Freight and Fuel Transportation Optimization Tool Quick Start Scenarios Documentation

FTOT 2019.3 Public Release Version

DOT-VNTSC-FAA-19-07

DOT/FAA/AEE/2020-02

October 31, 2019

Prepared for:

Federal Aviation Administration
Office of Environment and
Energy Washington, DC

U.S. Department of Transportation
John A. Volpe National Transportation Systems Center

Volpe

Notice

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 31, 2019	Document, 9/2018-9/2019

4. TITLE AND SUBTITLE	5a. FUNDING NUMBERS
Freight and Fuel Transportation Optimization Tool Quick Start Documentation: FTOT 2019.3 Public Release Version	FB48CS/SG287 and SG291
6. AUTHOR(S) Matthew Pearlson, Alexander Oberg, Olivia Gillham, Amy Vogel, Kristin C. Lewis, Scott Smith, Gary Baker	5b. CONTRACT NUMBER 693KA9-18-N-00022
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Volpe National Transportation Systems Center, 55 Broadway, Cambridge, MA 02142	8. PERFORMING ORGANIZATION REPORT NUMBER DOT-VNTSC-FAA-19-07
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Federal Aviation Administration, 800 Independence Ave, SW, Washington, DC 20591	10. SPONSORING/MONITORING AGENCY REPORT NUMBER DOT/FAA/AEE/2020-02
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Volpe created the Freight and Fuel Transportation Optimization Tool (FTOT) to support the FAA, DOE, and the U.S. Navy's Office of Naval Research to assess optimal transport options for freight and fuel supply chains. FTOT is a flexible scenario-testing tool that optimizes the transportation of materials for future energy and freight scenarios. FTOT models and tracks commodity-specific information and can take into account conversion of raw materials to products (e.g., crude oil to jet fuel/diesel) and fulfillment of downstream demand. This report documents the Quick Start Scenarios developed to help the user explore the functionality of the FTOT public release 2019.3.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Freight, fuel, geospatial information systems, GIS, network analysis, transportation optimization.	49
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

298-102

Quick Start Documentation

Overview

Assuming you've got FTOT installed (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:

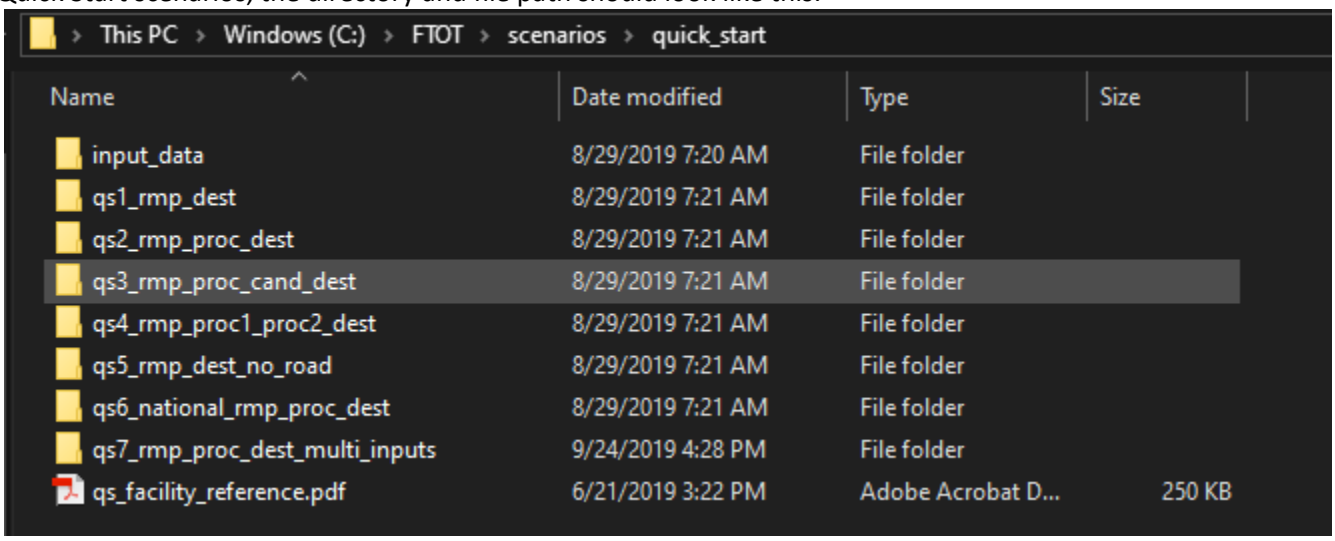

Figure 1: FTOT Quick Start Folder Structure

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 seven 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

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.

*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, which can be found in the documentation folder you downloaded from box.com (FTOT_Documentation_2019_3.pdf).

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.

Trouble Shooting

See the troubleshooting guide at the end of FTOT_Documentation_2019_3.pdf for tips on how to resolve common issues like runtime dependency errors (missing software), missing input data, and missing base maps.

Contents

Table of Figures and Tables

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_inputs

Table 2: Quick Start 1-7 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 in FTOT) 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. 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 in the attribute are shown below.

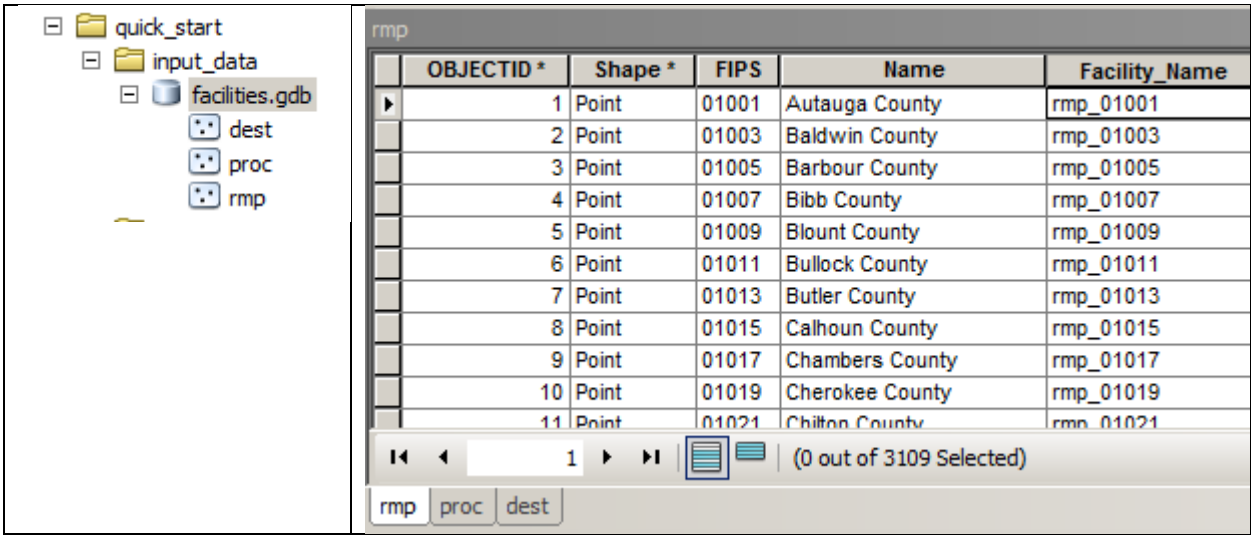

Figure 2: Example Geodatabase (GDB). The structure of the GDB (left) and an example of the records in the rmp attribute table (right) are shown.

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 is 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 ton or per thousand gallon-mile dollar cost of traversing each mode. The weights act as multipliers on the dollar cost (and 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.).

```
<Scenario xmlns="FTOTv5.0.0">
 <Scenario_Schema_Version>5.0.0</Scenario_Schema_Version>
 <Scenario_Name>Quick Start: RMP to Destination</Scenario_Name>
 <Scenario_Description>This scenario demonstrates simple movements from a RMP to a
  destination.</Scenario_Description>
 <Scenario_Inputs>
                                          . . .
  <Base_Network_Gdb>C:\FTOT\scenarios\common_data\networks\Public_Intermodal_Network_20
   19_1.gdb</Base_Network_Gdb>
                                          . . .
  <Base_RMP_Layer>C:\FTOT\scenarios\quick_start\input_data\facilities.gdb\rmp</Base_RMP
   _Layer>
  <Base_Destination_Layer>C:\FTOT\scenarios\quick_start\input_data\facilities.gdb\dest<
   /Base_Destination_Layer>
                                          . . .
  <RMP_Commodity_Data>C:\FTOT\scenarios\quick_start\qs1_rmp_dest\Default\input_data\rmp
   .csv</RMP_Commodity_Data>
  <Destinations_Commodity_Data>C:\FTOT\scenarios\quick_start\qs1_rmp_dest\Default\input
   _data\dest.csv</Destinations_Commodity_Data>
  <Processors_Commodity_Data>None</Processors_Commodity_Data>
  <Processors_Candidate_Commodity_Data>None</Processors_Candidate_Commodity_Data>
                                          . . .
  <Default_Units_Solid_Phase>tonnes</Default_Units_Solid_Phase>
  <Default_Units_Liquid_Phase>kgal</Default_Units_Liquid_Phase>
 </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 the 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 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.

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 three 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, 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. At the top of the dashboard are the scenario name and a summary table of key input parameters used in the analysis. A map of the optimal routes used to flow supply to demand is displayed by mode in the center pane. In QS1 only road is utilized in the scenario (displayed in red). On the right hand side, the size and utilizations of facilities is displayed. There is a small toggle box allowing the user to switch between demand (default view) and supply facilities. No processors are present in QS1 and therefore none are enumerated in the dashboard drop down.

Below the key input parameter summary and maps, the dashboard summarizes some key results. One such result is the quantity of optimal versus total supply and demand. In QS1 all of the supply was used to meet all of the demand. Below that, the number of optimal facilities is compared to the total number of facilities for supply and demand. Finally, the material moved, scenario cost, VMT, and CO2 Emissions are all displayed by commodity and mode. In the case of QS1, only road and blueberries were utilized. For more complex scenarios, see the Tableau dashboards in the subsequent QS scenarios.

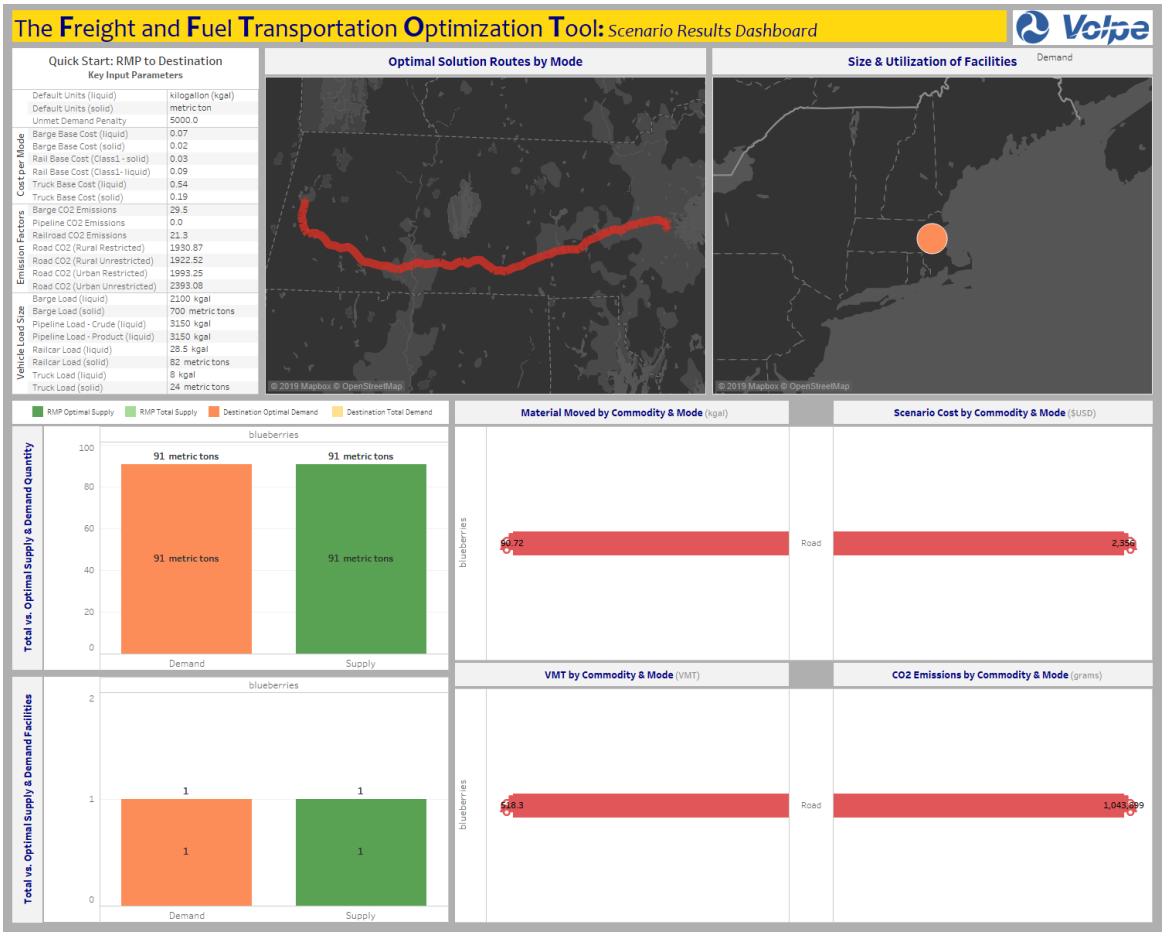

Figure 5: QS1 Tableau Dashboard

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.**

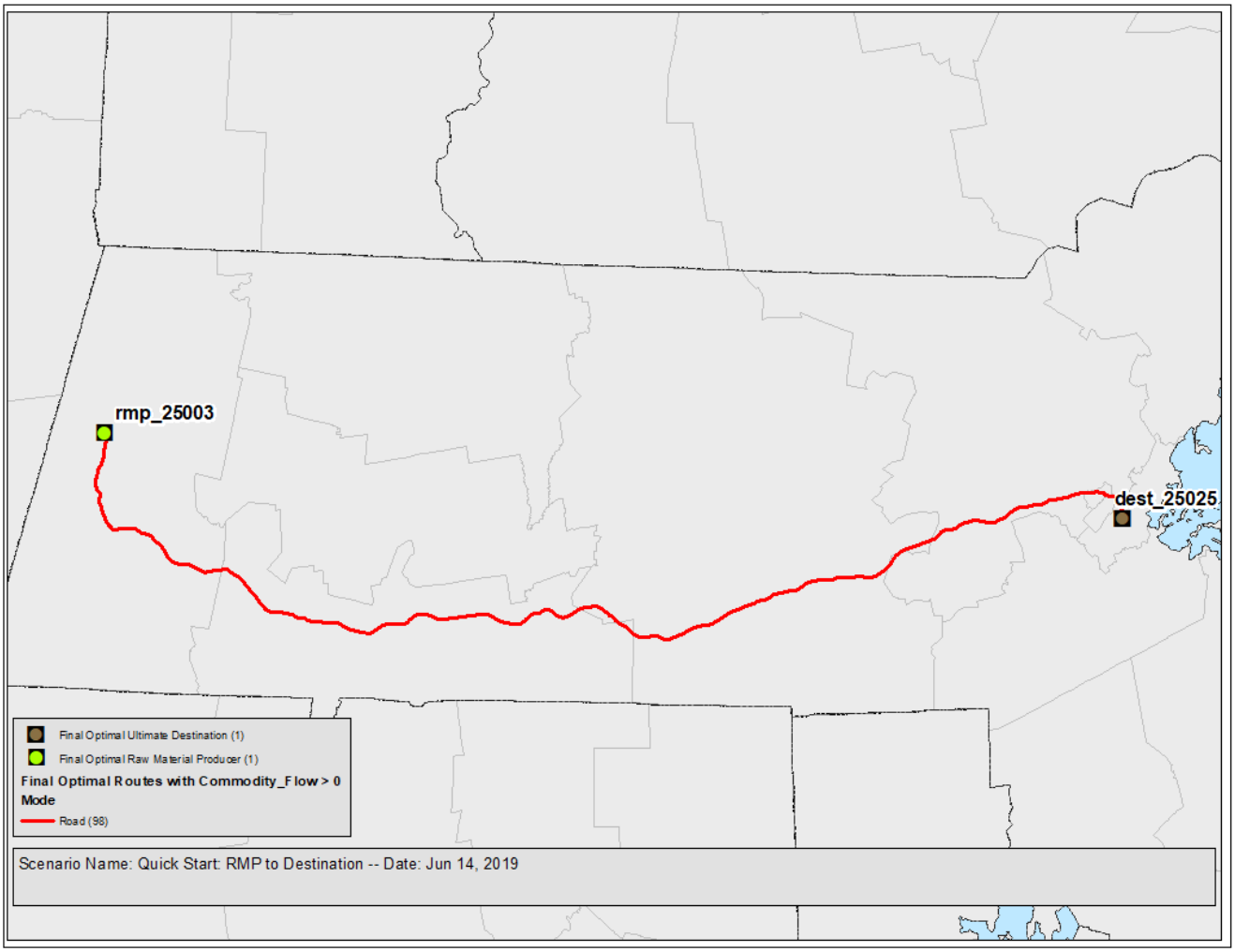

Figure 6: QS1 Optimal Solution

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 rmp.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 rmp and destinations. FTOT supports multiple commodities from each facility. The user can add additional records to the rmp.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 rmp.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

E

Figure 7: 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 maximum processing capacity, and the conversion ratio of the facility. 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 for simplicity. However, the user is free to specify more realistic product slates.

	A	B	C	D	E	F	G
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io
2	proc_25015	processor	blueberries	100	tons	solid	i
3	proc_25015	processor	jam	100	tons	solid	o

Figure 8: 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 9: 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.

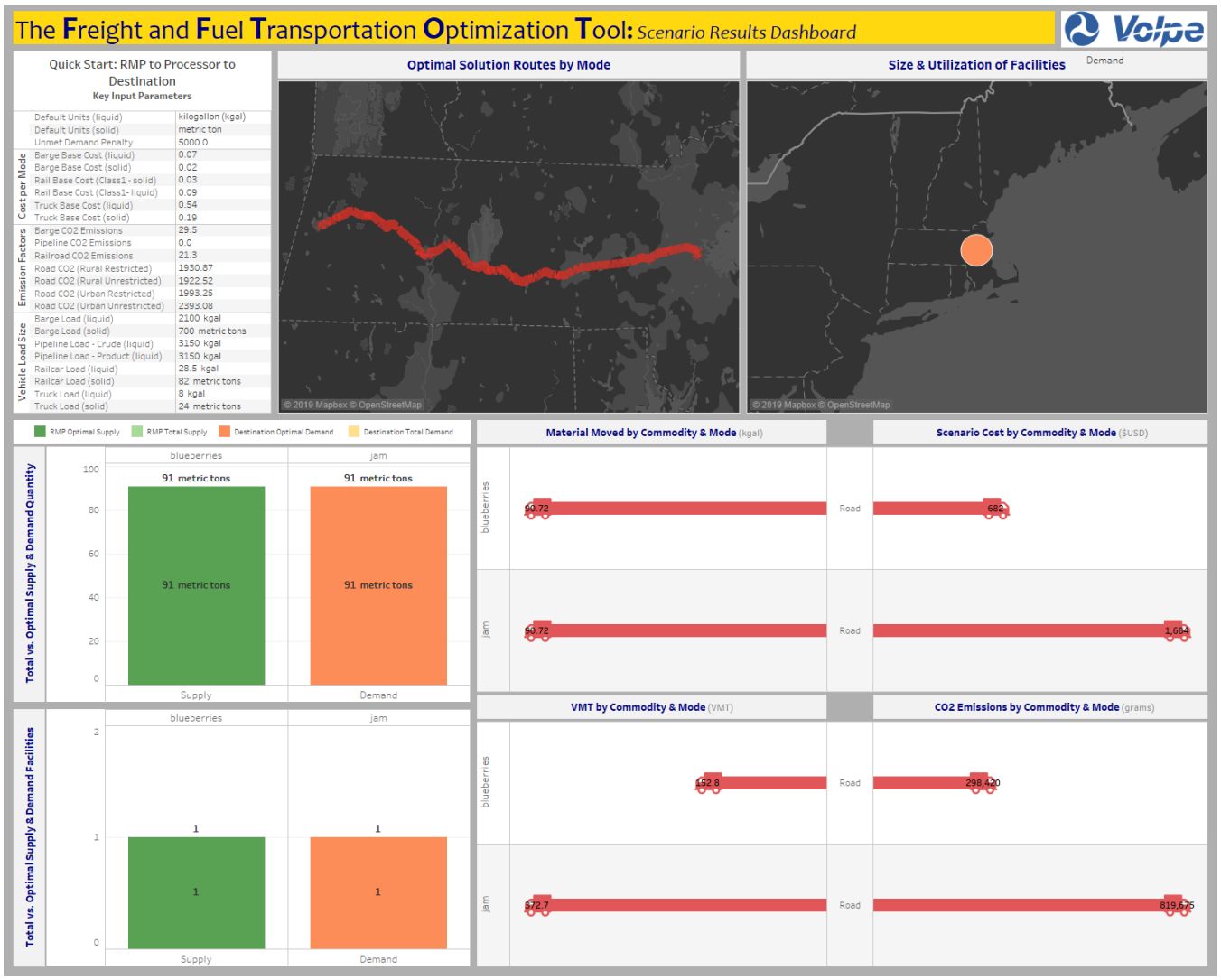

Figure 10: QS2 Tableau Dashboard

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.**

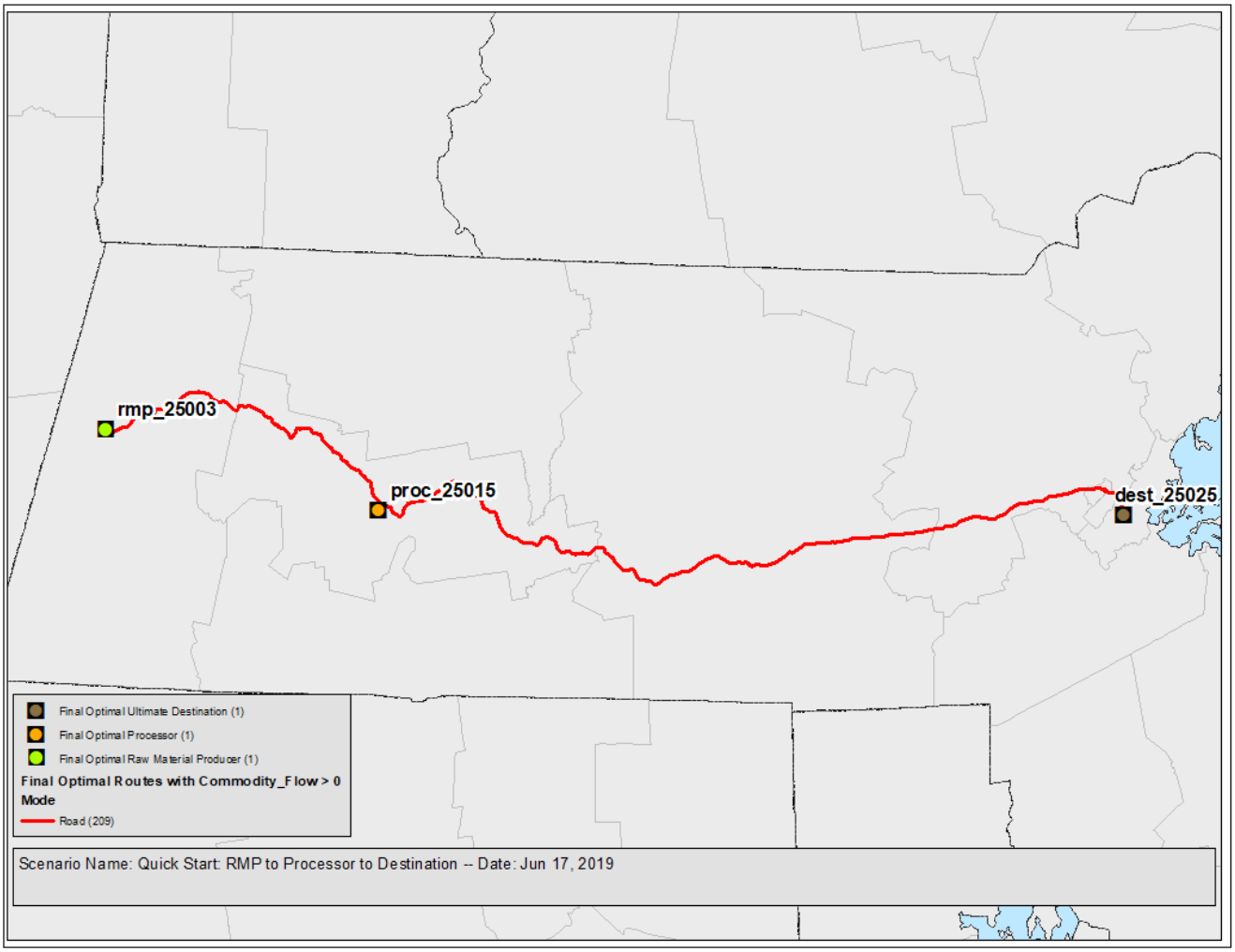

Figure 11: QS2 Optimal Solution

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. 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 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.)

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 contains will be used to specify the three feature classes; RMPs 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 was 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 transportation 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_2019_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 12: 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 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 50 tons, FTOT will generate a candidate anywhere on the network where the aggregated flow of feedstock is at least 50 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_jammery	processor	blueberries	100	ton	solid	i
3	candidate_jammery	processor	jam	100	ton	solid	o
4	candidate_jammery	processor	minsize	50	ton	solid	
5	candidate_jammery	processor	maxsize	100	ton	solid	
6	candidate_jammery	processor	min_aggregation	10	ton	solid	
7	candidate_jammery	processor	cost_formula	1	USD/ton		

Figure 13: 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 14: 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 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

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):     $2,565
...
P_ :  COMMODITY_SUMMARY_DOLLAR_COST_BLUEBERRIES__TOTAL:   1,851.50 :     USD
...
P_ :  FACILITY_SUMMARY_CANDIDATE_JAMMERY_15831_PROCESSOR_INPUT_BLUEBERRIES_ROAD:    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.

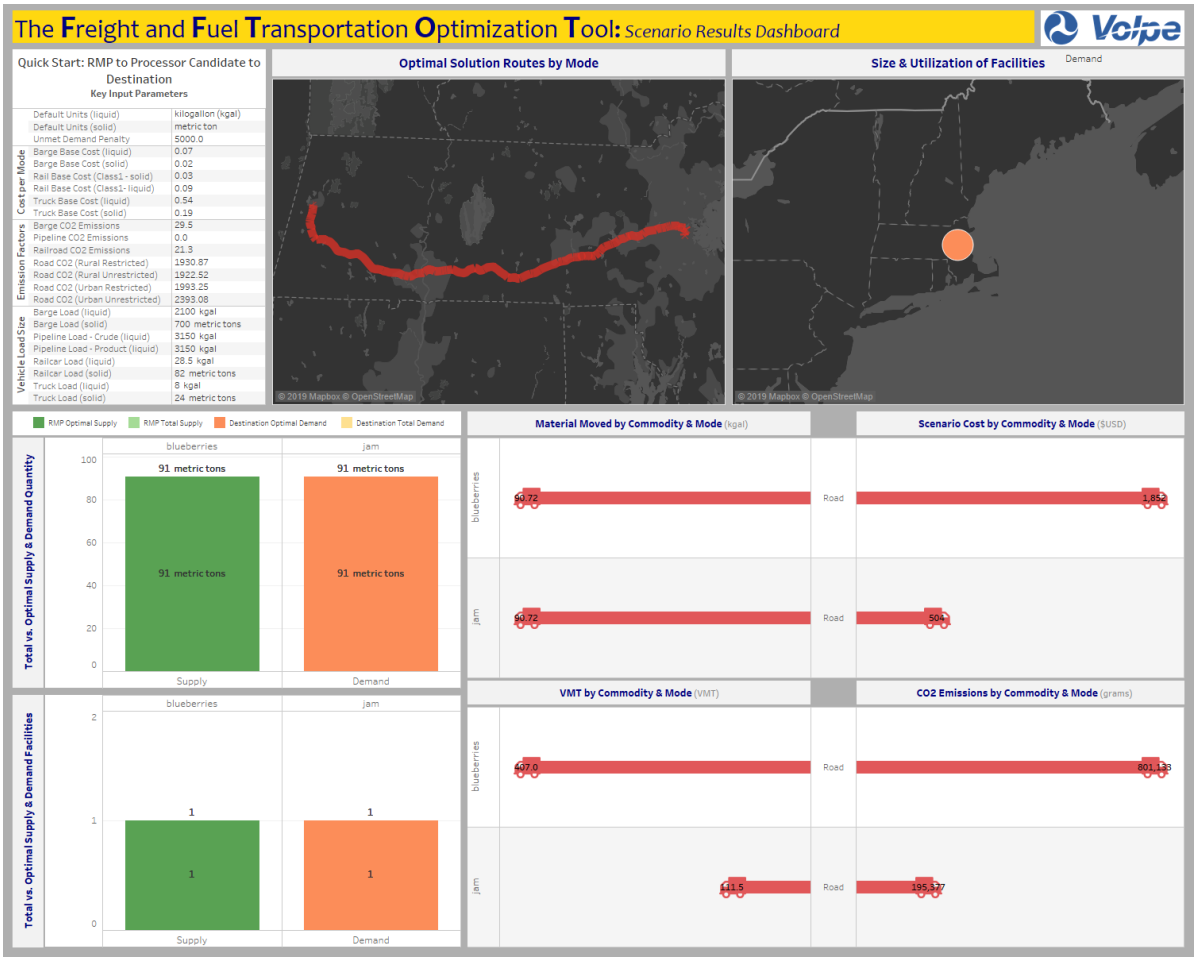

Figure 15: QS3 Tableau Dashboard

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.

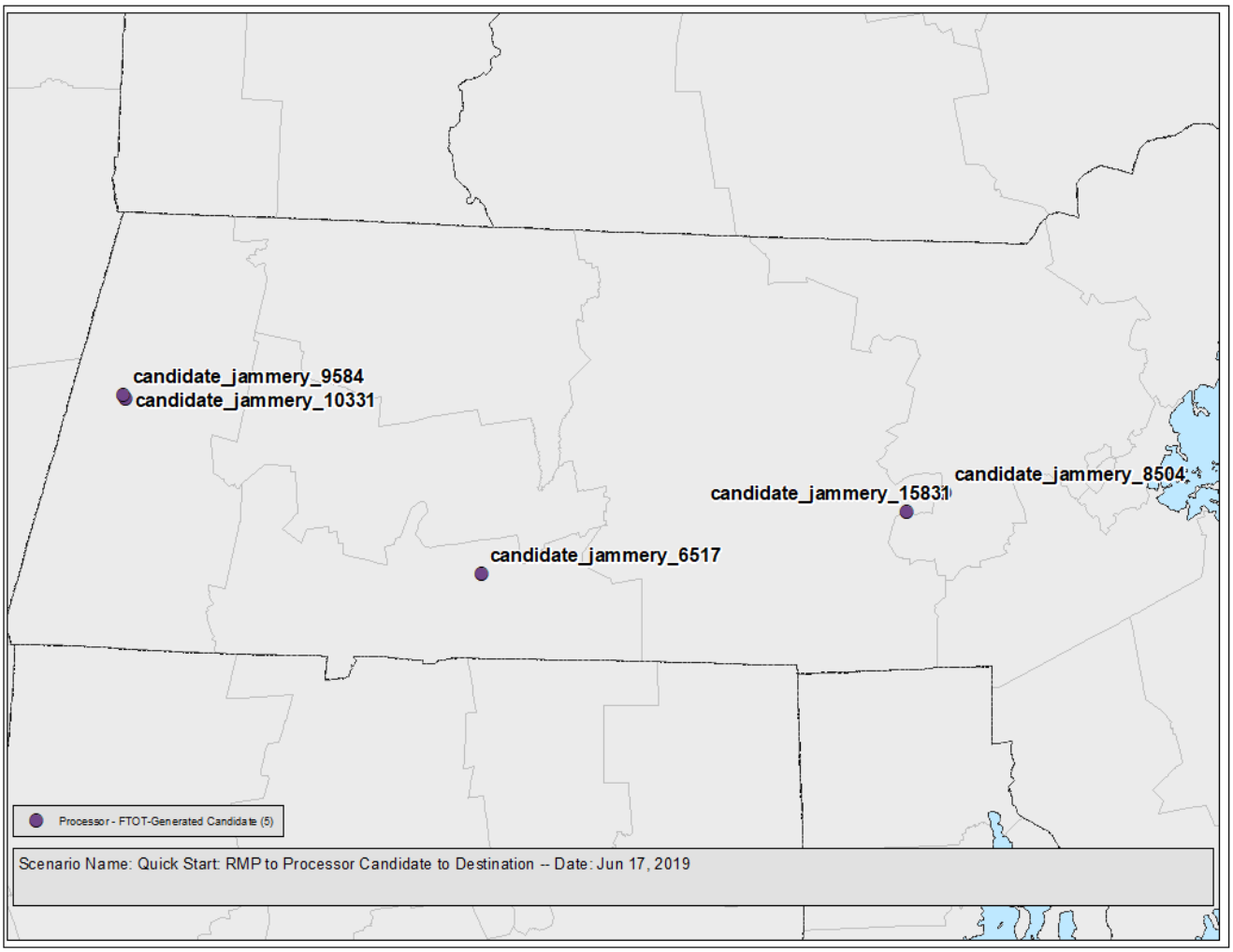

Figure 16: QS3 Candidate Processor Locations Map

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.**

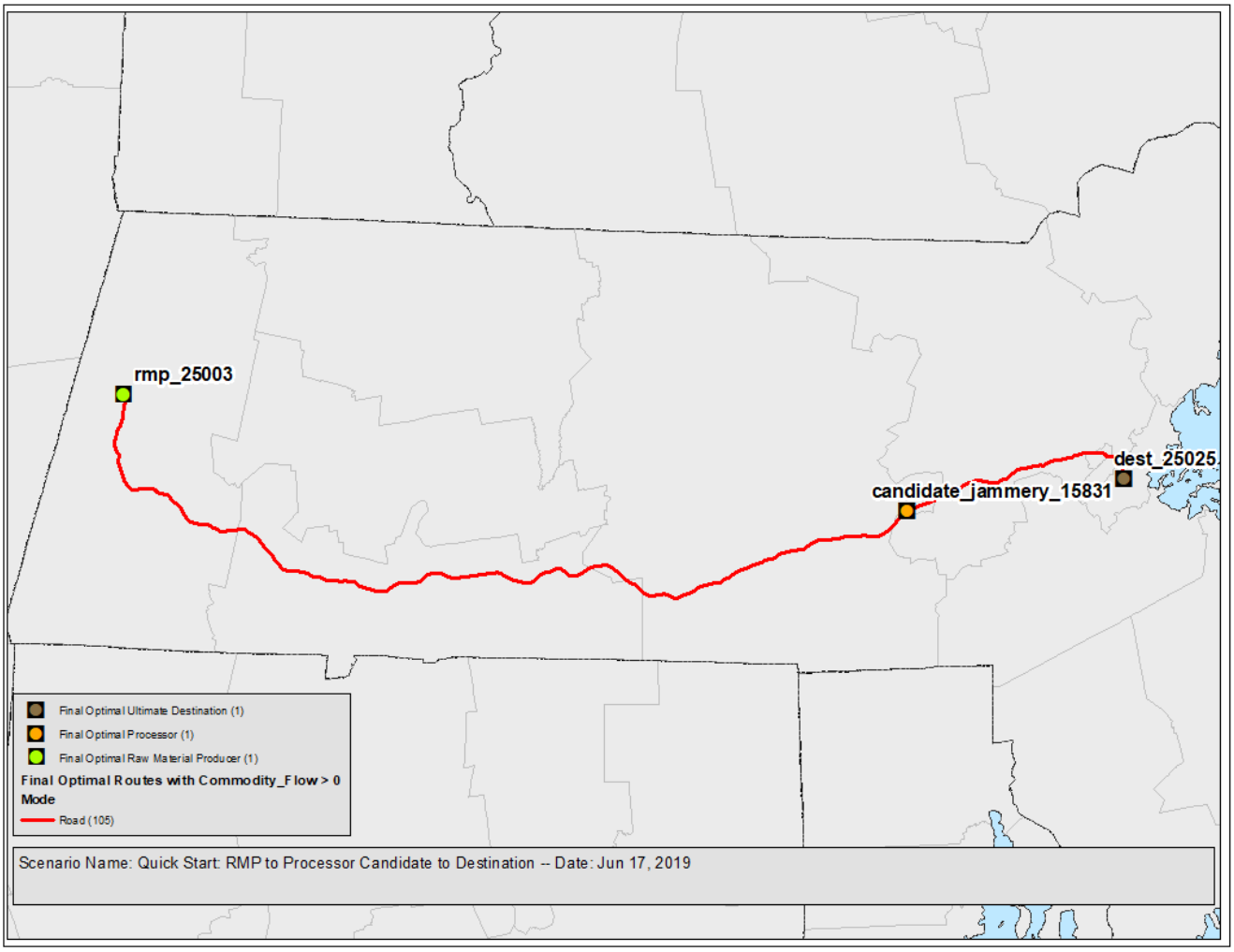

Figure 17: QS3 Optimal Solution Map

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_jammery_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_bluberries 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 18: 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. The second processor takes stored_blueberries as an input and sends out jam. The second processor in this case serves as a jam production factory. 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
1	facility_name	facility_type	commodity	value	units	phase_of_matter	io
2	proc_25015	processor	blueberries	100	tons	solid	i
3	proc_25015	processor	stored_blueberries	100	tons	solid	o
4	proc_25027	processor	stored_blueberries	100	tons	solid	i
5	proc_25027	processor	jam	100	tons	solid	o

Figure 19: 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 20: 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_bluberries. 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>
```

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
...
P_ :  FACILITY_SUMMARY_PROC_25015_PROCESSOR_INPUT_BLUEBERRIES__TOTAL:    1.00 :    fraction
...
P_ :  FACILITY_SUMMARY_PROC_25015_PROCESSOR_OUTPUT_STORED_BLUEBERRIES__TOTAL:     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.

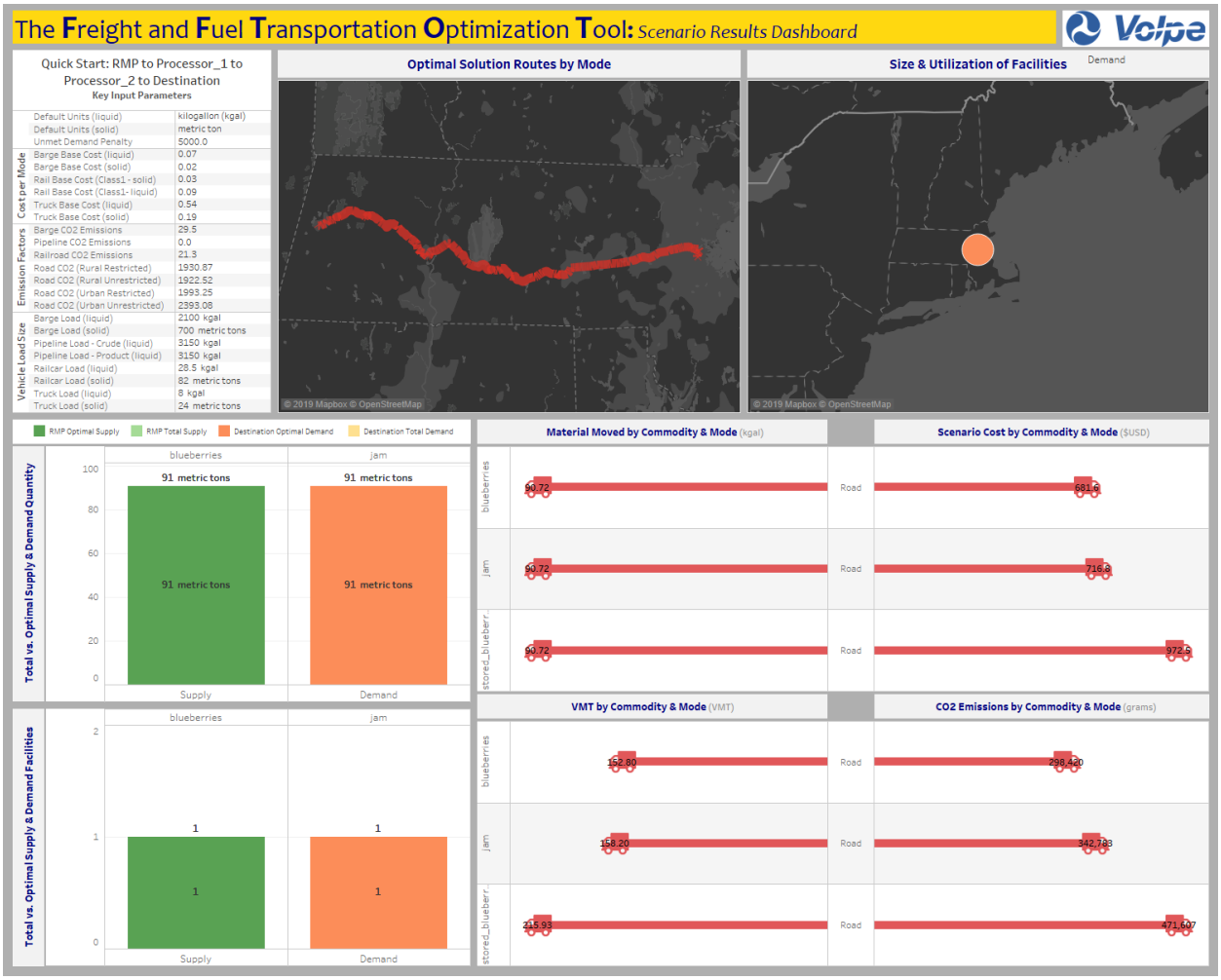

Figure 21: QS4 Tableau Dashboard

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.**

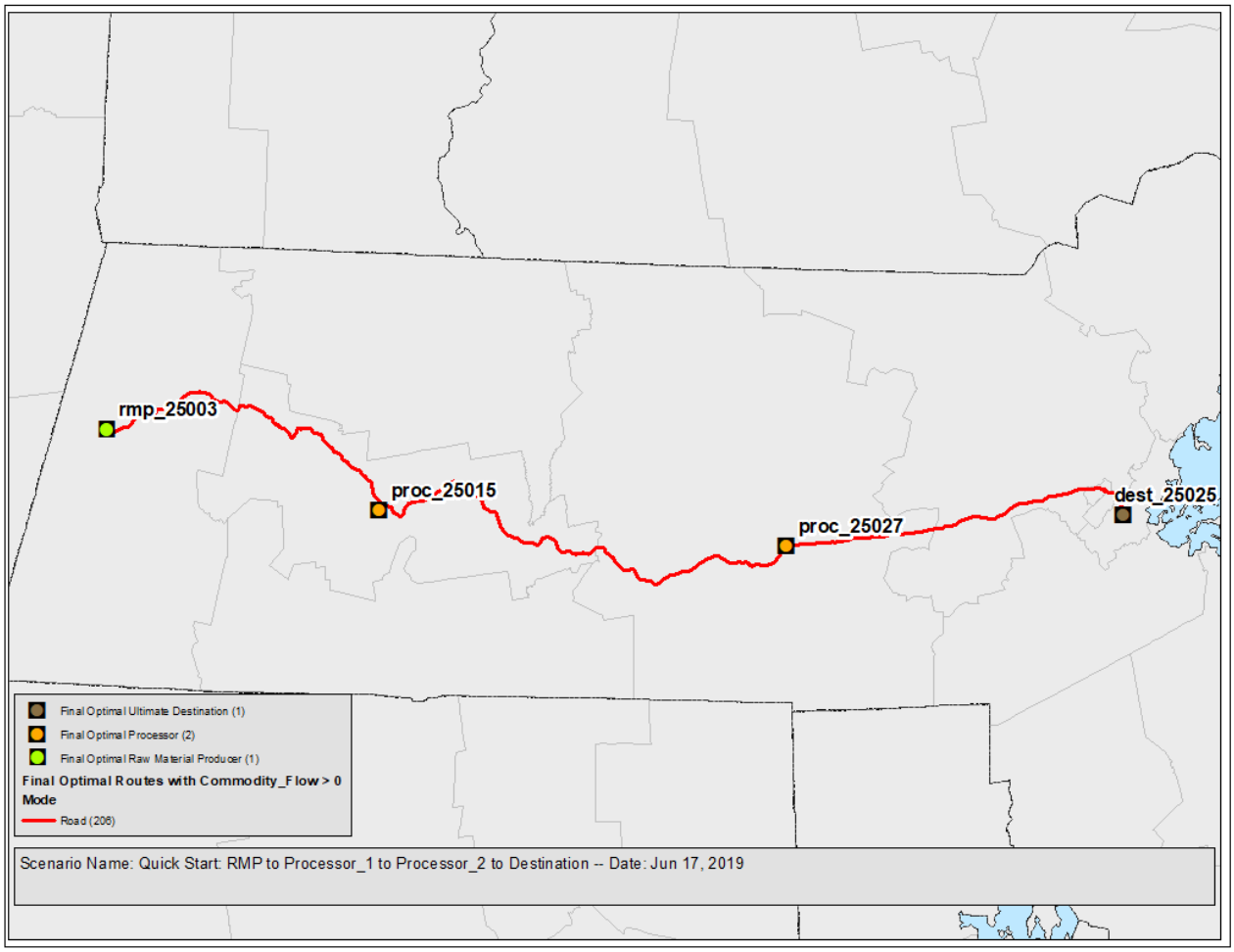

Figure 22: QS4 Optimal Solution Map

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
         should be allowed for routing any flows in the scenario-->
124    <!--The default is for all modes to be on-->
125    <Road>False</Road>
126    <Rail>True</Rail>
127    <Water>True</Water>
128    <Pipeline_Crude>True</Pipeline_Crude>
129    <Pipeline_Prod>True</Pipeline_Prod>
130   </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.

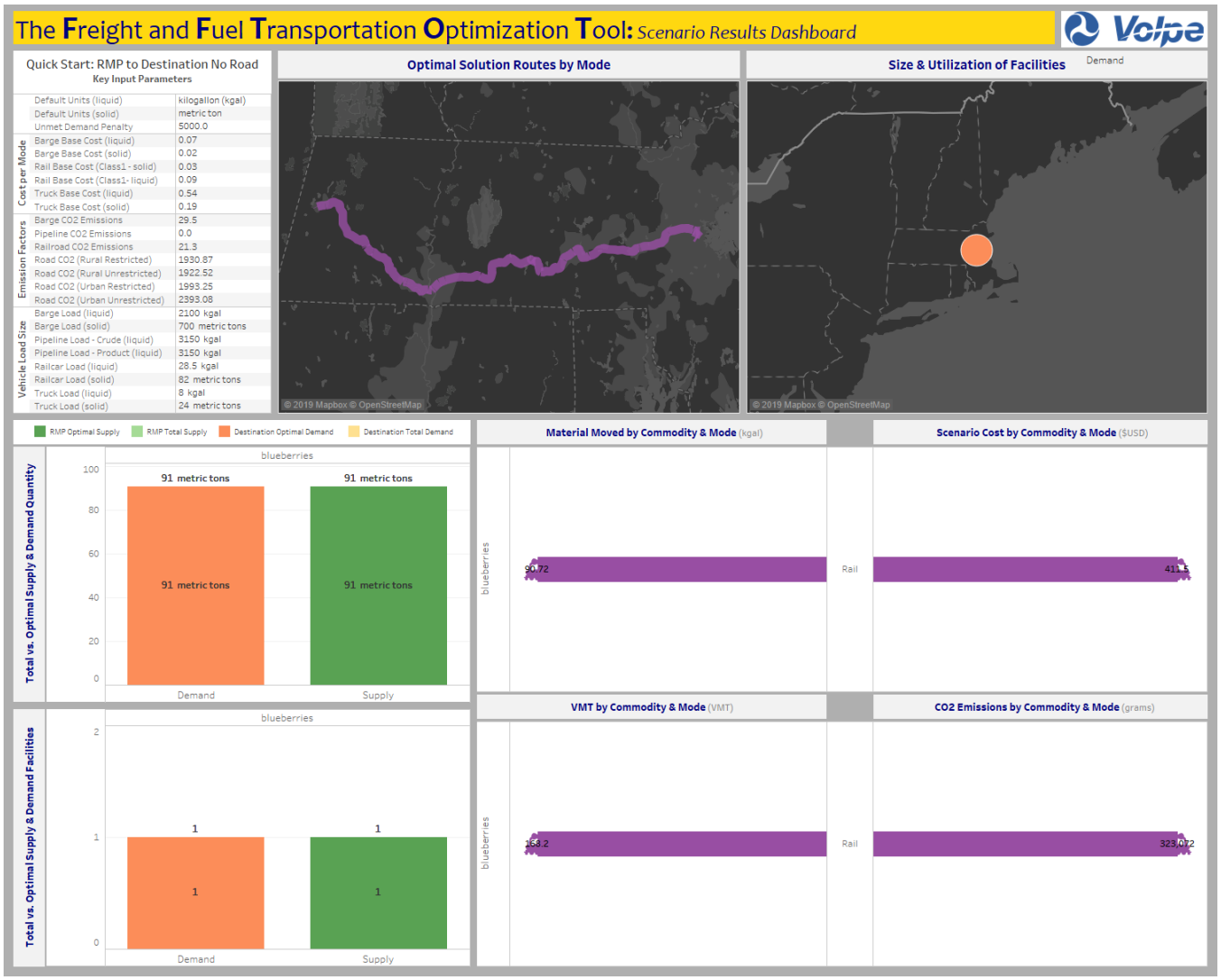

Figure 23: QS5 Tableau Dashboard

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.**

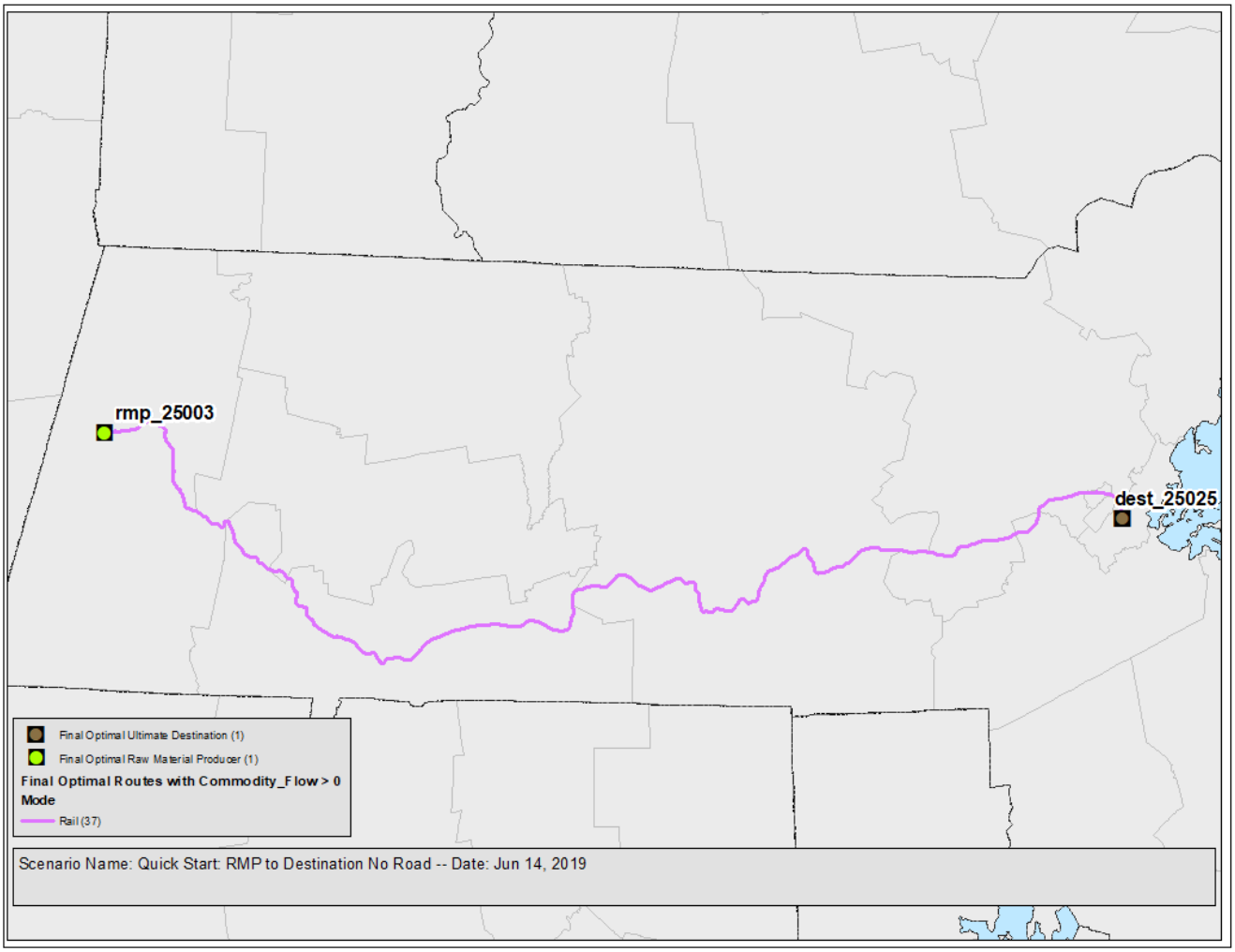

Figure 24: QS5 Optimal Solution Map

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.

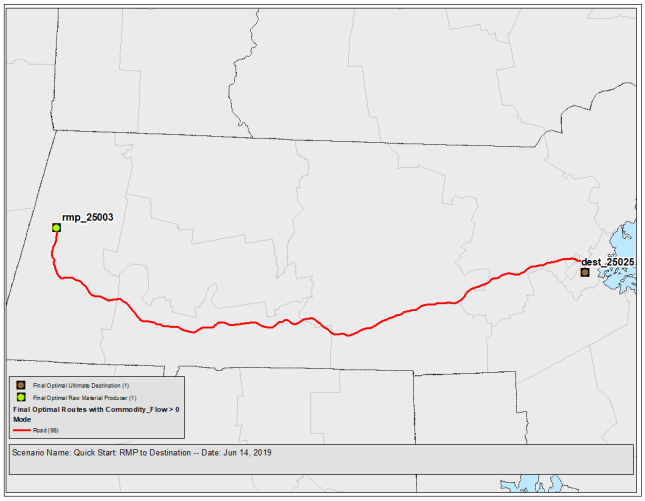

Figure 25: Optimal Solution with Road Network

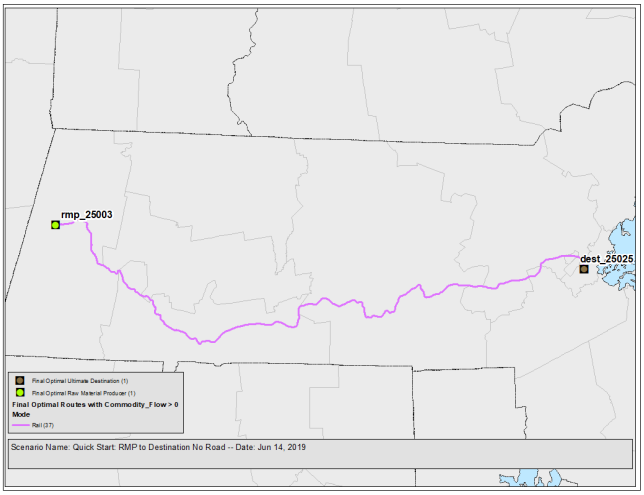

Figure 26: Optimal Solution with Rail Network

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 processors have a combined processing 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
         should be allowed for routing any flows in the scenario-->
124    <!--The default is for all modes to be on-->
125    <Road>False</Road>
126    <Rail>True</Rail>
127    <Water>True</Water>
128    <Pipeline_Crude>True</Pipeline_Crude>
129    <Pipeline_Prod>True</Pipeline_Prod>
130   </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):  $63,531,725,953
...
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:   295,938,730.21 :      USD
...
P_ :  COMMODITY_SUMMARY_MILES_A_SUPPLY_RAIL:           21,481.35 :           miles
...
P_ :  COMMODITY_SUMMARY_MILES_A_SUPPLY_WATER:          2,460.15 :            miles
...
P_ :  COMMODITY_SUMMARY_MILES_B_PROCESSED__TOTAL:      6,369.54 :            miles
...
P_ :  COMMODITY_SUMMARY_VMT_B_PROCESSED__TOTAL:        120,627,444.28 :      VMT
...
P_ :  FACILITY_SUMMARY_PROC_18007_PROCESSOR_INPUT_A_SUPPLY__TOTAL:          0.97 :     fraction
...
P_ :  FACILITY_SUMMARY_PROC_21195_PROCESSOR_INPUT_A_SUPPLY__TOTAL:          0.50 :     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.

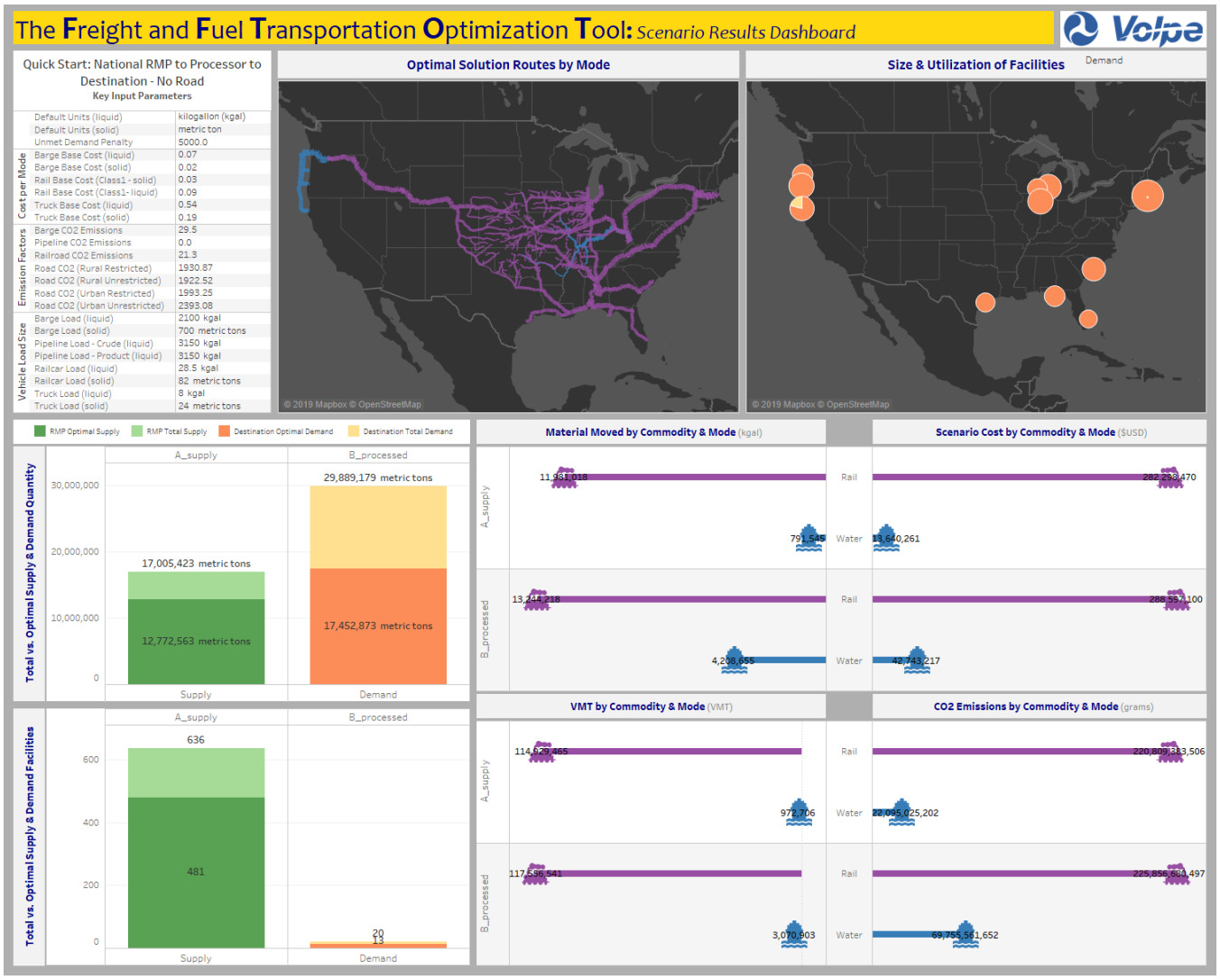

Figure 27: QS6 Tableau Dashboard

Maps

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

In the map called 02d_F_Step.png, the processors, destinations, and all possible 636 RMs are displayed.

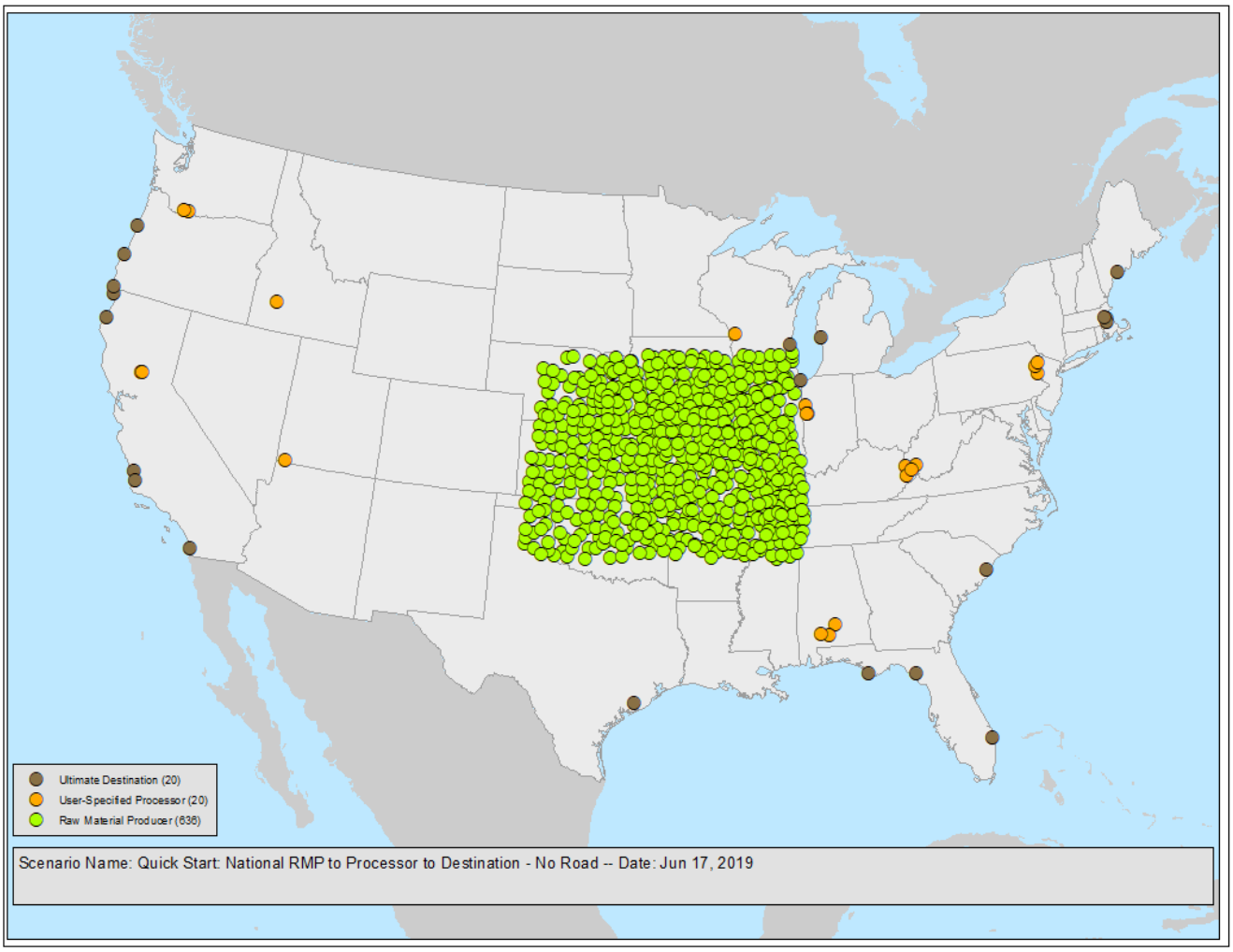

Figure 28: QS6 facility locations maps

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.png.**

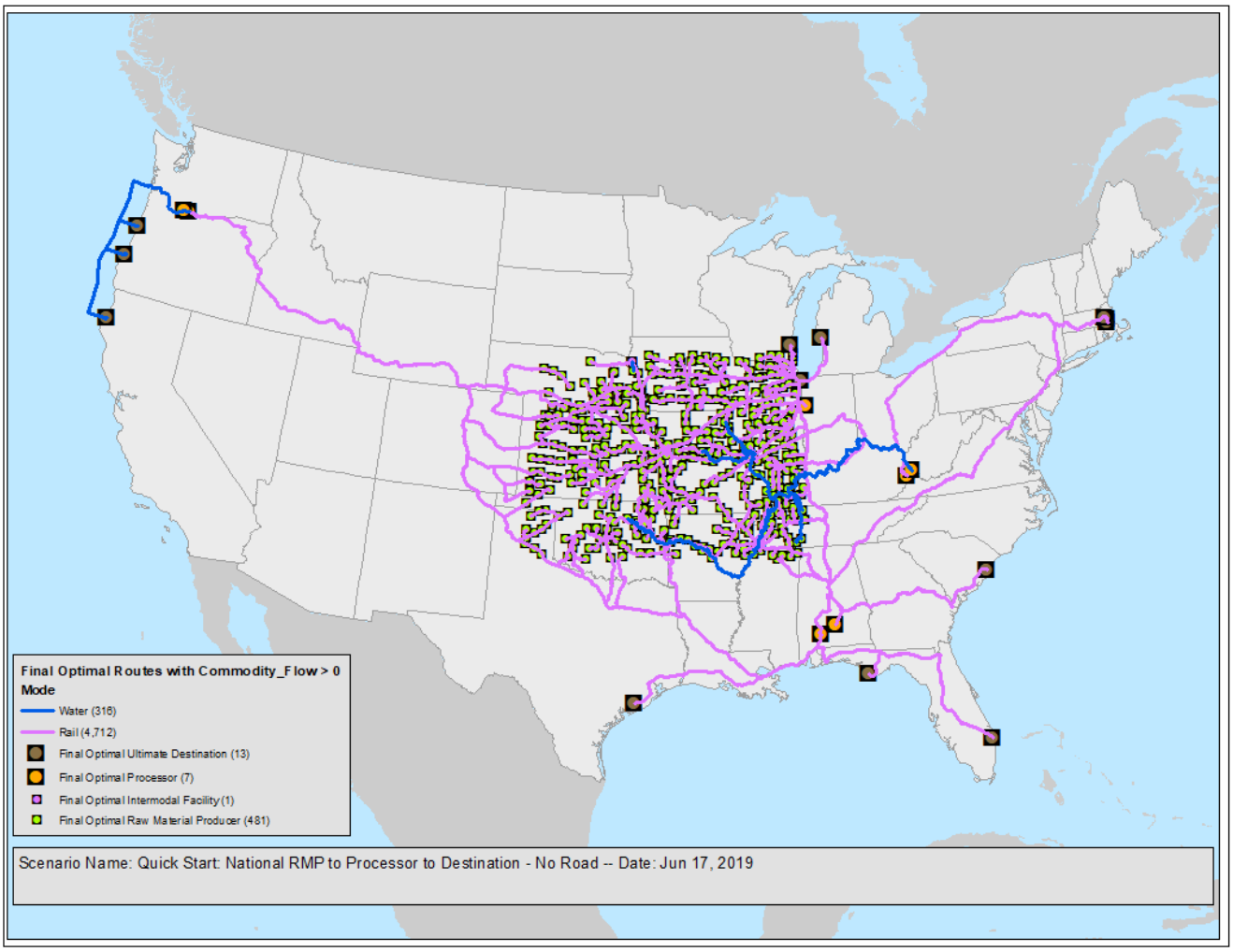

Figure 29: QS6 Optimal Solution Map

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 481 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 (line 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?

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 addition 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 is 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 at 100 tons each. Jam is specified as the only output, and created at a ratio of 100 tons output per (100 tons of sugar + 100 tons of blueberries). 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 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.

```
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 scenarnio.

Figure 30: QS7 Tableau Dashboard

Maps

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

In the map called 02d_F_Step.png, the processors, destinations, and all RMPs are displayed.

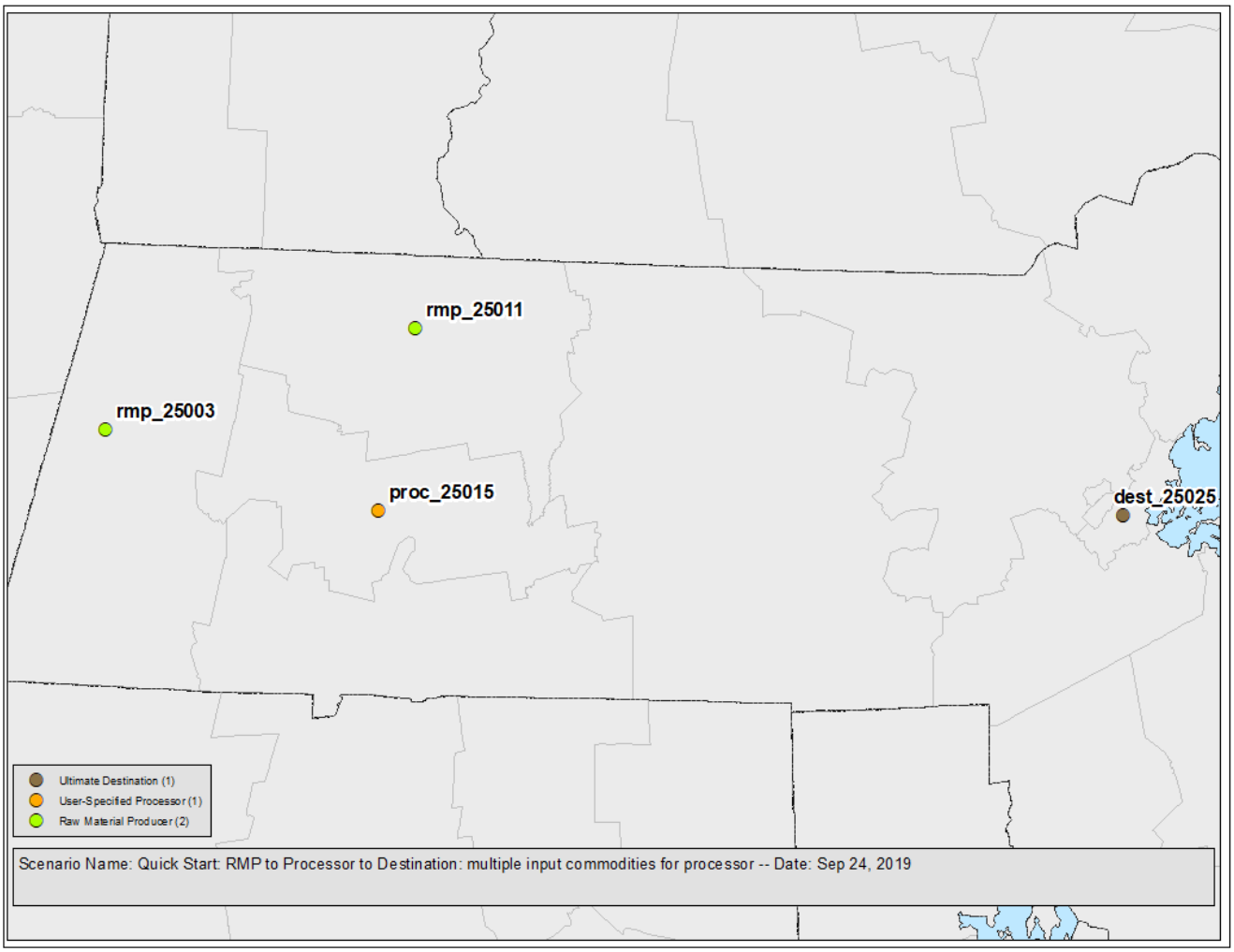

Figure 31: QS7 Facility locations map

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.**

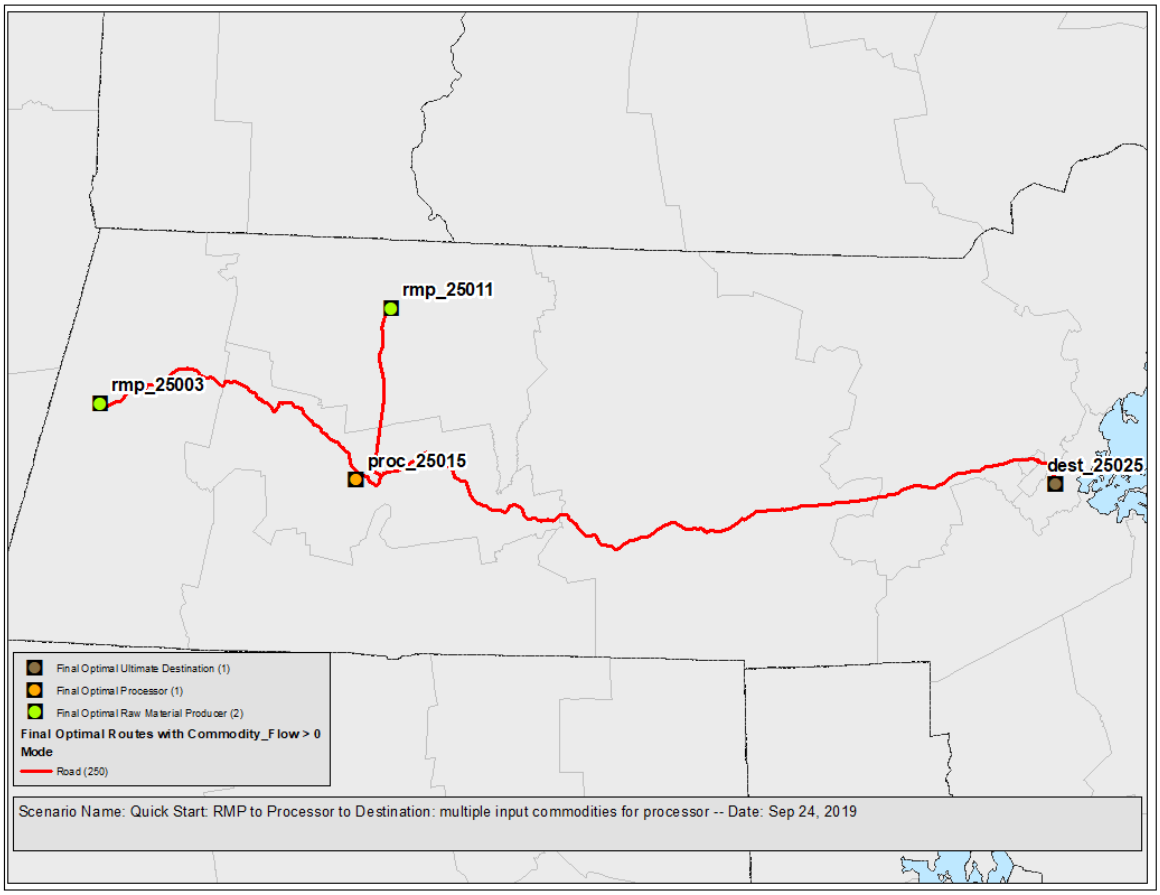

Figure 32: QS7 Optimal Solution Map

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?

Acknowledgements

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through FAA contract 693KA9-18-N-00022 under the supervision of Nathan Brown. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA.