



## SEVENTH FRAMEWORK PROGRAMME

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### ***Deliverable 4.1 - “A technical documentation of the model structure and operation”***

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The following table shows the abbreviations used throughout the deliverable with the meaning of the abbreviation.

Abbreviation	Explanation
Calc	Calculation, used as name for the temporary data used during model calculation.
DTU	Technical University Denmark
GB	Gigabyte
.gdb	File system extension for File Geodatabase.
MXD	ArcMap Map document
PDF	Portable Document Format
SCN	Scenario, used as prefix in table names.
SQL	Structured Query Language
SQL Server	Database product from Microsoft.
TT	Transtools
TT3	Transtools version 3

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## Summary



### Scope

The scope of this deliverable is to document the technical structure of, and how to operate the TT3 model.

### Methodology

The methodology has been describing the software used, and document how to use the new user interface.

### Results

The results of the technical documentation effort are, together with the data structure documentation, a documentation that will allow users to start operate the Transtools model.

### Next Step

This document can be used to start operate the Transtools 3 mode. Parts of this Deliverable will be revised for the final Transtools 3 user guide.

## 1. Introduction

This deliverable is produced under WP4: Flexible modelling framework. The note describes the user interface and technical operation of Transtools 3 (TT3).

This note builds on the previous work in (Brun & Nielsen, Transtools 3 Deliverable 3.1 Guidelines for model configurations, 2012), (Brun, Transtools 3 Deliverable 3.2 User Interface Design, 2012), (Brun, Transtools 3 Deliverable 3.3 Model Configurations, 2016) and (Brun, Transtools3 Deliverable 3.4 Data Structure, 2016).

At the stage of application for the TT3 project, it was realised that some changes to the overall structure of the Transtools modelling system were needed in order to ensure a modular and flexible model implementation. Improvements were foreseen within these areas:

- User interface design
- Software architecture
- Data structure

The overall model logic in TT1 and TT2 was implemented in the ArcGIS Geoprocessing framework. Consequently, the user interface for TT1 and TT2 has simply been ArcGIS (mainly the ArcCatalog application). This has given all users flexibility to manipulate the model structure and its detailed composition as well as the precise sequencing of all of its individual steps.

TT3 will use a new interface for managing scenarios and executing TT model runs:

The new user interface is much easier to operate than the one available in previous Transtools versions; also for model-users who are not experienced ArcGIS users.

### 1.1 Objective of the deliverable

The objective of this deliverable is to enable users to understand and operate the new user interface of the Transtools 3 model.

This document forms the first version of the user guide, which together with (Brun, Transtools3 Deliverable 3.4 Data Structure, 2016) gives technical understanding of the Transtools 3 model.

Parts of this document will be revised in the Transtools 3 user guide (Cochrane & Brun, 2016).

### 1.2 Methodology and results

The process followed in preparation for this deliverable has been to combine the need for an easy user interface in Transtools1 and Transtools2 with the well-functioning user interface in the National Danish Model.

Transtools3 will reap the benefits of the work put into the National Danish Model. This will enable users of the user interface to have flexibility needed for performing most tasks. If further possibilities for altering the model are required, the users can take advantage of the advanced user interface.

## 2. Technical Model Structure

The architecture of the model, separates the calculation from the scenario data. The many benefits of this are described in (Brun, Transtools3 Deliverable 3.4 Data Structure, 2016). The scenario data, which can be controlled in detail, must be imported to the calculation system, and results must be exported from the calculation system. The model manger is used for that before and after a scenario run.

Figure 1 shows the data flow in the technical model structure surrounding the scientific calculation. The scientific calculation takes place in the Scenario Run, as illustrated by the small process diagram inside the Scenario Run.

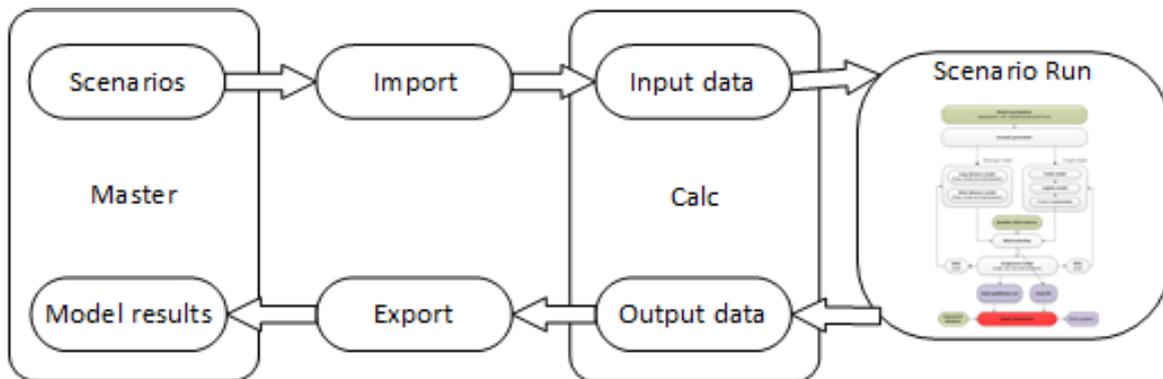


Figure 1 TT3 technical model structure

The above described technical model structure is the same regardless of the configuration (Brun, Transtools 3 Deliverable 3.3 Model Configurations, 2016) used for the scenario run. A scenario run with a new road can use a simple configuration in the above structure. A scenario run for establishing a new future year reference scenario (Rich, 2016) will use a more thorough configuration, again using the same technical model structure above.

## 3. Software for the model and database

The software in this project is built on a proven approach, which has been used in a number of very large scale modelling projects, including Transtools and the Danish National Transport Model. This approach is evolutionary rather than revolutionary.

Transtools 1 and 2 used a cumbersome user interface, but this is changed completely in Transtools 3, which uses the concept from the Danish national model.

Proven industry standard software, ArcGIS and SQL Server, is used as the technical basis. In addition, Commercial assignment model software is used and custom software is developed for other model components.

The architecture and overall approach is described in detail in the following sections.

The overall software architecture is described in this section.

First a bit of background is given, covering experience gained in previous large-scale modelling projects. Then, the software components, the architecture of the complete model and the data-flows and are described.

### 3.1 Background

DTU Transport and Rapidis have a long history of collaborating on large-scale modelling projects. A number of technical requirements have turned out to be common for most of these projects.

For more than decade, DTU Transport and Rapidis has focused on meeting these requirements by using industry standard software tools. The software architecture described in the following is based on experiences gained in prior projects.

Transtools3 is very much based on the software architecture used in the national Danish transport model. This is an architecture, which has evolved over a period of 5 years from 2010 to 2015 with a very heavy involvement of end users and many iterative changes to the user experience in the model based on user feedback.

The development of the national Danish model drew heavily on experiences from developing Transtools versions 1 and 2, but the architecture is very different, primarily because we have listened very carefully to the feedback from users of these early Transtools versions. The feedback was far from altogether positive, which is why – in the Danish national model and in Transtools3 – we have changed many aspects of the software architecture. Like:

- ArcGIS Model Builder is replaced as the user interface for running the model. It is replaced with a dedicated application, which presents a high-level interface to the modelling system and lets user get on modelling tasks without worrying too much about technical matters.
- A completely new architecture for scenario management. Early Transtools version effectively did not have a system for managing scenarios. The national Danish model and Transtools3 has very strong systems for scenario management, which cuts across databases, editing, and user interface and result storage.
- Microsoft Access with its 4 GB per database file limit is replaced with SQL Server and File geodatabases

### 3.2 Software components

The main technical components of the technical solution are SQL Server, ArcGIS and Traffic Analyst. Below, a short overview is given for each software component in the solution.

Using this platform offers fast and flexible development of complex calculation processes in addition to the ability to handle large amounts of data. Experience has shown that this platform makes it is easy to integrate calculation models from multiple partners as well as facilitating import and export of data.

### 3.2.1 SQL Server

Microsoft SQL Server is one of the world's leading relational database management systems and it integrates very well with ArcGIS.

SQL Server has been used successfully in large-scale transportation models, which uses terabytes of data as input and output for a model run.

SQL Server has excellent performance for moving bulk data. The product includes a powerful management and development suite, enabling easy development of stored procedures and SQL queries.

### 3.2.2 ArcGIS

ArcGIS is the world leading GIS platform from Esri.

The model calculation flows will be constructed and orchestrated with ArcGIS Geoprocessing.

The infrastructure network connectivity is ensured by ArcGIS Network Datasets.

The maps generated are produced by ArcMap and can be used by other applications inside the European Commission if such applications need to show data from this transport model.

### 3.2.3 Network Analyst

Network Analyst is an extension to ArcGIS, it contains a robust methods and storage for network data including topology, this is an improvement over previous versions of Transtools where correct network topology was the responsibility of the users. Network Analyst also includes utilities for basic pathfinding, traveling salesman, navigation etc., which are not used in the Transtools 3 model.

### 3.2.4 Traffic Analyst

Transtools version 1 and 2 used Rapidis' Traffic Analyst software for assignment. Traffic Analyst embeds assignment functions into desktop ArcGIS software (ArcMap and ArcCatalog). It was very easy for model developers to integrate assignment model calculations into the overall model workflow

The route choice model in Transtools version 1 and 2 (implemented using Traffic Analyst software) used Stochastic User Equilibrium route choice with Monte Carlo Simulation, which had very poor convergence on a European network and caused very long model run times. In this project, we change the route choice modelling from using Stochastic User Equilibrium route choice with Monte Carlo Simulation to using RSUE path based assignment. This requires more memory, but due to 64-bit and larger much cheaper computer memory, this is now feasible. This eliminates entire categories of convergence problems, and reduces assignment model execution times.

In Transtools 3 the assignment models (Nielsen, Rasmussen, & Pedersen, 2016) are implemented using Traffic Analyst.

### 3.2.5 Custom software for demand models

Demand models are implemented as purpose built 64-bit software for this project. The programming language is C#, which is a general purpose programming language with wide support for building optimized memory based data structures, for managing highly parallel code effectively and which approaches C++ in terms of raw performance, but which only require a fraction of the development effort and which helps tremendously in preventing errors.

Previous versions of Transtools (1 & 2) used a mixed bag of:

- Old programming languages (Delphi) for the TT 1 trade model
- Obscure simulation tools (VenSim) for the TT 1 passenger model
- 32-bit single-threaded Visual Basic .NET code for the TT 1 logistics model
- A SQL Server database program for the TT 2 passenger model

Using a modern performance-oriented programming language with support for 64-bit memory space and parallel execution will yield a massive performance gain compared to previous models.

In Transtools 3, the Passenger demand model (Berglund & Algiers, 2015) and the freight demand model (de Jong, et al., 2015) are implemented as purpose built 64-bit software.

## 3.3 Calculation process

The ArcGIS platform includes a Model orchestration and execution framework across its different software products. It is named Geoprocessing and is exceptionally well suited for designing and implementing complex modelling workflows. ArcGIS Geoprocessing has been used successfully for this in all versions of Transtools.

A very big change to the usage of ArcGIS Geoprocessing is implemented in Transtools3. In previous models (Transtools 1 & 2), ArcGIS Geoprocessing was also user as the primary user interface for running the transport model. This is completely changed in Transtools3, where end users never have to interact with ArcGIS Geoprocessing.

The transport model as a whole consists of many different models and steps, which need to execute in the correct sequence. Many steps are pieces of software, which in themselves are implemented using several different technologies. So the mechanism for managing the overall model flow sequence needs to be able to work with many different technologies, and Geoprocessing does that.

This orchestration and the technology used to implement it are invisible and irrelevant to ordinary users. Ordinary users will only see the user interface. The model orchestration works behind the scenes while the model is running.

## 4. User interface

This is a description of the elements in the user interface in the Transtools 3 model. It starts with a walkthrough of the basic parts in the Model Manager user interface. Then the general concepts of Sub Scenarios, Main Scenarios, Configurations and Model Runs are explained.

### 4.1 Model Manager user interface

Scenario management and model runs are done in the application called Model Manager, with further description below.

Data editing is mostly done in ArcMap. Some edits could be done using SQL Server Management Studio.

#### 4.1.1 Elements in the user interface

This is the Transtools 3 user interface, shown in Figure 2.

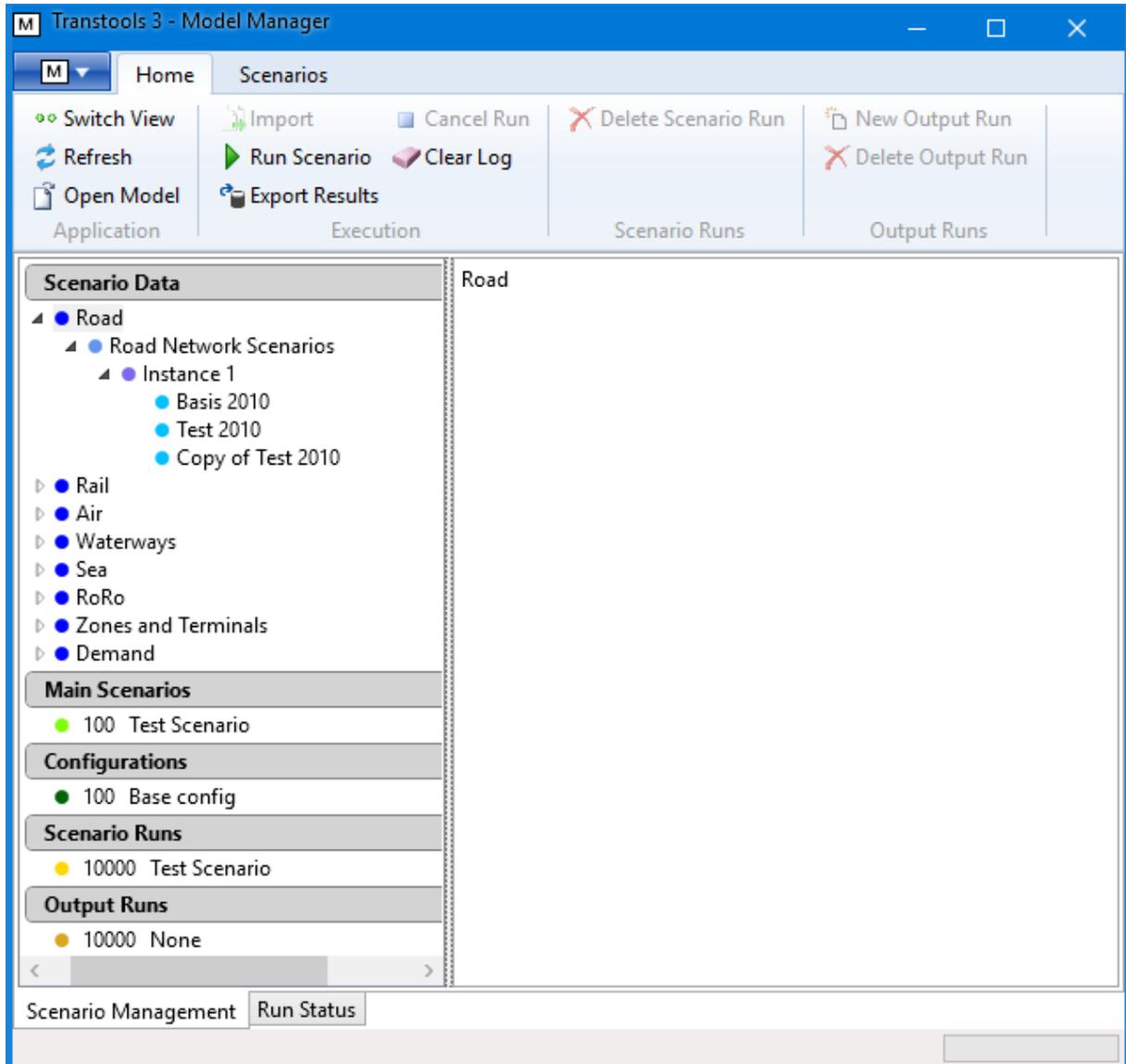


Figure 2 Transtools 3 User interface

All scenario information is read from the master database, and any changes made in the manager are applied to the master database.

#### 4.1.2 Top toolbar

The top toolbar (also called ribbon) contains the most used tools. Some of them are also found on the context menu when right clicking on certain features in the user interface.

"Run Scenario" starts the imported scenario.

“Cancel run” is only active when running a model. It cancels the model run. That is the correct way to cancel a run. It is not advised to just close the Model Manager. Sometimes the Cancel operation itself may take a few minutes. It is not advisable to attempt to cancel a model run immediately after it has been started, as this may crash the manager. Instead wait at least a few minutes until at least a few lines of status messages have been displayed.

“Import” will import a selected main scenario to the calculation database.

“Clear Log” will clear the log window.

“Refresh” rereads information shown in the tree structure from the master database.

### 4.1.3 Tree structure

When the application starts, the contents of the master database is shown in a tree structure. It is divided in Scenario Data, Configurations, Main Scenarios, Scenario Runs, Output Runs.

For the elements in the tree, a range of symbols are shown.

- Headlines with grey background.
- A small triangle ( ▸ when not expanded, ▴ when expanded) used to expanding the tree structure (it might not look like a triangle when using the application through a remote desktop.)
- A dot with a colour used to distinguish different types of elements
  - ● Data scenario groups, grouped logically in Road, Rail, Air, etc.
  - ● Data scenario types
  - ● Instances of data sets in data scenario types
  - ● Individual scenarios
  - ● Main scenarios
  - ● Configuration
  - ● Scenario Runs
  - ● Output Runs
- The name of the element.

Figure 2 show functionality of the small triangle, expanding the tree structure. The individual scenarios that are part of “Road” come into view one hierarchy level at a time.

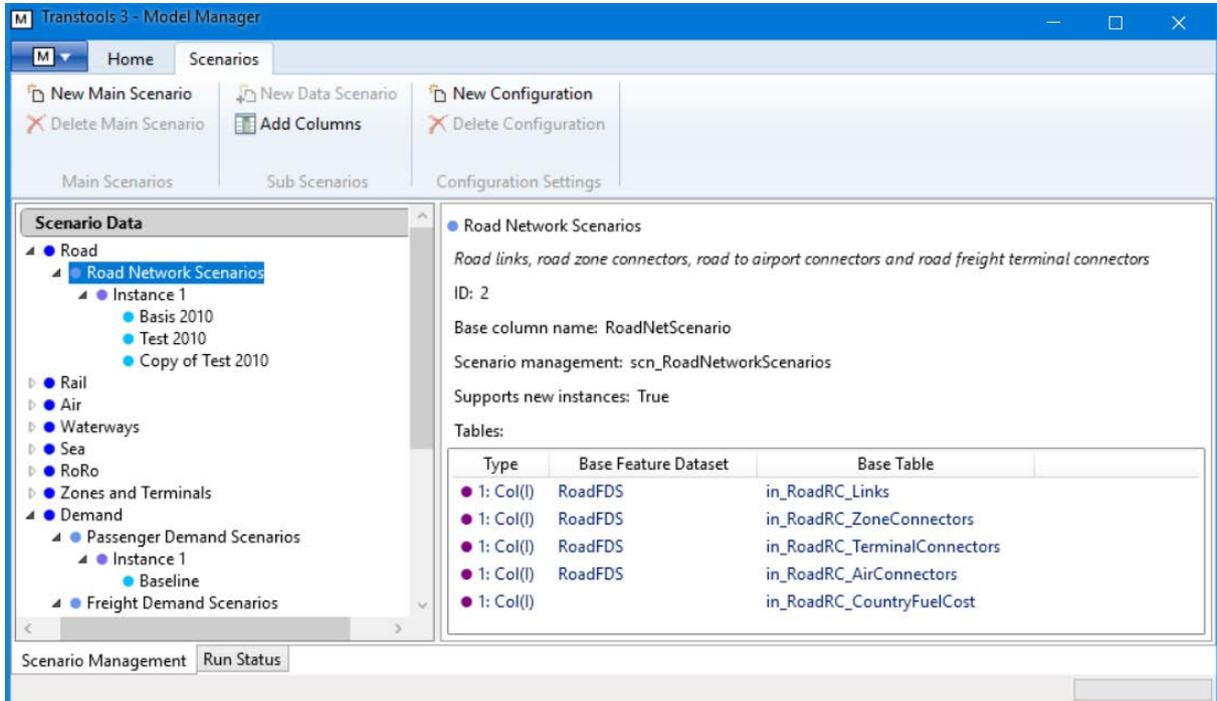
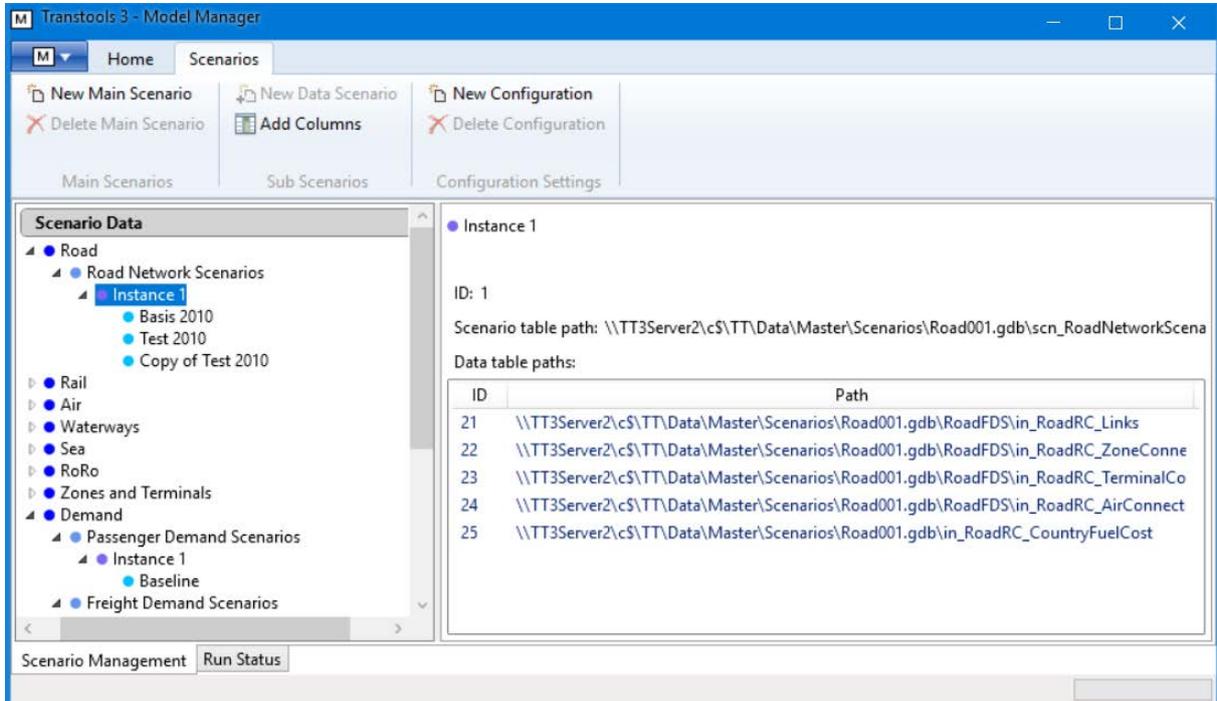


Figure 3 TT3 user interface, Road Network Scenarios selected

Figure 3 shows the user interface with “Road Network Scenarios” selected. The right pane shows the tables that are scenario controlled together as “Road Network Scenarios”, (Links, various Connectors and country fuel cost). Links and Connectors are features located in a Feature Dataset.



**Figure 4 TT3 user interface Road Network Scenarios, Instance 1 selected**

Selecting the Instance (Figure 4) displays the location of the data sets for the instance. The instance in this example is located in the geodatabase called Road001.gdb.

One of the scenario versions in the instance is selected in Figure 5. The right pane shows the id of the scenario version and its parents id.

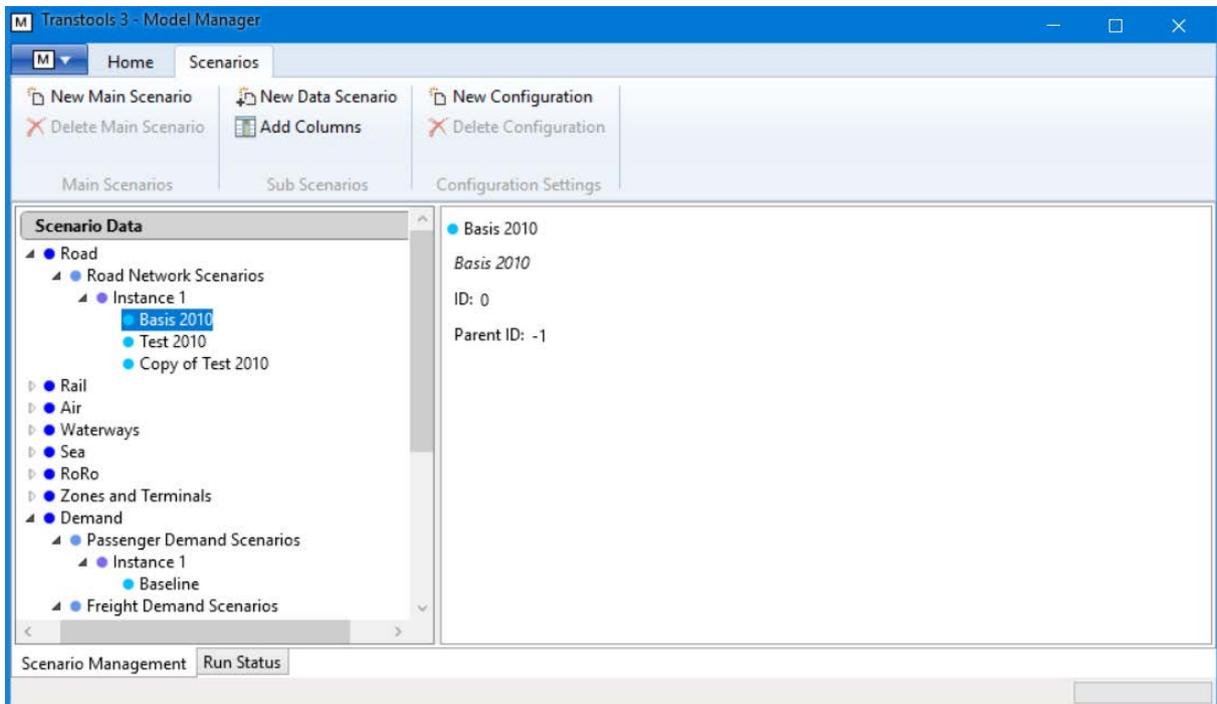


Figure 5 TT3 user interface Road scenarios

Clicking the New Data Scenario button shows the dialog in Figure 6. Users can choose which fields to be changed in the scenario.

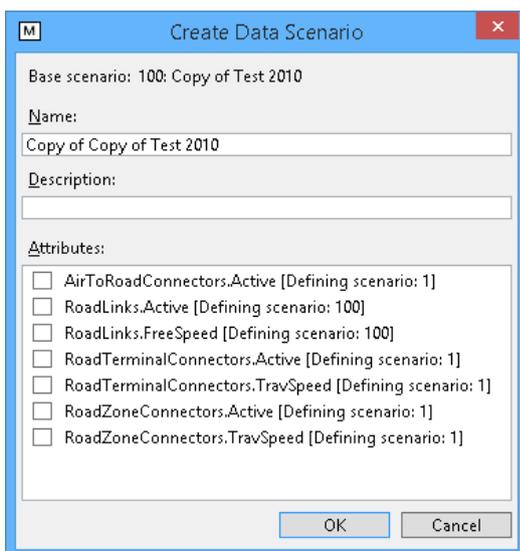


Figure 6 TT3 user interface, Create new data scenario

## 4.2 Data scenario

In TT3 the key concept of the scenario management is the data scenarios types. The input data for the model has been divided into logical groups which describe separate parts of the model assumptions, e.g. Road Network, Rail Network, Passenger Demand Matrices. These groups are referred to as a data scenario type.

A data scenario in TT3 is one version of the assumptions for a given data scenario type. This could be a basis 2010 passenger demand or 2020 rail network. Within each data scenario type any given number of data scenarios can be created.

In order to manage the data scenarios within a data scenario type one of two principles are applied on each table/feature class.

Data can be scenario controlled as:

- Row based
  - A data scenario (version of data) is a set of rows in from the database table.
  - Each row in the table belongs to one and only one data scenario. The identified using individual scenario ID column.
  - Table names starting with “in\_” are input.
  - Table names starting with “inout\_” are input and output. The output of one model run can be used as input in another model run.
- Column based
  - Data stored in feature classes (geographic data)
  - Each feature is unique, and not duplicated for each scenario.
  - A scenario consists of new columns with values for the specific scenario
  - Inheritable, a new scenario only overrides necessary columns.

In a given data scenario type all tables use one of the two scenario control methods. However, it can be mixed so some tables are row-based and other column-based.

In the “tree-structure”, the data scenario types are grouped after model area (e.g. the data scenario group ‘Rail’ has 3 data scenario types: Rail net, Rail Ticket price and Rail Frequency).

In the “tree-structure” of the model manager, are options for creating new scenarios.

For column-based data tables, a new data scenario is created by copying rows for an existing data scenario.

For the column based data tables, a new data scenario is created by inheriting from an existing data scenario.

### 4.2.1 Best practice for managing columns based data scenarios

Column-based tables are mostly networks. The primary way to create a new column based scenario is to inherit from an existing scenario.

The point of the inheriting operation is to be able to selectively decide which columns in the network should reuse the values from the data scenario from which the new data scenario should inherit and which columns should be overridden (changed in the specific scenario).

For each data scenario type (Zone scenario, Road Network scenario, Rail Network scenario, etc.), there exists always in the master database at least one data scenario. This first data scenario will be data scenario number 0 and it will represent the 2010 base situation. In addition the master database will contain other baseline scenarios for other years – 2020, 2030, etc.

It is a good practice to never edit any of these baseline scenarios, since such edits can never be “erased”. In other words, the baseline scenarios should be left alone as “clean” points from which to inherit other data scenarios in the future.

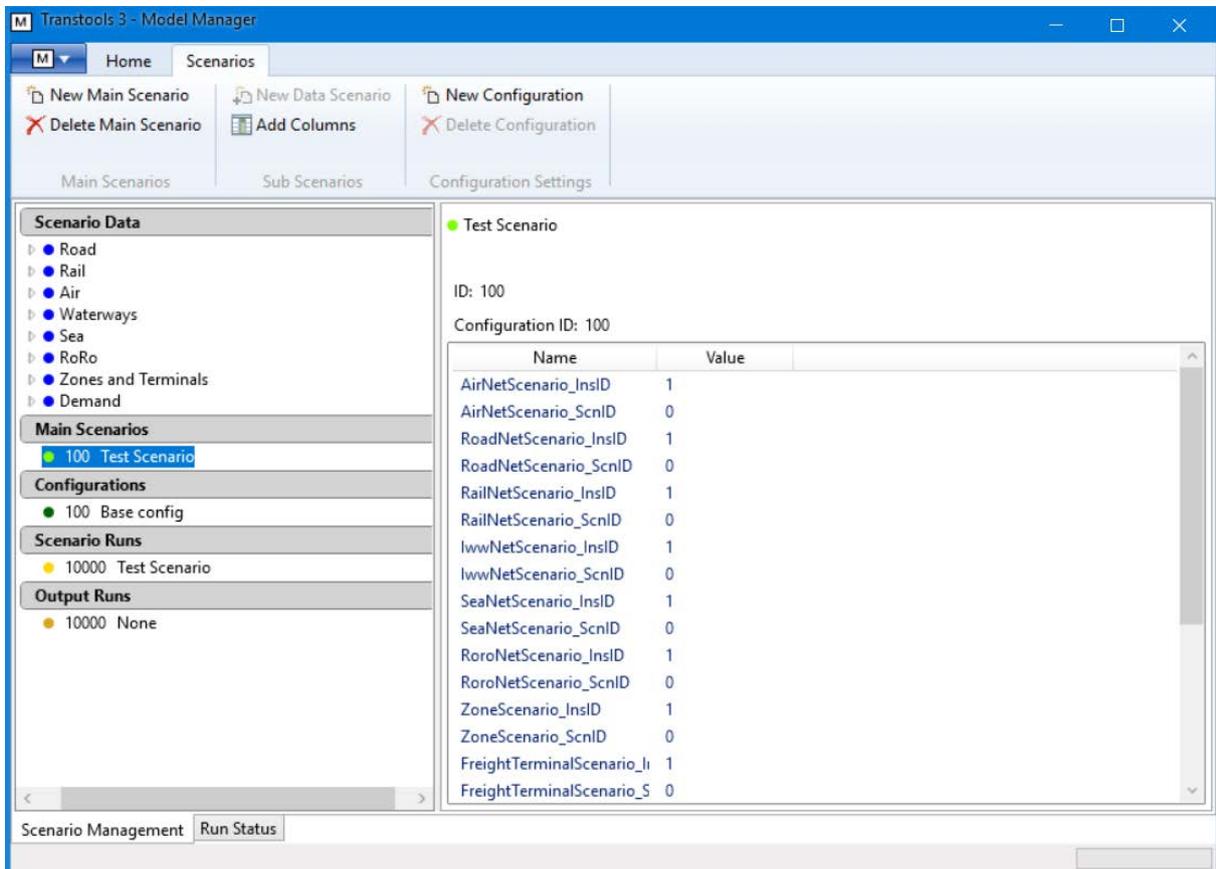
When beginning a new project, where a variety of different alternatives will be studied, it is therefore a best practice to start by creating project specific baseline data scenario for the years, which are to be examined and then inherit variant from this.

If – at the outset – no project specific changes are foreseen to the baseline scenarios, it is a best practice not to override any attributes when creating the project specific baseline, but rather to override these attributes on an “on demand” basis – i.e. if at some point during the project it is determined that adjustments need to be made to some aspects of road congestion modelling, then attributes like QueueSpeed, LaneHCFor, LaneHCBack, LanesFor, LanesBack, etc. could be overridden as necessary.

### 4.3 Main Scenarios

When users start a model run it is done on a Main Scenario. A Main Scenario can be run more several times. Each time a Main Scenario is run, a Scenario Run is created.

Main scenarios are marked by bright green dots ● in the tree structure. Clicking the small triangle next to “Main Scenarios” expands the list of scenarios.

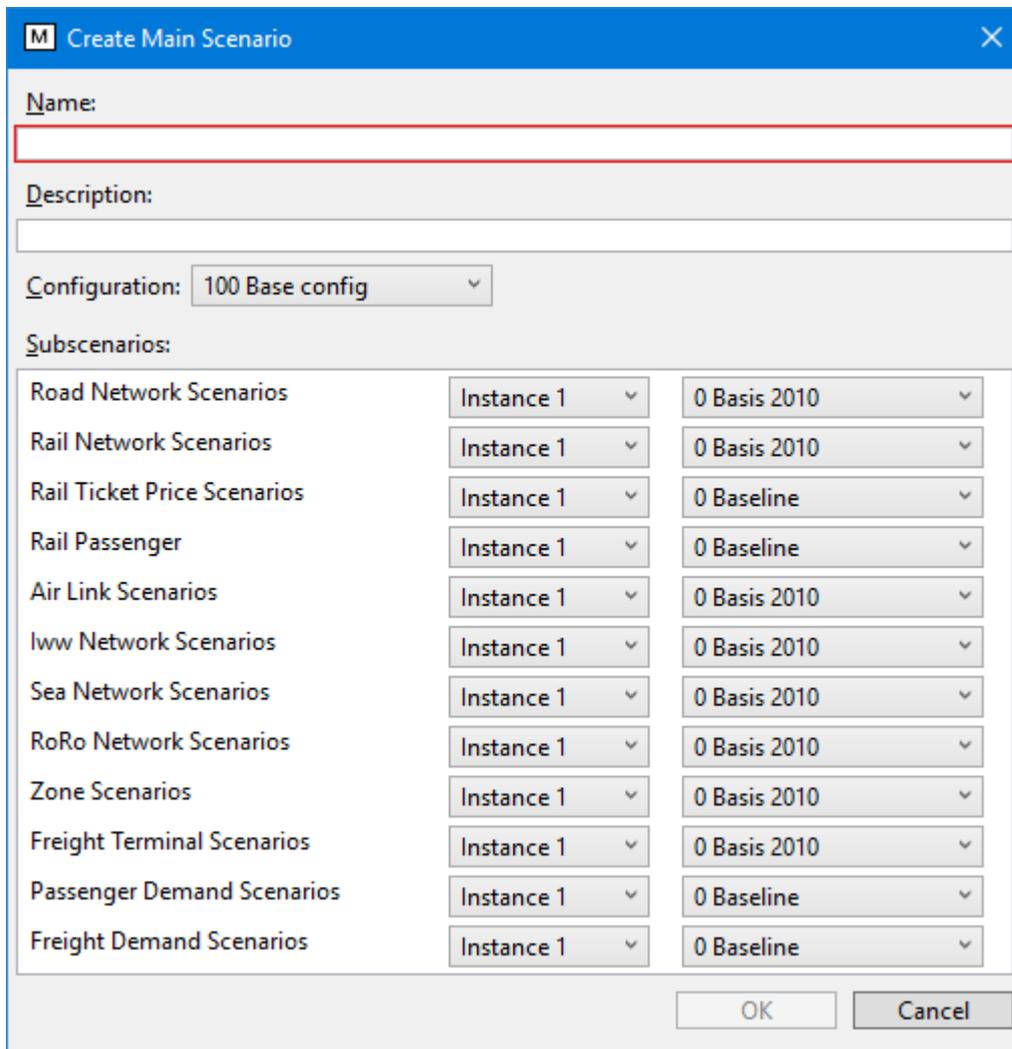


**Figure 7 TT3 user interface, Main Scenarios**

A Main Scenario has a full collection of data scenarios (one scenario for each data scenario type) and a configuration.

Selecting a main scenario will display information for that main scenario on the right side, see Figure 7.

Creating a Main Scenario can be done by clicking “New Main Scenario” or if a Main Scenario is selected: “Copy Main Scenario”. If copying, the data instances and scenarios and configuration will be set to the same as the original. Name Description and year must be filled. Configuration and data Scenarios can be selected using the dropdown boxes, see Figure 8.



**M Create Main Scenario** [X]

Name:

Description:

Configuration: 100 Base config ▾

Subscenarios:

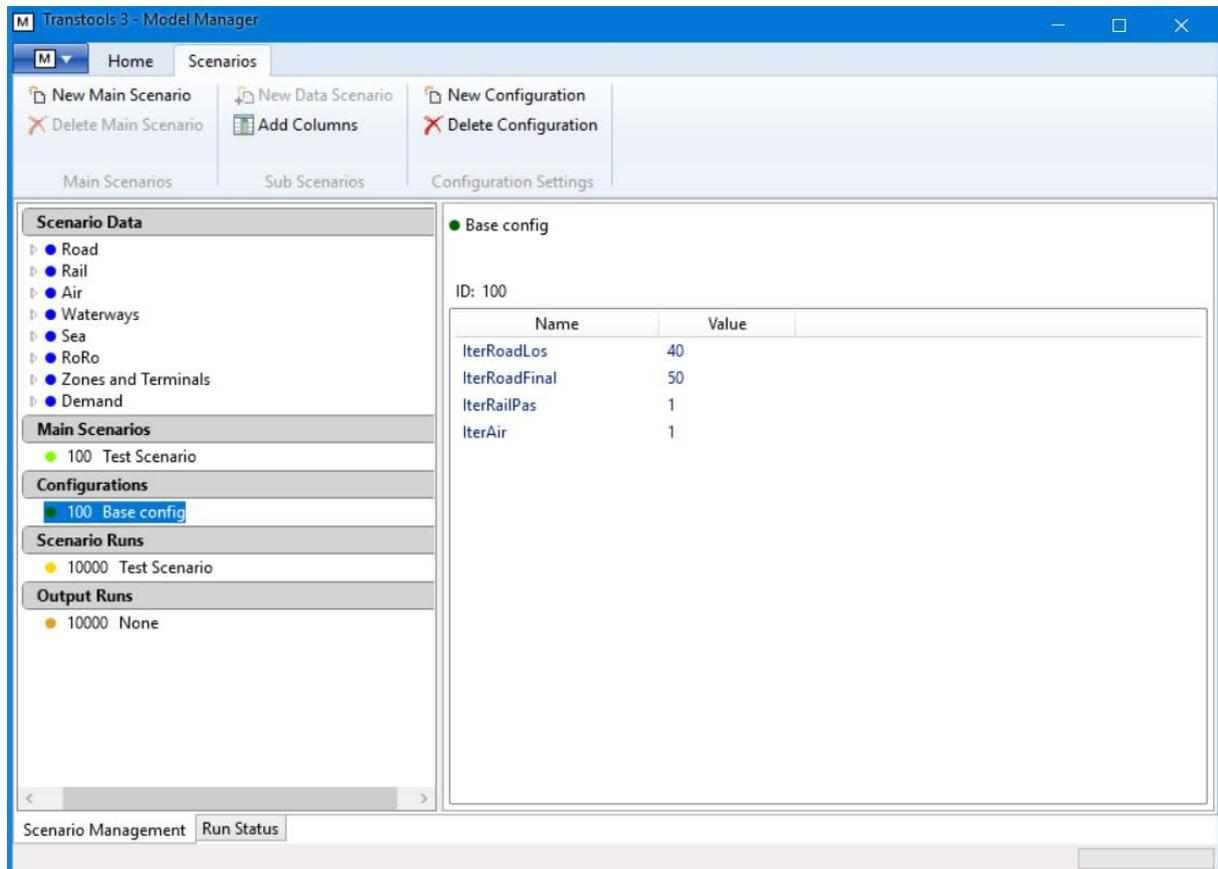
Road Network Scenarios	Instance 1 ▾	0 Basis 2010 ▾
Rail Network Scenarios	Instance 1 ▾	0 Basis 2010 ▾
Rail Ticket Price Scenarios	Instance 1 ▾	0 Baseline ▾
Rail Passenger	Instance 1 ▾	0 Baseline ▾
Air Link Scenarios	Instance 1 ▾	0 Basis 2010 ▾
Iww Network Scenarios	Instance 1 ▾	0 Basis 2010 ▾
Sea Network Scenarios	Instance 1 ▾	0 Basis 2010 ▾
RoRo Network Scenarios	Instance 1 ▾	0 Basis 2010 ▾
Zone Scenarios	Instance 1 ▾	0 Basis 2010 ▾
Freight Terminal Scenarios	Instance 1 ▾	0 Basis 2010 ▾
Passenger Demand Scenarios	Instance 1 ▾	0 Baseline ▾
Freight Demand Scenarios	Instance 1 ▾	0 Baseline ▾

OK Cancel

Figure 8 TT3 user interface, create new Main Scenario

#### 4.4 Configurations

Dark green dots ● mark configurations. When clicking the little triangle next to “Configuration” all current configurations are shown.



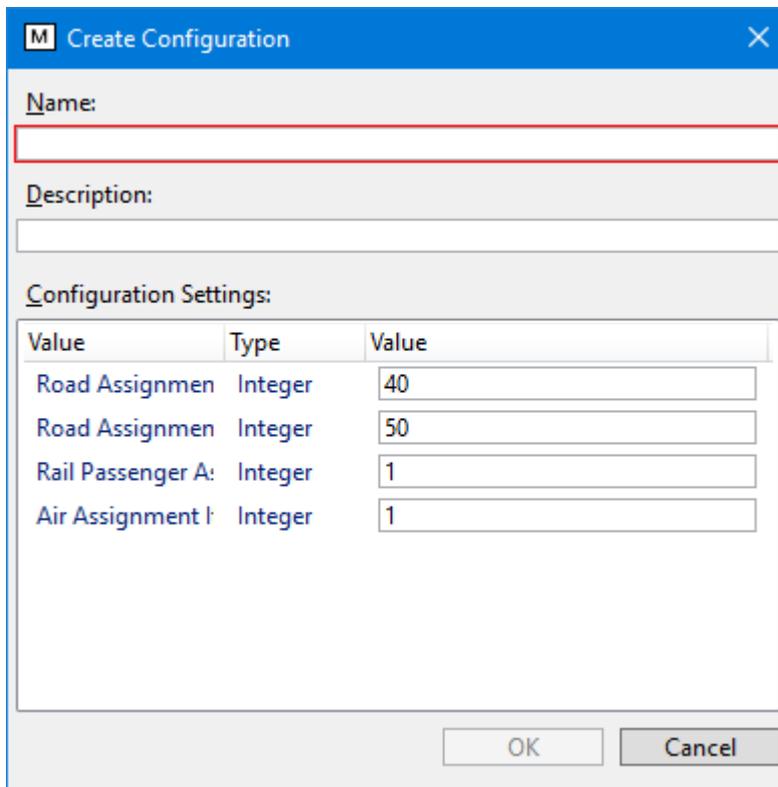
**Figure 9 TT3 user interface, Configurations**

When selecting a specific configuration, the details for that configuration are displayed on the right side, shown in Figure 9.

A configuration has the following information

- ID, automatically assigned.
- Name, assigned when creating new configuration
- Description, assigned when creating new configuration, also shown at top of right pane
- Road Assignment iterations for Level of service
- Road Assignment iterations for final flows
- Rail Passenger Assignment iterations
- Air iterations.

A new configuration can be created by right clicking on an existing configuration and select “Copy Configuration”, the Create configuration window is shown. Name and Description are not copied, see Figure 10.



Value	Type	Value
Road Assignmen	Integer	40
Road Assignmen	Integer	50
Rail Passenger A:	Integer	1
Air Assignment I	Integer	1

Figure 10 TT3 user interface, create new Configuration

## 4.5 Model Runs

Running the Transtools 3 model means running a Main Scenario, that has specified data scenarios and configuration. The central processes in a model run are:

- Import: This copies all specified scenario inputs from the scenario database to a calculation database
- Scenario Run: This executes the transport model, working only on a calculation database
- Export: This copies all model results from a calculation database to the results database

The import step needs to be done separately, because it alters the calculation data. The run step also performs the export step after the run. The export step can be performed alone, but is normally not necessary.

### 4.5.1 The process to run a main scenario

#### Step 1 import

Select a Main Scenario and click "Import"

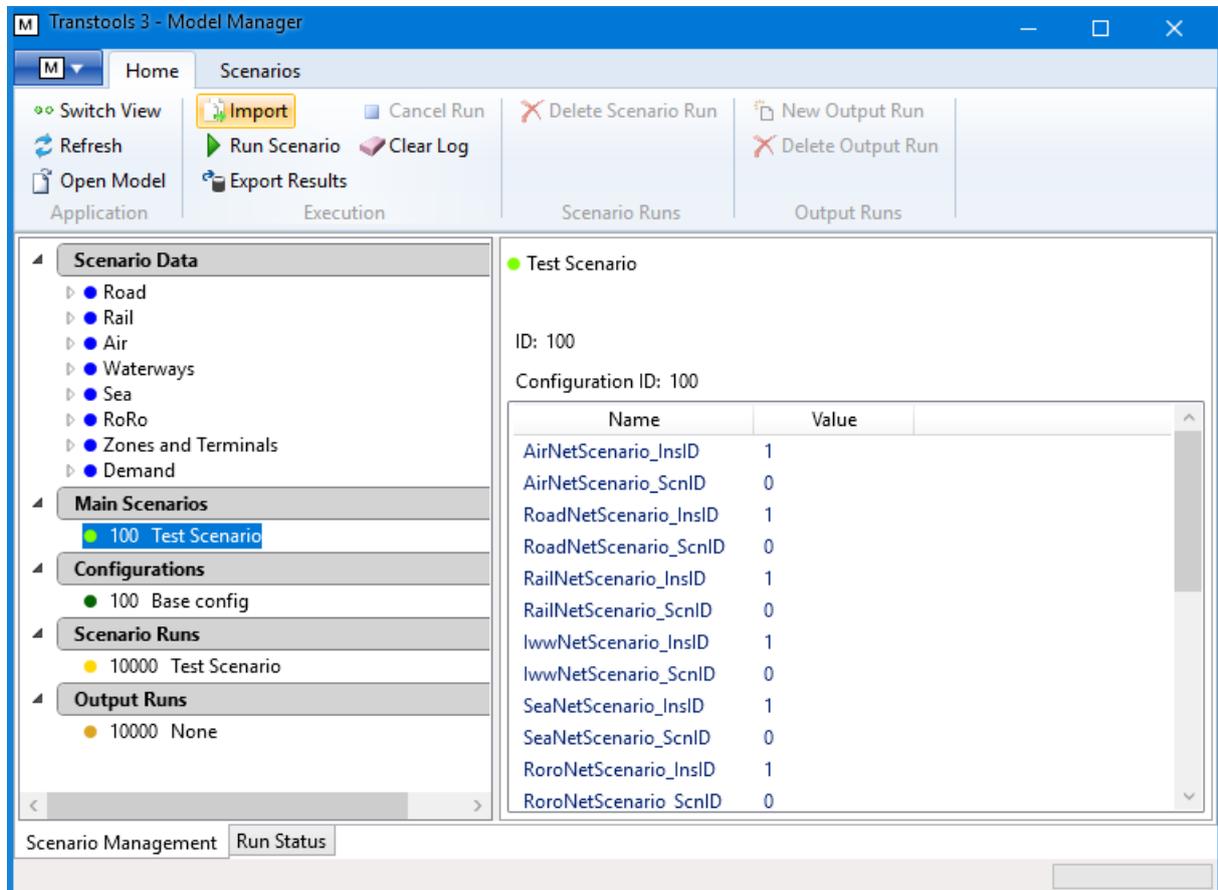
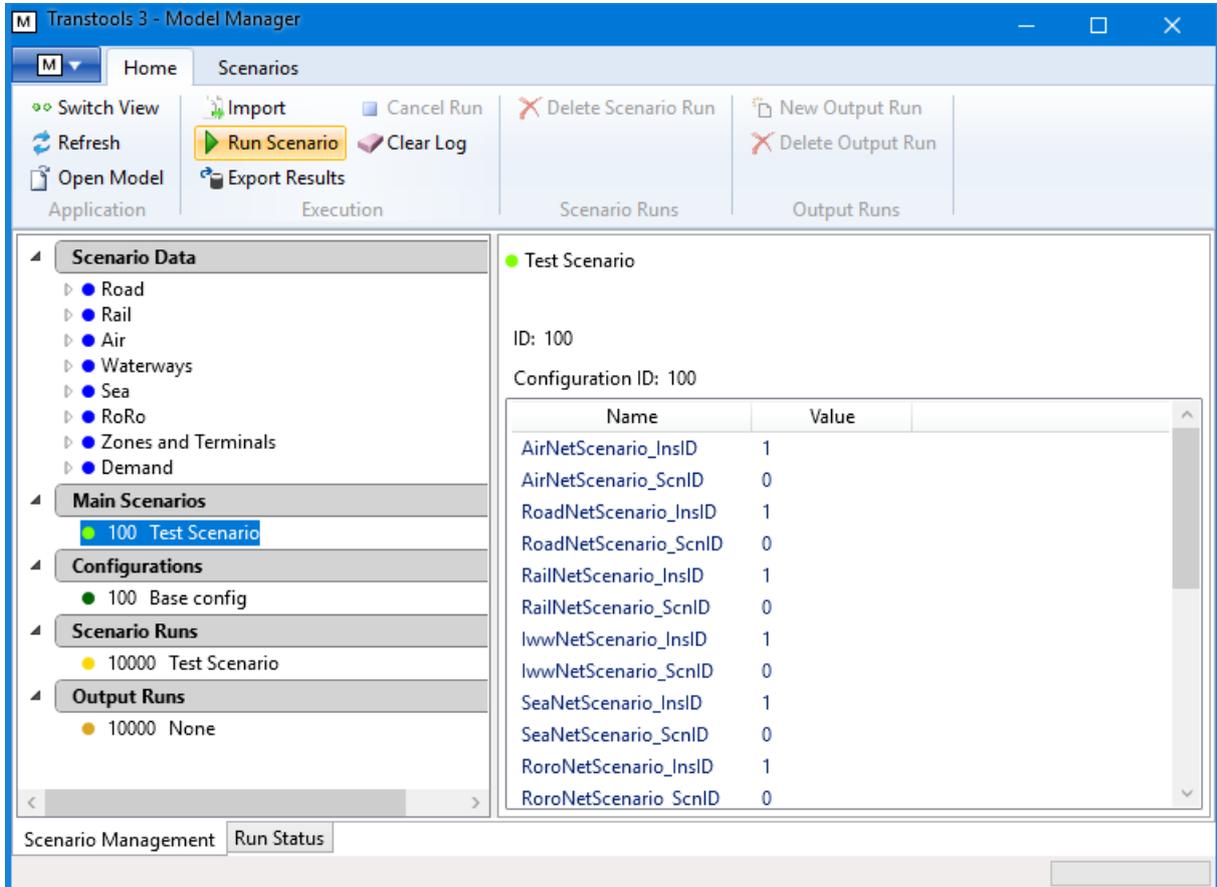


Figure 11 TT3 user interface, import Main Scenario

The import step transfers data from the selected Main Scenario in the master database to the calc database. This is called importing because the Model Manager is used from the Calc computer. A Scenario Run record with information on the run, is created in the master database each time a Main Scenario is run.

### Step 2 Run Scenario

Click "Run Scenario". This runs the model on the imported main scenario, and exports results to the master database.



**Figure 12 TT3 user interface, Run scenario**

During model calculation The user interface will switch to the display Run Status, showing the log from the model run.

#### 4.5.2 Logs

The master database stores run information when the calculation starts. When the calculation is done the finish-time and the log is also stored in the master database. Logs of previous calculations can be seen in the Model Manager.

## 5. Results

Scenario Runs produces model results and exports the results to the master database. An output run produces maps for a Scenario Run, or differences between two Scenario Runs.

### 5.1 Model run results

Each scenario run produces large amounts of data: Detailed results, aggregated numerical results and maps. All result data for all model runs is stored in the results database. Result maps can be accessed as pdf-files produced during the model execution.

This chapter describes which types of results are produced by the model.

#### 5.1.1 Full detailed results

The detailed results of a model run include:

- Origin-destination demand matrices
- Level of service matrices including
  - Journey times (with and without congestion effects)
  - Cost
  - Distances matrices
- Link traffic flows: passenger cars, trucks, tons.

The detailed results will be stored in the master database associated with the model run for identification.

#### 5.1.2 Aggregated Numerical Results

In addition to the full detailed results, several different types of aggregated results are provided. These include:

- Traffic activity: passenger-km, car-km, truck-km, train-ton-km, barge-ton-km, per average working day / per year.
- Aggregate figures of transport activity expressed in passenger-km and ton-km, by mode and country.

In methodological terms, the transport activity reported at country level will follow the territoriality principle.

Transport activity will include all traffic in the entire transport network, going beyond TEN-T and including internal traffic in the individual zones.

#### 5.1.3 Output run results

Output Runs produces maps and can also be used to compare two model results. This will produce diff-maps and diff-aggregated Numerical Results.

Maps are designed using ArcGIS, which is a very powerful and highly configurable mapping application. Users can customise the look and feel of maps.

The maps include link related traffic flows: passenger cars, trucks, tons. Flow volumes are displayed per average working day.

## 5.2 Comparing results

Users can perform a scenario result comparison, which will compare the results of a model run to a baseline model run.

Comparing Aggregated Numerical Results will produce a similar set of Aggregated Numerical Results, where the values will be the difference between the scenario and the baseline scenario.

Comparing Maps will produce a similar set of maps, where the values will be the difference between the scenario and the baseline scenario. The displayed values can be negative, so the map style templates used will be different from maps depicting the results of a scenario.

## 5.3 Map production module

The Transtools 3 user interface includes an option for Output Runs.

Output Runs operates on templates created in map documents (mxd-files) which are processed into pdf-files. The layout of the templates can be customized from ArcMap. Setting up bookmarks in template will in addition make it possible to print multiple zooms from each map document.

### 5.3.1 Customizing templates

The layout for each of the provided map templates can be altered in ArcMap. Likewise, any number of new templates can be added to the mxd folder. Working with templates there is a couple of considerations that should be taken into account. These are explained in the following sections. A template example is shown in Figure 13.

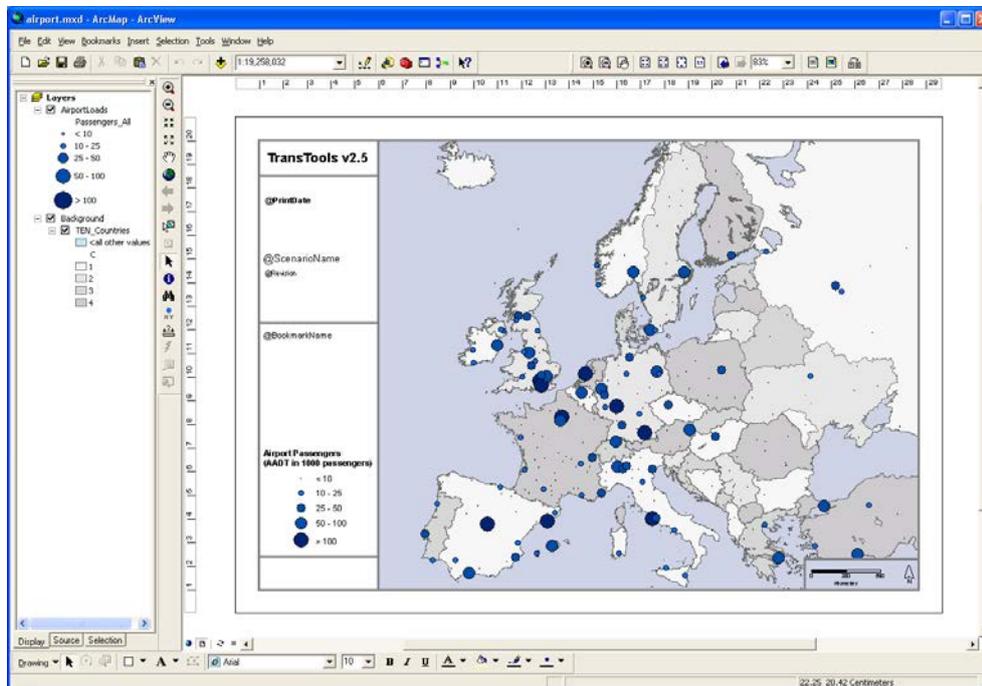


Figure 13: Airport map template

### 5.3.2 Relative paths for source data

Using relative path to data sources will ensure that templates can be reused for different scenarios. This way source data will not be stored with full path and when the mxd document is copied to a new scenario it will load data from the corresponding flow databases.

Using relative paths is a setting for the ArcMap document under: File -> Document properties -> Data Source options.

### 5.3.3 Legends

Different scenarios will have different amount of traffic. However, the legend intervals in the templates are not updated automatically when these are copied between scenarios. Therefore, it must be ensured that intervals are able to show ranges across all scenarios.

### 5.3.4 Bookmarks

Any given number of bookmarks can be defined in each template. When the map production module is executed, it will zoom to each of the bookmarks a print the current view. Bookmarks are created and managed in ArcMap from the bookmarks menu. For the provided templates some bookmarks with different zooms have been setup.

### 5.3.5 [Layout view](#)

In the ArcMap layout view text elements can be added to the layout. The map production module will search through all text elements and replace predefined keywords with information such as scenario name, scenario year etc. This way the templates can dynamically be updated in each run.

## 6. References

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