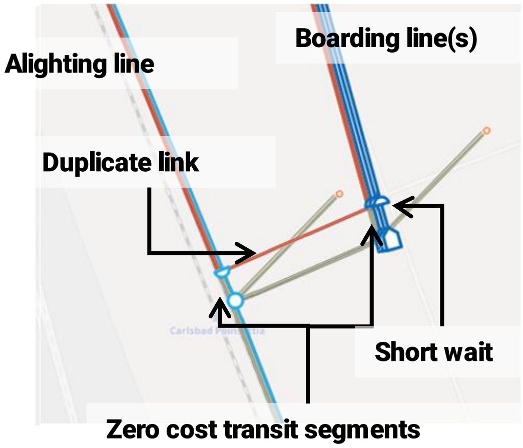


Figure 12 - Illustration of network modifications to represent timed transfers.

Circle-line free transfer

There are several transit lines in the SANDAG network which are circle lines that start and end at the same location. Some operate in bi-directional loops. Passengers are able to stay on board and continue around the loop past the layover stop. To represent free transfers to the same line at layover points a separate layover node is added to the network, duplicating the general layover stop, with links connecting to the new node and the circle line starting and ending at the new node. Transit passengers may transfer here without experiencing any additional wait time or transfer penalty. The passengers cannot walk to this node and no other transit line has a stop here. There is a fixed dwell time of 5 minutes at this stop that the passengers do experience to represent the layover time.

Access mode to transfer mode prohibition

Transit passengers are always willing to consider walking to a different stop (if the mode is available) and will do so if it reduces the expected travel time. To force passengers to board the immediately adjacent stop to a TAP centroid they cannot be provided a walk link to any other stops.

For stops in the SANDAG network which have both a transfer walk link and a TAP access / egress connector the stop must be split into a separate TAP stop and transfer stop. The TAP connector is split and all transit lines with a stop are re-routed such that they also go through a new TAP-only stop. Walking is not permitted on the link which connects the TAP stop to the transfer stop. All the transit segments which operate on this link will have zero-cost.

On the left of Figure 13 is the original network and on the right, is the modified network with the split link and additional TAP-only stop. The TAP centroid is shown as a pink circle, a bus route in blue with a white circle indicating the stops, and an orange transfer walk link to a different stop (not pictured).

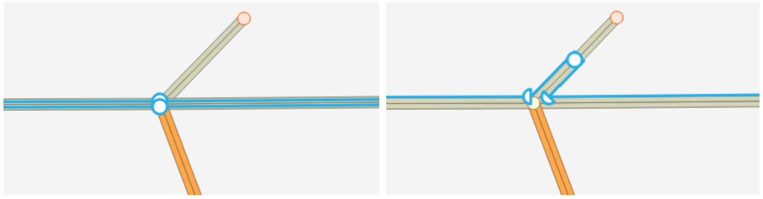
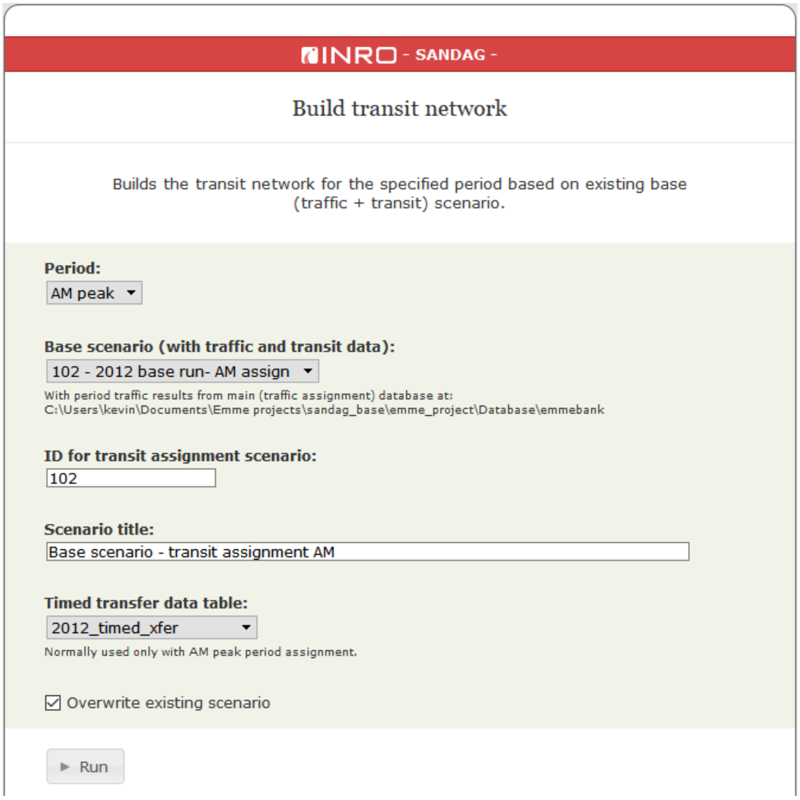


Figure 13 - Illustration of network modification to prohibit walking to a different stop on a transfer link for the initial boarding from a TAP.

Build transit network tool

The *Build transit network* tool generates a new scenario in the Transit database (under the `Database_transit` directory) as a copy of a scenario in the base (traffic assignment) database. The base traffic scenario should have valid results from a traffic assignment for the travel times on links to be available for transit lines in mixed traffic operation.

The *Build transit network* tool deletes the TAZ centroids and connectors from the network, and converts the TAP nodes to TAP centroids (using the "`@tap_id`" as the zone ID). The custom network adjustments described starting on page 28 are also applied: timed-transfer between lines, free circle-line transfers at layovers and access mode to transfer mode prohibition. The fare attributes as described starting on page 27 are calculated.



Build transit network

Builds the transit network for the specified period based on existing base (traffic + transit) scenario.

Period:
AM peak ▾

Base scenario (with traffic and transit data):
102 - 2012 base run- AM assign ▾
With period traffic results from main (traffic assignment) database at:
C:\Users\kevin\Documents\Emme projects\sandag_base\emme_project\Database\emmebank

ID for transit assignment scenario:
102

Scenario title:
Base scenario - transit assignment AM

Timed transfer data table:
2012_timed_xfer ▾
Normally used only with AM peak period assignment.

☑ Overwrite existing scenario

Figure 14 - user interface for *Build transit network* tool

The tool has the following inputs, as shown in Figure 14:

- *Period*: the corresponding period for the scenario
- *Base scenario*: the base traffic assignment scenario in the main Emme database
- *Scenario ID*: the ID to use for the new scenario in the Transit Emme database
- *Scenario title*
- *Timed transfer data table*: the source data table for the timed transfer line pairs (can select none if no timed transfers)
- *Overwrite*

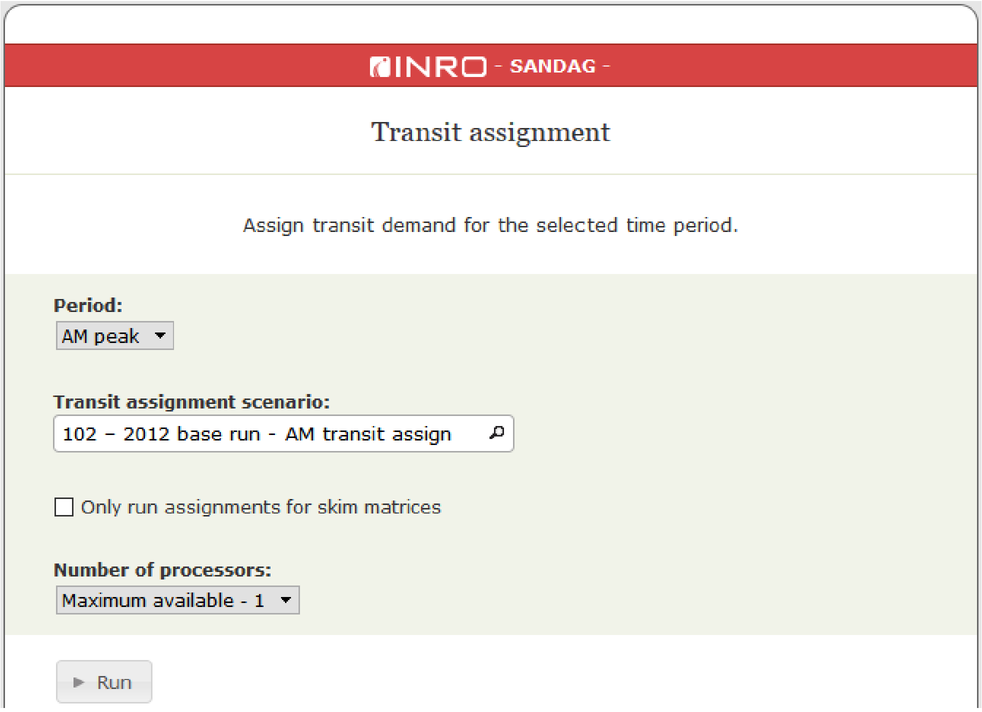
This tool must be run to prepare the transit network prior to assignment. It can be run with either database open and any scenario as the primary scenario, as the scenario is specified as a tool input.

Transit assignment tool

The *Transit assignment* tool runs the transit assignment and skims for each period on the current primary scenario. The tool has the following inputs (see also Figure 15):

- *Period*: the time-of-day period, one of EA, AM, MD, PM, EV.
- *Transit assignment scenario*
- *Only run assignment for skim matrices*: if checked, only two assignments are run to generate the skim matrices for the BUS and ALL skim classes. Otherwise, all 15 assignments are run to generate the total network flows.
- *Number of processors*: number of processors to use for the traffic assignments.

The *Build transit network* tool (page 30) must be run first to prepare the scenario for assignment. Note that this tool must be run with the Transit database (under the `Database_transit` directory) open (as the active database in the Emme desktop).



Transit assignment

Assign transit demand for the selected time period.

Period: AM peak

Transit assignment scenario: 102 – 2012 base run - AM transit assign

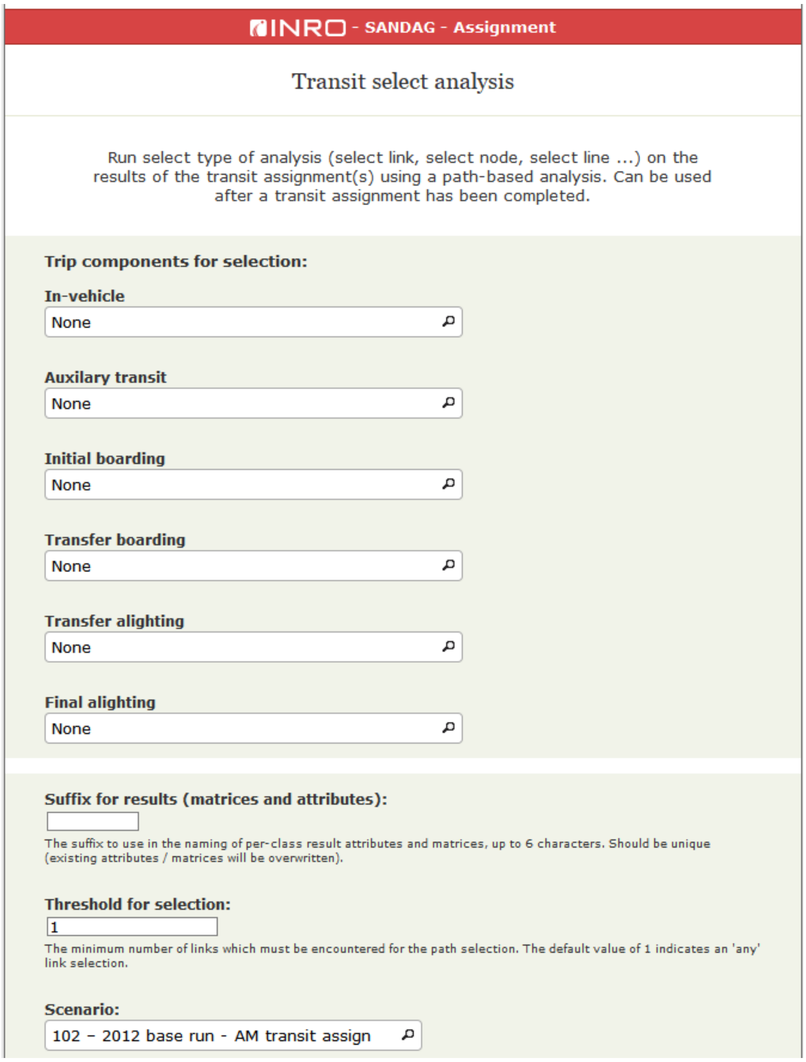
□ Only run assignments for skim matrices

Number of processors: Maximum available - 1

Figure 15 - user interface for SANDAG *Transit assignment* tool

Transit select analysis

This tool runs select type network analysis on the results of one or more transit assignments. It is run as a post-process tool after the assignment tools are complete, using the saved transit strategies. Any number of analyses can be run without needing to rerun the assignments. The analysis will correspond to the transit demand classes that have been run, normally the 15 classes of demand following the final transit assignment. It supports general select analysis for link, node, line, segment, or zone, by in-vehicle, walking, boarding, alighting, or transfer activity, as well as other custom analyses using combinations of these.



Transit select analysis

Run select type of analysis (select link, select node, select line ...) on the results of the transit assignment(s) using a path-based analysis. Can be used after a transit assignment has been completed.

Trip components for selection:

In-vehicle: None

Auxilary transit: None

Initial boarding: None

Transfer boarding: None

Transfer alighting: None

Final alighting: None

Suffix for results (matrices and attributes):

The suffix to use in the naming of per-class result attributes and matrices, up to 6 characters. Should be unique (existing attributes / matrices will be overwritten).

Threshold for selection: 1

The minimum number of links which must be encountered for the path selection. The default value of 1 indicates an 'any' link selection.

Scenario: 102 – 2012 base run - AM transit assign

Figure 16 - user interface for *Transit select analysis* tool

The operation of the tool is similar to select link analysis for traffic. The workflow to use the *Transit select analysis* tool is to first identify the network elements of interest using one (or more) extra attributes of the appropriate type. The link (or node, etc.) can be marked with a value of "1" for this attribute using the *Network editor* or *Network calculator*. The tool has the following inputs as shown in Figure 16:

- *Trip components for selection*: pick one or more extra attributes which identify the network elements of interest by trip component. For example, to identify passengers on-board a vehicle on a given link, pick the prepared link extra attribute under "In-vehicle". Or, to identify passengers boarding at a given node, pick the node extra attribute under "Initial boarding" and "Transfer boarding".
- *Result suffix*: the suffix to use in the naming of per-class result attributes and matrices, up to 6 characters. Should be unique (existing attributes / matrices will be overwritten).
- *Threshold*: the minimum number of elements which must be encountered for the path selection. The default value of '1' indicates an "any" link selection.
- *Scenario*: the scenario to analyze.

The tool must be used with the Transit database (under the `Database_transit` directory) open. The analysis is implemented using the Path-based analysis tool, which can also be used to implement other types of path analyses.

10. Aggregate demand models and other tools

Truck model

The truck model is implemented in two separate tools, found under the Model → Truck directory in the SANDAG toolbox: *Generation* and *Distribution*. A *Run truck model* tool executes both these tools in sequence. These tools take as input the directory for their input files, which defaults to the standard `input` directory and does not normally need to be changed.

Generation

Truck trip productions and attractions are calculated for three categories of truck types: light, medium and heavy in two steps. The standard truck trips use trip rates stored in `TruckTripRates.csv` and employment by type and households from `mgra13_based_inputYEAR.csv` (where `YEAR` is the year of interest identified in `conf/sandag_abm.properties` by the `truck.FFyear` token). Both files are found under the `input` directory. The special truck trips (e.g. military, cruise ship terminal) are calculated based on `specialGenerators.csv`. The truck trips by type are balanced to the average of the productions and attractions. Regional truck trip ends, internal-external, external-internal and external-external (IE, EI, and EE), are read from separate files in the `input_truck` directory.

Distribution

The distribution step distributes the truck trips using friction factors which are negative exponentials of the mid-day travel time for the "generic" truck skim, `MD_TRK_TIME`. The external trips (IE, EI, EE) are distributed separately and added to the truck types (light, medium and heavy) using fixed proportions. The total truck trips by type are split by time-of-day using fixed factors for all OD pairs, except those crossing the border which have a separate set of time-of-day factors.

The truck toll diversion (split between toll access and GP lanes only) is calculated using toll and GP skims (`TIME` and `TOLLCOST`) by truck type and time-of-day. The final stored truck demand matrices are adjusted to PCEs for assignment, and a controlled rounding process (reduce matrix precision) applied which removes demand if below a specified threshold (`RunModel.MatrixPrecision` in `sandag_abm.properties`) and adjusts remaining cells by the ratio of the difference to maintain the same total demand.

Commercial vehicle model

The commercial vehicle model is implemented in four tools found under the Model → Commercial vehicle directory in the SANDAG toolbox: *Generation*, *Distribution*, *Time of day*, and *Toll diversion*. A *Run commercial vehicle model* tool executes these tools in sequence. These tools take as input the directory for their input files, which defaults to the standard `input` directory and does not normally need to be changed. The very small truck generation model is based on the Phoenix four-tire truck model documented in the TMIP Quick Response Freight Manual.

Generation

The generation step calculates total productions and attractions from employment by category and total households per TAZ, read from `input/mgra13_based_inputYEAR.csv` (`YEAR` is replaced by `truck.FFyear` in the `conf/sandag_abm.properties` file). The attractions are balanced so the total matches the total productions.

Distribution

The distribution step is based on a blended impedance skim of `1/3 AM_SOVGP_TIME` and `2/3 MD_SOVGP_TIME`. The blended skim is used to lookup friction factors from a table stored in `input/commVehFF.csv`, which is then used in the matrix balancing to calculate the total daily production-attraction matrix.

Time of day

The five time-of-day matrices are calculated using fixed proportions of the average of the total daily production-attraction matrix and its transpose $(PA + AP)/2$.

Toll diversion

The toll diversion (split between toll access and GP lanes only) is calculated using the SOV toll and GP skims (`TIME` and `TOLLCOST`) by time-of-day. The final commercial vehicle demand is added to the SOV demand by the *Import auto demand* tool (discussed below).

External models

Two tools calculate the external demand which is not covered by the disaggregate models. The *External external* tool calculates the cross-regional demand, and the *External internal* tool calculates the demand from the external USA gateways to within the San Diego region.

External internal

The *External internal* tool runs the external USA to internal San Diego region demand model. The demands are calculated for work and non-work purposes by time-of-day and toll / GP-only and later added to the auto demand for assignment. Work and non-work trip gateway total trips (control totals) are read from `input/externalInternalControlTotalsByYear.csv` for the `scenarioYear` token in `sandag_abm.properties`. If this file does not exist at runtime `input/externalInternalControlTotals.csv` is used instead.

The trip end probability is generated from the employment totals by type and households (from `input/mgra13_based_inputYEAR.csv`) and multiplied by the vector of gateway control totals to obtain a production-attraction matrix (PA). The time-of-day matrices and traffic occupancy class matrices (SOV, HOV2, and HOV3) are calculated using fixed proportions of the average of the total daily demand and its transpose $(PA + AP)/2$ for both work and non-work.

The toll diversion model splits the demand between toll access and GP lanes only for the SOV classes, and between toll access and HOV access for the HOV classes. This is calculated using the toll and GP skims (`TIME` and `TOLLCOST`) by time-of-day for each of work and non-work separately. The final external-internal demand is added to the auto demand matrices by the *Import auto demand* tool (discussed below).

External external

The total daily external demand is imported from `input/externalExternalTripsByYear.csv`, using the demand for the `scenarioYear` token in `sandag_abm.properties`. If this file does not exist, the values `externalExternalTrips.csv` will be used instead. The total daily demand is split by time-of-day and traffic class `SOVGP`, `HOV2HOV`, and `HOV3HOV` using fixed factors.

Data management tools

Initialize transit database

The *Initialize transit database* creates the transit database and copies a base scenario from the base database using the *Build transit scenario* tool (page 30). The Emme database is created under 'Database_transit' directory, and will overwrite any existing database. The TAZs from the base scenario are removed and the TAP nodes are converted to centroids.

The transit database must be created prior to running the transit assignment and skims.

Initialize matrices

The *Initialize matrices* tool coordinates the initialization of all matrices. The matrix names are listed for each of the model components / steps, and the matrix IDs are assigned consistently from the complete list of matrices names. In each of the other model tools the matrices are only referenced by name, never by ID. The matrix name convention is explained in section 11 Appendix (page 39). The inputs for this tool are:

- Components: A list of the model components / steps for which to initialize matrices. One or more of "`traffic_demand`", "`transit_demand`", "`traffic_skims`", "`transit_skims`", "`external_internal_model`", "`external_external_model`", "`truck_model`", or "`commercial_vehicle_model`".
- Periods: A list of periods for which to initialize matrices, "`EA`", "`AM`", "`MD`", "`PM`", "`EV`"

The initialize matrices tool must be run prior to any other tool which references matrix data, which is all tools except *Import network*, and *Initialize transit database*.

<u>Import seed demand</u>

The *Import seed demand* tool imports the warm start demand matrices from specified OMX files for auto, truck and transit. The imported truck demand can be converted to PCE values in preparation for the assignment (default behavior). The mapping from the names in the OMX files to the matrix names in the Emme database is:

- Auto demand matrices by period:
  - `SOV_GP: SOVGP`
  - `SOV_PAY: SOVTOLL`
  - `SR2_GP: HOV2GP`
  - `SR2_HOV: HOV2HOV`
  - `SR2_PAY: HOV2TOLL`
  - `SR3_GP: HOV3GP`
  - `SR3_HOV: HOV3HOV`
  - `SR3_PAY: HOV3TOLL`
- Truck seed demand by period:
  - `hhdn: TRKHGP`
  - `hhdt: TRKHTOLL`
  - `lhdn: TRKLGP`
  - `lhdt: TRKLTOLL`
  - `mhdn: TRKMGP`
  - `mhdt: TRKMTOLL`
- Transit seed demand by period:
  - `WLK_LOC: WLKBUS`
  - `WLK_LRT: WLKLRT`
  - `WLK_CMR: WLKCMR`
  - `WLK_EXP: WLKEXP`
  - `WLK_BRT: WLKBRT`
  - `PNR_LOC: PNRBUS`
  - `PNR_LRT: PNRLRT`
  - `PNR_CMR: PNRCMR`
  - `PNR_EXP: PNREXP`
  - `PNR_BRT: PNRBRT`
  - `KNR_LOC: KNRBUS`
  - `KNR_LRT: KNRLRT`
  - `KNR_CMR: KNRCMR`
  - `KNR_EXP: KNREXP`
  - `KNR_BRT: KNRBRT`

The auto and truck matrices are stored in the same OMX file by time period, with the name `trip_pp.omx` where pp is one of the five time-of-day periods. Note that the transit seed demand is not imported during the *Master run* as it is not needed for the initial skim assignments. This demand can, however, be used to prepare demand for an independent run of the transit assignment.

<u>Import auto demand</u>

The *Import auto demand* tool imports the auto demand generated from an iteration of the disaggregate demand models (CT-RAMP) and adds the saved disaggregated demand matrices to generate the total auto demand in preparation for the auto assignment. The disaggregate demand models save O-D trip matrices by TAZ in the following files under the `output` directory, where pp is one of the five time-of-day periods:

- `autoTrips_pp.mtx`
- `autoInternalExternalTrips_pp.mtx`
- `autoVisitorTrips_pp.mtx`
- `autoCrossBorderTrips_pp.mtx`
- `autoAirportTrips_pp.mtx`

The OMX name to Emme database name mapping is the same as listed for Import seed demand. A summary of the imported demand is recorded in the logbook.

Import transit demand

The *Import transit demand* tool imports the transit demand generated from an iteration of the disaggregate demand models (CT-RAMP) in preparation for the transit assignment. The disaggregate demand models save O-D trip matrices by TAP in the following files under the `output` directory, where pp is one of the five time-of-day periods:

- `tranVisitorTrips_pp.mtx`
- `tranCrossBorderTrips_pp.mtx`
- `tranAirportTrips_pp.mtx`
- `tranTrips_pp.mtx`
- `tranInternalExternalTrips_pp.mtx`

The OMX name to Emme database name mapping is the same as listed for Import seed demand. A summary of the imported demand is recorded in the logbook.

Export traffic skims

The *Export traffic skims* tool exports the traffic skim matrices to OMX format for the selected period for use in the next disaggregate demand model iteration or the data loader process. See Section 11 Appendix (page 39) for the list of the matrix names. The OMX files are defined in the *Master run* tool, and are `traffic_skims_pp.omx` in the `output` directory, where pp is one of the set of five time-periods.

Export transit skims

The *Export transit skims* tool exports the transit skim matrices to OMX format for use in the next disaggregate demand model iteration or the data loader process. See Section 11 Appendix (page 39) for the list of the matrix names.

This tool includes an option to filter large values from the skim matrices and replace with zeros values ("Replace big values (>10E6) with zero"). This is used in the final iteration skim (after the demand models are complete) to filter large values from the OMX files which are not compatible with the data loader process. The transit assignment will assign a large value of 10e20 for TAP pairs which are disconnected (there is no feasible route).

The OMX file is defined in the *Master run* tool, and it is `transit_skims.omx` in the `output` directory.

Export data loader network

The *Export data loader network* tool generates CSV files with the network results used by the Java Data export process and the Data loader for the reporting database. The files are created under the `report` directory. These are:

- `hwyload_pp.csv`: (pp is one of "`EA`", "`AM`", "`MD`", "`PM`", "`EV`"), traffic class flows by time period
    - The class flows are reported in vehicles; note that the per-class results in the Emme database are stored in PCEs
- `hwy_tcad.csv`: total traffic flows, travel times, and other link attributes for all time periods

- `transit_aggflow.csv`: transit link level results by class and time period
- `transit_flow.csv`: transit segment results by class and time period
- `transit_onoff.csv`: transit stop results by class and time period

Export data loader matrices

The *Export data loader matrices* tool generates OMX and CSV files with the network results used by the Java Data export process and the Data loader for the reporting database. The OMX files are created under the `output` directory and the CSV file is created under the `report` directory. The files and their contents (the OMX key to Emme matrix mapping) are as follows:

- OMX format files, `pp` is replaced by "`EA`", "`AM`", "`MD`", "`PM`", and "`EV`". Note that there is no extension used for these files.
  - `commVehTODTrips`: total, toll, and GP commercial vehicles trips by time period.
    - `OD Trips: COMVEH_TOTAL_DEMAND`
    - `pp Trips: pp_COMVEH`
    - `pp NonToll: pp_COMVEHGP`
    - `pp Toll: pp_COMVEHTOLL`
  - `Trip_pp`: truck trips by class and time period
    - `lhdn: pp_TRKLGP`
    - `mhdn: pp_TRKMGP`
    - `hhdn: pp_TRKHGP`
    - `lhdt: pp_TRKLTOLL`
    - `mhdt: pp_TRKMTOLL`
    - `hhdt: pp_TRKHTOLL`
  - `usSdwrk_pp`, `usSdNon_pp`: external-internal demand for work (`EIWORK`), and non-work (`EINONWORK`) respectively
    - `DAN: pp_SOVGP`
    - `DAT: pp_SOVTOLL`
    - `S2N: pp_HOV2HOV`
    - `S2T: pp_HOV2TOLL`
    - `S3N: pp_HOV3HOV`
    - `S3T: pp_HOV3TOLL`
  - `externalExternalTrips`: external-external demand
    - `Trips: ALL_TOTAL_EETRIPS`
  - `implocl_ppo`: transit skim results for local bus mode
    - `Walk Time: pp_BUS_TOTALWALK`
    - `Initial Wait Time: pp_BUS_FIRSTWAIT`
    - `Transfer Wait Time: pp_BUS_XFERWAIT`
    - `Fare: pp_BUS_FARE`
    - `Number of Transfers: pp_BUS_XFERS`
  - `impprem_ppo`: transit skim results for all modes (premium)
    - `Walk Time: pp_ALL_TOTALWALK`
    - `Initial Wait Time: pp_ALL_FIRSTWAIT`
    - `Transfer Wait Time: pp_ALL_XFERWAIT`
    - `Fare: pp_ALL_FARE`
    - `Number of Transfers: pp_ALL_XFERS`
    - `Length:LB: pp_ALL_BUSDIST`
    - `Length:LR: pp_ALL_LRTDIST`
    - `Length:CR: pp_ALL_CMRDIST`
    - `Length:EXP: pp_ALL_EXPDIST`
    - `Length:BRT: pp_ALL_BRTDIST`
  - `impdan_pp`: auto skim results for `SOVGP`
    - `*SCST_{0}: GENCOST`
    - `*STM_{0} (Skim): TIME`
    - `Length (Skim): DIST`
  - `impdat_pp`: auto skim results for `pp_SOVTOLL`

        - *SCST_{0}: GENCOST
        - *STM_{0} (Skim): TIME
        - Length (Skim): DIST
        - dat_{0} - itoll_{0}: TOLLCOST
    - imps2nh_pp: auto skim results for pp_HOV2HOV
        - *H2CST_{0}: GENCOST
        - *HTM_{0} (Skim): TIME
        - Length (Skim): DIST
    - imps2th_pp: auto skim results for pp_HOV2TOLL
        - *H2CST_{0}: GENCOST
        - *HTM_{0} (Skim): TIME
        - Length (Skim): DIST
        - s2t_{0} - itoll_{0}: TOLLCOST
    - imps3nh_pp: auto skim results for pp_HOV3HOV
        - *H3CST_{0}: GENCOST
        - *HTM_{0} (Skim): TIME
        - Length (Skim): DIST
    - imps3th_pp: auto skim results for pp_HOV3TOLL
        - *H3CST_{0}: GENCOST
        - *HTM_{0} (Skim): TIME
        - Length (Skim): DIST
        - s3t_{0} - itoll_{0}: TOLLCOST
    - imphhdn_pp: truck skim results for pp_ TRKHGP
        - *SCST_{0}: GENCOST
        - *STM_{0} (Skim): TIME
        - Length (Skim): DIST
    - imphhdt_pp: truck skim results for pp_ TRKHTOLL
        - *SCST_{0}: GENCOST
        - *STM_{0} (Skim): TIME
        - Length (Skim): DIST
        - hhdt - ITOLL2_{0}: TOLLCOST
- CSV file
    - ../report/trucktrip.csv: truck trips by class and time period

11. Appendix

Matrix naming convention

The Emme database stores matrices by internal number ID, with one matrix table of values per ID slot. The matrices are given names of up to 40 characters which can be used to reference them in expressions, inputs, worksheets, scripts and so on. The full matrices are identified using the two-character prefix "mf", e.g. `mfAM_SOVGP_GENCOST` for the AM peak period SOV General Purpose lanes (drive-alone, no toll) class generalized cost skim. To maintain consistent correspondence of matrices the generation of matrices is coordinated by the *Initialize matrices* tool. For the full list of matrices, see the *Full matrix directory* (under *General -> Matrices*) in Emme Desktop following a model run.

All assigned demand and skim matrices are preceded by the time period, EA, AM, MD, PM, EV, or ALL (for total matrices for all day). This is followed by the class name, and, in the case of skim matrices only, the name of the skim component. These three identifiers are separated by underscores, `TP_CLASSNAME_SKIMNAME`. For transit, while there are 15 classes of demand per time period, there are only two classes of skims: BUS for local bus only, and ALL for access to all modes (premium mode).

The traffic class names are as follows:

- SOVGP
- SOVTOLL
- HOV2GP
- HOV2HOV
- HOV2TOLL
- HOV3GP
- HOV3HOV
- HOV3TOLL
- TRKHGP
- TRKHTOLL
- TRKLGP
- TRKLTOLL
- TRKMGP
- TRKMTOLL

The traffic skim components are as follows:

- GENCOST: total generalized cost
- TIME: travel time from evaluation of volume-delay functions
- DIST: travel distance
- Toll classes only (class names ending with TOLL)
    - TOLLCOST: total toll cost
    - TOLLDIST: total distance on toll facilities
    - MLCOST: toll cost for managed lane facilities
- HOV classes only (class names starting with HOV)
    - HOVDIST: distance on HOV facilities

The transit class names (demand only) are as follows:

- WLKBUS: walk access local bus
- WLKLRT: walk access light-rail (trolley/sprinter)
- WLKCMR: walk access commuter rail (coaster)
- WLKBRT: walk access bus rapid transit
- WLKEXP: walk access express and premium bus
- PNRBUS: park-and-ride access local bus
- PNRLRT: park-and-ride access light-rail (trolley/sprinter)

- PNRCMR: park-and-ride access commuter rail (coaster)
- PNRBRT: park-and-ride access bus rapid transit
- PNREXP: park-and-ride access express and premium bus
- KNRBUS: kiss-and-ride access local bus demand
- KNRLRT: kiss-and-ride access light-rail (trolley/sprinter)
- KNRCMR: kiss-and-ride access commuter rail (coaster)
- KNRBRT: kiss-and-ride access bus rapid transit
- KNREXP: kiss-and-ride access express and premium bus

The transit skim components (skim type group is either BUS or ALL) are as follows:

- GENCOST: total generalized cost which includes perception factors from assignment
- FIRSTWAIT: actual wait time at initial boarding point
- XFERWAIT: actual wait time at all transfer boarding points
- TOTALWAIT: total actual wait time
- FARE: fare paid
- XFERS: number of transfers
- ACCWALK: access actual walk time prior to initial boarding
- EGRWALK: egress actual walk time after final alighting
- TOTALWALK: total actual walk time
- TOTALIVTT: total actual in-vehicle travel time
- DWELLTIME: total dwell time at stops
- For BUS skim class only
    - DIST: distance travel in-vehicle
- For ALL skim class only
    - BUSIVTT: actual in-vehicle travel time on local bus mode
    - LRTIVTT: actual in-vehicle travel time on LRT mode
    - CMRIVTT: actual in-vehicle travel time on commuter rail mode
    - EXPIVTT: actual in-vehicle travel time on express bus mode
    - LTDEXPIVTT: actual in-vehicle travel time on premium bus mode
    - BRTREDIVTT: actual in-vehicle travel time on red BRT mode
    - BRTYELIVTT: actual in-vehicle travel time on yellow BRT mode
    - BUSDIST: distance travel in-vehicle on local bus mode
    - LRTDIST: distance travel in-vehicle on LRT mode
    - CMRDIST: distance travel in-vehicle on commuter rail mode
    - EXPDIST: distance travel in-vehicle on express/premium bus modes
    - BRTDIST: distance travel in-vehicle BRT mode

The list of additional matrices from the aggregate truck model is below. Note that the final demand matrices for trucks are listed under the traffic assignment matrices. The first three names are per time period matrices, while the remainder are single matrices.

- TRKL: light truck demand (per period)
- TRKM: medium truck demand (per period)
- TRKH: heavy truck demand (per period)
- TRKL_FRICTION: light truck friction factors
- TRKM_FRICTION: medium truck friction factors
- TRKH_FRICTION: heavy truck friction factors
- TRKIE_FRICTION: internal-external truck friction factors
- TRKEI_FRICTION: external-internal truck friction factors
- TRKL_DEMAND: total all day light truck demand
- TRKM_DEMAND: total all day medium truck demand
- TRKH_DEMAND: total all day heavy truck demand
- TRKIE_DEMAND: total all day internal-external truck demand
- TRKEI_DEMAND: total all day external-internal truck demand
- TRKEE_DEMAND: total all day external-external truck demand

The list of matrices for the commercial vehicle model is below. The first three names are per time period matrices, while the remainder are single matrices.

- COMVEH: total commercial vehicle demand (per time period)
- COMVEHGP: commercial vehicle general purpose lanes (non-toll) demand (per time period)
- COMVEHTOLL: commercial vehicle toll demand (per time period)
- COMVEH_BLENDED_SKIM: blended AM and MD skim for CV model
- COMVEH_FRICTION: friction factors for CV model
- COMVEH_TOTAL_DEMAND: total all day commercial vehicle demand

The other matrices used for the aggregate external models are as follows:

- EIWORK: external-internal (USA-San Diego) demand for work trips by time period and 6 auto modes
    - SOVGP
    - SOVTOLL
    - HOV2HOV
    - HOV2TOLL
    - HOV3HOV
    - HOV3TOLL
- EINONWORK: external-internal (USA-San Diego) demand for non-work trips by time period and 6 auto modes
    - SOVGP
    - SOVTOLL
    - HOV2HOV
    - HOV2TOLL
    - HOV3HOV
    - HOV3TOLL
- ALL_TOTAL_EETRIPS: total all day external-external vehicle trips
- SOVGP_EETRIPS: external-external trips for SOV, general purpose lanes (per time period)
- HOV2HOV_EETRIPS: external-external trips for HOV2, HOV lanes (per time period)
- HOV3HOV_EETRIPS: external-external trips for HOV3+, HOV lanes (per time period)

Attribute name mappings

A runtime list of attribute mappings is recorded in the Logbook during a run of the *Import network* tool. The full list of available keywords (both built-in and user defined) can be found by type in Emme Desktop under *Window -> Attribute list -> TYPE Attributes*.

Table 10 - Traffic link attribute name mapping from hwycov.e00

hwycov.e00 name	**Emme name**	**Source**	**Emme type**	**Description**
HWYCOV-ID	@tcov_id	TWO_WAY	EXTRA	SANDAG-assigned link ID
SPHERE	@sphere	TWO_WAY	EXTRA	Jurisdiction sphere of influence
NM	#name	TWO_WAY	STRING	Street name
FXNM	#name_from	TWO_WAY	STRING	Cross street at the FROM end
TXNM	#name_to	TWO_WAY	STRING	Cross street name at the TO end
DIR	@direction_cardinal	TWO_WAY	EXTRA	Link direction
ASPD	@speed_adjusted	TWO_WAY	EXTRA	Adjusted link speed (miles/hr)
IYR	@year_open_traffic	TWO_WAY	EXTRA	The year the link opened to traffic
IPROJ	@project_code	TWO_WAY	EXTRA	Project number for use with hwyproj.xls
IJUR	@jurisdiction_type	TWO_WAY	EXTRA	Link jurisdiction type
IFC	type	TWO_WAY	STANDARD	
IHOV	@lane_restriction	TWO_WAY	EXTRA	Link operation type
ITRUCK	@truck_restriction	TWO_WAY	EXTRA	Truck restriction code (ITRUCK)
ISPD	@speed_posted	TWO_WAY	EXTRA	Posted speed limit (mph)
IMED	@median	TWO_WAY	EXTRA	Median type
AU	@lane_auxiliary	ONE_WAY	EXTRA	Number of auxiliary lanes
CNT	@traffic_control	ONE_WAY	EXTRA	Intersection control type
TL	@turn_thru	ONE_WAY	EXTRA	Intersection approach through lanes
RL	@turn_right	ONE_WAY	EXTRA	Intersection approach right-turn lanes
LL	@turn_left	ONE_WAY	EXTRA	Intersection approach left-turn lanes
GC	@green_to_cycle_init	ONE_WAY	EXTRA	Initial green-to-cycle ratio
CHO	@capacity_hourly_op	ONE_WAY	EXTRA	Off-Peak hourly mid-link capacity
CHA	@capacity_hourly_am	ONE_WAY	EXTRA	AM Peak hourly mid-link capacity
CHP	@capacity_hourly_pm	ONE_WAY	EXTRA	PM Peak hourly mid-link capacity
ITOLLO	@toll_ *pp*	TWO_WAY		Expanded to EA, MD and EV
ITOLLA	@toll_ am	TWO_WAY	--	
ITOLLP	@toll_ pm	TWO_WAY	--	
LNO	@lane_*pp*	ONE_WAY	--	Expanded to EA, MD and EV
LNA	@lane_am	ONE_WAY	--	
LNP	@lane_pm	ONE_WAY	--	
CPO	@capacity_link_ *pp*	ONE_WAY	--	Expanded to EA, MD and EV
CPA	@capacity_link_am	ONE_WAY	--	
CPP	@capacity_link_ *pp*	ONE_WAY	--	
CXO	@capacity_inter_am	ONE_WAY	--	Expanded to EA, MD and EV
CXA	@capacity_inter_am	ONE_WAY	--	
CXP	@capacity_inter_pm	ONE_WAY	--	
TMO	@time_link_ *pp*	ONE_WAY	--	Expanded to EA, MD and EV
TMA	@time_link_am	ONE_WAY	--	
TMP	@time_link_pm	ONE_WAY	--	
TXO	@time_inter_*pp*	ONE_WAY	--	Expanded to EA, MD and EV
TXA	@time_inter_am	ONE_WAY	--	
TXP	@time_inter_pm	ONE_WAY	--	

hwycov.e00 name	Emme name	Source	Emme type	Description
TLB	--	ONE_WAY	--	
RLB	--	ONE_WAY	--	
LLB	--	ONE_WAY	--	
--	@cost_operating	DERIVED	EXTRA	Fuel and maintenance cost
--	@cost_auto_ea	DERIVED	EXTRA	Early AM toll + cost autos
--	@cost_auto_am	DERIVED	EXTRA	AM Peak toll + cost autos
--	@cost_auto_md	DERIVED	EXTRA	Mid-day toll + cost autos
--	@cost_auto_pm	DERIVED	EXTRA	PM Peak toll + cost autos
--	@cost_auto_ev	DERIVED	EXTRA	Evening toll + cost autos
--	@cost_hov_ea	DERIVED	EXTRA	Early AM toll (non-mngd) + cost HOV
--	@cost_hov_am	DERIVED	EXTRA	AM Peak toll (non-mngd) + cost HOV
--	@cost_hov_md	DERIVED	EXTRA	Mid-day toll (non-mngd) + cost HOV
--	@cost_hov_pm	DERIVED	EXTRA	PM Peak toll (non-mngd) + cost HOV
--	@cost_hov_ev	DERIVED	EXTRA	Evening toll (non-mngd) + cost HOV
--	@cost_med_truck_ea	DERIVED	EXTRA	Early AM toll + cost medium trucks
--	@cost_med_truck_am	DERIVED	EXTRA	AM Peak toll + cost medium trucks
--	@cost_med_truck_md	DERIVED	EXTRA	Mid-day toll + cost medium trucks
--	@cost_med_truck_pm	DERIVED	EXTRA	PM Peak toll + cost medium trucks
--	@cost_med_truck_ev	DERIVED	EXTRA	Evening toll + cost medium trucks
--	@cost_hvy_truck_ea	DERIVED	EXTRA	Early AM toll + cost heavy trucks
--	@cost_hvy_truck_am	DERIVED	EXTRA	AM Peak toll + cost heavy trucks
--	@cost_hvy_truck_md	DERIVED	EXTRA	Mid-day toll + cost heavy trucks
--	@cost_hvy_truck_pm	DERIVED	EXTRA	PM Peak toll + cost heavy trucks
--	@cost_hvy_truck_ev	DERIVED	EXTRA	Evening toll + cost heavy trucks
--	@cycle_ea	DERIVED	EXTRA	Early AM cycle length (minutes)
--	@cycle_am	DERIVED	EXTRA	AM Peak cycle length (minutes)
--	@cycle_md	DERIVED	EXTRA	Mid-day cycle length (minutes)
--	@cycle_pm	DERIVED	EXTRA	PM Peak cycle length (minutes)
--	@cycle_ev	DERIVED	EXTRA	Evening cycle length (minutes)
GCO	@green_to_cycle_ea	DERIVED	EXTRA	Early AM green to cycle ratio
GCA	@green_to_cycle_am	DERIVED	EXTRA	AM Peak green to cycle ratio
GCO	@green_to_cycle_md	DERIVED	EXTRA	Mid-day green to cycle ratio
GCP	@green_to_cycle_pm	DERIVED	EXTRA	PM Peak green to cycle ratio
GCo	@green_to_cycle_ev	DERIVED	EXTRA	Evening green to cycle ratio
CPO	@capacity_link_ea	DERIVED	EXTRA	Early AM mid-link capacity
CPA	@capacity_link_am	DERIVED	EXTRA	AM Peak mid-link capacity
CPO	@capacity_link_md	DERIVED	EXTRA	Mid-day mid-link capacity
CPP	@capacity_link_pm	DERIVED	EXTRA	PM Peak mid-link capacity
CPO	@capacity_link_ev	DERIVED	EXTRA	Evening mid-link capacity
CXO	@capacity_inter_ea	DERIVED	EXTRA	Early AM approach capacity
CXA	@capacity_inter_am	DERIVED	EXTRA	AM Peak approach capacity
CXO	@capacity_inter_md	DERIVED	EXTRA	Mid-day approach capacity
CXP	@capacity_inter_pm	DERIVED	EXTRA	PM Peak approach capacity
CXO	@capacity_inter_ev	DERIVED	EXTRA	Evening approach capacity
ITOLLO	@toll_ea	DERIVED	EXTRA	Early AM toll cost (cent)
ITOLLA	@toll_am	DERIVED	EXTRA	AM Peak toll cost (cent)
ITOLLO	@toll_md	DERIVED	EXTRA	Mid-day toll cost (cent)
ITOLLP	@toll_pm	DERIVED	EXTRA	PM Peak toll cost (cent)

hwycov.e00 name	Emme name	Source	Emme type	Description
ITOLLO	@toll_ev	DERIVED	EXTRA	Evening toll cost (cent)
LNO	@lane_ea	DERIVED	EXTRA	Early AM number of lanes
LNA	@lane_am	DERIVED	EXTRA	AM Peak number of lanes
LNO	@lane_md	DERIVED	EXTRA	Mid-day number of lanes
LNP	@lane_pm	DERIVED	EXTRA	PM Peak number of lanes
LNO	@lane_ev	DERIVED	EXTRA	Evening number of lanes
TMO	@time_link_ea	DERIVED	EXTRA	Early AM link time in minutes
TMA	@time_link_am	DERIVED	EXTRA	AM Peak link time in minutes
TMO	@time_link_md	DERIVED	EXTRA	Mid-day link time in minutes
TMP	@time_link_pm	DERIVED	EXTRA	PM Peak link time in minutes
TMO	@time_link_ev	DERIVED	EXTRA	Evening link time in minutes
TXO	@time_inter_ea	DERIVED	EXTRA	Early AM intersection delay time
TXA	@time_inter_am	DERIVED	EXTRA	AM Peak intersection delay time
TXO	@time_inter_md	DERIVED	EXTRA	Mid-day intersection delay time
TXP	@time_inter_pm	DERIVED	EXTRA	PM Peak intersection delay time
TXO	@time_inter_ev	DERIVED	EXTRA	Evening intersection delay time

Table 11 - Transit link attribute name mapping from trcov.e00

trcov.e00 name	Emme name	Source	Emme type	Description
TRCOV-ID	@tcov_id	TWO_WAY	EXTRA	SANDAG-assigned link ID
NM	#name	TWO_WAY	STRING	Street name
FXNM	#name_from	TWO_WAY	STRING	Cross street at the FROM end
TXNM	#name_to	TWO_WAY	STRING	Cross street name at the TO end
DIR	@direction_cardinal	TWO_WAY	EXTRA	Link direction
OSPD	@speed_observed	TWO_WAY	EXTRA	Observed speed
IYR	@year_open_traffic	TWO_WAY	EXTRA	The year the link opened to traffic
IFC	type	TWO_WAY	STANDARD	
IHOV	@lane_restriction_tr	TWO_WAY	EXTRA	Link operation type
ISPD	@speed_posted_tr_l	TWO_WAY	EXTRA	Posted speed limit (mph)
IMED	@median	TWO_WAY	EXTRA	Median type
TMO	--	ONE_WAY	--	Expanded to EA, MD and EV
--	@trtime_link_ea	DERIVED	EXTRA	Early AM transit link time in minutes
TMA	@trtime_link_am	ONE_WAY	EXTRA	AM Peak transit link time in minutes
--	@trtime_link_md	DERIVED	EXTRA	Mid-day transit link time in minutes
TMP	@trtime_link_pm	ONE_WAY	EXTRA	PM Peak transit link time in minutes
--	@trtime_link_ev	DERIVED	EXTRA	Evening transit link time in minutes
MINMODE	@mode_hierarchy	TWO_WAY	EXTRA	Transit mode type

Table 12 - Transit route attribute name mapping from trrt.csv and mode5tod.dbf

trrt.csv / mode5tod.dbf name	Emme name	Source	Type	Description
AM_Headway	@headway_am	TRRT	EXTRA	AM Peak actual headway
PM_Headway	@headway_pm	TRRT	EXTRA	PM Peak actual headway
OP_Headway	@headway_op	TRRT	EXTRA	Off-Peak actual headway
Night_Headway	@headway_night	TRRT	EXTRA	Night actual headway
AM_Headway_rev	@headway_rev_am	DERIVED	EXTRA	AM Peak revised headway
PM_Headway_rev	@headway_rev_pm	DERIVED	EXTRA	PM Peak revised headway
OP_Headway_rev	@headway_rev_op	DERIVED	EXTRA	Off-Peak revised headway
WT_IVTPK	@vehicle_per_pk	MODE5TOD	EXTRA	Peak in-vehicle perception factor
WT_IVTOP	@vehicle_per_op	MODE5TOD	EXTRA	Off-Peak in-vehicle perception factor
WT_FAREPK	@fare_per_pk	MODE5TOD	EXTRA	Peak fare perception factor
WT_FAREOP	@fare_per_op	MODE5TOD	EXTRA	Off-Peak fare perception factor
DWELLTIME	--	MODE5TOD	--	Used in segment dwt standard attribute
Fare	@fare	TRRT	EXTRA	Boarding fare ($)
--	@transfer_penalty	DERIVED	EXTRA	Transfer penalty (min)
Route_ID	@route_id	TRRT	EXTRA	Transit line internal ID
Night_Hours	@night_hours	TRRT	EXTRA	Night hours
Config	@config	TRRT	EXTRA	Config ID (same as route name)

Table 13 - Transit segment (and stop) attribute name mapping from trstop.csv

trstop.csv name	Emme name	Source	Type	Description
Stop_ID	@stop_id	TRSTOP	EXTRA	Stop ID from trcov
Pass_Count	@pass_count	TRSTOP	EXTRA	Number of times this stop is passed
Milepost	@milepost	TRSTOP	EXTRA	Distance from start of line
FareZone	@fare_zone	TRSTOP	EXTRA	Fare zone ID
StopName	#stop_name	TRSTOP	STRING	Name of stop
--	@coaster_fare_board	DERIVED	EXTRA	Boarding fare for Coaster
--	@coaster_fare_inveh	DERIVED	EXTRA	Incremental fare for Coaster