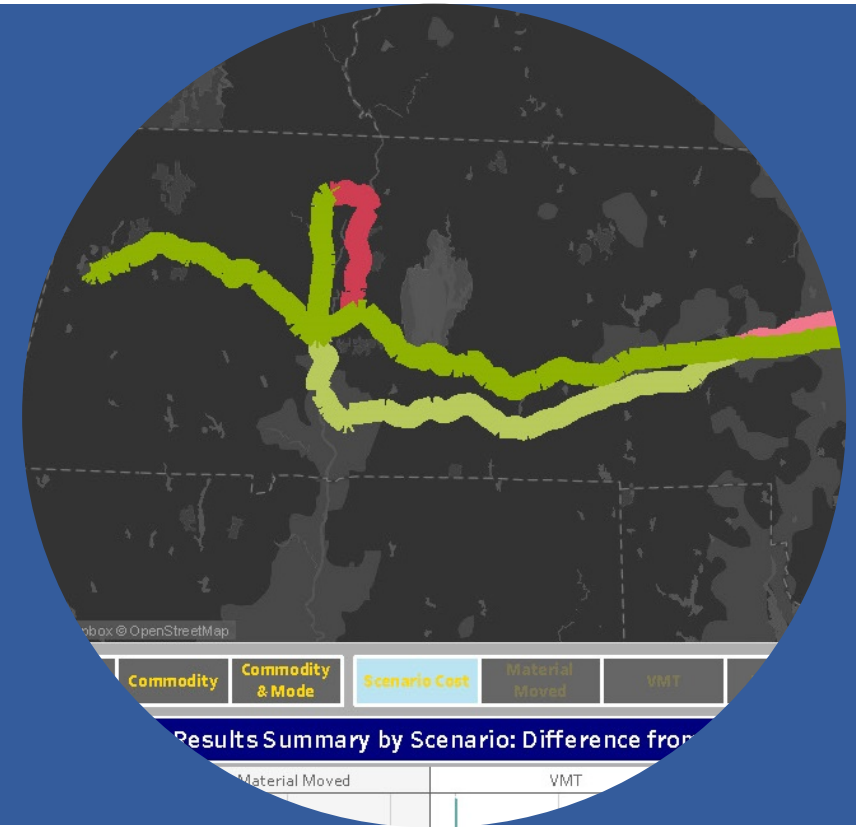


# FTOT Link Removal Resiliency Testing Use Case

Question: How resilient is my solution  
to disruptions?



[https://github.com/dflynn-volpe/FTOT-Public-Link Removal](https://github.com/dflynn-volpe/FTOT-Public-Link-Removal)

Dan Flynn [daniel.flynn@dot.gov](mailto:daniel.flynn@dot.gov)

50  
YEARS  
1970 - 2020



U.S. Department of Transportation  
**Volpe Center**

TRANSPORTATION INNOVATION FOR THE PUBLIC GOOD

# Overview

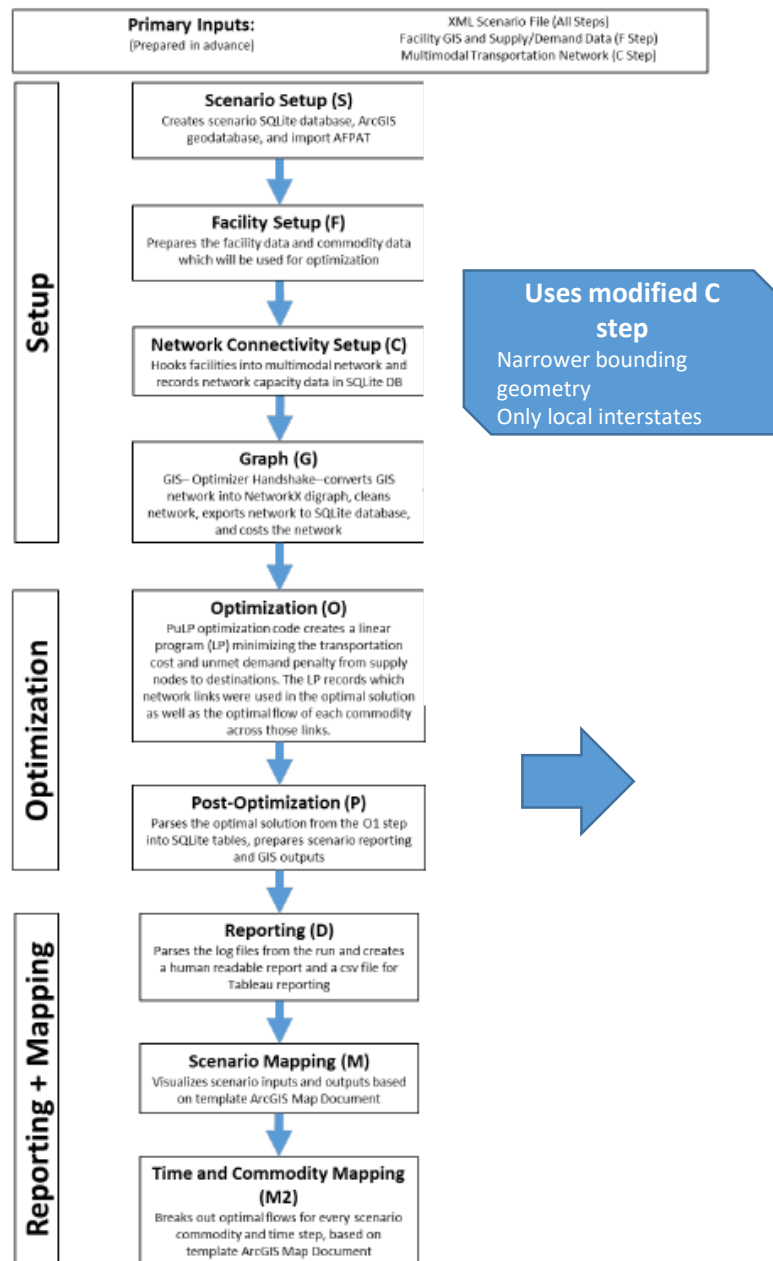
## Process

- Complete baseline run in FTOT
- Rank edges by ‘importance’
- Disruptions applied by removing edges from optimal solution
- Re-calculate new optimal solution and calculate total scenario cost

## Assumptions

- Importance calculations are for road network only
- Use as a screening tool to assess resiliency of network to disruption
- Most useful for comparing multiple scenarios
- Uses Jupyter Notebooks in addition to standard FTOT setup (based off 2020.3 currently)

# Complete FTOT run for base scenario



## Link Removal Resiliency Testing Code

Apply Disruption and Optimize  $n$  times

Compile results and visualize

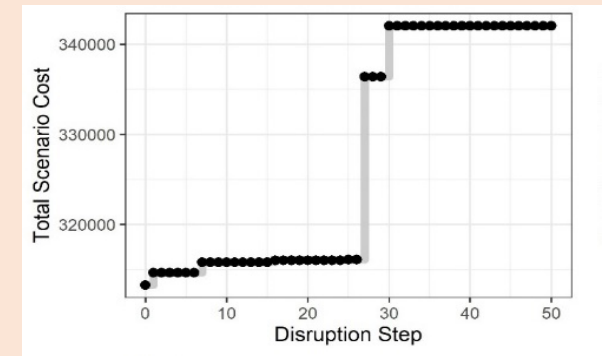
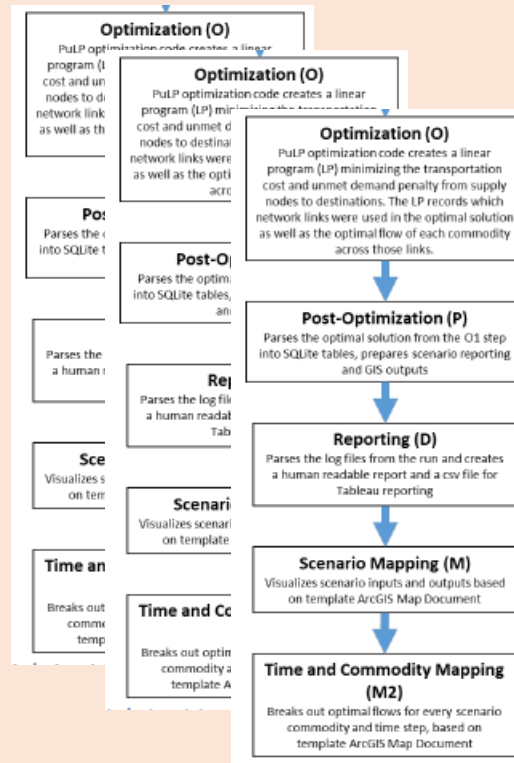
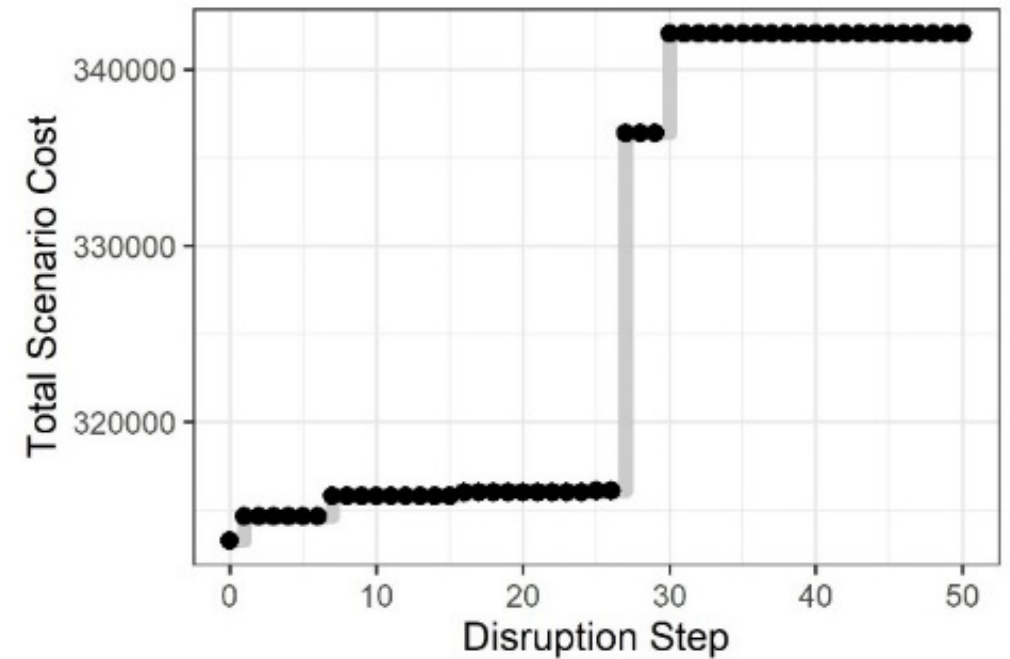
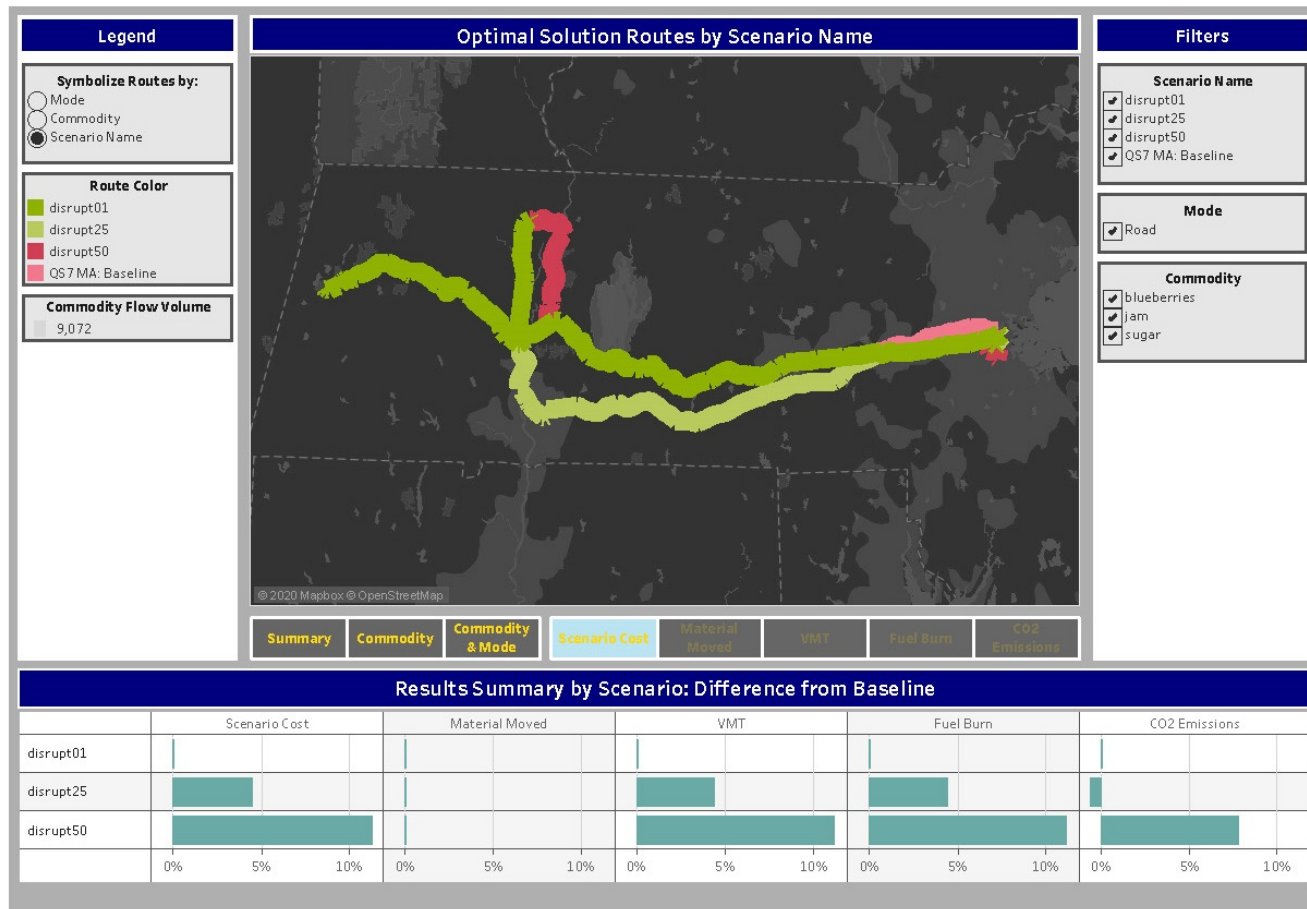


Figure 3 - Analytical tool data flow schematic showing the key components/roles of each component of the FTOT

# Example outputs



See Quick Start 9 for Scenario Comparison Tool usage

# Development scenarios

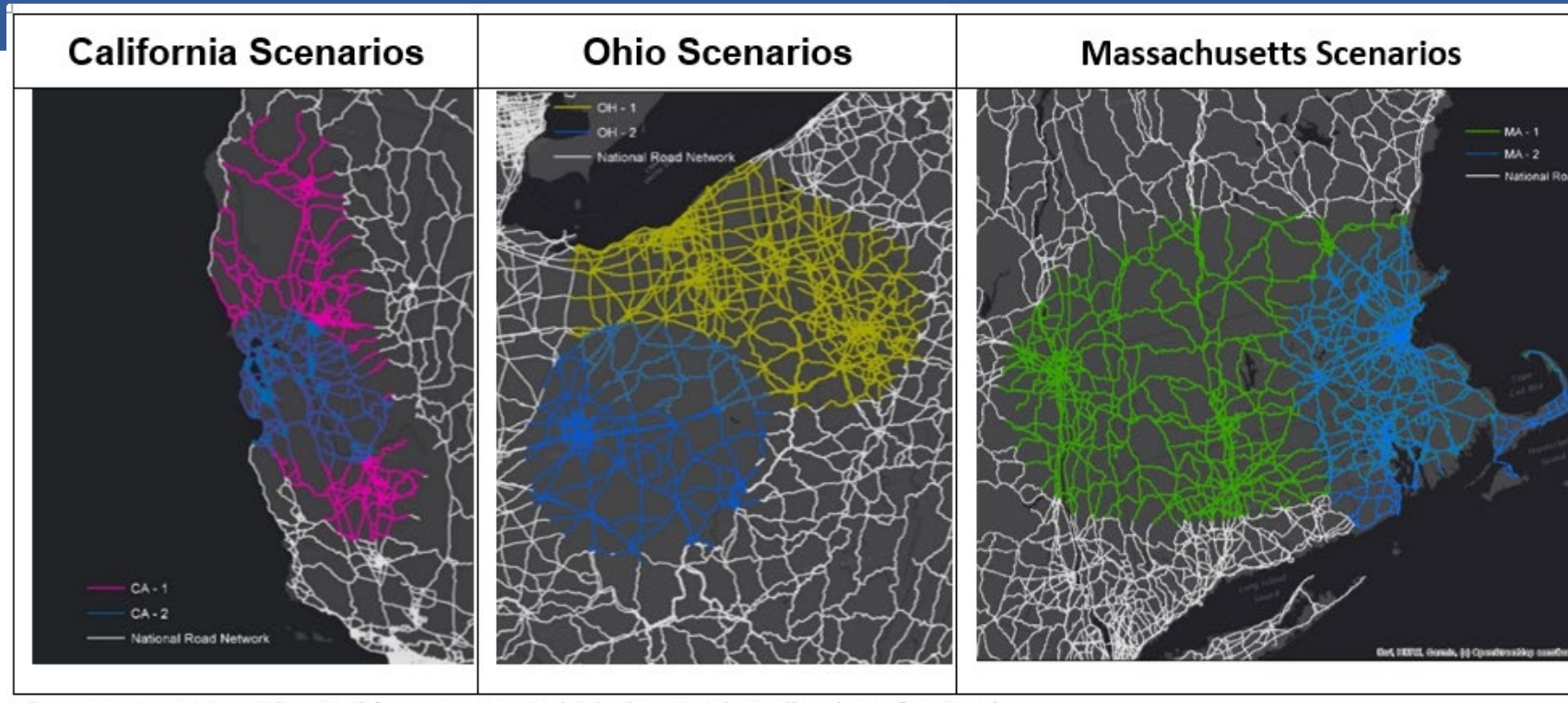
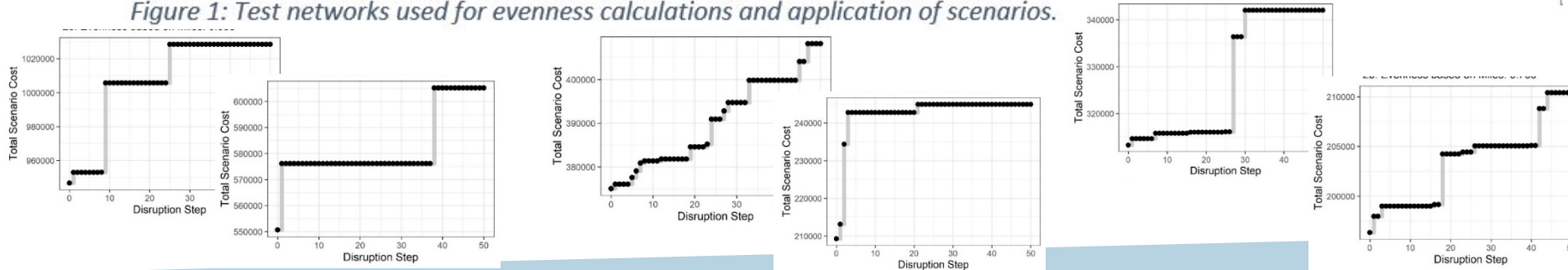


Figure 1: Test networks used for evenness calculations and application of scenarios.



# Demo

- To FTOT-Public Wiki

The screenshot shows a web browser displaying the GitHub repository page for VolpeUSDOT / FTOT-Public. The browser's address bar shows the URL `github.com/VolpeUSDOT/FTOT-Public/wiki/FTOT-Projects-and-Use-Cases`. The GitHub navigation bar is visible, with the repository name `VolpeUSDOT / FTOT-Public` and a `Watch` button. Below the navigation bar, a horizontal menu contains links for `Code`, `Issues` (with a count of 5), `Pull requests`, `Actions`, `Projects`, `Wiki` (which is underlined), `Security`, and `Insights`. The main content area is titled `FTOT Projects and Use Cases` and includes a note that `Matthew Pearson` edited the page 7 days ago with 3 revisions. A single bullet point lists the `Network Resiliency and Link Removal Tool`. On the right side, there is a `Pages` sidebar with a count of 4, a search box labeled `Find a Page...`, and a list of pages: `Home`, `Documentation and Scenario Datasets`, `FTOT Installation Guide`, and `FTOT Projects and Use Cases`. At the bottom right, there is a section titled `Clone this wiki locally` with a text input field containing the URL `https://github.com/VolpeUSDOT/FTI` and a copy icon.



# Demo

The screenshot shows a web browser window displaying a GitHub repository. The browser's address bar shows the URL: `github.com/dflynn-volpe/FTOT-Public-Link_Removal/tree/master/usecase/link Removal`. The repository page header includes the repository name `dflynn-volpe / FTOT-Public-Link_Removal`, a note that it is forked from `VolpeUSDOT/FTOT-Public`, and statistics for Watch (0), Star (0), and Fork (3). Navigation tabs for Code, Pull requests, Actions, Projects, Wiki, Security, Insights, and Settings are visible. The main content area shows the file tree for the `master` branch at the path `FTOT-Public-Link_Removal / usecase / link Removal`. A status bar indicates the branch is 6 commits ahead and 4 commits behind `VolpeUSDOT:master`. A commit history table is displayed below.

Commit Hash	Author	Message	Time
b110bba	dflynn-volpe	Update README.md	6 hours ago
..			
		.ipynb_checkpoints	Update R packages for smaller footprint 29 days ago
		__pycache__	Update R packages for smaller footprint 29 days ago
		Calculate_Evenness_Compile_Disruption.R	Completed readme, completed evenness calc notebook 29 days ago
		Calculating_Evenness.ipynb	Adding R tools to render Markdown report 29 days ago
		Conduct_Link_Removal.ipynb	Update R packages for smaller footprint 29 days ago
		Disruption_Results.Rmd	Update R packages for smaller footprint 29 days ago
		Disruption_Results.html	Update R packages for smaller footprint 29 days ago
		README.md	Update README.md 6 hours ago
		Rutil.R	Update R packages for smaller footprint 29 days ago
		compile_report.R	Adding R tools to render Markdown report 29 days ago
		compile_report.py	Update R packages for smaller footprint 29 days ago
		environment.yml	Adding R tools to render Markdown report 29 days ago
		ftot_networkx.py	Completed readme, completed evenness calc notebook 29 days ago
		ftot_routing.py	Completed readme, completed evenness calc notebook 29 days ago

# Demo

The screenshot shows a web browser window with multiple tabs. The active tab is titled 'Conduct\_Link\_Removal - Jupyter Notebook' and shows a Jupyter Notebook interface. The browser's address bar indicates the URL is 'localhost:8888/'. A tooltip for the active tab shows the notebook name and the local address.

Below the browser window, a file browser interface is displayed. It has tabs for 'Files', 'Running', and 'Clusters'. The 'Files' tab is selected, showing a list of files and folders in the directory 'Documents / git / FTOT-Public / usecase / link\_removeal'. The interface includes a search bar, a 'Select items to perform actions on them.' prompt, and buttons for 'Upload', 'New', and a refresh icon.

	Name	Last Modified	File size
<input type="checkbox"/>	..	seconds ago	
<input type="checkbox"/>	Calculating_Evenness.ipynb	Running a month ago	21 kB
<input type="checkbox"/>	Conduct_Link_Removal.ipynb	Running a minute ago	60.3 kB
<input type="checkbox"/>	BC_Disruption_Cost.jpg	6 minutes ago	142 kB
<input type="checkbox"/>	Calculate_Evenness_Compile_Disruption.R	4 months ago	7.55 kB
<input type="checkbox"/>	compile_report.py	6 minutes ago	809 B
<input type="checkbox"/>	compile_report.R	a month ago	127 B
<input type="checkbox"/>	Disruption_Results.html	6 minutes ago	4.75 MB
<input type="checkbox"/>	Disruption_Results.Rmd	11 minutes ago	3.77 kB
<input type="checkbox"/>	environment.yml	a month ago	5.52 kB
<input type="checkbox"/>	Evenness_Calcs.csv	6 hours ago	146 B
<input type="checkbox"/>	Evenness_Disruption_Fig.jpeg	6 hours ago	406 kB
<input type="checkbox"/>	One_Panel_Max_Pct_Change_4Evenness_Fig.jpeg	6 hours ago	281 kB
<input type="checkbox"/>	One_Panel_Pct_Change_Evenness_Disruption_Fig.jpeg	6 hours ago	281 kB
<input type="checkbox"/>	README.md	4 hours ago	2.02 kB
<input type="checkbox"/>	resiliency_disruptions.py	a month ago	11 kB
<input type="checkbox"/>	RoadLayer.RData	6 hours ago	160 MB
<input type="checkbox"/>	Rutil.R	a month ago	725 B



# Demo

The screenshot shows a Jupyter Notebook interface in a web browser. The browser tabs include 'Documents/git/FTOT-Public/use...', 'Conduct\_Link\_Removal - Jupyter', 'New Tab', and 'dflynn-volpe/FTOT-Public-Link...'. The address bar shows 'localhost:8888/notebooks/Documents/git/FTOT-Public/usecase/link\_removal/Conduct\_Link\_Removal.ipynb'. The Jupyter interface has a menu bar (File, Edit, View, Insert, Cell, Kernel, Help) and a toolbar with icons for file operations, running, and markdown. The notebook title is 'Conduct\_Link\_Removal' with a status 'Last Checkpoint: 2 minutes ago (unsaved changes)'. The environment is 'Python [conda env:FTOTenv]'. The notebook content is as follows:

## Sequential removal of links and resiliency testing

- Disruption of a network by removal of links, based on:
  - Sum of betweenness centrality of from and to nodes
  - Link length
  - Volume of commodity flow
- Calculation of performance in terms of cost and unmet demand by re-running disrupted network on FOT
- Plot link removal along x-axis and performance on y-axis, comparing networks of differing evenness. Dynamic report generated in an Rmarkdown automatically from this Notebook.

### Assumptions

- Working in a Python 3.x environment for this notebook
  - Refer to the README in this repository for instructions on setup of all dependencies with `conda`
- Python 2.7 installed as part of ArcGIS
- 64 bit background geoprocessing enabled
- Access to ArcGIS license server if necessary

### Reference

- [NetworkX Documentation](#)

```
In [5]: import pandas as pd
import geopandas as gpd
import sqlalchemy
import networkx as nx
import os
import matplotlib.pyplot as plt
import pickle

import resiliency_disruptions

# Uses Quick Start 7 as an example. Modify `scen_name` and `scen_path` for your scenario.
scen_name = 'qs7_rmp_proc_dest_multi_inputs'

scen_path = os.path.join("C:\\FTOT\\scenarios\\quick_start\\", scen_name)

chn_path = os.path.join(scen_path, 'temp_networkx_shp_files')
```

# Demo

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## Sequential removal of links and resiliency testing

- Disruption of a network by removal of links, based on:
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  - Link length
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# Demo

