@@ 1 INTRODUCTION

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 and diesel) and the fulfillment of downstream demand. FTOT was developed at the US Department of Transportation's Volpe National Transportation Systems Center in support of the Federal Aviation Administration, the Department of Energy, and the Office of Naval Research.

This user guide document provides comprehensive details for how users can interact with FTOT to run their own scenarios. Section 2 explains how to install FTOT. Section 3 details how to customize FTOT inputs to run a basic scenario. Section 4 explains the configurations needed to run more advanced FTOT scenarios (e.g., customizing the GIS network, incorporating schedules). Section 5 guides the user through manually running an FTOT scenario. Section 6 describes the FTOT outputs and explains the interpretation of each output. Section 7 details the various FTOT supplementary tools that supplement the core tool. Section 8 provides a troubleshooting guide. Appendix A contains legacy installation instructions for older versions of ArcGIS. Appendix B provides full documentation of the scenario XML input file.

New FTOT functionalities and user materials are added every quarterly release. Specific details on updates associated with the latest release (and previous releases) can be found in the change log on the GitHub code hosting site at https://github.com/VolpeUSDOT/FTOT-Public/releases.

@@ 3 SETTING UP A STANDARD SCENARIO

This section describes how to edit FTOT configuration files and inputs the user will need to create their own scenarios. Section 4 details how to configure FTOT inputs for more complex FTOT functionalities, which the user can reference as needed for their own scenario.

FTOT's Quick Start and Reference Scenarios datasets include several ready-to-use example scenarios and input files. See https://volpeusdot.github.io/FTOT-Public/data_download.html for the latest scenario and documentation files. In addition to demonstrating FTOT functionalities, the Quick Start and Reference Scenarios can also serve as templates for creating user-specified scenario configuration and input files.

Getting Started

FTOT's Quick Start and Reference Scenarios are stored in the C:\FTOT\scenarios\quick_start and C:\FTOT\scenarios\reference_scenarios folders, respectively, once downloaded. Each scenario includes its own dedicated subfolder for storing the scenario configuration, inputs, and outputs. Each unique FTOT scenario requires a batch (.bat) file, a scenario XML file, and an 'input_data' directory with the relevant facility-commodity input CSV files.

A batch file is a file used to run FTOT in a command-line interface (see Section 5 for more information on this file and how it works). A scenario XML configuration file defines key input parameters applied to the network and optimization. FTOT scenarios also require geospatial information for the network itself (associated network attributes such as costs, impedances and weightings, capacity, movement restrictions, and schedules are specified in the scenario XML). The FTOT network inputs must also include the facilities (origins, processors/waypoints, destinations) associated with the supply chain being analyzed, as well as their associated attributes such as facility minimum and maximum size, available supply/demand of input and output commodities, and associated efficiency/conversion to products. This facility-level supply chain data is defined in a set of comma-delimited files.

To ensure you have all necessary files to run a new FTOT scenario, the user can

1. Copy over a Quick Start or Reference Scenario folder based on the intended supply chain structure of the user's FTOT scenario, and then
2. Customize the starter files according to the user's specific scenario needs.

For example, use files from Quick Start 2 for a scenario where freight flows from a raw material producer (rmp) to a processor (proc) to a destination (dest); use Reference Scenario 2 as a template for a candidate processor generation scenario. To then adapt the starter scenario, the user will need to update the scenario XML (Section 3.1) at a minimum. Most custom scenarios will also require creating new facility-level GIS data (Section 3.2) and supply chain data (Section 3.3). Finally, customization of the scenario's batch file will also be necessary (discussed in detail in Section 5).

@@ 4 ADVANCED SCENARIO OPTIONS

4.1 Customizing the FTOT GIS Network

After installing FTOT, the default multimodal network utilized in FTOT is available for download with all the other supporting data and quick start scenarios on the FTOT GitHub site. The feature classes included with the network are shown in Figure 9 and are available in the scenarios/common_data/networks subdirectory. Full metadata for the multimodal network can be accessed in ArcGIS Pro. Additional technical discussion of the FTOT GIS Network is provided in Section 2.2 of the FTOT Technical Documentation.

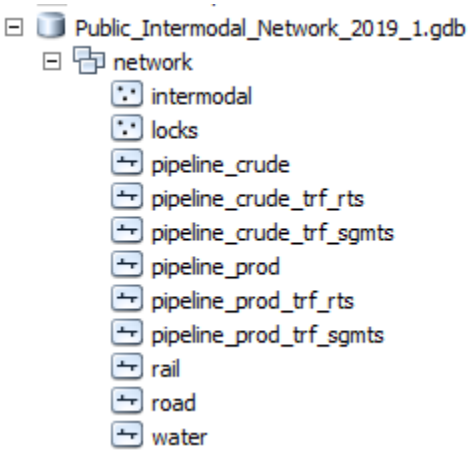

Figure 9: Default multimodal network feature classes included in base FTOT network.

For most FTOT scenarios, users should utilize the default multimodal GIS network. Due to the complexity of the underlying multimodal GIS network structure, FTOT does not currently support using other networks. The key limitations are the fact that the network currently requires certain attributes (some of which are not easily available in other networks) and must be fully connected and flowable—including the existence of artificial links that connect the network segments to intermodal facilities.

In some circumstances, an FTOT user may wish to customize the existing default FTOT multimodal network. For example, a user may wish to add an additional network segment (or handful of new network segments) to the network. This is achievable provided the FTOT user has some existing GIS experience and the patience to customize the GIS layers provided by FTOT, as the process is not automated. Adding network segments is not recommended if the user intends to add more than a dozen or so additional network segments, due to the complexity of integrating new data into an existing network. Section 4.1.1 walks through this process in detail.

In addition, segments can be automatically removed from the default FTOT network (i.e., 'disrupted') through the creation of an optional disruption data csv. The process for this is described in Section 4.1.2.

4.1.1 Adding Segments to the FTOT Network

Adding segments to the existing default FTOT Multimodal Network may be useful in scenarios in which a key link is missing from the default FTOT network, or if you wish to include a proposed or under construction link in your analysis.

Note that for pipeline, the process is somewhat more complicated—feel free to skip the **PIPELINE NOTE ONLY** sections if adding segments to other modes in the FTOT network (road, rail, and water).

1. Make a copy of the default FTOT multimodal network geodatabase (e.g., C:/FTOT/scenarios/common_data/networks/Public_Intermodal_Network_2010_3.gdb). You can save it the same directory, but make sure to rename it to distinguish it from the default network.
2. Open your GIS software of choice (e.g., ArcGIS Pro) and navigate to the copy you just made of the network geodatabase. Identify the mode for which you wish to add additional network segments (road, rail, water, crude pipeline, or petroleum product pipeline). If not pipeline, finding the right feature class to modify is simple—choose the 'road', 'rail' or 'water' feature class and add it to an existing map. If pipeline, read the following note.

PIPELINE NOTE ONLY: There are three pipeline feature classes provided for both crude oil and petroleum products. The reason for the added complexity is due to the unique nature of the pipeline network—unlike the other modes, FTOT limits possible movements along the pipeline to known origin-destination pairs for which tariffs have been designated and does not allow commodities to flow freely on or off the network as it does for other modes. To help enforce that restriction, FTOT utilizes three different feature classes for each commodity. Section 2 of the main FTOT documentation provides a brief description of how each feature class differs. Once you determine the commodity you are utilizing (crude or petroleum product), you should focus on the feature class ending in "trf_rts". The FTOT team currently does not support the modification of the other two pairs of feature classes (pipeline_crude and pipeline_crude_trf_sgmts / pipeline_prod and pipeline_prod_trf_sgmnts), which are only utilized in capacity-constrained scenarios. As a result, we only recommend adding additional pipeline movements to the FTOT network in scenarios where the capacity constraint and background flows are disabled.

3. Once you have opened your desired network mode's GIS feature class, use your GIS functionality to digitize new segments where necessary. When adding new segments, use your GIS to draw a new connection between an origin and destination. For guidance on creating polyline features in ArcGIS Pro, refer to the ArcGIS Pro documentation.[12] For road, rail, and water, ensure that any new segments are snapped into the existing network.[13] You will also need to split the existing network at any new junctions in the network that are made.[14] If you do not split existing segments where your new segments intersect the existing network, they will

[12] https://pro.arcgis.com/en/pro-app/latest/help/editing/create-polyline-features.htm
[13] https://pro.arcgis.com/en/pro-app/latest/help/editing/snap-while-creating-geometry.htm
[14] https://pro.arcgis.com/en/pro-app/latest/help/editing/split-a-feature.htm

be unreachable from the rest of the network. In most cases, this prevents them from being utilized in FTOT scenarios.

PIPELINE NOTE ONLY: Make sure to start drawing at the origin and end at the destination of a particular pipeline movement—the order matters, as two-way movements along pipelines are not allowed as is the case for the other modes.

4. Once you have completed generating your new feature geometry, you will need to specify the new feature attributes.

For road, attributes that must be populated include:

- FCLASS (Functional Class)—using the FHWA approved Functional Classification System.[15]
- URBAN_CODE (U.S. Census Urban Area Code).[16] When in doubt, utilize the same urban code that is entered for existing road segments in the surrounding area. This attribute is necessary to determine whether the roadway is classified as urban or rural, which impacts emissions reporting.
- Artificial—should be set to 0 for all added segments.
- MODE_TYPE—should be set to 'road'.
- MILES—select any new or modified road segments (including any segments that you split in order to connect in new road segments) and use the Calculate Geometry[17] tool to calculate the mileage of each road segment.
- Additionally, volume, capacity, and VCR (volume capacity ratio) must be populated if capacity or background flows are enabled. Volume and capacity must be entered in terms of vehicles per day and volume capacity ratio simply needs to be entered as volume divided by capacity.
- All other attributes are optional.

For rail, attributes that must be populated include:

- Density_Code: Valid values include any number from 3 to 7. A higher number within this range means FTOT will prioritize flows over lower numbers with mileage being equal. Density codes for the public network are based on the following rules:
    - Density Code 7—STRACNET (Strategic Rail Corridor Network)- Class 1 Ownership
    - Density Code 6—Other STRACNET (non-Class 1 Ownership)
    - Density Code 5—Class 1 Ownership (non-STRACNET)
    - Density Code 4—Class 1 Rights (non-STRACNET)
    - Density Code 3—Non-Class 1 (non-STRACNET)
- Artificial—should be set to 0 for all added segments.
- MODE_TYPE—should be set to 'rail'.

[15] https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/page04.cfm#toc249159687
[16] https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/page04.cfm#toc248828519
[17] https://pro.arcgis.com/en/pro-app/latest/tool-reference/data-management/calculate-geometry-attributes.htm

- MILES—select any new or modified rail segments (including any segments that you split in order to connect in new rail segments) and use the Calculate Geometry[18] tool to calculate the mileage of each rail segment.
- Additionally, capacity must be populated if you plan to use the network for capacitated scenarios. Capacity must be entered in terms of train cars per day. The public FTOT network does not have background flow data available— therefore, the volume and VCR fields for new segments can be left blank.
- All other attributes are optional.

For water, attributes that must be populated include:

- TOT_UP_DWN (the tonnage of any freight that flows on the segment)— this data is populated in other segments by the USACE National Waterway Network and can be estimated or based on nearby segments.
- Artificial—should be set to 0 for all added segments.
- MODE_TYPE—should be set to 'water'.
- MILES—select any new or modified water segments (including any segments that you split in order to connect in new water segments) and use the Calculate Geometry[19] tool to calculate the mileage of each water segment.
- All other attributes are optional.

For pipeline, attributes that must be populated include:

- Base_Rate (this is the cost to flow this particular movement in cents per barrel)
- Tariff_ID (sequential unique number— use any number that is not already used)
- Artificial—should be set to 0 for all added segments.
- Commodity ('Crude Oil' or 'Petroleum Products' depending on the commodity)
- MODE_TYPE—should be set to 'pipeline_crude_trf_rts' or 'pipeline_prod_trf_rts' depending on the commodity.
- MILES—select any new or modified pipeline segments (including any segments that you split in order to connect in new pipeline segments) and use the Calculate Geometry[20] tool to calculate the mileage of each pipeline segment.
- All other attributes are optional.

Following Steps 1-4 above will allow scenarios to utilize these new segments— except in cases where these new segments need to be directly connected to existing intermodal facilities (e.g., to allow for multimodal movements). For enabling multimodal movements with these new segments, continue on with steps 5-6 below. Otherwise, skip to Step 7.

[18] Ibid.
[19] Ibid.
[20] Ibid.

5. In some cases, particularly in situations where you have added new pipeline tariffs, you may need to add additional intermodal facilities to the network. Open your custom network's 'intermodal' feature class. The easiest method is to add intermodal facilities at the new segment's start or end points— this eliminates the need to digitize artificial links to connect the new segments to the new intermodal facilities. You can use GIS functionality to 'snap' these points to exactly the start and end points of the segment(s) that were added. Modify the attributes of these new intermodal facilities off of the attributes provided for the other intermodal facilities. The essential columns to populate for each new intermodal facility are to populate "Y" for any modes that the intermodal facility is supposed to connect to.
6. Artificial links will need to be manually added to connect any other relevant modes to these new intermodal facilities. This involves opening the relevant mode feature class and tracing new connections between the intermodal facility and the mode's closest existing segment. It is easiest to trace these connectors so they connect into existing nodes (intersections) in the mode's network. Otherwise, you will have to split the existing network at these new nodes to ensure that the artificial links are actually accessible from the rest of the mode's network. The Split tool[21] can help with that functionality in ArcGIS Pro. If you do split features in the existing network, you'll need to recalculate the "MILES" field with updated mileage. Once the new artificial segment is digitized, assign each new artificial link an "Artificial" attribute of 1 and a MODE_TYPE consistent with the other features in the layer (e.g., 'road' for the road feature class). Also, calculate the MILES of the new segment using "Calculate Geometry". Other attributes can be left blank.
7. Modify your scenario files accordingly to reference your new network. You are now ready to run scenarios using the network.

Disruption Data