

# Freight and Fuel Transportation Optimization Tool Quick Start Scenarios Documentation

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**Volpe**

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# Quick Start Documentation

## Overview

Assuming you have installed FTOT (installation wiki is here: <https://github.com/VolpeUSDOT/FTOT-Public/wiki>), this is the place to learn how to run FTOT scenarios and view the results. After downloading the Quick Start scenarios, the directory and file path should look like this:

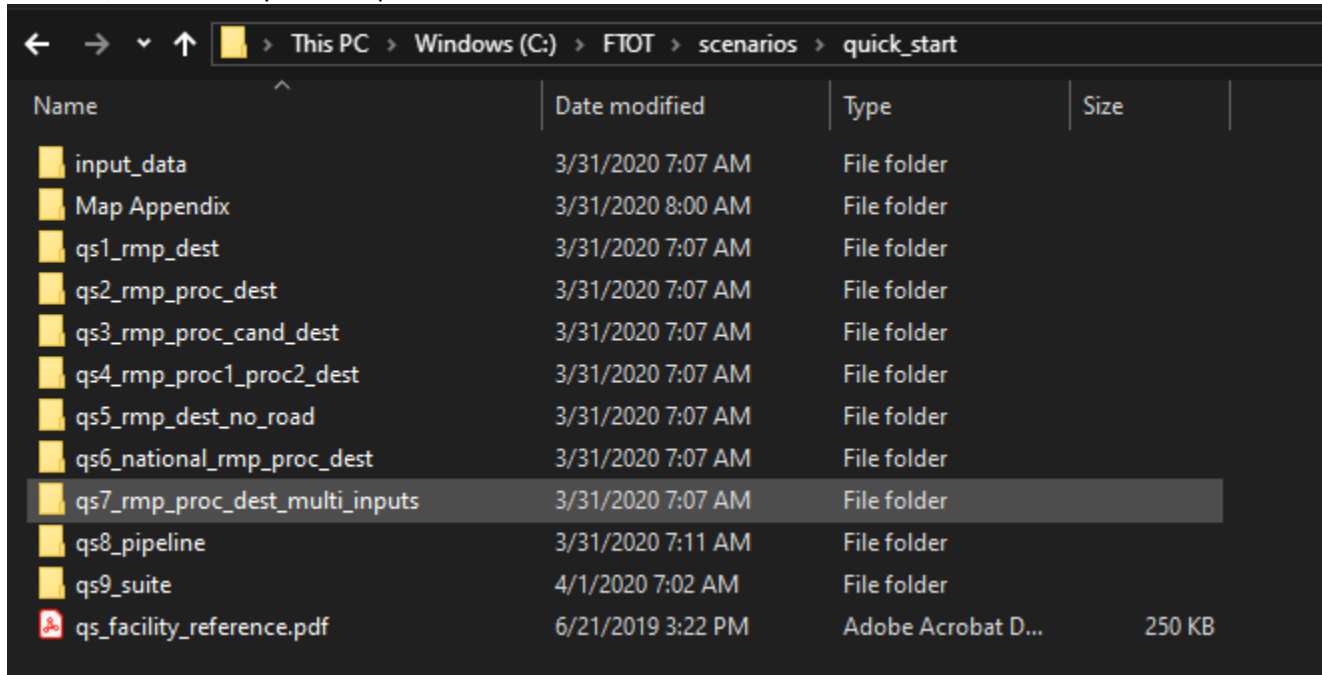


Figure 1: FTOT Quick Start Folder Structure

The Quick Start series is a set of simple scenarios designed to introduce supply chain modeling in FTOT. The first scenario (Quick Start 1) is the simplest. Each subsequent scenario demonstrates a different aspect of FTOT functionality. The nine Quick Start (QS) scenarios are summarized in the table below.

#	Summary	Complexity
1	Simple supply chain with no intermediate processing	Low
2	Simple supply chain with intermediate processing	Low
3	Candidate processing facilities are generated for the supply chain by FTOT	Med
4	Supply chain with two intermediate processing steps; storage followed by conversion	Med
5	Road network is excluded from the optimization, forcing FTOT To find alternative solutions	Low
6	National supply chain with no road network	Med
7	Processor takes two input commodities	Low
8	Pipeline Scenarios: Crude, Products, and both	Med
9	Scenario Comparisons	Med

Table 1: Quick Start scenarios summaries and complexity rating.

## Getting Started

- FTOT scenarios are stored C:\FTOT\scenarios\quick\_start folder. Within this directory, each default scenario and exercise includes its own dedicated subfolder for storing the scenario configuration and outputs.

- FTOT is a command line tool that runs in a sequence of steps.
- Each scenario (e.g. qs1\_rmp\_to\_dest\Default) contains a batch script file called **run\_v5\_1.bat**.\*
- The batch script files are included in each of the Quick Start scenario folders to automate each step required.
- You can run the batch script by double clicking it or manually executing it in the Command Prompt.  
NOTE: If you are running any version of ArcGIS other than ArcGIS 10.6/10.6.1, you will need to edit the Python path environment for each batch script that you run to appropriately reflect the actual path to your Python directory. This will depend on the version of ArcGIS that you have installed (e.g. change "c:\PYTHON27\ArcGISx6410.6\python.exe" to "c:\PYTHON27\ArcGISx6410.8\python.exe" if you have ArcGIS 10.8 installed).

\*If you were unable to install the ArcGIS 64-bit background geoprocessing, you should run FTOT in 32-bit by using the batch script files called **run\_v5\_1\_32bit.bat**. This 32-bit option is not available for Quick Start 6.

### During the Run

- Informational logging is available in the command shell during the run. Detailed logging is available in the **.\logs** folder.
- The logs are prefixed with a letter and timestamp indicating the FTOT step and time the log was generated.
- The user is encouraged to read the logs to familiarize themselves with the FTOT operations occurring during each step.

### Results

- FTOT generates results in the **.\Reports** and **.\Maps** folders of the scenario. The reports and maps are also timestamped.
- The report is found in the **.\Reports** directory of the scenario. It is generated in the D step of the FTOT sequence. The FTOT report shows a summary of the results for each step in the analysis. The report is broken into the following sections: run time summary of each step, intermediate calculations and optimal results, configurations, warnings, and errors.
- A Tableau Dashboard (**tableau\_dashboard.twbx**) can also be found in a timestamped **tableau\_dashboard** folder within the **.\Reports** directory of the scenario. This can be opened in Tableau Reader.
- The map files can be found in the **.\Maps** directory of the scenario. The maps for the scenario are generated in the M step at the end of the FTOT scenario sequence. FTOT generates a series of maps for each FTOT step to help the user see what happens during the scenario.

For more information on interpreting results, see the complete FTOT Documentation.

### More Information

The complete Quick Start documentation details the nuances of each run and provides brief overviews of the main results. Additional exercises are suggested at the end of some chapters. The user is encouraged to complete these exercises to become familiar with modifying a scenario before creating their own. **It is highly recommended that the user read through the documentation for Quick Start 1, as that contains the most**

**detail.** The documentation for subsequent scenarios is more focused on highlighting the differences among scenarios and demonstrating various FTOT features.

### **Troubleshooting**

See the troubleshooting guide at the end of [FTOT\\_Documentation\\_2020\\_4\\_1.pdf](#) for tips on how to resolve common issues like runtime dependency errors (missing software), missing input data, and missing base maps.

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# Executive Summary

The quick start scenarios are designed to bring the user up to speed on FTOT capabilities. Several scenarios are listed below. The series starts with the simplest use case and progressively adds complexity or variations to the supply-chain.

The following scenarios are included:

Scenario	Description	Directory
QS1	Raw Material Producer (RMP) to Destination	qs1_rmp_to_dest
QS2	RMP to Processor to Destination	qs2_rmp_proc_dest
QS3	RMP to Candidate Processor to Destination	qs3_rmp_proc_cand_dest
QS4	RMP to Processor 1 to Processor 2 to Destination	qs4_rmp_proc1_proc2_dest
QS5	RMP to Destination – no road network	qs5_rmp_dest_no_road
QS6	RMP to Processor to Destination – national scenario, no road network	qs6_national_rmp_proc_dest
QS7	RMP to Processor (multiple inputs) to Destination	qs7_rmp_proc_dest_multi_in puts
QS8	Pipeline Movements: Crude and Petroleum Products	qs8_pipeline
QS9	Scenario Suite Compare	qs9_suite

Table 2: Quick Start 1-9 scenario descriptions and directory names.

In addition to demonstrating the FTOT functionality, the Quick Start scenarios can also serve as a template for creating user-specified scenarios.

## Quick Start 1 (QS1) - RMP to Destination

**Instructions: to run the QS1 scenario, execute run\_v5\_1.bat in quick\_start\qs1\_rmp\_dest\Default. The run should take about 5-10 minutes. A full description of this scenario is below, including the expected results.**

### Purpose

QS1 is the simplest supply chain model. The purpose of this scenario is to demonstrate the movement of one commodity from a single origin (known as a raw material producer, or RMP) to a single destination.

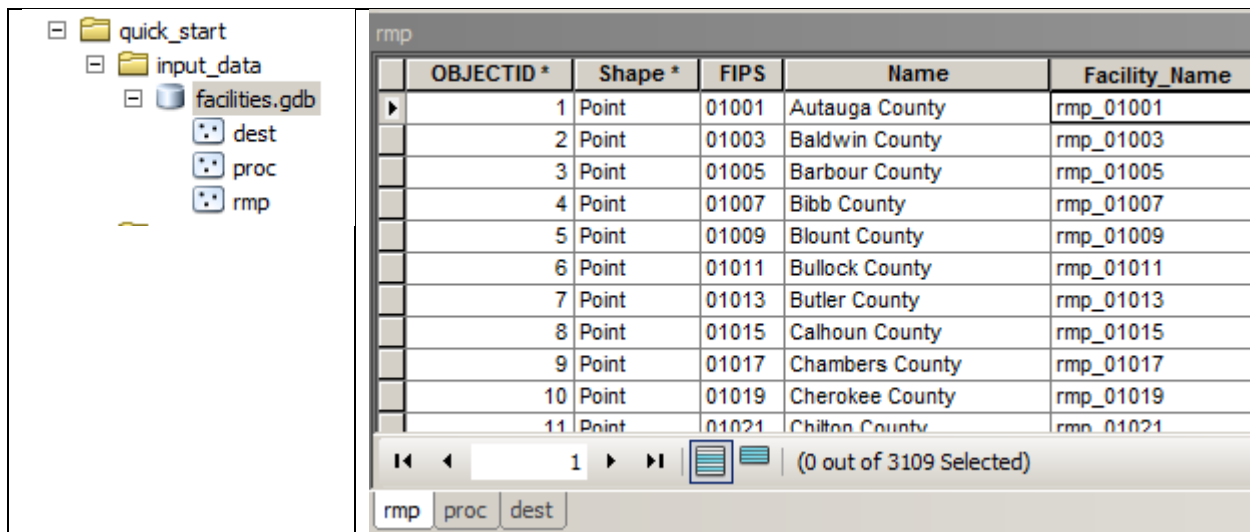
### Input Data

FTOT requires two sets of input data to model the supply chain: (i) geospatial facility location data and (ii) facility-commodity data.

### Geospatial Data

The geospatial facility location data identifies the location of each facility being modeled. This information is stored in an ESRI geodatabase (GDB). FTOT models three kinds of facilities: raw material producers, intermediate processors, and destinations. Each of the facility types are stored in a point feature class with a unique facility\_name. All of the Quick Start scenarios use county centers as a proxy for the hypothetical facility locations used in this series.

The top-level input\_data folder in the Quick Start scenarios folder contains a facilities.gdb file. It contains three feature classes; raw material providers (rmp), intermediate processors (proc), and destinations (dest). The structure of the GDB and an example of the records are shown below.



The screenshot displays a GIS application interface. On the left, a tree view shows the folder structure: 'quick\_start' contains 'input\_data', which contains 'facilities.gdb'. Inside 'facilities.gdb', there are three feature classes: 'dest', 'proc', and 'rmp'. On the right, the 'rmp' attribute table is open, showing a list of records. The table has columns: 'OBJECTID \*', 'Shape \*', 'FIPS', 'Name', and 'Facility\_Name'. The records list 11 counties in Alabama, each with a unique facility name starting with 'rmp\_'. At the bottom, there are navigation buttons for 'rmp', 'proc', and 'dest', and a status bar indicating '(0 out of 3109 Selected)'.

OBJECTID *	Shape *	FIPS	Name	Facility_Name
1	Point	01001	Autauga County	rmp_01001
2	Point	01003	Baldwin County	rmp_01003
3	Point	01005	Barbour County	rmp_01005
4	Point	01007	Bibb County	rmp_01007
5	Point	01009	Blount County	rmp_01009
6	Point	01011	Bullock County	rmp_01011
7	Point	01013	Butler County	rmp_01013
8	Point	01015	Calhoun County	rmp_01015
9	Point	01017	Chambers County	rmp_01017
10	Point	01019	Cherokee County	rmp_01019
11	Point	01021	Chilton County	rmp_01021

Figure 2: Example Geodatabase (GDB). The structure of the GDB (left) and an example of the records in the rmp attribute table (right) are shown.

## Facility-Commodity Data

The facility-commodity data are specified in a series of csv files located within the specific scenario's input\_data folder. Each facility-type (RMP, proc, dest) has a separate csv file, and all facilities of that type are recorded there. The facility\_name field must match the facility\_name specified in the GIS.

In the default QS1 scenario, a single RMP is specified in the rmp.csv file (shown below). The record for facility\_name 'rmp\_25003' indicates it has 100 tons of blueberries available as an "output" to supply the scenario.

	A	B	C	D	E	F	G
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io
2	rmp_25003	raw_material_producer	blueberries	100	tons	solid	o

Figure 3: QS1 raw material supplier input commodity file (rmp.csv) example entry

Similarly, the dest.csv file contains a single destination: dest\_25025, indicates 100 tons of blueberries are demanded as an "input" to this ultimate\_destination facility.

	A	B	C	D	E	F	G
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io
2	dest_25025	ultimate_destination	blueberries	100	tons	solid	i

Figure 4: QS1 destination input commodity file (dest.csv) example entry

There are no intermediate processors in this scenario, and therefore no proc.csv file is needed.

## Running a Scenario

A scenario configuration file (e.g. scenario.XML) is used to define the locations of the files and parameter values used in the FTOT run. Executing the batch script (run\_v5\_1.bat) will initiate an FTOT run and execute a sequence of steps.

### Scenario XML File

The scenario XML file contains the paths to different files and parameters FTOT needs to complete a run. The QS1 scenario file defines the scenario name and descriptions (lines 3-4), points to the base transportation network that is distributed with FTOT (line 12), as well as geospatial input data for the rmp and destination feature classes (lines 16-17), and facility\_commodity files (lines 21-22). Note that since there is no processor in this supply chain scenario, the processor commodity and candidate processor commodity data fields contain the word "None" (lines 23-24). Finally, the default units for the solid and liquid phases are defined (lines 29-30). These specifications are all shown in the code snippet below, as well as in the scenario.xml file.

Starting at line 57 in the scenario XML are a series of costs and weights (also known as impedances) which help define the costs associated with flowing commodities over the transportation network. The base costs represent the per metric ton-mile or per thousand gallon-mile dollar cost of traversing each mode. The weights act as multipliers on the dollar cost to produce a distinct routing cost, which helps encourage FTOT to route on portions of the network where you would expect to see more flow. For example, interstate highways over local roads, and Class 1 railways over Class 2 railways. Dollar costs being equal, segments with lower impedances are favored over segments with higher impedances. Ultimately, both the dollar and routing costs are reported in the

scenario results. The rail impedances provided in the quick start scenario XMLs are exaggerated to favor flows on the road network, but feel free to modify them on your own when exploring different exercises and other scenario variations. For routine runs in FTOT, we recommend increasing impedance levels by 0.1 between each category (e.g. 1.0 for the first tier, 1.1 for the second tier, etc.).

```

2  <Scenario xmlns="FTOTv5.0.0">
3    <Scenario_Schema_Version>5.0.0</Scenario_Schema_Version>
4    <Scenario_Name>Quick Start: RMP to Destination</Scenario_Name>
5    <Scenario_Description>This scenario demonstrates simple movements from a RMP
6      to a destination.</Scenario_Description>
7    <Scenario_Inputs>
8      . . .
12    <Base_Network_Gdb>C:\FTOT\scenarios\common_data\networks\Public_Intermodal_Network_20
13      19_1.gdb</Base_Network_Gdb>
14    . . .
16    <Base_RMP_Layer>C:\FTOT\scenarios\quick_start\input_data\facilities.gdb\rmp</Base_RMP
17      Layer>
18    <Base_Destination_Layer>C:\FTOT\scenarios\quick_start\input_data\facilities.gdb\dest<
19      /Base_Destination_Layer>
20    . . .
21    <RMP_Commodity_Data>C:\FTOT\scenarios\quick_start\qs1_rmp_dest\Default\input_data\rmp
22      .csv</RMP_Commodity_Data>
23    <Destinations_Commodity_Data>C:\FTOT\scenarios\quick_start\qs1_rmp_dest\Default\input
24      _data\dest.csv</Destinations_Commodity_Data>
25    <Processors_Commodity_Data>None</Processors_Commodity_Data>
26    <Processors_Candidate_Commodity_Data>None</Processors_Candidate_Commodity_Data>
27    . . .
29    <Default_Units_Solid_Phase>tonnes</Default_Units_Solid_Phase>
30    <Default_Units_Liquid_Phase>kgal</Default_Units_Liquid_Phase>
31  </Scenario_Inputs>

```

*Note that the default units for the solid phase of matter is metric tonnes, whereas the input data were given in Imperial Tons. The user is free to specify facility\_commodity data in any units they prefer, with the added stipulation that solid materials must be defined in terms of mass and liquids must be defined in terms of volume. FTOT will convert each record to the default scenario units using Pint, a python module for converting units.*

### Run.bat Script

The run.bat file specifies a scenario.xml file that contains the parameters to be used for the run, and then executes a sequence of steps required for an FTOT analysis.

The default run should take ~5-10 minutes to complete and will provide informational messages in the command line it is executing in. The command line logs are also stored for each step in the .\logs folder and can be viewed at any time. More detailed logging information is also saved to the log files. It may be useful for the user to read the logs to understand more about what is happening within each step.

The basic FTOT sequence for the QS1 scenario is:

1. S – setup; prepare the scenario files and transportation network
2. F – add the facility GIS and facility-commodity data to the scenario files
3. C – connect the facilities to the transportation network
4. G – export a NetworkX graph for the optimization
5. O1 – prepare the optimization problem
6. O2 – setup and solve the optimization problem
7. P – post process the optimal solution

8. D – generate reports for the run
9. M – generate maps of the run

## Viewing Results

FTOT generates four main products from a scenario: a human readable report, a CSV-formatted report that can be analyzed using desktop data analysis software such as Excel or Tableau, a packaged Tableau workbook, and a sequence of maps showing each of the steps in the FTOT run.

## FTOT Report

The report is found in the .\Reports directory of the scenario. **To quickly check your QS1 results, look for the following lines in the generated report and compare your values to those below.**

```
RESULTS
-----
...
O2 : Total Scenario Cost = (transportation + unmet demand penalty + processor construction):      $2,430
...
P_ : COMMODITY_SUMMARY_DOLLAR_COST_BLUEBERRIES__TOTAL:      2,355.59 :      USD
...
P  : FACILITY SUMMARY DEST 25025 DESTINATION DEMAND OPTIMAL BLUEBERRIES ROAD:      90.72 :      metric ton
...
P_ : FACILITY_SUMMARY_RMP_25003_RMP_SUPPLY_OPTIMAL_BLUEBERRIES_ROAD:      90.72 :      metric_ton
```

*Note: The results are shown in units of metric\_tonnes because of the default\_units\_solid\_phase parameter specified in the Scenario XML. The user is free to change the default units in the XML file to suit their purpose.*

## Tableau Dashboard

The Tableau Dashboard (tableau\_dashboard.twbx) can be found in a timestamped tableau\_dashboard folder within the .\Reports directory of the scenario.

In Tableau Reader, the QS1 dashboard will look like the figure below upon opening.

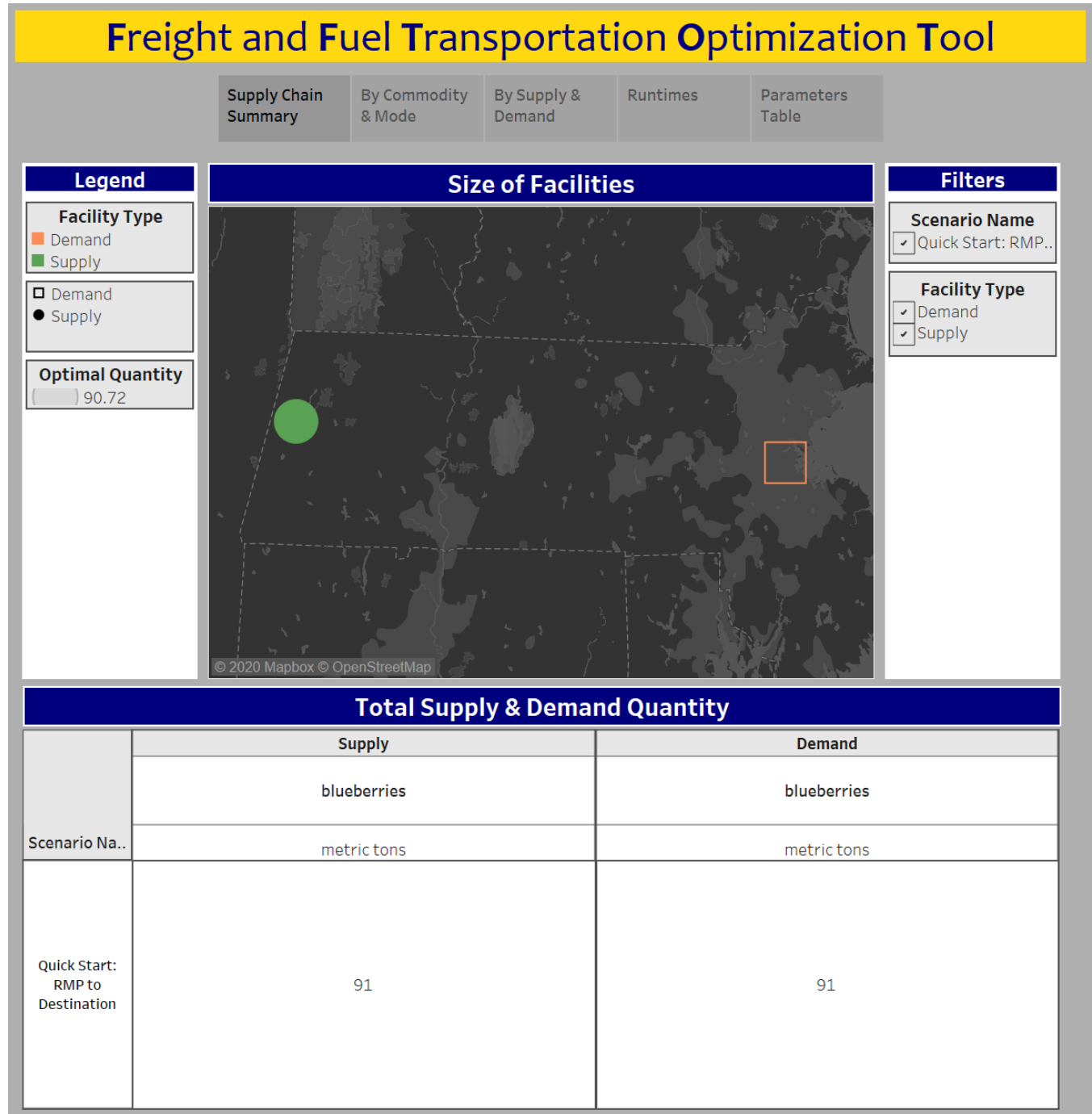


Figure 5: QS1 Tableau Story: Supply Chain Summary Dashboard

At the top of the workbook are story points: supply chain summary, followed by results displayed by commodity and mode, supply and demand, and scenario runtimes.

The supply chain summary indicates the locations and relative size of the facilities in the supply chain. Demand centers are displayed with orange triangles. The supply centers have green circles. The user can filter the facility types shown on the right hand side under the Facility Type filter. The quantity of material available for each facility type is shown in the table below the map.

The routing results are shown in the By Commodity and Mode story point. Routes can be colored using the legend options on the left hand side of the screen. Options include coloring by mode [as shown], commodity, or scenario name (this becomes more useful when comparing multiple scenarios, see QS9). The filters on the right hand side allow the user to turn various elements on or off, and it applies to both the map and the results summary chart at the bottom of the dashboard. Scenario filters include scenario name, mode, and commodity. Results reported by FTOT include scenario cost, material moved, VMT, fuel burn, and CO2 emissions. The results can be graphed and grouped by commodity or commodity and mode.

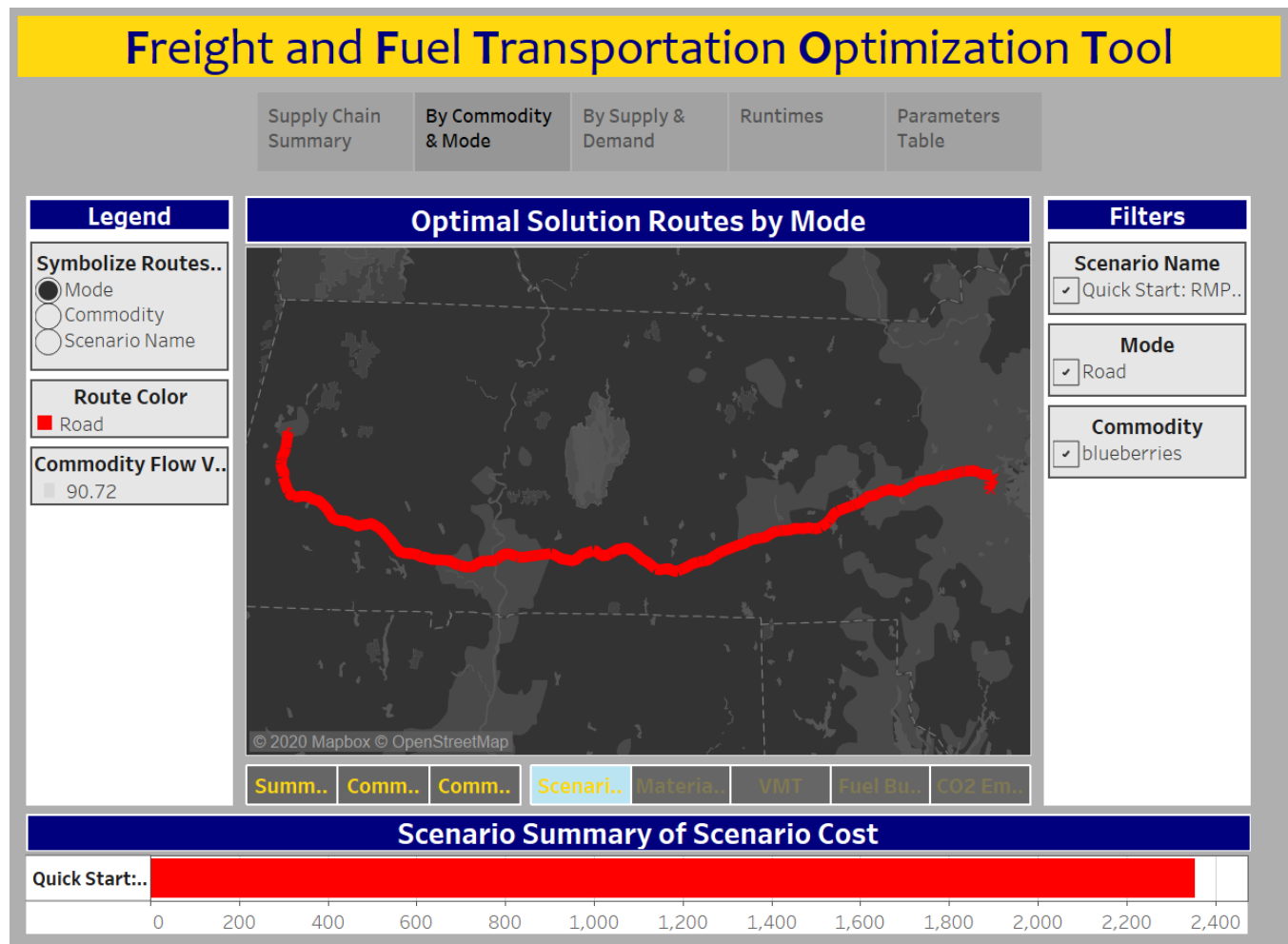
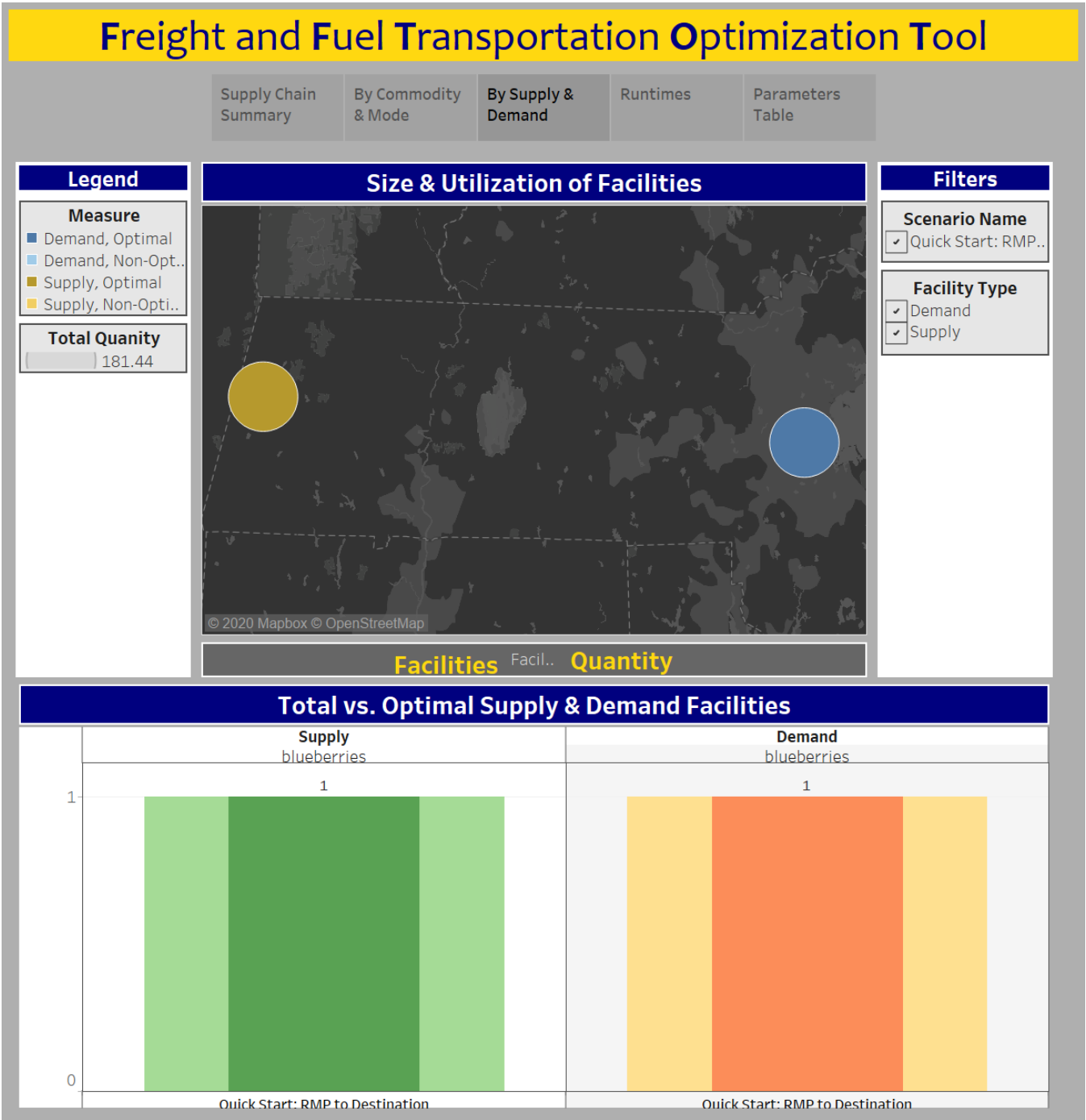


Figure 6: QS1 Tableau Story: Results by Commodity and Mode

The results by Supply and Demand dashboard summarizes the optimal results by facility. The Size and Utilization of Facilities Map shows the relative size of supply and demand facilities, as well as the utilization of those facilities. The user may toggle between facility counts and total quantities using the slider under the map.





The next dashboard in the story summarizes the runtimes of each step in the run, as well as the cumulative total runtime. Hovering over an individual color will provide a tooltip with additional information.

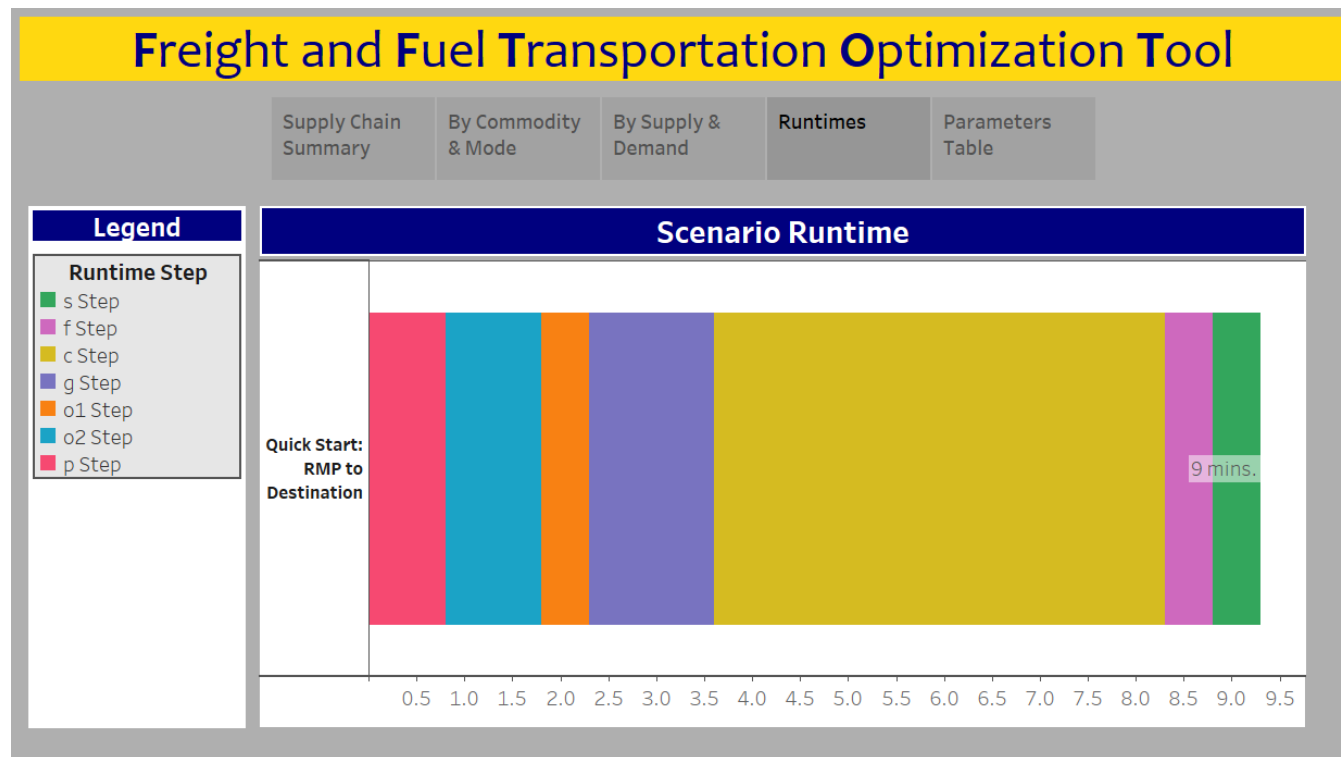


Figure 8: QS1 Tableau Story: Runtimes

The parameters table dashboard is the last dashboard in the story. It shows the parameters used in the scenario. Parameters are grouped together by sections, such as cost per mode, emissions factors, and vehicle load sizes.

Freight and Fuel Transportation Optimization Tool				
		Supply Chain Summary	By Commodity & Mode	By Supply & Demand
Scenario	Parameters	Summary	By Commodity & Mode	By Supply & Demand
Scenario Inputs	scenario_run_directory	Quick Start: RMP to ..	C:\ftot\scenarios\quick_start\qs1_rmp_dest\Default	
	base_destination_layer	Quick Start: RMP to ..	C:\FTOT\scenarios\quick_start\input_data\facilities.gdb\dest	
	base_network_gdb	Quick Start: RMP to ..	C:\FTOT\scenarios\common_data\networks\Public_Intermodal_Network_2019_3.gdb	
	base_processors_layer	Quick Start: RMP to ..	None	
	base_rmp_layer	Quick Start: RMP to ..	C:\FTOT\scenarios\quick_start\input_data\facilities.gdb\rmp	
	commodity_mode_data	Quick Start: RMP to ..	None	
	common_data_folder	Quick Start: RMP to ..	C:\FTOT\scenarios\common_data	
	Default Units (liquid)	Quick Start: RMP to ..	kilogallon (kgal)	
	Default Units (solid)	Quick Start: RMP to ..	metric ton	
	destinations_commodity_data	Quick Start: RMP to ..	C:\FTOT\scenarios\quick_start\qs1_rmp_dest\Default\input_data\dest.csv	
	processors_candidate_slate	Quick Start: RMP to ..	None	
	processors_commodity_data	Quick Start: RMP to ..	None	
	rmp_commodity_data	Quick Start: RMP to ..	C:\FTOT\scenarios\quick_start\qs1_rmp_dest\Default\input_data\rmp.csv	
	schedule_data	Quick Start: RMP to ..	None	
Vehicle Load Size	Barge Load (liquid)	Quick Start: RMP to ..	2,100.0 kgal	
	Barge Load (solid)	Quick Start: RMP to ..	700.0 metric tons	
	Pipeline Load - Crude (liquid)	Quick Start: RMP to ..	3,150.0 kgal	
	Pipeline Load - Product (liquid)	Quick Start: RMP to ..	3,150.0 kgal	
	Railcar Load (liquid)	Quick Start: RMP to ..	28.5 kgal	
	Railcar Load (solid)	Quick Start: RMP to ..	82.0 metric tons	
	Truck Load (liquid)	Quick Start: RMP to ..	8.0 kgal	
	Truck Load (solid)	Quick Start: RMP to ..	24.0 metric tons	
Network Impedences	Barge Base Cost (liquid)	Quick Start: RMP to ..	0.1	
	Barge Base Cost (solid)	Quick Start: RMP to ..	0.0	
	Rail Base Cost (Class1 - solid)	Quick Start: RMP to ..	0.0	
	Rail Base Cost (Class1 - liquid)	Quick Start: RMP to ..	0.1	
	rail_dc_0	Quick Start: RMP to ..	10.0	
	rail_dc_1	Quick Start: RMP to ..	2.6	
	rail_dc_2	Quick Start: RMP to ..	2.4	
	rail_dc_3	Quick Start: RMP to ..	2.1	
	rail_dc_4	Quick Start: RMP to ..	1.9	
	rail_dc_5	Quick Start: RMP to ..	1.6	
	rail_dc_6	Quick Start: RMP to ..	1.3	
	rail_dc_7	Quick Start: RMP to ..	1.0	
	transloading_dollars_per_th..	Quick Start: RMP to ..	40.0	
	transloading_dollars_per_ton	Quick Start: RMP to ..	12.4	
	Truck Base Cost (liquid)	Quick Start: RMP to ..	0.5	
	Truck Base Cost (solid)	Quick Start: RMP to ..	0.2	
	truck_interstate	Quick Start: RMP to ..	1.0	
	truck_local	Quick Start: RMP to ..	1.3	
Artificial Links	truck_m_art	Quick Start: RMP to ..	1.2	
	truck_pr_art	Quick Start: RMP to ..	1.1	
	water_high_vol	Quick Start: RMP to ..	1.0	
	water_low_vol	Quick Start: RMP to ..	1.6	
	water_med_vol	Quick Start: RMP to ..	1.3	
	water_no_vol	Quick Start: RMP to ..	10.0	
	pipeline_crude_max_artifici..	Quick Start: RMP to ..	5.0	
	pipeline_prod_max_artificial..	Quick Start: RMP to ..	5.0	
Emission Factors	rail_max_artificial_link_dist	Quick Start: RMP to ..	5.0	
	road_max_artificial_link_dist	Quick Start: RMP to ..	5.0	
	water_max_artificial_link_di..	Quick Start: RMP to ..	5.0	
	Barge CO2 Emissions	Quick Start: RMP to ..	18.1	
	Pipeline CO2 Emissions	Quick Start: RMP to ..	0.0	
	railFuelEfficiency	Quick Start: RMP to ..	10.2	
	Railroad CO2 Emissions	Quick Start: RMP to ..	21.0	
	Road CO2 (Rural Restricted)	Quick Start: RMP to ..	1,649.5	

Figure 9: QS1 Tableau Story: Parameters Table

## Maps

The map files can be found in the .\Maps directory of the scenario.

To check that the QS results are accurate, the user can compare their output maps to those in the Map Appendix folder within the quick\_start directory. **For a quick comparison, compare the map below with the FTOT-generated map called 04a\_O\_Step\_Final\_Optimal\_Routes\_With\_Commodity\_Flow.png.**

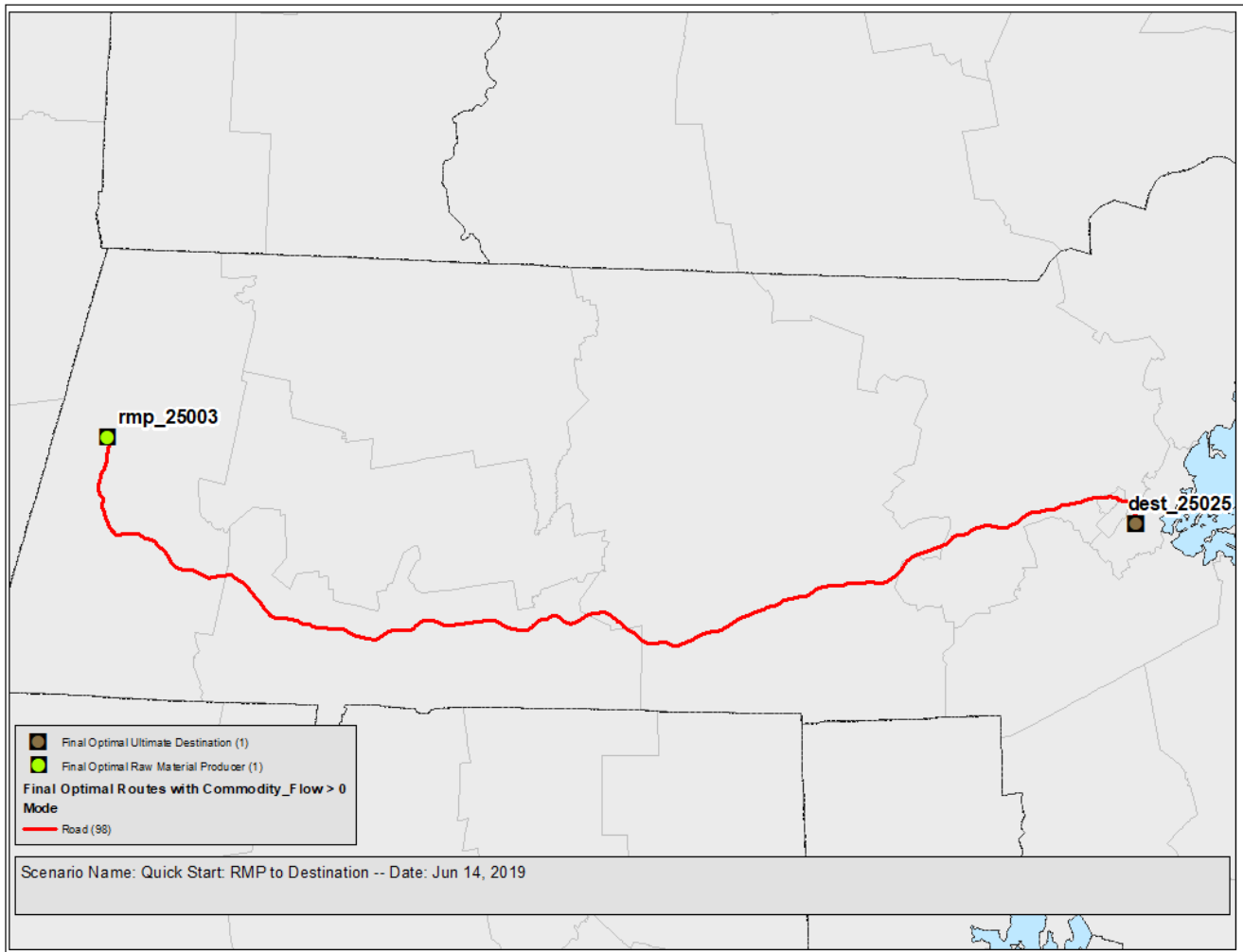


Figure 10: QS1 Optimal Solution

The optimal solution shows that the material travels over the road network from the RMP to the destination. In this case, the Massachusetts Turnpike (Interstate 90) is used for the majority of the trip.

## Exercises

The following exercises are left for the user to explore. The user may return to the main QS1 folder and enter the appropriate sub-folder for each respective exercise. Each exercise folder starts off identical to the Default folder; the user is encouraged to make changes to the input files in accordance with the instructions below.

- 1) Increase the quantity of material available at the RMP by a factor of 1000 using the `rpm.csv` in the Exercise 1\input\_data folder. Does the quantity of material flowing in the optimal solution increase?
- 2) Increase the quantity of material demanded at the destination by a factor of 500 using the `dest.csv` in the Exercise 2\input\_data folder. Why does the increase in demand change the optimal flow from the RMP?
- 3) Add additional commodities to the `rpm` and destinations. FTOT supports multiple commodities from each facility. The user can add additional records to the `rpm.csv` and `dest.csv` files in the Exercise 3\input\_data folder. The same `facility_name` can be used. Get creative with commodity names and quantities. Just be sure to correctly identify the inputs and outputs, and stick to liquid and solid phases of matter. (For liquids, use `kgal` units.)
- 4) A new raw material producer has just opened in Middlesex County, and it can produce 50 tons of blueberries. Add this facility to the `rpm.csv` file in the Exercise 4\input\_data folder, taking care to match the `facility_name` from the respective geospatial data feature classes. (This data can be opened in ArcGIS; for your convenience, a PDF of some of these data can be found in the Quick Start folder.)
- 5) Open the `scenario.xml` in the Exercise 5 folder and adjust all of the `Rail_Density_Code` weights to 1.0 (lines 65-72). This will make rail movements more attractive to FTOT as no rail lines will be impeded. Do the resulting scenario flows switch to rail?

## Quick Start 2 (QS2) - RMP to Processor to Destination

**Instructions: to run the QS2 scenario, execute run\_v5\_1.bat in quick\_start\qs2\_rmp\_proc\_dest\Default. The run should take about 5-10 minutes. A full description of this scenario is below, including the expected results.**

### Purpose

QS2 increases the complexity of the supply chain by including an intermediate processing facility. The purpose of this scenario is to demonstrate the movement of one commodity from a single RMP to an intermediate processor facility where the commodity is converted to a new material, and then delivered to a single destination. In this case, the RMP supplies blueberries and the destination demands jam. An intermediate processor will take blueberries as an input and convert it to jam using the facility-commodity input data specified by the user.

### Input Data

#### Geospatial Data

The same “top-level” geospatial data are used for QS2. The intermediate processor feature class (facilities.gdb\proc) is used in this run but was ignored in the previous scenario.

#### Facility-Commodity Data

In QS2, a single RMP is specified in the rmp.csv file (shown below). The record for facility\_name ‘rmp\_25003’ indicates it has 100 tons of blueberries available as an “output” to supply the scenario.

	A	B	C	D	E	F	G
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io
2	rmp_25003	raw_material_producer	blueberries	100	tons	solid	o

Figure 11: QS2 raw material supplier input commodity file (rmp.csv)

QS2 adds intermediate processing capabilities. The proc.csv file contains two records: one for the input commodity, and one for the output commodity. The quantity of material is used to specify the conversion ratio of the facility. The max\_processor\_input field defines the maximum processing capacity by limiting the amount of material that can enter the facility. It also sets the minimum processing capacity to one-half the maximum. In this case, the processor simply converts between 75 and 150 tons of blueberries to an equal quantity of jam. There are no other inputs, co-products, or losses associated with this process for simplicity. However, the user is free to specify more realistic product slates.

The max\_processor\_input field is optional and can be left blank for some or all processors; these processors will have no restriction on the amount of material they process, though the processing ratio is still constrained by the “value” field. If the field is filled, it should be the same for all rows of a processor, as in Figure 12.

	A	B	C	D	E	F	G	H
	facility_name	facility_type	commodity	value	units	phase_of_matter	io	max_processor_input
	proc_25015	processor	blueberries	100	tons	solid	i	150
	proc_25015	processor	jam	100	tons	solid	o	150

Figure 12: QS2 processor input commodity file (proc.csv)

The dest.csv file contains a single destination: dest\_25025 and demands 100 tons of jam.

	A	B	C	D	E	F	G
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io
2	dest_25025	ultimate_destination	jam	100	tons	solid	i

Figure 13: QS2 destination input commodity file (dest.csv)

## Running a Scenario

### Scenario XML File

The QS2 scenario configuration file is basically the same as the QS1 scenario, except for the following changes to include processors.

- Scenario Name and Scenario Description were changed to note processors are included.
- The base processor GIS layer and processor commodity data input CSV file are now specified (lines 18 and 23, respectively). Previously, these fields were labeled “None.”

```
2  <Scenario xmlns="FTOTv5.0.0">
3  <Scenario_Schema_Version>5.0.0</Scenario_Schema_Version>
4  <Scenario_Name>Quick Start: RMP to Processor to Destination</Scenario_Name>
5  <Scenario_Description>This scenario demonstrates simple movements from a RMP
   to an intermediate Processor to a Destination. This scenario moves
   blueberries from an RMP to a Processor. The processor converts the
   blueberries to jam. The jam then flows from the processor to the
   destination.</Scenario_Description>
6  <Scenario_Inputs>
   . . .
18  <Base_Processors_Layer>C:\FTOT\scenarios\quick_start\input_data\facilities.gd
   b\proc</Base_Processors_Layer>
   . . .
23  <Processors_Commodity_Data>C:\FTOT\scenarios\quick_start\qs2_rmp_proc_dest\De
   fault\input_data\proc.csv</Processors_Commodity_Data>
   . . .
31 </Scenario_Inputs>
```

*The Base Processors Layer (line 18) and Processors Commodity Data (line 23) point to the location of the input geospatial and facility-commodity data, respectively.*

### Run.bat Script

Execute the run.bat file in the default QS2 scenario directory.

The run.bat file specifies a different scenario.xml file than QS1. The same sequence of steps used in QS1 is repeated in QS2. The run should take ~5-10 minutes to complete and will provide informational messages in the command line in which it is executing. More detailed logging information is also recorded in the log files.

## QS2 Results

### FTOT Report

The report is found in the .\Reports directory of the QS2 scenario. **To quickly check your QS2 results, look for the following lines in the generated report and compare your values to those below.**

```
RESULTS
-----
...
O2 : Total Scenario Cost = (transportation + unmet demand penalty + processor construction):    $2,660
...
P_ : COMMODITY_SUMMARY_DOLLAR_COST_BLUEBERRIES__TOTAL:    681.62 :    USD
...
P_ : FACILITY_SUMMARY_DEST_25025_DESTINATION_DEMAND_OPTIMAL_JAM_ROAD:    90.72 :    metric ton
...
P_ : FACILITY_SUMMARY_RMP_25003_RMP_SUPPLY_OPTIMAL_BLUEBERRIES_ROAD:    90.72 :    metric ton
```

## Tableau Dashboard

The Tableau Dashboard (tableau\_dashboard.twbx) can be found in a timestamped tableau\_dashboard folder within the .\Reports directory of the scenario.

## Maps

The map files can be found in the .\Maps directory of the scenario.

To check that their QS results are accurate, the user can compare their output maps to those in the Map Appendix folder within the quick\_start directory. **For a quick comparison, compare the map below with the FTOT-generated map called 04a\_O\_Step\_Final\_Optimal\_Routes\_With\_Commodity\_Flow.png.**

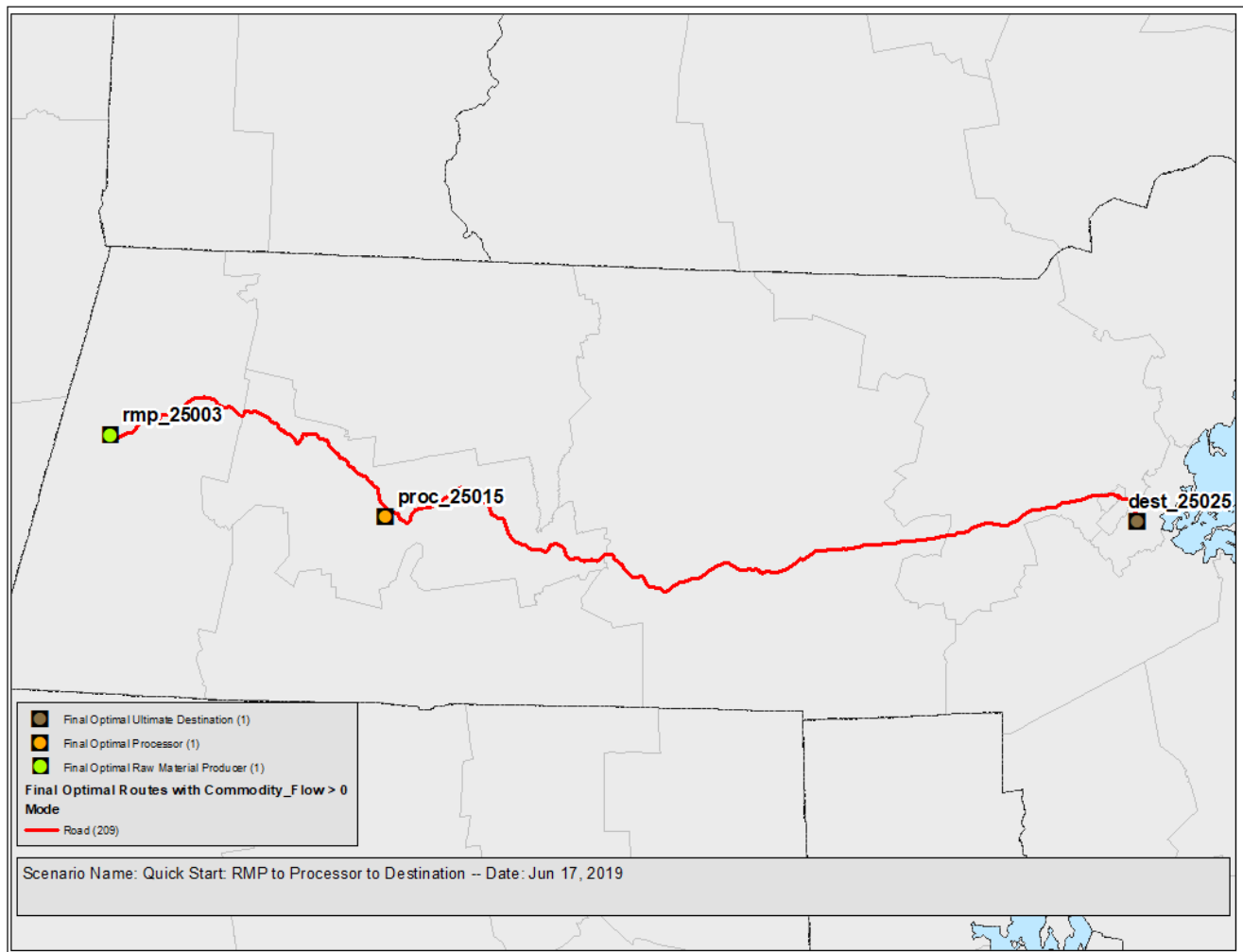


Figure 14: QS2 Optimal Solution

The optimal solution shows that the material travels over the road network from the RMP to processor, and then from the processor to the destination. Note the route change from the RMP to the Proc compared to QS1. In this case, FTOT found a new optimal route to get from Western to Central Massachusetts.



## Exercises

The following exercises are left for the user to explore. The user may return to the main QS2 folder and enter the appropriate sub-folder for each respective exercise. Each provided exercise folder starts off identical to the Default folder; the user is encouraged to make changes to the input files in accordance with the instructions below. For adding new facilities, please refer to the geospatial data in ArcGIS, or the reference PDF in the quick\_start folder.

- 1) Increase the supply from the RMP. Then, add facilities to process the additional supply. Likewise, increase the demand at the destination facility. Increase max\_processor\_input capacity if necessary. Rerun the scenario and observe how material flows between facilities.
- 2) Add demand for an additional commodity, supply for that commodity's raw material, and a new processor for the commodity. Ensure that each supply commodity is matched to a downstream processor capable of converting the material to a commodity demanded by the destination. (Example: Add demand for juice to the dest.csv file; in the proc.csv file, add a new processor to take oranges as input and output juice; add production of oranges to the rmp.csv file.)  
*Note: it is fine to use the same facility names for RMPs and destinations; however, it is important to use a different processor name for processing the additional commodity, because processors can only have a single input.*
- 3) Repeat exercise 2, but add additional destinations and demand for a new commodity to the dest.csv file. Without changing the rmp.csv file, modify the proc.csv file so that a processor outputs two commodities from a single input. (Example: Add demand for juice and marmalade to the dest.csv file; in the proc.csv file, add a processor to take oranges as input and output both juice and marmalade; add production of oranges to the rmp.csv file.)
- 4) Repeat exercise 1, but add schedules for the facilities by filling in the 'schedule' column in the rmp.csv, proc.csv, and dest.csv files with schedule names from the first column of schedule.csv. Try setting different schedules for each processor to see how the processors are utilized differently each day of the 3 day scenario.  
*Note: The scenario.xml file has an additional element Schedule\_Data pointing to the schedule.csv file. The .bat file includes an additional step m2 that creates maps for each day of the scenario. The maps appear in a new folder called "Maps\_Time\_Commodity."*

## Quick Start 3 (QS3) - RMP to Candidate Processor to Destination

**Instructions: to run the QS3 scenario, execute run\_v5\_1.bat in quick\_start\qs3\_rmp\_proc\_cand\_dest\Default. The run should take about 25-30 minutes. A full description of this scenario is below, including the expected results.**

### Purpose

QS3 increases the complexity of the supply chain by generating candidate processor locations between the existing RMP and ultimate destination. The purpose of this scenario is to demonstrate candidate processor generation functionality. In this scenario, FTOT does a pre-optimization between the RMP and destination to find where along the network sufficient material would flow to satisfy the requirements of a candidate process. FTOT then does a second optimization to identify the optimal flow including the candidate processors and the flow of the commodity through a candidate processor where it is converted to a new material.

### Input Data

#### Geospatial Data

As with the previous scenarios, the facilities.gdb file in the input\_data directory will be used to specify the three feature classes; RMPs, processors, and destinations. Note that the processors feature class is set to none in the scenario xml, since FTOT will be generating the locations of the candidate processor facilities as part of the run.

#### Facility-Commodity Data

In QS3, a single RMP is specified in the rmp.csv file (shown below). The record for facility\_name 'rmp\_25003' indicates it has 100 tons of blueberries available as an "output" to supply the scenario. The max\_transport\_distance field is now included to reflect a restriction in the supply chain. This field is omitted in previous runs because max\_transport\_distance is optional for optimizing "non-candidate processor" scenarios.

In this case, FTOT will not allow movements greater than 120 miles on the network for blueberries originating from the 'rmp\_25003' facility. This field is mandatory for all candidate generation scenarios (see no-flow section of troubleshooting in FTOT\_Documentation\_2020\_4\_1.pdf). The value in this field instructs FTOT to use a more specific method for creating the optimization problem. This considerably increases the run-time of a scenario.

	A	B	C	D	E	F	G	H
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io	max_transport_distance
2	rmp_25003	raw_material_producer	blueberries	100	tons	solid	o	120

Figure 15: QS3 raw material supplier input commodity file (rmp.csv)

QS3 adds candidate processor generation capabilities. A new facility\_commodity csv file is introduced in this scenario: proc\_cand.csv. It contains six records: one for the input commodity, and one for the output commodity as usual, plus minimum and maximum facility sizes (minsize and maxsize, respectively), minimum amount of material aggregation on the network to place a candidate facility (min\_aggregation) and cost\_formula. The input and output commodities relationship are stored in FTOT per unit of input material. Therefore, the user is free to use whatever relationship is convenient for them. The candidate processor size is limited by the minsize and maxsize parameters. The minsize of the facility is the minimum amount of material that must flow through the facility during the optimization for FTOT to utilize it as a candidate. The maxsize is the largest size facility (by input commodity) that FTOT will generate. The max\_processor\_input field will be

populated with this max\_size value when the ftot\_generated\_processor\_candidates.csv file is generated. The min\_aggregation is the quantity of material that must flow over a given link on the network to generate a candidate node.

In this case, the processor simply converts 100 tons of blueberries to 100 tons of jam. There are no other inputs, co-products, or losses associated with this process, but the user is free to specify more realistic product slates. Additionally, since the minimum aggregation size is set to 10 tons, FTOT will generate a candidate anywhere on the network where the aggregated flow of blueberries is at least 10 tons. Finally, the amortized capital cost of the candidates is specified as a formula. In this case, 1 USD/ton of input material is specified. The amortized capital cost of the facility is added to the optimization problem and included in the total scenario cost.

	A	B	C	D	E	F	G
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io
2	candidate_jammary	processor	blueberries	100	ton	solid	i
3	candidate_jammary	processor	jam	100	ton	solid	o
4	candidate_jammary	processor	minsize	50	ton	solid	
5	candidate_jammary	processor	maxsize	100	ton	solid	
6	candidate_jammary	processor	min_aggregation	10	ton	solid	
7	candidate_jammary	processor	cost_formula	1	USD/ton		

Figure 16: QS3 Candidate processor commodity file (cand\_proc.csv)

The dest.csv file contains a single destination: dest\_25025 and demands 100 tons of jam.

	A	B	C	D	E	F	G
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io
2	dest_25025	ultimate_destination	jam	100	tons	solid	i

Figure 17: QS3 destination input commodity file (dest.csv)

## Running a Scenario

### Run.bat Script

Execute the run.bat file in the default QS3 scenario directory.

The run.bat file specifies a different scenario.xml file than QS1 and QS2. A new sequence of steps is introduced in this scenario that was not used in the previous quick start examples. Candidate generation requires two rounds of optimizations. In the first optimization, commodities flow raw material producers towards ultimate destinations as the raw material commodity. Upon reaching the max transport distance, FTOT converts the raw material into the processed commodity. From here the material continues to flow towards the destinations to meet demand. After the optimization, a post processing step looks for points on the network where the flow was aggregated at an amount between the minimum and maximum facility size. A candidate processors feature class is then generated in the scenario gdb, and an FTOT generated candidate processors facility-commodity csv file (e.g. ftot\_generated\_processor\_candidates) is stored in the .\debug folder.

FTOT will now process the new facilities in the same fashion as other known locations. It will rerun the facility, connectivity, and graph steps (this time with the number 2 for logging purposes, e.g. f2, c2, g2). At this point, the scenario is functionally the same as in QS2, except instead of user-specified processors, FTOT will optimize based

### Quick Start 3 (QS3) - RMP to Candidate Processor to Destination

on the candidate facilities and include the amortized capital cost in the optimization. The steps that FTOT will follow in this run are:

1. S – setup; prepare the scenario files and transportation network
2. F – add the facility GIS and facility-commodity data to the scenario files
3. C – connect the facilities to the transportation network
4. G – export a NetworkX graph for the optimization
5. OC – pre-candidate generation optimization
6. F2 – add generated facility locations and commodity data to the scenario (specified as F2 to distinguish from pre-defined processor facilities)
7. C2 – connect the new facilities to the transportation network
8. G2 – export a new NetworkX graph for the optimization
9. O1 – prepare the optimization problem
10. O2 – setup and solve the optimization problem
11. P – post process the optimal solution
12. D – generate reports for the run
13. M – generate maps of the run

The run should take ~25-30 minutes to complete and will provide informational messages in the command line as it is executing. More detailed logging information is also sent to the log files. It may be useful for the user to read the logs to understand more about what is happening within each step.

#### Scenario XML File

The QS3 scenario XML file is the same as the previous scenarios, except for the following changes:

In QS3, (i) we set the processor feature class and facility\_commodity csv file to None, and (ii) a new facility\_commodity csv file is used in the Processors\_Candidate\_Commodity\_Data field. The new input facility\_commodity csv file specifies the candidate processor properties (detailed in Input Data section above).

Scenario Name and Scenario Description are updated to reflect that candidate processors are also included (lines 4 and 5, respectively). Additionally, the base processor GIS layer (line 18) and processor commodity data input CSV file (line 23) are set to None, since FTOT will generate the processor locations instead of using the user-specified locations. The facility\_commodity csv file for the Processors\_Candidate\_Commodity\_Data field is specified and points to the proc\_cand.csv file detailed in the Input Data section above (line 24).

```
2  <Scenario xmlns="FTOTv5.0.0">
3  <Scenario_Schema_Version>5.0.0</Scenario_Schema_Version>
4  <Scenario_Name>Quick Start: RMP to Processor Candidate to
   Destination</Scenario_Name>
5  <Scenario_Description>This scenario demonstrates candidate processor
   generation for commodities converted along the way of movements from an RMP
   to a Destination.</Scenario_Description>
6  <Scenario_Inputs>
   - . . .
18  <Base_Processors_Layer>None</Base_Processors_Layer>
   - . . .
23  <Processors_Commodity_Data>None</Processors_Commodity_Data>
24  <Processors_Candidate_Commodity_Data>C:\FTOT\scenarios\quick_start\qs3_rmp_proc_cand_
   dest\Default\input_data\proc_cand.csv</Processors_Candidate_Commodity_Data>
   - . . .
31 </Scenario_Inputs>
```

## QS3 Results

### FTOT Report

The report is found in the .\Reports directory of the QS3 scenario. **To quickly check your QS3 results, look for the following lines in the generated report and compare your values to those below.**

```
RESULTS
-----
...
OC : Total Scenario Cost = (transportation + unmet demand penalty + processor construction):    $2,430
...
O2 : Total Scenario Cost = (transportation + unmet demand penalty + processor construction):    $2,475
...
P_ : COMMODITY_SUMMARY_DOLLAR_COST_BLUEBERRIES__TOTAL:    1,851.50 :    USD
...
P_ : FACILITY_SUMMARY_CANDIDATE_JAMMERY_15831_PROCESSOR_INPUT_BLUEBERRIES_ROAD:    1.00 :    fraction
```

### A note about QS3 results

Due to the heuristic nature of the candidate generation algorithm that FTOT uses, there may be some slight variations in the results you see across runs of this scenario. That is to be expected, and it does not necessarily mean that the run did not work.

### Tableau Dashboard

The Tableau Dashboard (tableau\_dashboard.twbx) can be found in a timestamped tableau\_dashboard folder within the .\Reports directory of the scenario.

### Maps

The map files can be found in the .\Maps directory of the scenario.

This QS scenario is unique compared to QS1 and QS2 because it also generates candidate processors. In the map called 03b\_F2\_Step\_Processors\_All\_With\_Labels.png, those facilities are displayed.

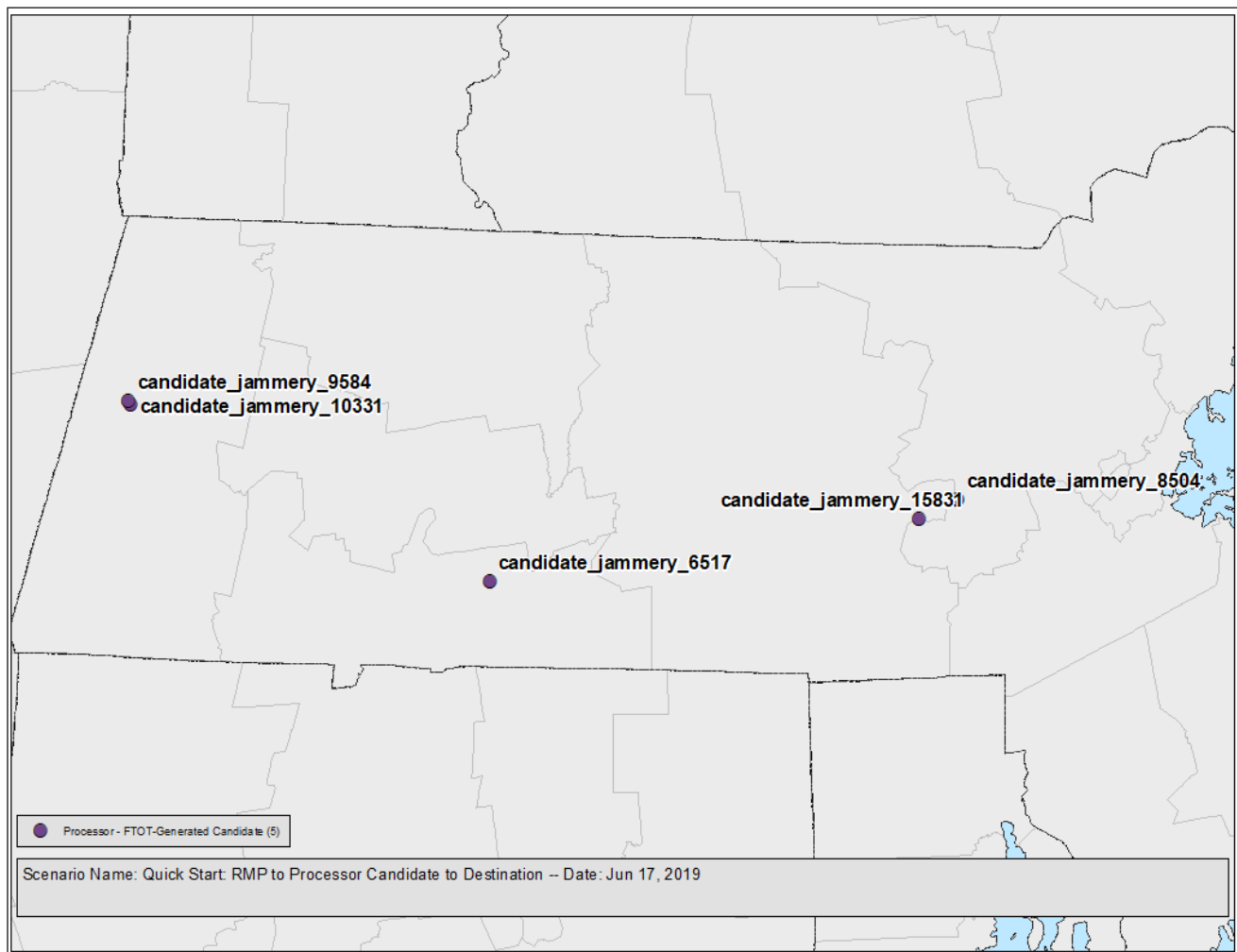


Figure 18: QS3 Candidate Processor Locations Map

To check that their QS results are accurate, the user can compare their output maps to those in the Map Appendix folder within the quick\_start directory. **For a quick comparison, compare the map below with the FTOT-generated map called 04a\_O\_Step\_Final\_Optimal\_Routes\_With\_Commodity\_Flow.png.**

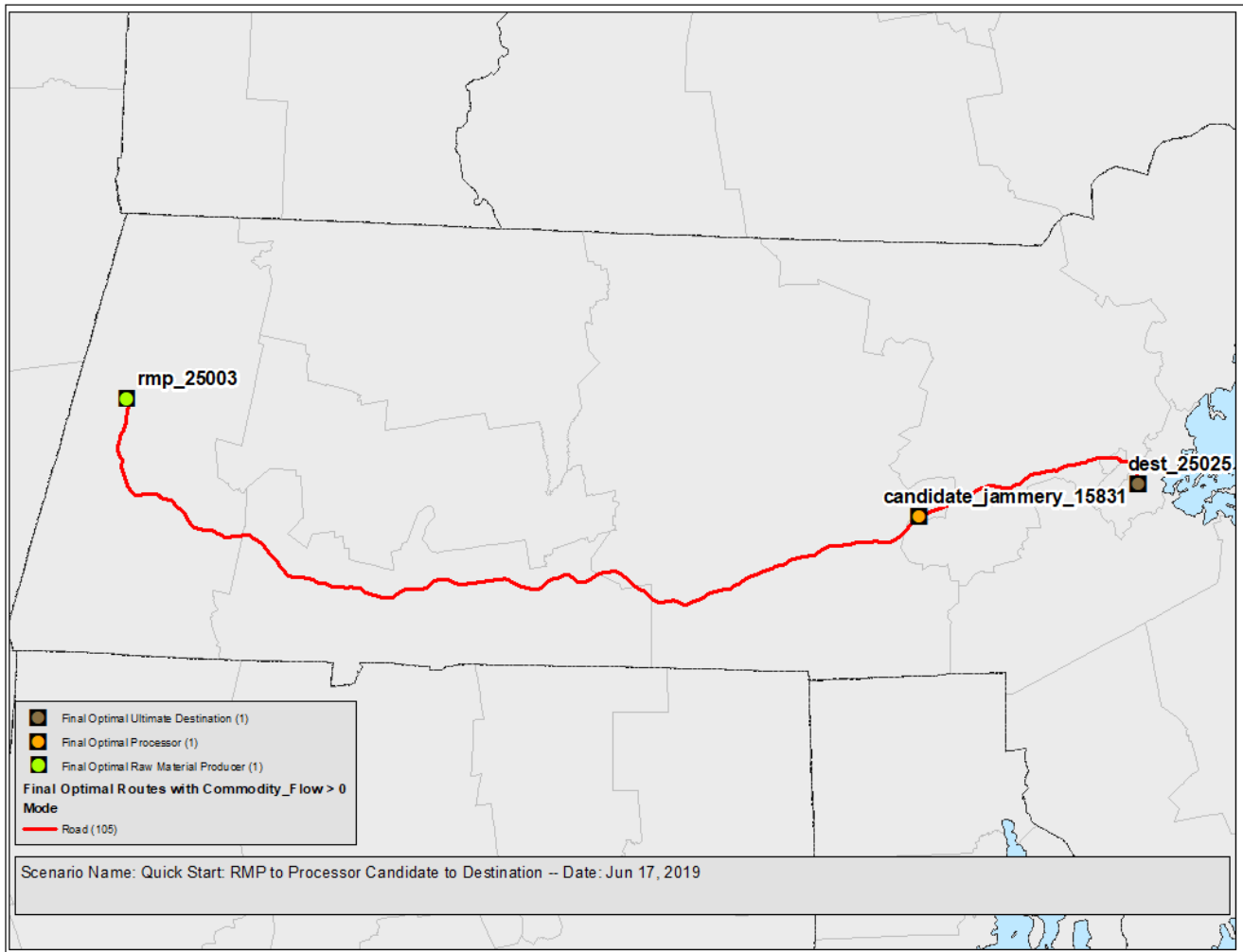


Figure 19: QS3 Optimal Solution Map

The optimal solution shows that the material travels over the road network from the RMP to the candidate processor, and then from the candidate processor to the destination. In this case, only one candidate processor (candidate\_jammary\_15831) was needed to use the available material from the raw material producer (RMP) and satisfy demand at the destination.

Note also how the generated candidate's solution identifies a different optimal scenario than in QS2 when the processor was located in central Massachusetts. The added flexibility of this scenario results in a route that is similar to that of QS1, in which there was no processor.

## Quick Start 4 (QS4) - RMP to Processor 1 to Processor 2 to Destination

**Instructions: to run the QS4 scenario, execute run\_v5\_1.bat in quick\_start\qs4\_rmp\_proc1\_proc2\_dest\Default. The run should take about 5-10 minutes. A full description of this scenario is below, including the expected results.**

### Purpose

QS4 adds a second intermediate processor to the supply chain. This scenario reflects a more complex supply chain that involves the conversion of the raw material into two distinct sequential products before delivery to the ultimate destination. In this case, blueberries are converted to stored\_blueberries at the first processors, and from stored\_blueberries to jam at the second processor. Note how FTOT treats the commodities with distinct names to force the flow through the supply chain in the proper sequence.

### Input Data

#### Geospatial Data

Like the previous scenarios, the facilities.gdb file in the input\_data directory will be used to specify the three feature classes; raw material providers (rmp), and destinations (dest), and processors. Please note that candidate generation in a multi-processor scenario is not currently supported.

#### Facility-Commodity Data

In QS4, a single RMP is specified in the rmp.csv file (shown below). The record for facility\_name 'rmp\_25003' indicates it has 100 tons of blueberries available as an "output" to supply the scenario. The max\_transport\_distance field is left blank (Null/None values) to increase the speed of the optimization step. This field is omitted in non-candidate processor scenarios because max\_transport\_distance is optional.

	A	B	C	D	E	F	G
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io
2	rmp_25003	raw_material_producer	blueberries	100	tons	solid	o

Figure 20: QS4 raw material supplier input commodity file (rmp.csv)

QS4 includes two processors in the facility\_commodity csv file. The first processor proc\_25015 takes blueberries as an input, and outputs stored\_blueberries. This first processor is modeling a storage facility, or blueberry warehouse, and has a maximum capacity of 100 tons. The second processor takes stored\_blueberries as an input and sends out jam, and has a maximum capacity of 101 tons. The second processor in this case serves as a jam production factory. The capacities are set differently purely to demonstrate how the max\_processor\_input field should be consistent for each facility but can be different for different processors. In this example, there are no processing losses or additional co-products for simplicity. However, it should be noted that FTOT will correctly scale the outputs of the facility based on the conversion factors specified in the processor facility\_commodity csv file.



	A	B	C	D	E	F	G	H
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io	max_processor_input
2	proc_25015	processor	blueberries	10	tons	solid	i	100
3	proc_25015	processor	stored_blueberries	10	tons	solid	o	100
4	proc_25027	processor	stored_blueberries	10	tons	solid	i	101
5	proc_25027	processor	jam	10	tons	solid	o	101

Figure 21: QS4 processor input commodity file (proc.csv)

The dest.csv file contains a single destination: dest\_25025 and demands 100 tons of jam.

	A	B	C	D	E	F	G
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io
2	dest_25025	ultimate_destination	jam	100	tons	solid	i

Figure 22: QS4 destination input commodity file (dest.csv)

## Running a Scenario

### Run.bat Script

Execute the run.bat file in the default QS4 scenario directory.

The run.bat file specifies the same sequence of events as QS1 and QS2.

The run should take ~5-10 minutes to complete and will provide informational messages in the command line as it is executing. More detailed logging information is also sent to the log files. It may be useful for the user to read the logs to understand more about what is happening within each step.

### Scenario XML File

The QS4 scenario XML file is the same as the previous scenarios, except for the following changes:

In QS4, the Scenario Name and Scenario Description were updated to reflect the new run directory qs4\_rmp\_proc1\_proc2\_dest. Since this is not a candidate generation scenario the Processors\_Candidate\_Commodity\_Data field is set to None (line 24), while the Processors\_Commodity\_Data field points to the processors input data (line 23).

```

2  <Scenario xmlns="FTOTv5.0.0">
3  <Scenario_Schema_Version>5.0.0</Scenario_Schema_Version>
4  <Scenario_Name>Quick Start: RMP to Processor_1 to Processor_2 to
   Destination</Scenario_Name>
5  <Scenario_Description>This scenario demonstrates simple movements from a RMP
   to two intermediate Processors before sending it to a Destination. The first
   processor converts the blueberries to stored blueberries. The stored blueberries
   then flow from Processor_1 to Processor_2 where it is converted to jam. The jam
   then flows from the processor to the destination.</Scenario_Description>
6  <Scenario_Inputs>
   . . .
23  <Processors_Commodity_Data>
   C:\FTOT\scenarios\quick_start\qs4_rmp_proc1_proc2_dest\Default\input_data\proc
   .csv </Processors_Commodity_Data>
24  <Processors_Candidate_Commodity_Data>None</Processors_Candidate_Commodity_Data>
   . . .
31 </Scenario_Inputs>

```

## Quick Start 4 (QS4) - RMP to Processor 1 to Processor 2 to Destination

## QS4 Results

### FTOT Report

The report is found in the .\Reports directory of the QS4 scenario. **To quickly check your QS4 results, look for the following lines in the generated report and compare your values to those below.**

```
RESULTS
-----
...
O2 : Total Scenario Cost = (transportation + unmet demand penalty + processor construction):    $2,710
...
P  : COMMODITY SUMMARY DOLLAR COST BLUEBERRIES TOTAL:    681,62 :    USD
...
```

### Tableau Dashboard

The Tableau Dashboard (tableau\_dashboard.twbx) can be found in a timestamped tableau\_dashboard folder within the .\Reports directory of the scenario.

### Maps

The map files can be found in the .\Maps directory of the scenario.

To check that their QS results are accurate, the user can compare their output maps to those in the Map Appendix folder within the quick\_start directory. **For a quick comparison, compare the map below with the FTOT-generated map called 04a\_O\_Step\_Final\_Optimal\_Routes\_With\_Commodity\_Flow.png.**

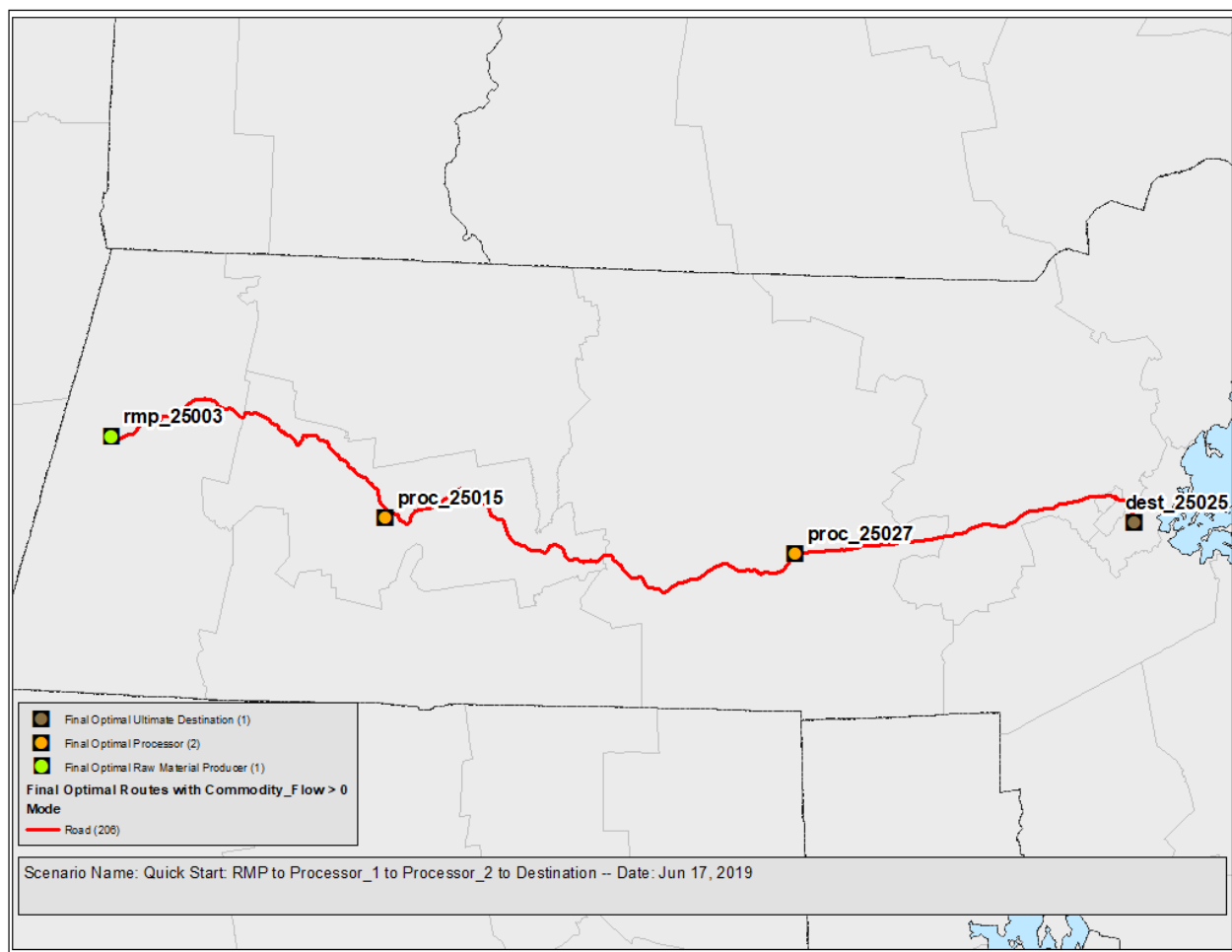


Figure 23: QS4 Optimal Solution Map

The optimal solution shows that the material travels over the road network from the RMP to the first processor. From the first processor it travels to the second processor. Finally, it travels from the second processor to the ultimate destination.

## Quick Start 5 (QS5) - RMP to Destination, No Road

**Instructions: to run the QS5 scenario, execute `run_v5_1.bat` in `quick_start\qs5_rmp_dest_no_road\Default`. The run should take about 5 minutes. A full description of this scenario is below, including the expected results.**

### Purpose

The purpose of QS5 is to demonstrate FTOT's ability to exclude elements of the multimodal network. To exclude a network mode, the user can edit the `Route_Optimization_Script` section of the scenario XML file. In this case, the road network is already set to `False` (line 125). FTOT will exclude the road network from the optimization and look for alternative flows.

The user should expect to see results that are similar to QS1, but without use of the road network. Since the results from QS1 relied exclusively on the road network, FTOT must have identified that particular series of road segments as having the lowest routing cost (taking into account the per mile mode costs *and* the impedances used to encourage flows on certain network segments) from the RMP to the ultimate destination. As a result, in QS5 the user should expect a higher scenario routing cost in the optimal solution as it must use more expensive links on the rail and water modes.

### Input Data

The input geospatial and `facility_commodity` data are the same as used in QS1. They are duplicated in the QS5 scenario `input_data` folder.

### Running a Scenario

#### Run.bat Script

Execute the `run.bat` file in the default QS5 scenario directory.

The `run.bat` file specifies the same sequence of events as QS1.

The run should take ~5 minutes to complete and will provide informational messages in the command line as it is executing. More detailed logging information is also sent to the log files. It may be useful for the user to read the logs to understand more about what is happening within each step.

## Scenario XML File

The QS5 scenario XML file is essentially the same as QS1 with the following changes to reflect the new scenario:

- Scenario name and scenario description were updated to QS5.
- The rmp, processor, and destination CSV files were updated to point to the QS5 input\_data directory in the scenario folder.
- The Road field was set to False under the Permitted\_Modes section of the Route\_Optimization\_Script settings.

All other settings and parameters were left unchanged compared to the QS1 scenario.

```
121 <Route_Optimization_Script>
122   <Permitted_Modes>
123     <!--The following True/False flags determine whether or not a particular mode
124           should be allowed for routing any flows in the scenario-->
125     <!--The default is for all modes to be on-->
126     <Road>False</Road>
127     <Rail>True</Rail>
128     <Water>True</Water>
129     <Pipeline_Crude>True</Pipeline_Crude>
130     <Pipeline_Prod>True</Pipeline_Prod>
131   </Permitted_Modes>
```

## QS5 Results

### FTOT Report

The report is found in the .\Reports directory of the QS5 scenario. **To quickly check your QS5 results, look for the following lines in the generated report and compare your values to those below.**

```
RESULTS
-----
...
O2 : Total Scenario Cost = (transportation + unmet demand penalty + processor construction):    $2,454
...
P_ : COMMODITY_SUMMARY_DOLLAR_COST_BLUEBERRIES__TOTAL:    411.48 :    USD
...
P_ : COMMODITY_SUMMARY_FUEL_BURN_BLUEBERRIES_RAIL:    16.57 :    Gallons
...
P_ : FACILITY_SUMMARY_DEST_25025_DESTINATION_DEMAND_OPTIMAL_BLUEBERRIES_RAIL:    90.72 :    metric ton
...
P_ : FACILITY_SUMMARY_RMP_25003_RMP_SUPPLY_OPTIMAL_FRAC_BLUEBERRIES_RAIL:    1.00 :    fraction
```

## Tableau Dashboard

The Tableau Dashboard (tableau\_dashboard.twbx) can be found in a timestamped tableau\_dashboard folder within the .\Reports directory of the scenario.

## Maps

The map files can be found in the .\Maps directory of the scenario.

To check that their QS results are accurate, the user can compare their output maps to those in the Map Appendix folder within the quick\_start directory. **For a quick comparison, compare the map below with the FTOT-generated map called 04a\_O\_Step\_Final\_Optimal\_Routes\_With\_Commodity\_Flow.png.**

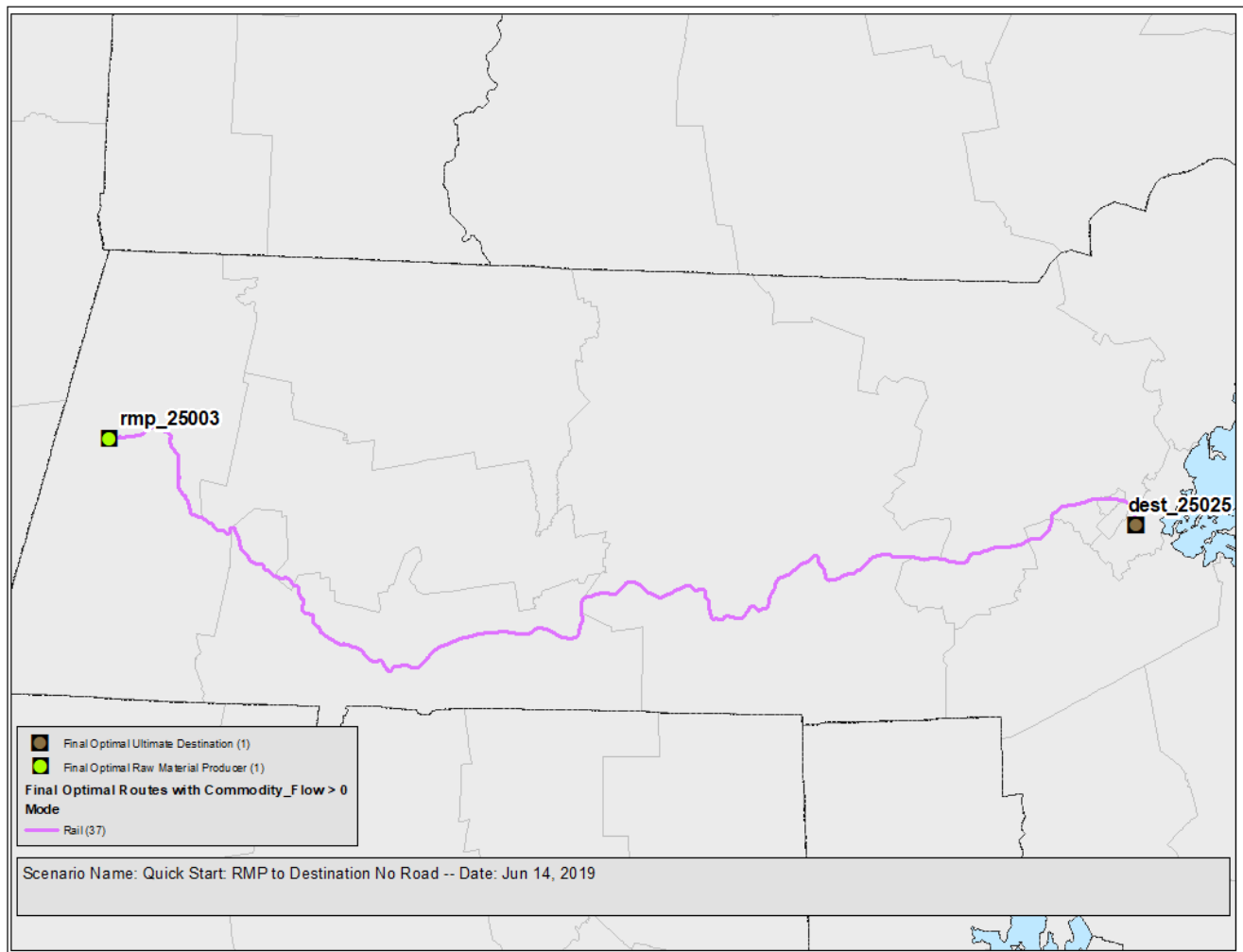


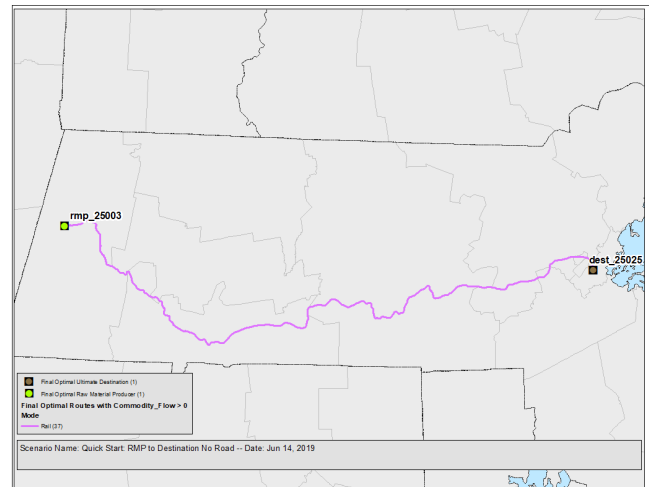
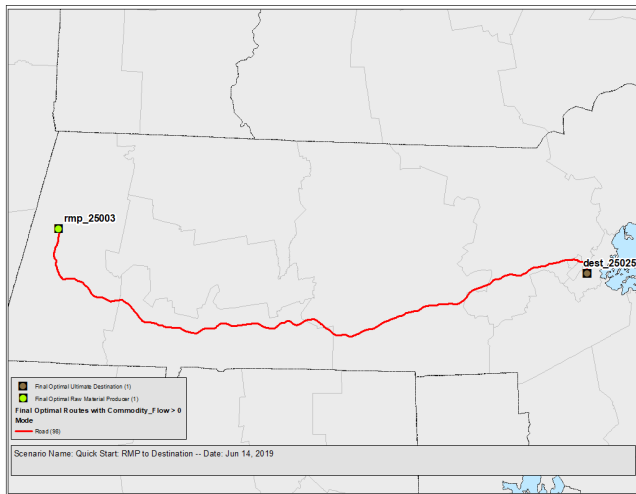
Figure 24: QS5 Optimal Solution Map

The optimal solution shows that the material travels exclusively over the rail network from the RMP to ultimate destination.

## Comparison of QS5 and QS1

The QS5 and QS1 results are identical in the F (facilities) and C (connectivity) steps. This is because the input data was the same in both scenarios. However, since the road was excluded from the permitted modes in the QS5 scenario XML file, the road movements are replaced with the rail.

Of note here is the total scenario routing cost. In QS5 it is \$2,454 utilizing the rail network. In QS1, the total scenario routing cost is \$2,430 using the road network. The total scenario routing cost includes the routing cost, the amortized cost of building candidate facilities (not used in this scenario), and the penalty for unmet demand at the destinations. In this case, the routing cost is the only contribution to the total scenario cost because no candidates are used and all of the demand at the destination was met. However, it should be pointed out that FTOT is tracking two distinct transportation costs: the dollar cost and the routing cost. The routing cost includes a user-specified impedance multiplier for using under-utilized links in the rail network. The dollar cost is just the sum of the movements over the transportation network using the user-specified costs. While the dollar cost for rail movements is lower in QS5 than the dollar cost for road movements in QS1, the routing costs are the opposite. This explains why FTOT selected the road network in the optimal solution in QS1 when road was not restricted from the permitted modes list.



## Quick Start 6 (QS6) - RMP to Processor to Destination, National Level, No Road

**Instructions: to run the QS6 scenario, execute `run_v5_1.bat` in**

**`quick_start\qs6_national_rmp_proc_dest\Default`. The run should take between 15-45 minutes. A full description of this scenario is below, including the expected results.**

**\*`run_v5_1_32bit.bat` is not available for this scenario. If you are unable to run 64-bit FTOT, you should skip this scenario.**

### Purpose

The purpose of QS6 is to demonstrate a national level RMP to Processor to Destination scenario. It is similar to the QS2 scenario, but expanded in geographic scope and number of facilities. To improve run-time, the road network was excluded in the same way as in QS5.

### Input Data

The input geospatial and facility\_commodity data are updated to include a larger number of facilities across the continental United States. The same feature classes in the facilities.gdb located in the top level `.\quick_start\input_data` folder is specified.

The facility-commodity input data CSV files were changed to include multiple facilities. The RMP CSV file contains 636 facilities. All facilities have 18.7MM tons of commodity A\_Supply. There are 20 Processors that convert A\_Supply into B\_Processed. The conversion factor is roughly 1 to 1, but the input and output quantities were generated with a random number generator, so these conversion efficiency figures vary from facility to facility. The same input quantities are set as the maximum input allowed at each processor, with the minimum input fixed at half the maximum (if the facility is used – input for any processor is still allowed to be zero). The processors have a combined maximum capacity of 59MM tons of input, and 49MM tons of output. A total of 20 destinations, mostly located along the East and West Coast, and Great Lakes region were selected. The destinations demand a total of 33MM tons of B\_Processed.

### Running a Scenario

#### Run.bat Script

Execute the run.bat file in the QS6 scenario directory. The run.bat file specifies the same sequence of events as QS2.

The run should take ~15-45 minutes to complete and will provide informational messages in the command line as it is executing. More detailed logging information is also sent to the log files. It may be useful for the user to read the logs to understand more about what is happening within each step.



## Scenario XML File

The QS6 scenario XML file is essentially the same as QS2 with the following changes to reflect the new scenario:

- Scenario name and scenario description were updated to QS6.
- The rmp, processor, and destination CSV files were updated to point to the QS6 input\_data directory in the scenario folder. The input data span the entire U.S., rather than just Massachusetts.
- The Road field was set to False under the Permitted\_Modes section of the Route\_Optimization\_Script settings (line 125).

All other settings and parameters were left unchanged compared to the QS2 scenario.

```
121 <Route_Optimization_Script>
122   <Permitted_Modes>
123     <!--The following True/False flags determine whether or not a particular mode
124           should be allowed for routing any flows in the scenario-->
125     <!--The default is for all modes to be on-->
126     <Road>False</Road>
127     <Rail>True</Rail>
128     <Water>True</Water>
129     <Pipeline_Crude>True</Pipeline_Crude>
130     <Pipeline_Prod>True</Pipeline_Prod>
131   </Permitted_Modes>
```

## QS6 Results

### FTOT Report

The report is found in the .\Reports directory of the QS6 scenario. It is generated in the D step following the FTOT optimization sequence. Note that 80% of the RMP supply was utilized and met 60% of the total destination demand.

```
RESULTS
-----
...
O2 : Total Scenario Cost = (transportation + unmet demand penalty + processor construction): $59,958,778,036
...
P_ : Scenario Total Utilization of Supply and Demand
P_ : -----
P_ : total utilization is defined as (total flow / net available)
P_ : commodity_name | facility_type | io | utilization | units
P_ : -----|-----|----|-----|-----
P_ : a_supply        raw_material_pr o          0.8 fraction
P_ : a_supply        processor      i          0.2 fraction
P_ : b_processed      processor      o          0.4 fraction
P_ : b_processed      ultimate_destin i        0.6 fraction
P_ : -----
...
P_ : COMMODITY_SUMMARY_DOLLAR_COST_A_SUPPLY__TOTAL: 293,995,999.36 : USD
...
P_ : COMMODITY_SUMMARY_MILES_A_SUPPLY_RAIL: 21,698.04 : miles
...
P_ : COMMODITY_SUMMARY_MILES_A_SUPPLY_WATER: 1,768.83 : miles
...
P_ : COMMODITY_SUMMARY_MILES_B_PROCESSED__TOTAL: 6,343.55 : miles
...
P_ : COMMODITY_SUMMARY_VMT_B_PROCESSED__TOTAL: 127,739,429.03 : VMT
...
P_ : FACILITY_SUMMARY_PROC_18007_PROCESSOR_INPUT_A_SUPPLY__TOTAL: 4,710,648.00 : metric_ton
...
P_ : FACILITY_SUMMARY_PROC_21195_PROCESSOR_INPUT_A_SUPPLY__TOTAL: 1,613,259.00 : metric_ton
```

### Tableau Dashboard

The Tableau Dashboard (tableau\_dashboard.twbx) can be found in a timestamped tableau\_dashboard folder within the .\Reports directory of the scenario.

### Maps

The map files can be found in the .\Maps directory of the scenario.

In the map called 02d\_F\_Step\_default\_basemap.png, the processors, destinations, and all possible 636 RMPs are displayed.

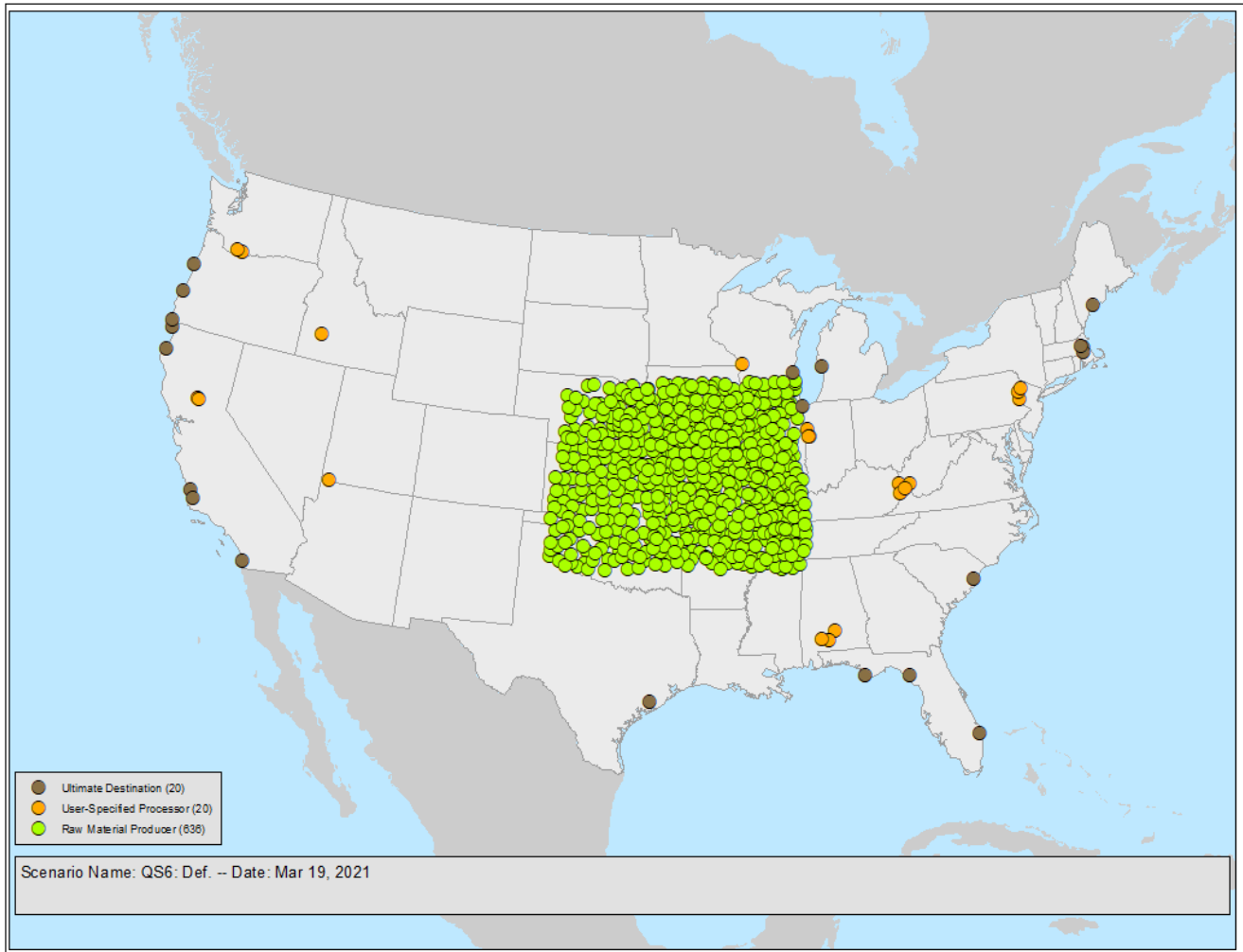


Figure 27: QS6 facility locations maps

To check that their QS results are accurate, the user can compare their output maps to those in the Map Appendix folder within the quick\_start directory. **For a quick comparison, compare the map below with the FTOT-generated map called**

**04a\_O\_Step\_Final\_Optimal\_Routes\_With\_Commodity\_Flow\_NO\_LABELS\_default\_basemap.png.**

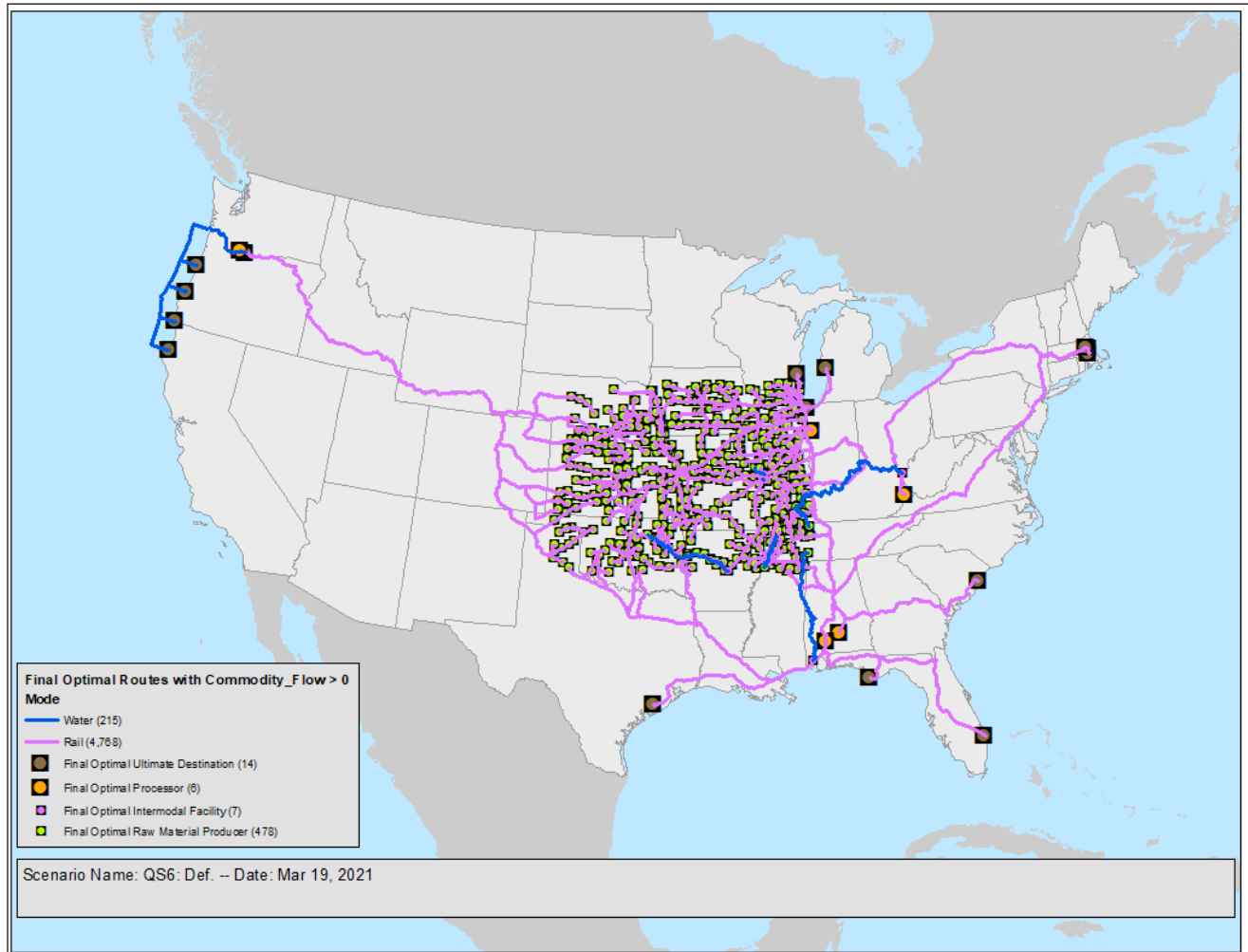


Figure 28: QS6 Optimal Solution Map

The optimal solution shows that the material travels exclusively over the rail and water networks. Intermodal movements are also utilized where material shifts from the rail to the water network, or vice versa. Only 478 of the 636 RMPs were selected as optimal. This could be due to the fact that some RMPs were not connected to the rail or water networks (but were not considered stranded since they were hooked into the road network), or the routes on the rail and water network were not optimal for the given constraints of the system.

## Exercises

The following exercises are left for the user to explore. The user may return to the main qs6 folder and enter the appropriate sub-folder for each respective exercise. Each exercise folder starts off identical to the Default folder; the user is encouraged to make changes to the input files in accordance with the instructions below.

- 1) In the scenario.xml file in the Exercise 1 directory, increase the artificial link distance for rail and water from 5 miles to 15 miles (lines 115 and 116) and rerun the scenario from scratch. What happens to the total flow of A\_Supply in the new solution?
- 2) In the scenario.xml file in the Exercise 2 directory, switch the road network in the Permitted\_Modes list (line 125) from False to True. Rerun the scenario from scratch. (Note that the run time for the scenario will increase from ~15 minutes to ~10 hours.) What happens to the flow of A\_Supply? Does the quantity of B\_Processed increase?
- 3) In the scenario.xml file in the Exercise 3 directory, enable the network presolve step by setting the NDR\_On parameter to True in order to improve runtime for the national level scenario. Enabling this functionality triggers a network density reduction (NDR) calculation using the NetworkX shortest path algorithm in the G step, which simplifies the optimization problem. Performing the optimization steps on the less dense shortest path network decreases the runtimes of the O steps, but can result in a sub-optimal solution. NDR is recommended for either unimodal scenarios (e.g., just road) or in cases where the goal of the analysis is high-level results and relative information across scenarios rather than detailed routing information, and cannot be used in combination with candidate generation or capacity constraints. Compare the results of Exercise 3 to the results for the Default scenario. How does the network presolve step affect the runtime of each step in the report? Is there a change in the total scenario routing cost found in the report?

*Note: The scenario.xml file has an additional element NDR\_On located in the Route\_Optimization\_Script section that takes a True or False value. NDR\_On is an optional element of the scenario.xml file; running the tool with a scenario.xml file missing the NDR\_On element will not cause an error. The default setting for NDR\_On if the element is missing is False, (e.g., the network presolve step is disabled).*

## Quick Start 7 (QS7) - RMP to Processor (multiple inputs) to Destination

**Instructions: to run the QS7 scenario, execute run\_v5\_1.bat in**

**quick\_start\qs7\_rmp\_to\_proc\_to\_dest\_multi\_inputs\Default. The run should take between 7-10 minutes. A full description of this scenario is below, including the expected results.**

### Purpose

The purpose of QS7 is to demonstrate a processor facility that can co-process two distinct input commodities. It is similar to QS2, but has an additional input requirement for the processor.

### Input Data

The facility\_commodity data files are updated to include an additional RMP facility to supply sugar, and the processor facility commodity data file also includes sugar as an additional input commodity to the previously used facility. The same feature classes in the facilities.gdb located in the top level `.\quick_start\input_data` folder are specified.

In this scenario, 100 tons of blueberries from rmp\_25003 and 100 tons of sugar from rmp\_25011 are sent to the processor facility proc\_250115. Both commodities are specified as inputs and jam is specified as the only output, and created at a ratio of 10 tons output per (10 tons of sugar + 10 tons of blueberries). The maximum processor input is set to 200 tons, which defaults the minimum input to 100 tons. This applies to the total input, which in this case means a minimum of 50 tons and a maximum of 100 tons for each of blueberries and sugar. Losses and co-products are not recorded in the scenario. Note that FTOT requires both commodities to be available in order to generate the output. FTOT will not use the facility if one commodity is missing. If one of the input commodities is limited, then FTOT will generate up to the limiting amount of input material.

### Running a Scenario

#### Run.bat Script

Execute the run.bat file in the QS7 scenario directory. The run.bat file specifies the same sequence of events as QS2.

The run should take ~7-10 minutes to complete and will provide informational messages in the command line as it is executing. More detailed logging information is also sent to the log files. It may be useful for the user to read the logs to understand more about what is happening within each step.

## Scenario XML File

The QS7 scenario XML file is essentially the same as QS2 with the following changes to reflect the new scenario:

- Scenario name and scenario description were updated to QS7.
- The rmp, processor, and destination CSV files were updated to point to the QS7 input\_data directory in the scenario folder.

All other settings and parameters were left unchanged compared to the QS2 scenario.

## QS7 Results

### FTOT Report

The report is found in the .\Reports directory of the QS7 scenario. It is generated in the D step following the FTOT optimization sequence.

```
TOTAL RUNTIME
-----
S_:      s Step - Total Runtime (HMS):    00:00:27
F_:      f Step - Total Runtime (HMS):    00:00:24
C_:      c Step - Total Runtime (HMS):    00:01:47
G_:      g Step - Total Runtime (HMS):    00:00:19
O1:      o1 Step - Total Runtime (HMS):    00:00:16
O2:      o2 Step - Total Runtime (HMS):    00:00:54
P_:      p Step - Total Runtime (HMS):    00:00:43

RESULTS
-----
...
O2:      Total Scenario Cost = (transportation + unmet demand penalty + processor construction):    $3,133
...
P_:      -----
...
P_:      COMMODITY_SUMMARY_DOLLAR_COST_BLUEBERRIES_TOTAL:    681.62 :    USD
P_:      COMMODITY_SUMMARY_DOLLAR_COST_BLUEBERRIES_ROAD:    681.62 :    USD
...
P_:      COMMODITY_SUMMARY_DOLLAR_COST_JAM_TOTAL:    1,684.46 :    USD
P_:      COMMODITY_SUMMARY_DOLLAR_COST_JAM_ROAD:    1,684.46 :    USD
...
P_:      COMMODITY_SUMMARY_DOLLAR_COST_SUGAR_TOTAL:    421.55 :    USD
P_:      COMMODITY_SUMMARY_DOLLAR_COST_SUGAR_ROAD:    421.55 :    USD
```

## Tableau Dashboard

The Tableau Dashboard (tableau\_dashboard.twbx) can be found in a timestamped tableau\_dashboard folder within the .\Reports directory of the scenario. Note that sugar commodity is fully utilized in this scenario.

## Maps

The map files can be found in the .\Maps directory of the scenario.

In the map called O2d\_F\_Step.png, the processors, destinations, and all RMPs are displayed.

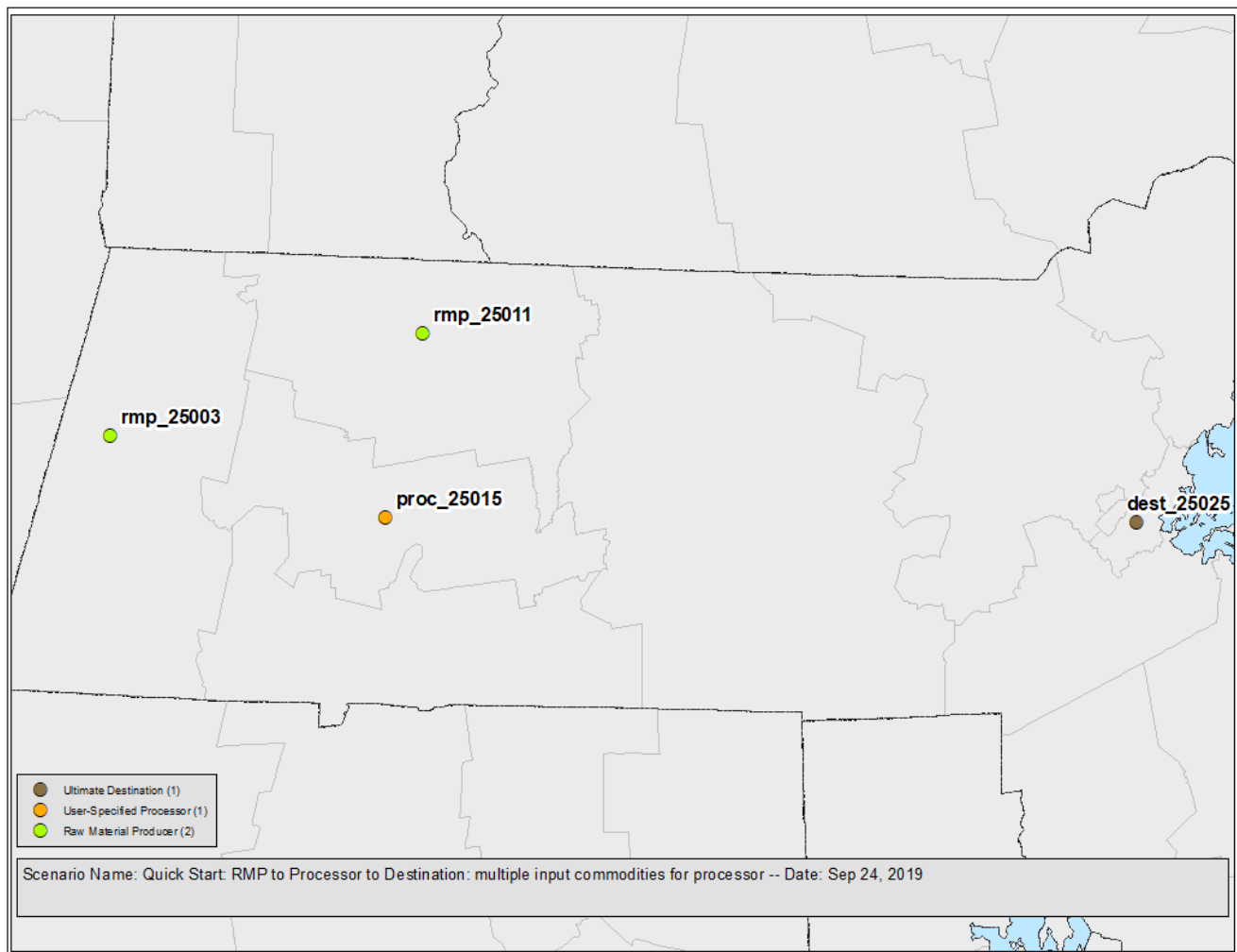


Figure 29: QS7 Facility locations map

To check that their QS results are accurate, the user can compare their output maps to those in the Map Appendix folder within the quick\_start directory. **For a quick comparison, compare the map below with the FTOT-generated map called 04a\_O\_Step\_Final\_Optimal\_Routes\_With\_Commodity\_Flow.png.**

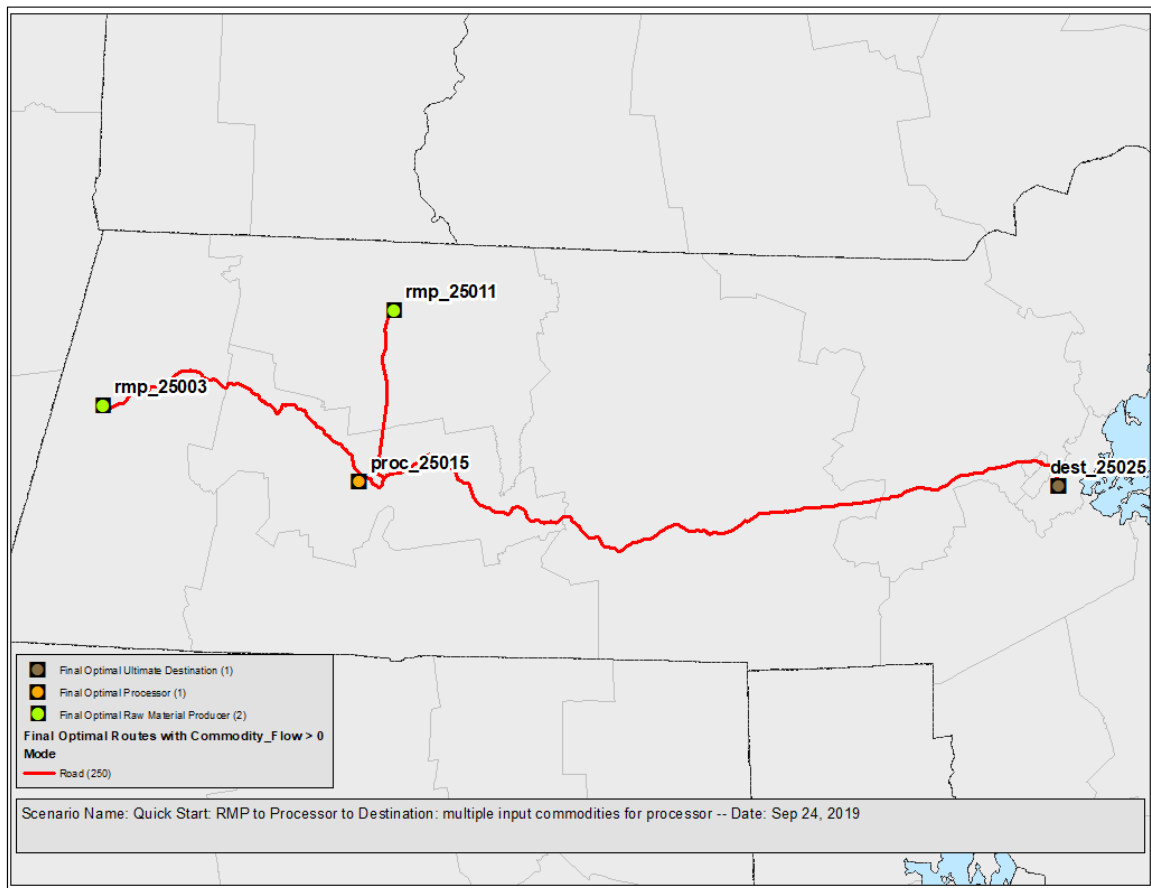


Figure 30: QS7 Optimal Solution Map

The optimal solution shows that the material travels exclusively over the road network. Compared to the QS2, an additional RMP is utilized, which sends sugar to the processor. The flow out of the processor to the destination remains unchanged.

## Exercises

The following exercises are left for the user to explore. The user may return to the main qs7 folder and enter the appropriate sub-folder for each respective exercise. Each exercise folder starts off identical to the Default folder; the user is encouraged to make changes to the input files in accordance with the instructions below.

- 1) In the rmp.csv file in the input\_data directory, decrease the availability of sugar from 100 tons to 50 tons. What happens to the resulting output of jam that is produced and output from the processor?
- 2) In the rmp.csv file in the input\_data directory, decrease the availability of sugar from 50 tons (in the previous exercise) to 0 tons. Why is there a no flow solution?



## Quick Start 8 (QS8) - Pipelines

**Note:** QS8 contains three examples: one using the crude pipeline network, one using only the product pipeline network, and one using both the crude and product pipeline networks.

**Instructions:** to run the QS8 scenarios, execute `run_v5_1.bat` or `run_v5_1_32bit.bat` in the Example folders in `quick_start\qs8_pipeline`. The run should take 7-10 minutes. A full description of these scenarios is below, including the expected results.

### Purpose

The purpose of QS8 is to demonstrate use of the crude and product pipeline networks. The QS8 scenarios are similar to QS1 and QS2 but with additional inputs to designate which commodities can run on the pipeline networks.

### Input Data

QS8 contains three scenarios:

- Example 1 sends 100 kilogallons of crude oil from `rpm_40081` near Cushing, Oklahoma, to `dest_48201` near Houston, Texas.
- Example 2 sends 100 kilogallons of petroleum products from `rpm_48201` Houston, Texas area to `dest_34039` in New Jersey.
- Example 3 sends 100 kilogallons of crude oil from `rpm_40081` near Cushing, Oklahoma, to `proc_48201` near Houston, Texas, where it is refined into petroleum products and sent to `dest_34039` in New Jersey.

### Commodity Mode

Unlike previous scenarios, there's an additional CSV file in the `input_data` directory. `Commodity_mode.csv` designates `crude_oil` as being able to flow along the crude pipeline network and `pet_prods` as being able to flow along the product pipeline network. This CSV file is stored in the same place the other scenario input data, for example the facility commodity CSV files, are stored.

This csv file must be included in order to include pipelines in the solution. Pipelines are included in the FTOT network, but disabled for all commodities by default. This is to allow users to have flexibility in naming commodities while preventing commodities that aren't supposed to flow on pipeline from utilizing it in the optimal scenario, since it is usually the least expensive mode.

commodity	road	rail	water	pipeline_crude	pipeline_prod
crude_oil	Y	Y	Y	Y	N
pet_prods	Y	Y	Y	N	Y

Figure 31. `Commodity_mode.csv` example.

## Running a Scenario

### Run.bat Script

Execute the `.bat` file in any of the Example folders in the QS8 scenario directory. The `run.bat` file specifies the same sequence of events as QS1 for the Examples 1 and 2. Example 3 runs the same sequence of events as QS2 and can only be run with 64-bit background processing.

The run should take 10 minutes to complete and will provide informational messages in the command line as it is executing. More detailed logging information is also sent to the log files. It may be useful for the user to read the logs to understand more about what is happening within each step.

### Scenario XML File

The QS8 scenario XML files are essentially the same as QS1 or QS2 with the following changes to reflect the new scenario:

- Scenario name and scenario description were updated to QS8.
- The `rpm`, processor, and destination CSV files were updated to point to the QS8 `input_data` directory in the scenario folder.
- The file has an additional field, `Commodity_Mode_Data`, which points to the CSV file indicating which commodities can travel by each mode.
- The road, rail, and water networks are all turned off in the `Permitted_Modes` field to force the oil to flow on the pipeline network. This is not a required step, but is used to ensure that the pipeline is utilized, even if a less expensive transportation option is available for these hypothetical movements.
- The `Pipeline_Crude_Max_Artificial_Link_Distance_Miles` and `Pipeline_Products_Max_Artificial_Link_Distance_Miles` fields are increased from 5 to 25 miles to allow the county-level points to connect to the terminus of the pipeline network. The link distance was estimated by measuring the distance from the facility points to a pipeline hub in ArcMap.

All other settings and parameters were left unchanged compared to the QS1 or QS2 scenarios.

### QS8 Results

#### FTOT Report

The report is found in the `.\Reports` directory of the QS8 scenario. It is generated in the D step following the FTOT optimization sequence.

#### Example 1

```
TOTAL RUNTIME
-----
S_:      s Step - Total Runtime (HMS):    00:03:02
F_:      f Step - Total Runtime (HMS):    00:01:39
C_:      c Step - Total Runtime (HMS):    00:25:27
G_:      g Step - Total Runtime (HMS):    00:01:42
O1:      o1 Step - Total Runtime (HMS):    00:00:18
O2:      o2 Step - Total Runtime (HMS):    00:00:11
P_:      p Step - Total Runtime (HMS):    00:01:57

RESULTS
-----
...
O2:      Total Scenario Cost = (transportation + unmet demand penalty + processor construction):
$13,098...
P_:      -----
...
P_:      COMMODITY_SUMMARY_DOLLAR_COST_CRUDE_OIL_TOTAL:          12,666.67 :          USD
P_:      COMMODITY_SUMMARY_DOLLAR_COST_CRUDE_OIL_PIPELINE_CRUDE_TRF_RTS:  12,666.67 :          USD
```

## Tableau Dashboard

The Tableau Dashboard (tableau\_dashboard.twbx) can be found in a timestamped tableau\_dashboard folder within the .\Reports directory of the scenario.

## Maps

The map files can be found in the .\Maps directory of the scenario.

In the map called 02d\_F\_Step\_with\_Labels.png, the rmp, processor, and destination are displayed.

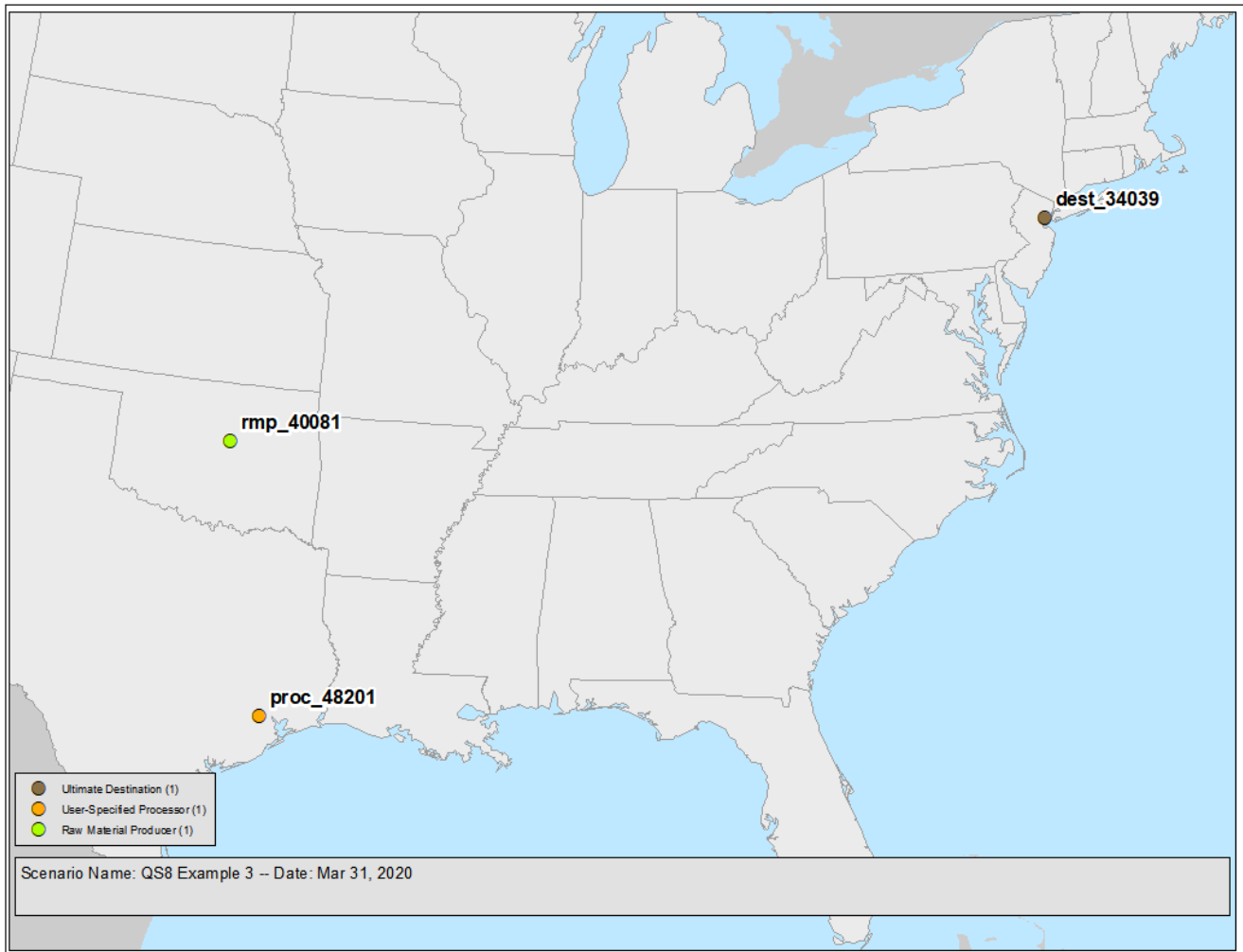


Figure 32: QS8, Example 3 Facility locations map

To check that their QS results are accurate, the user can compare their output maps to those in the Map Appendix folder within the quick\_start directory. **For a quick comparison, compare the map below with the FTOT-generated map called 04a\_O\_Step\_Final\_Optimal\_Routes\_With\_Commodity\_Flow.png.**

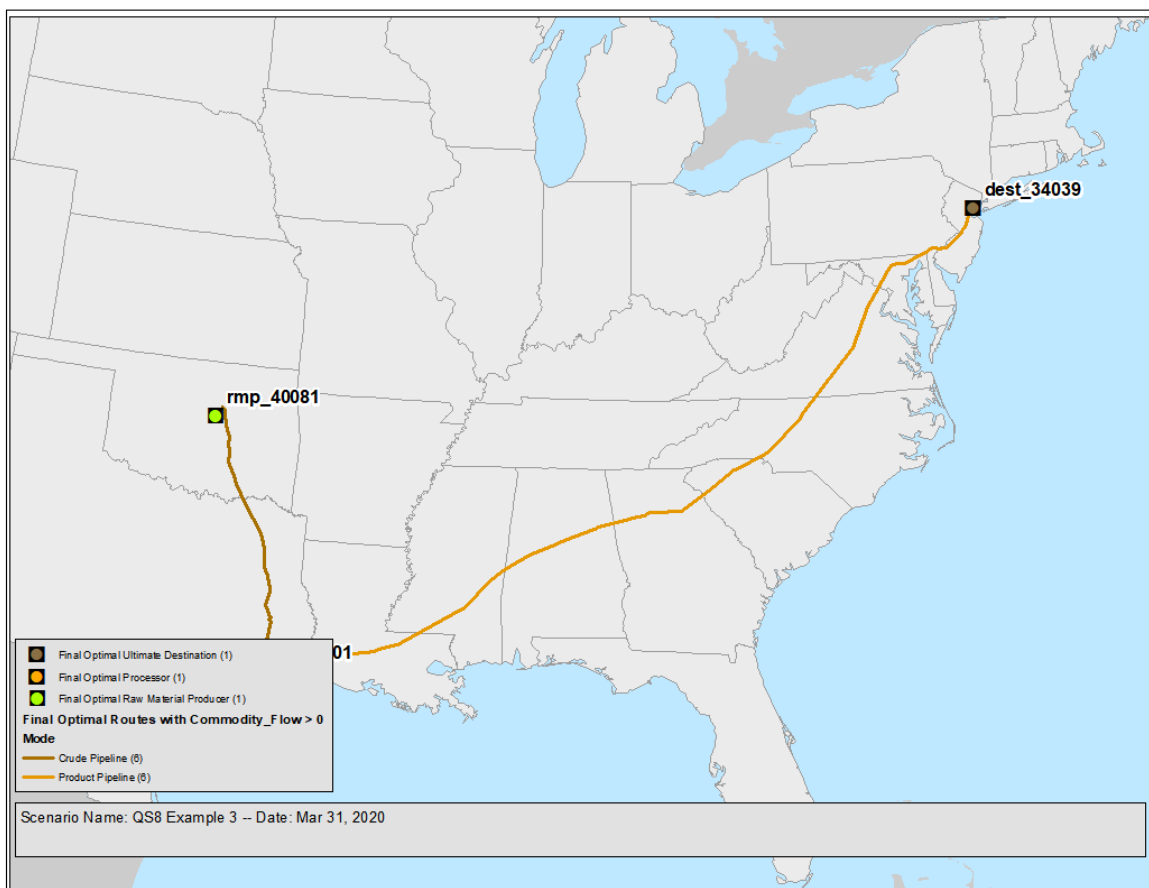


Figure 33: QS8, Example 3 Optimal Solution Map

The optimal solution for Example 3 shows that the material travels via the Colonial Pipeline from Texas to New Jersey.

## Quick Start 9 (QS9) – Scenario Suite for Comparison

Instructions: to run the QS9 scenario, execute the `run_v5_1.bat` in each of the subfolders in `quick_start\qs9_suite`. The runs should take between 7-10 minutes each. After all of the scenarios are complete, concatenate the results using the Scenario Compare Tool in `ftot_tools.py`. A full description of this scenario is below, including the expected results.

## Purpose

The purpose of QS9 is to demonstrate how to compare a number of scenarios using the Scenario Compare tool, which concatenates the data from several scenarios and packages them in a Tableau Workbook.

## Input Data

There are four scenarios in this example spread across the United State: (1) the Massachusetts area RMP-> Destination example from QS1, (2) a new hypothetical Southern California area RMP-> Destination moving agricultural commodities, (3) a new hypothetical Seattle area scenario moving plane engines, and (4) the RMP-> Proc-> Destination petroleum crude and products scenario from QS8 Example 3.

## Scenario XML File

The QS9 contains four scenario XML files for the four exercises. They are essentially the same as other scenarios, with the following changes to reflect the new scenario:

- Scenario name and scenario description were updated.
- The rmp, processor, and destination CSV files were updated to point to the QS7 input\_data directory in the scenario folder.
- The Exercise 4 scenario xml contains the Commodity Mode csv location to enable pipeline movements.

## Running a Scenario

## Run.bat Script

Execute the run.bat files in the QS9 sub-directories for each of the four exercises. Next, follow the instructions for the scenario compare tool below.

Scenario Compare Tool | FTOT Tools

Once the scenarios are finished running, the results are concatenated using the Scenario Compare utility in FTOT Tools. FTOT Tools can be launched using the command line:

```
%python path% c:\ftot\program\tools\ftot tools.py
```

50000

version 0.1

select an option below to activate a tool

```

[0] xml_tool
[1] bat_tool
[2] scenario_compare_tool
[3] aggregate_raster_data
[4] generate_template_csv_files
[5] breakpoint
[6] replace_xml_text
[7] exit
>>

```

Select the Scenario Compare Tool and follow the prompts. First specify an output folder for the tool to put the concatenated results and packaged Tableau workbook. If the folder does not exist, FTOT will create it, place temporary files, and open the window for you. For example, try:

```
c:\FTOT\scenarios\quick_start\qs9_suite\compare
```

```

You called compare_tool()
FTOT scenario comparison tool
-----
scenario comparison tool | step 1/2:
-----
scenario comparison output directory:
-----> C:\FTOT\scenarios\quick_start\qs9_suite\compare

```

Next, FTOT needs to generate a list of directories to search for the individual Tableau reports. The user can select two modes: (i) a recursive sub-folder search, or (ii) manually provide the paths to the scenarios. Select the recursive search (option 1) for this exercise, and then specify the QS9 directory (note: this is **not** the compare directory!)

```
C:\FTOT\scenarios\quick_start\qs9_suite
```

```

scenario comparison tool | step 2/2:
-----
Option 1: recursive directory search
Option 2: user-specified directories
Enter 1 or 2 or quit: >> 1
enter top level directory
-----> C:\FTOT\scenarios\quick_start\qs9_suite

```

Once the list of scenarios is created, the tool will loop through each subdirectory under the QS9 suite, search for the `.\Reports` folder, and find the latest `Tableau_Report_YYYY_MM_DD_HH_MM_SS` folder. If there are no `.\Reports` folders, then the tool skips that folder.

The records in the `tableau_report.csv` and `tableau_output.gdb` files from the latest report are then concatenated into the comparison files stored in the output directory.

When all of the scenarios directories have been searched, the concatenated results files are zipped up into a packaged workbook. Open the scenario compare dashboard by double clicking the `tableau_report.twbx` file.

## QS9 Results

### Reports and Maps

The individual maps, reports, Tableau dashboard, and logs are still available in each of the QS9 scenario directories.

The main product is in the packaged Tableau Workbook (.twbx) which contains the concatenated results from the four individual scenarios. Open the `tableau_dashboard` workbook in the output directory:

```
c:\FTOT\scenarios\quick_start\qs9_suite\compare\tableau_dashboard.twbx
```

There are no additional reports, maps, or logs generated by the scenario compare tool.

The Scenario Compare Dashboard resembles the individual scenario dashboard with a few notable differences:

# Freight and Fuel Transportation Optimization Tool

Supply Chain  
Summary

By Commodity  
& Mode

By Supply &  
Demand

Runtimes

Parameters  
Table

## Legend

### Facility Type

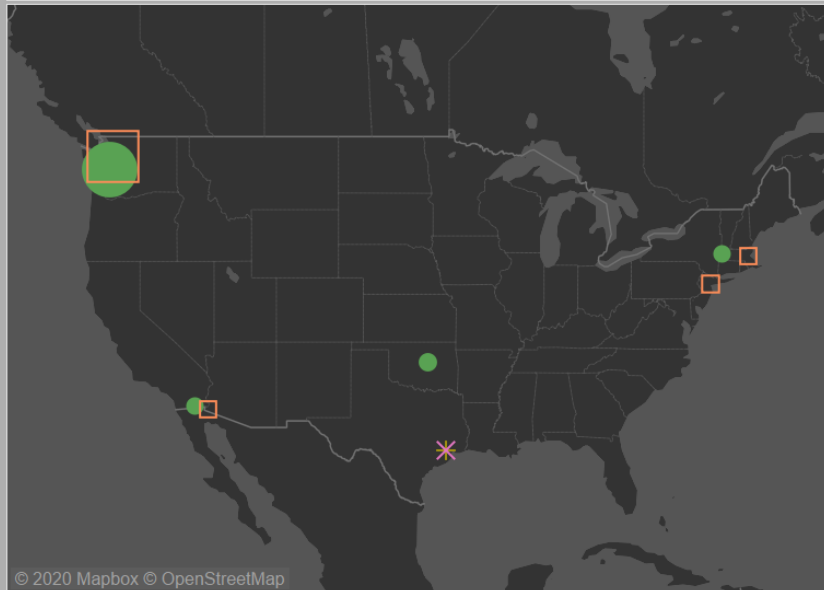
- Demand
- Processor (Input)
- Processor (Output)
- Supply

- Demand
- ✕ Processor (Input)
- + Processor (Output)
- Supply

### Optimal Quantity

- 90.7
- 200.0
- 400.0
- 600.0
- 800.0
- 907.2

## Size of Facilities



## Filters

### Scenario Name

- ☒ QS9 Exercise 1
- ☒ QS9 Exercise 2
- ☒ QS9 Exercise 3
- ☒ QS9 Exercise 4

### Facility Type

- ☒ Demand
- ☒ Processor (Input)
- ☒ Processor (Output)
- ☒ Supply

## Total Supply & Demand Quantity

Scenario Na..	Supply				Processor..	Processor..	Demand			
	blueberries	crude_oil	hay	plane_engines	crude_oil	pet_prods	blueberries	hay	pet_prods	plane_engines
	metric tons	kilogallon	metric tons	metric tons	kilogallon	kilogallon	metric tons	metric tons	kilogallon	metric tons
QS9 Exercise 1	91						91			
QS9 Exercise 2			91					91		
QS9 Exercise 3				907						907
QS9 Exercise 4		100			100	100			100	

Figure 34 The Scenario Comparison dashboard

## Filtering Results

The filters are located on the right hand side of the dashboard. The filters turn off the scenario results from the graphs, maps, and charts throughout. When Exercise 4 is disabled in the filter, the map and supply chain table update automatically.



# Freight and Fuel Transportation Optimization Tool

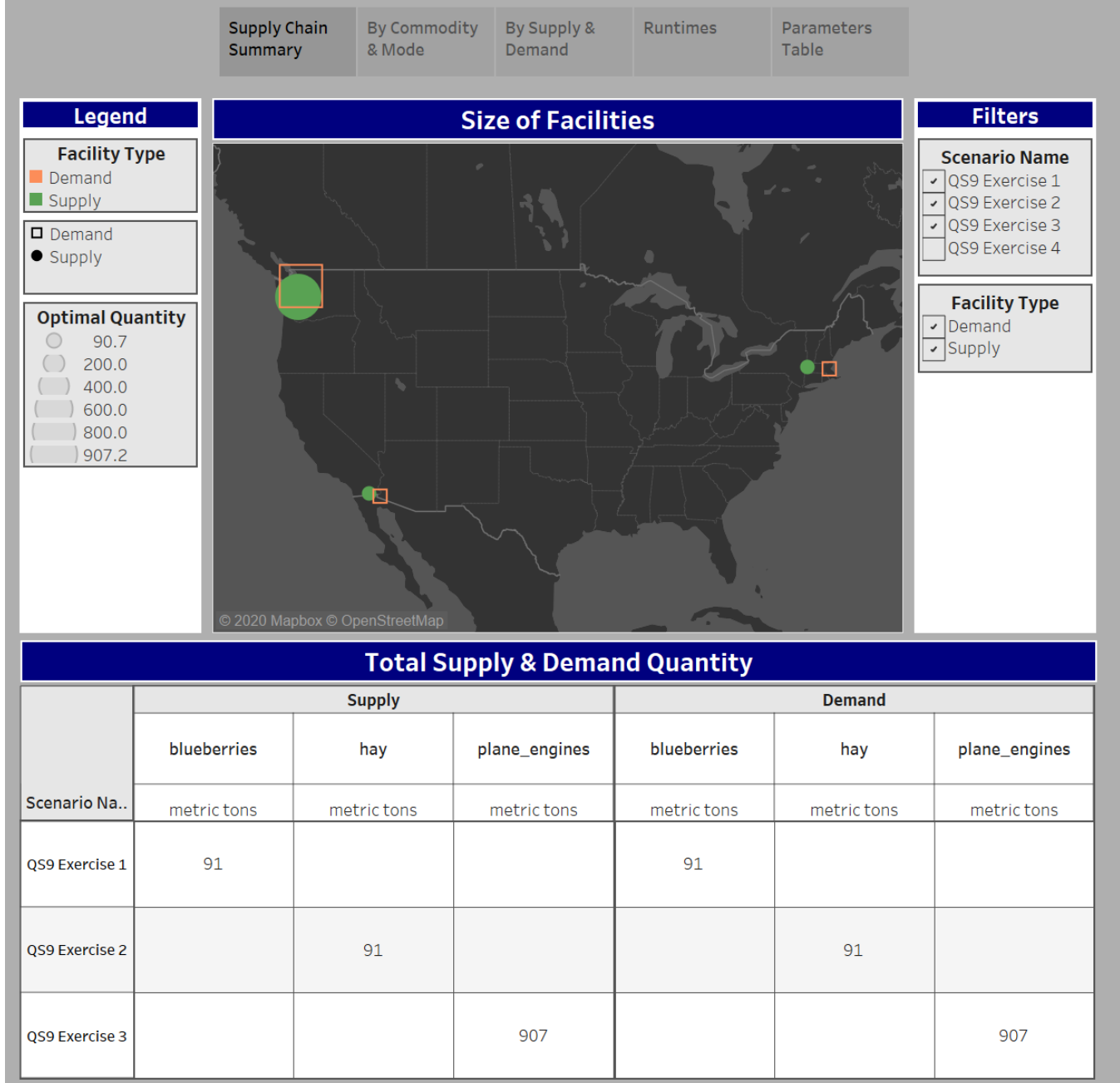


Figure 35 Scenario Comparison of QS9 Exercises 1, 2, and 3.

## Route Results

Returning to all four exercises again, the route results are displayed in the By Commodity and Mode dashboard. A high level scenario summary indicating the percent difference of scenario cost, material moved, VMT, fuel burn, and CO2 emissions are displayed relative to the first (“Baseline”) scenario. The results can be investigated

in more detail and visualized in a number of different ways. The left hand side legend provides three options for the route colors including mode, commodity, and scenario name. Additional graphs of the data can be used by selecting the different buttons below the maps. There is the high level summary by scenario, a commodity summary, and a commodity + mode summary. The legend coloring options on the left hand side, and the filters on the right hand side also change the result tables below.

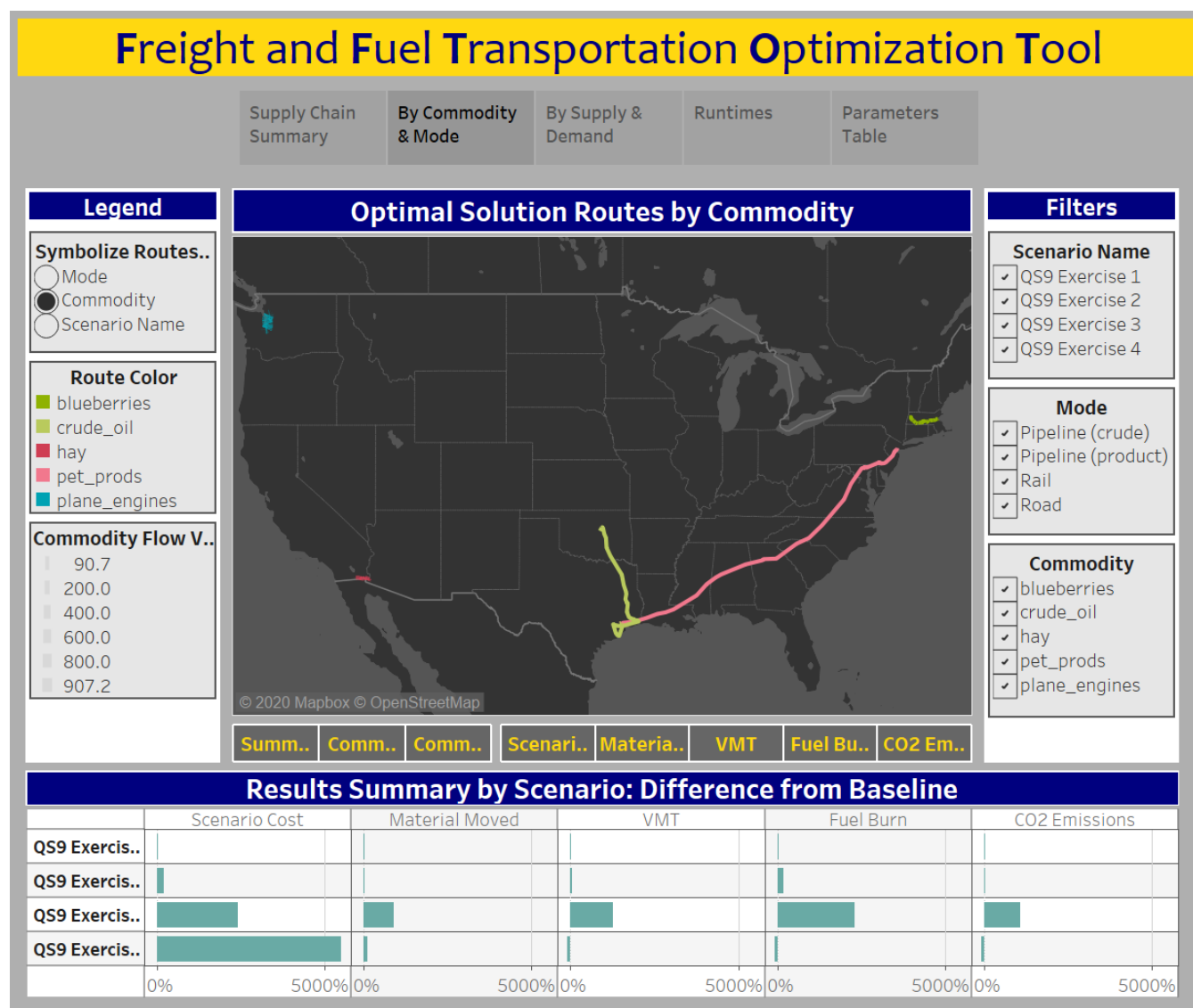


Figure 36 Scenario Results of QS9 Exercises 1, 2, 3, and 4.

## Acknowledgements

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