



# Capital District Transportation Authority: Route Restructuring

NYSAMPO Shared Transit Service Planning and Analytics Initiative  
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## Abstract

CDTA is preparing to update its Transit Development Plan (TDP) and develop a comprehensive route restructuring plan that will align CDTA's capital investments and service provisions with current and future travel patterns. This pilot study sought to identify and assess planning software and strategies that CDTA could utilize in its service analysis, route restructuring, and ridership projections. The study identifies latent demand in the City of Troy and introduces several bus service changes. To test the service modifications, the Research Team calibrated a TBEST ridership projection model to assess the potential impacts of these changes on ridership. TBEST was chosen as the software for running a ridership estimation model as a user-friendly, customizable transit ridership modeling software that supports multiple GTFS scenarios.

While the study introduces a series of potential service modifications, the primary goal was to test a concise, reproduceable methodology utilizing transit planning software and tools including Esri ArcGIS, Remix, and ridership modeling. The intention was to create an approach that can be used in the future by CDTA and other New York State transit agencies. The approach is a four-step process:

1. Gap Analysis
  - To identify latent ridership
2. Origin/Destination Analysis
  - To understand commute flows
3. Exploration of Service Modifications
  - To align service with latent ridership and known commute origins and destinations
4. Ridership Analysis
  - To test ridership changes based on network modifications

The result of the gap analysis showed that service is most concentrated in the city center, near the Rensselaer Polytechnic Institute (RPI), and in southwest Troy. A lower level of service extends north and south of downtown, along the Hudson River. Most of the areas where demand exceeds supply are located in the northern part of Troy, while areas with high supply are concentrated in the southern and western parts of the city. An origin-destination (O/D) analysis was conducted to determine the main travel patterns between Troy and other destinations in the Capital District. Based on this analysis, several bus service changes were proposed and a ridership projection model was employed to assess the potential impacts of these changes on ridership.

The model forecasted an increase in ridership throughout the market area. While some routes indicated a slight drop in ridership, Route 80 was estimated to increase substantially likely due to a drastic increase in length and connectivity between Troy and Albany. Routes that were not directly modified either had no change or a small increase in ridership—attributed to an increase in accessibility from Route 80's new service area.

## Problem Statement

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Transit service in Troy, New York is provided by the Capital District Transportation Authority (CDTA). Out of approximately 60 bus routes system-wide, 12 of CDTA's routes serve neighborhoods and employment centers within Troy, as well as transit connections to other major destinations, job centers, and central business districts (CBD) in the Capital District.

Like transit systems across the United States, CDTA has seen significant shifts in travel patterns as a result of the COVID-19 pandemic, including changes in commuting times, travel modes, and work-from-home levels, all of which have resulted in a reduction of bus ridership during 2020-2022. While system-wide ridership has returned to 85% of pre-pandemic levels (as of late 2022), CDTA is preparing to update its Transit Development Plan (TDP) and develop a comprehensive route restructuring plan that will align CDTA's capital investments and service provisions with current and future travel patterns.

This pilot study seeks to identify and assess planning software and strategies that CDTA could utilize in its service analysis, route restructuring, and ridership projections. More specifically, the study identifies latent demand in the City of Troy, a subset of the CDTA's service area. Based on this analysis, it introduces several bus service changes and applies a ridership projection model to assess the potential impacts of these changes on ridership.

## Solution

The study identified latent demand by analyzing gaps between the existing transit service and transit service demand within the City of Troy. Service changes were proposed to address the gaps and projected the potential impact on ridership through the use of an open-source transit planning software.

While the study introduces a series of potential service modifications, the overarching goal was to test a concise, reproduceable methodology utilizing transit planning software and tools including Esri ArcGIS, Remix, and ridership modeling. The intention was to create an approach to be used in the future by CDTA and other New York State transit agencies.

The study was designed to primarily test the capabilities of the Transit Boardings Estimation and Simulation Tool (TBEST) – a free, open-source transit planning ridership analysis software developed and maintained by Florida Department of Transportation<sup>1</sup>. Remix, a web-based transportation planning platform used for designing and evaluating of transit routes, schedules, and service modifications, was also used as part of this analysis.

Given the difference in the pre-and post-pandemic ridership patterns, 2019 data was used as the base for the analysis.

This section provides a high-level overview of the analysis. A more detailed description of the analysis is provided in the Technical Design section below. References and data sources can be found in the References section.

### 1. Gap Analysis

A gap analysis is an exercise that identifies areas where transit service could more successfully achieve agency priorities. Gaps or deficiencies may be identified by measuring and analyzing critical factors such as ridership, service investment levels, and potential demand.

The team used ArcGIS to analyze the gap between the demand for transit service within the City of Troy and the service provided by CDTA. The following steps were taken as part of the gap analysis:

- To assess the service demand, the team used CDTA's 2019 Transit Propensity Index (TPI). The index incorporates the main spatial indicators of transit demand, including population and job densities, commercial square footage, hospital beds, car ownership levels, as well as university/college students, elderly, and low-income populations (see full list of TPI attributes in **Table 1**). A TPI score was calculated for each census block group, with the most important indicators being weighed most heavily in the score.
- To assess the service provision, a GIS-based analysis was conducted to determine the distribution of 2019 service hours in the study area. Conceptually, the analysis incorporated the service hours allocated to each bus route that serves the city of Troy, showing how they are allocated by bus stops and census block groups.
- With both the service demand and provision at hand, the gaps between them were mapped to identify census block groups with a mismatch in service: either an oversupply or an undersupply.

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<sup>1</sup> <https://tbest.org/>

## **2. Origin/Destination Analysis**

An origin/destination (O/D) analysis was conducted using ArcGIS to map the prominent travel flows within the City of Troy and between Troy and other locations within the CDTA service area. Based on Census Transportation Planning Products (CTPP) data, the major origin/destination pairs in Troy were identified and mapped.

## **3. Exploration of Service Modifications**

The team explored service and rerouting modifications to address some of the service gaps identified in the gap analysis. Service changes were proposed to connect major O/D pairs that were not well served by CDTA. Route changes were mapped using Remix, a web-based transit planning platform, licensed to CDTA. The draft service modifications were reviewed and confirmed by CDTA staff.

Two General Transit Feed Specification (GTFS) datasets, the existing (2019) CDTA service (the baseline condition) and the modified CDTA service, were exported from Remix to be used as inputs for the TBEST software for comparison at the final step of the pilot study.

## **4. Ridership Analysis**

The team used TBEST to estimate system-wide bus stop level ridership under both the baseline condition and the modified service condition. This analysis included a robust data validation process, comparing the modeled ridership to reported CDTA ridership, as well as multiple sensitivity analysis to ensure the model indicators and weights were calibrated to reflect the Capital District conditions. The goal of this step was to project how ridership might change as a result of the route modifications.

## Outcomes

### 1. Gap Analysis

**Figure 1** shows the geographic allocation of fixed-route service in Troy, visualized as a transit service provision score. Service hours were based on each route's scheduled revenue hours summed up for a typical week in October 2019. Every variant of each bus route was assumed to serve an area within ¼ mile walking distance of the bus stops served by the route, and its service was assumed to be distributed evenly over that area. The service hours of various bus routes were then aggregated at the Census Block Group level to create a summary.

The result shows that service is most concentrated in the city center, near the Rensselaer Polytechnic Institute (RPI), and in southwest Troy. A lower level of service extends north and south of downtown, along the Hudson River.

To determine the demand for public transit, this study used CDTA's TPI, which incorporates 10 factors that are strongly correlated with transit demand. **Table 1** summarizes how these different factors are weighted into a composite score.

*Table 1. Factors and Weights in CDTA's 2019 Transit Propensity Index*

Factor	Weight (percentage)
Population per square mile	15
65+ population per square mile	5
Population income below poverty per square mile	10
Households with more workers than vehicles per mile	10
Students per square mile	10
Jobs per square mile	20
Low-paying jobs per square mile	5
4-way intersections per mile	10
Mall square feet per mile	10
Hospital beds per square mile	5
<b>Total</b>	<b>100</b>

**Figure 2** shows the TPI scores for Troy and categorizes this information into quintiles.<sup>2</sup> As shown, transit demand is strongest at the city center, RPI, and in the northern part of Troy.

The next step in identifying supply-demand gaps was to compare the service provision with the TPI. We assigned a value between 1 and 5 to each of the block group quintiles for both the transit supply and demand. The gaps were then identified as the difference between these two values. In block groups where the difference was less than or greater than 2, a mismatch was identified, as shown in **Table 2**.

<sup>2</sup> For this analysis, ranges were based on the distribution of results. Future analyses may select another classification approach.

Table 2. Gap Analysis Scores and Distribution

Difference between supply and demand indices (X)	Gap Analysis Distribution	Number of Block Groups in Troy	Portion of Block Groups in Troy
$2 < X < 4$	GAP - high demand	10	21%
$(-4) < X < (-2)$	GAP - high supply	9	19%
$(-2) < X < 2$	Match	29	60%

Figure 3 shows the Troy gap analysis map, displaying the block groups with a mismatch in supply and demand. Notably, most of the areas where demand exceeds supply are located in the northern part of Troy, while areas with high supply are concentrated in the southern and western parts of the city.

Figure 1 - Troy Transit Propensity Index

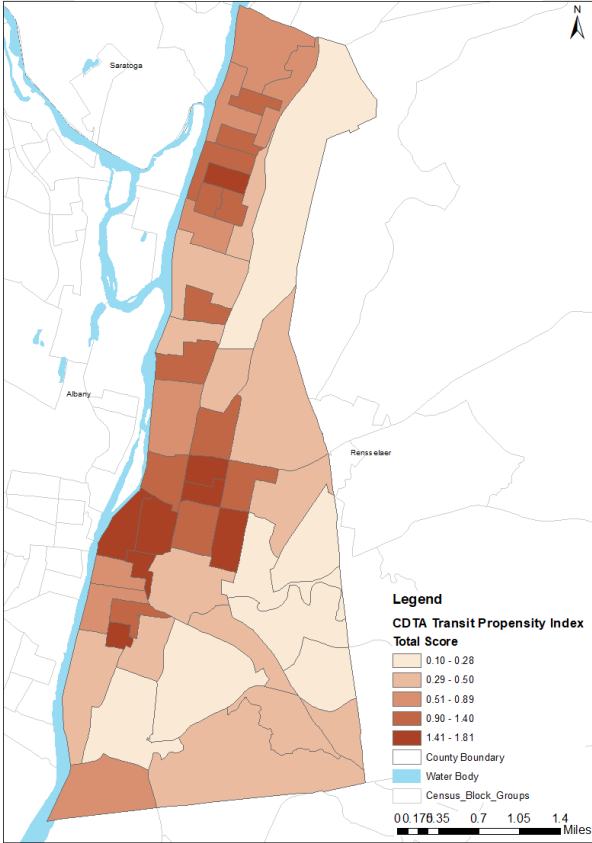


Figure 2 - Troy Transit Service Provision Scores

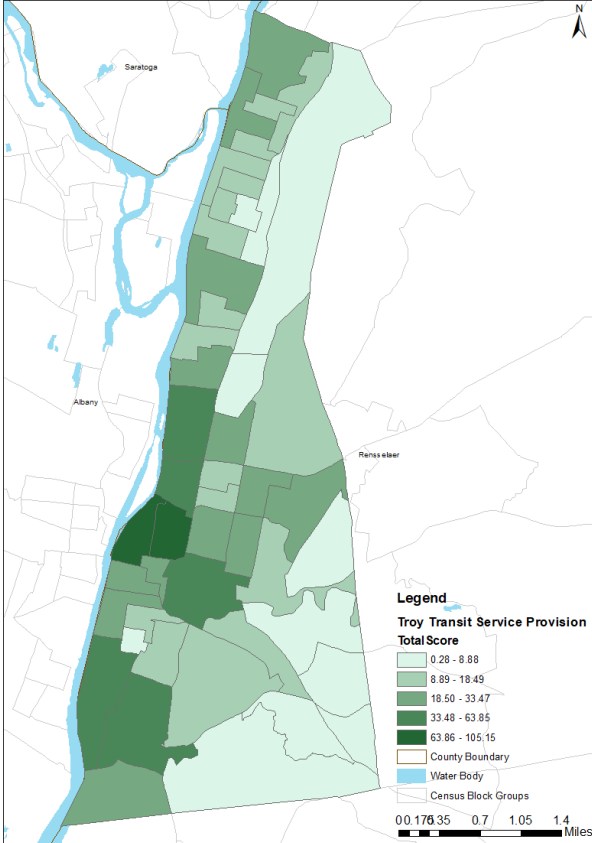
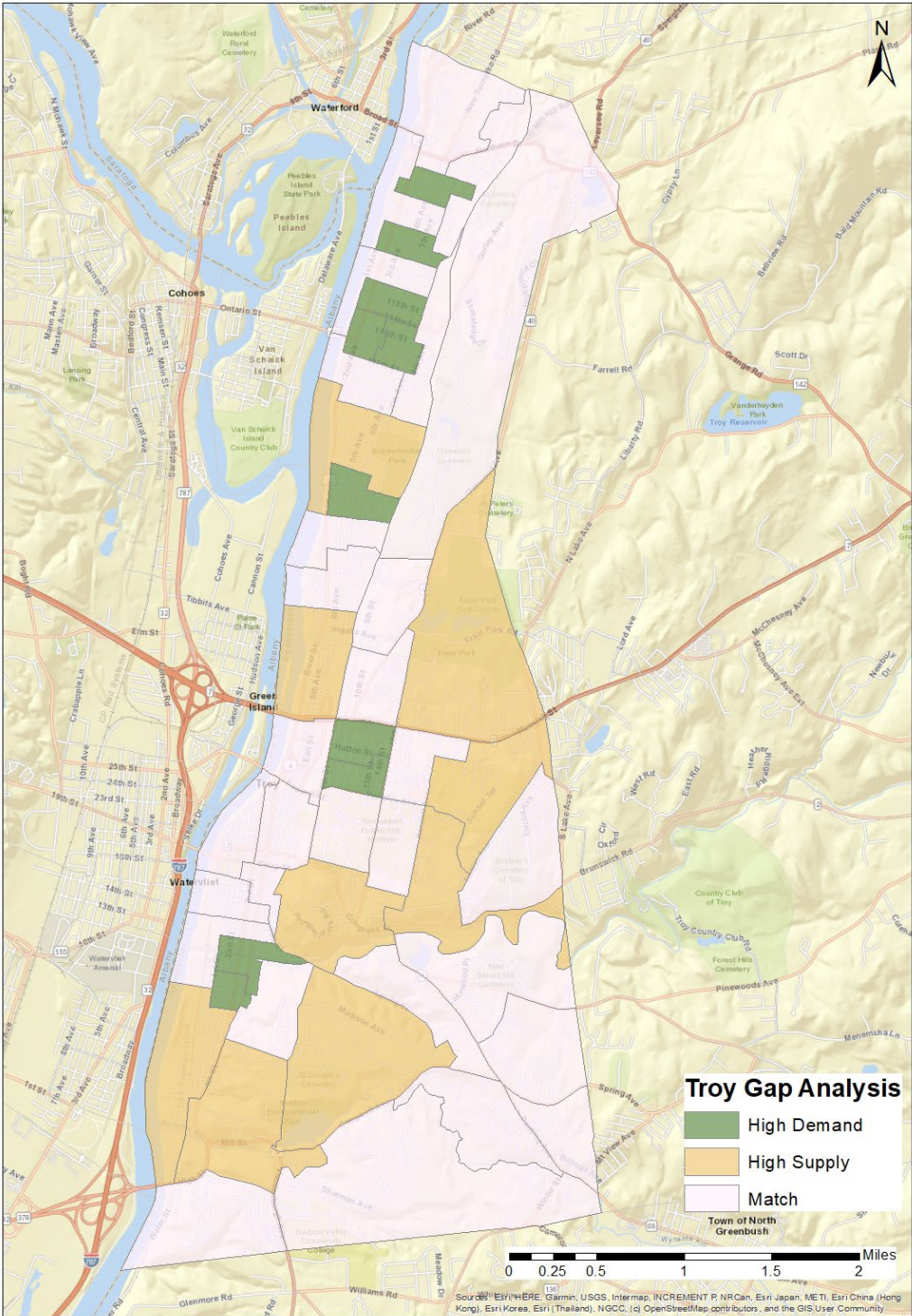




Figure 3. Transit Service Supply and Demand Gaps



## 2. Origin/Destination Analysis

An origin-destination (O/D) analysis was conducted to determine the main travel patterns within the city of Troy, as well as between Troy and other destinations in the Capital District. Many of the bus routes that serve Troy connect the city to other destinations in the Capital District, such as Downtown Albany and Schenectady.

This analysis was conducted at the census tract level using the Census Transportation Planning Program (CTPP) latest data for 2012-2016 (5 years). It included all work-related trips by workers over the age of 16. Two datasets were used in the analysis, one for trips originating in Troy and one for trips destined for Troy.

**Figures 4 and 5** display the O/D pairs with more than 50 commuter trips. Approximately 40% of the total trips take place within Troy, and the top 5 O/D pairs are shown in **Tables 3 and 4**.

Figure 5 - Trips Originating in Troy

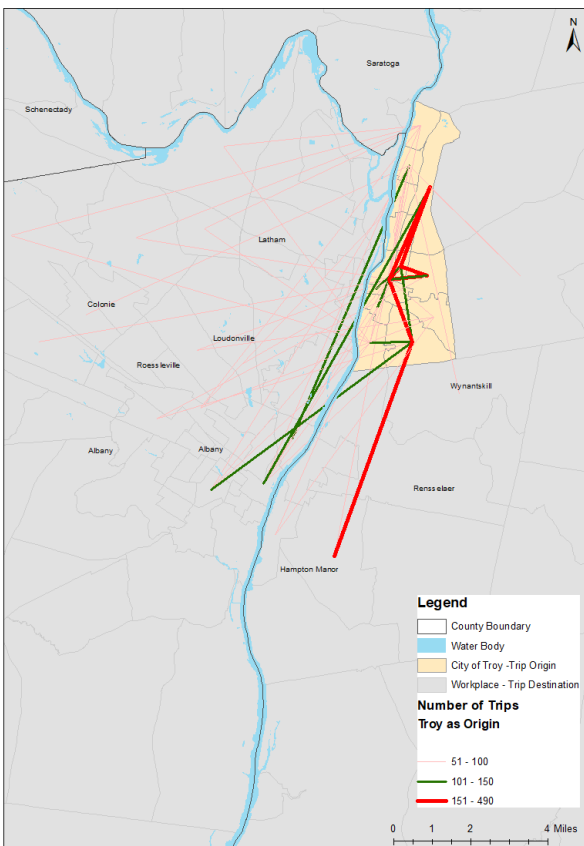


Figure 4 - Trips Destined for Troy

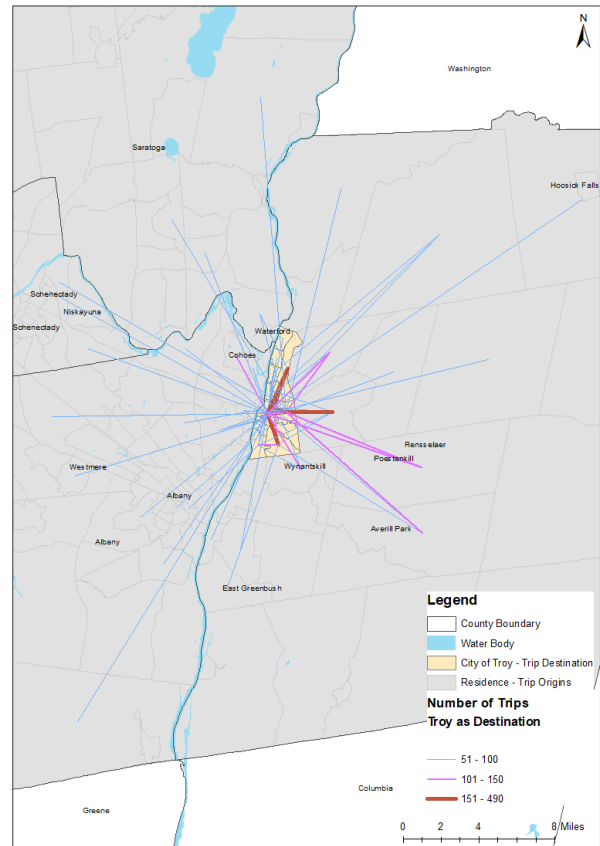


Table 3. Top 5 Destinations in Troy

Origin Census Tract	Destination Census Tract	Daily Commuters (2019)
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RPI East Campus & Samaritan Hospital	RPI West Campus	430
Hudson Valley Community College	Downtown Troy	340
Downtown Troy	RPI West Campus	290
Frear Park	RPI West Campus	215
Downtown Troy	RPI East Campus & Samaritan Hospital	185

Table 4. Top 5 Origins in Troy

Origin Census Tract	Destination Census Tract	Daily Commuters (2019)
RPI East Campus & Samaritan Hospital	RPI West Campus	430
Hudson Valley Community College	Downtown Troy	340
Downtown Troy	RPI West Campus	290
Frear Park	RPI West Campus	215
Downtown Troy	RPI East Campus & Samaritan Hospital	185

### 3. Exploration of Service Modifications

As discussed above, bus service and rerouting modifications were explored to address some of the service gaps identified in the gap analysis and O/D analysis. **Table 6** lists the service and route modifications included as part of this pilot. Out of the 12 routes examined as part of this analysis, the team explored changes for 5 routes: 4 routing changes and 1 schedule change.

Table 5. Bus Service Changes

Route	Routing Change	Schedule Change	Comments
22	Extend route in Troy	none	
87	Eliminate Samaritan Hospital diversion	none	Discontinued segment would be served by the #22
80	Extend route between Troy and Albany	none	
85	none	none	
182	none	none	
224	Reroute to link Troy and Hampton Manor	none	
286	none	none	
289	none	Increase peak frequency to 30 minutes	Maintain off-peak frequency at 60 minutes

370	none	none	
522	none	none	
809	none	none	
815	none	none	

## 4. Ridership Analysis

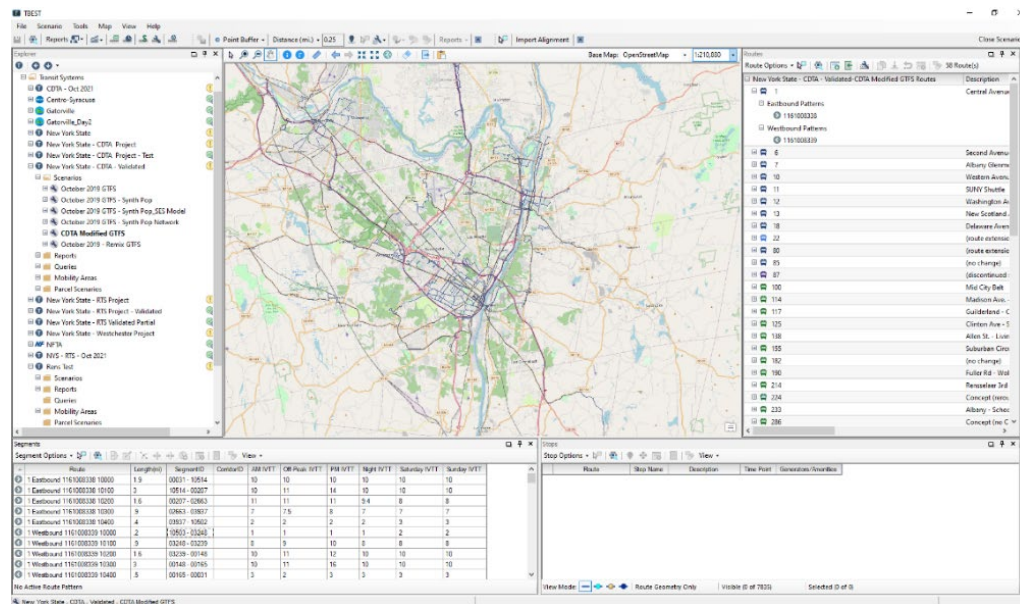
### Transit Boardings Estimation and Simulation Tool (TBEST) Overview

TBEST was chosen as the software for running a ridership estimation model as a user-friendly, customizable transit ridership modeling software that supports multiple GTFS scenarios. TBEST provides a series of tools for analyzing a transit network ecosystem. The most challenging component for utilizing the software was setup, but once complete the software performed well.

TBEST’s Ridership Estimation model generates ridership based on coefficients, demographics, and land use data within a quarter mile buffer around stops and/or segments. It then assigns the estimated riders to bus stops based on attractors. The model is a gravity model that utilizes American Community Survey (ACS) 5-Year Estimates, Longitudinal Employer-Household Dynamics’ (LEHD) Origin-Destination Employment Statistics (LODES), local parcel data, and a multi-linear regression model that provides coefficients for land uses.<sup>3</sup>

The Research Team decided to study the month of October in 2019 due to the network attributes for that month and due to the availability of a socio-economic (SE) data product that was created previously by Service Edge Solutions (SES) and the New York State Department of Transportation (NYSDOT) for use in a separate project.

Figure 6. A Full Screen Snapshot of the TBEST User Interface



### Calibration

The Research Team performed the TBEST Ridership Estimation model using an October 2019 CDTA GTFS file encompassing the entire network area. CDTA provided observed ridership data

<sup>3</sup> Bunner, R. (2021). *TBEST Socio-Economic Data Configuration*.



via Automatic Passenger Count (APC) to validate the model. TBEST provides a query tool for exporting stop-level data for estimated ridership. The Research Team exported estimated ridership demographics at the stop-level from TBEST for post-processing and analysis in Microsoft Excel.<sup>4</sup> Values were aggregated to the route-level for comparison against the APC data.

Compared to the APC data, the out-of-the-box model from TBEST was overestimating the number of riders that used bus stops near commercial and heavily populated areas while underestimating college ridership. To better align the model with the APC data the Research Team adjusted the coefficients associated with the ridership discrepancies but achieved surprisingly similar results each time. The Research Team determined that using TBEST’s recommended validation process “snapped” the model estimation results to the route level totals of the APC data. The Research Team decided to remove the TBEST model validation from the ridership model in favor of calibration using model coefficients, land use data adjustments, and attractor designations via a sensitivity analysis process. The resulting calibrated model, run on the 2019 October GTFS, was within a reasonable margin of error from the APC data.

The Research Team then utilized the calibrated ridership estimation model to run a scenario using the proposed modified GTFS. The output from the 2019 GTFS model was termed “Control” and the output from the scenario model was termed “Forecast.” The Control and Forecast models were compared and the results indicated that the modifications increased ridership overall.

Figure 7. Model Summary

Model	GTFS Package Used	Description	TBEST	Observed Average		Difference	% Difference
			Validation Performed?	Daily Boardings (APC)	Predicted Average Daily Boardings		
1	10/9/19 from TransitFeeds	First model run, used the out of the box TBEST Land Use Model.	Y	46065	46009	-56	0%
2	10/9/19 from TransitFeeds	Edited single coefficient to assess change impact.	Y	46065	46006	-59	0%
3	10/9/19 from TransitFeeds	Edited single coefficient more to better assess impact on model.	Y	46065	46009	-56	0%
4	10/9/19 from TransitFeeds	Edited multiple coefficients to adjust for outliers.	Y	46065	46004	-62	0%
5	10/9/19 from TransitFeeds	Edited multiple coefficients to adjust for outliers.	Y	46065	46003	-62	0%
6	10/9/19 from TransitFeeds	Edited multiple coefficients to adjust for outliers.	Y	46065	46003	-62	0%
7	10/9/19 from TransitFeeds	Utilized the ServiceEdge Solutions Premium model.	Y	46065	46001	-64	0%
8	10/9/19 from TransitFeeds	Attempted model without validation process to determine impact.	N	46065	14778	-31287	-212%
9	10/9/19 from TransitFeeds	Adjusted constant coefficients to tweak modeled total ridership closer to APC total	N	46065	39426	-6639	-17%
10	10/9/19 from TransitFeeds	Adjusted constant coefficients to tweak modeled total ridership closer to APC total	N	46065	59376	13311	22%
11	10/9/19 from TransitFeeds	Adjusted constant coefficients to tweak modeled total ridership closer to APC total	N	46065	46657	592	1%
12	Sam Schwartz Modified	Using Model 10's coefficients on the modified GTFS - results were drastically	N	46065	19451	-26614	-137%
13	Sam Schwartz Modified	Verifying the results of of Model 11 by performing the entire process again from Model 11 and 12 produced identical results that were drastically different from Model 10. Reconstructed Model 10 from scratch to ensure process was performed	N	46065	46657	592	1%
14	10/9/19 from TransitFeeds	Adjusted constant coefficients to tweak modeled total ridership closer to APC total ridership.	N	46065	18869	-27196	-144%
15	Sam Schwartz Unmodified (REMIX Export)	Adjusted constant coefficients to tweak modeled total ridership closer to APC total ridership.	N	46065	165795	119730	72%
16	Sam Schwartz Unmodified (REMIX Export)	Adjusted constant coefficients to tweak modeled total ridership closer to APC total ridership.	N	46065	157037	110972	71%
17	Sam Schwartz Unmodified (REMIX Export)	Adjusted constant coefficients to tweak modeled total ridership closer to APC total ridership and succeeded.	N	46065	42454	-3611	-9%
Control	Sam Schwartz Modified	Ran the successful Control model coefficients on the GTFS with modified routes.	N	46065	45367	-698	-2%
Forecast	Sam Schwartz Modified						

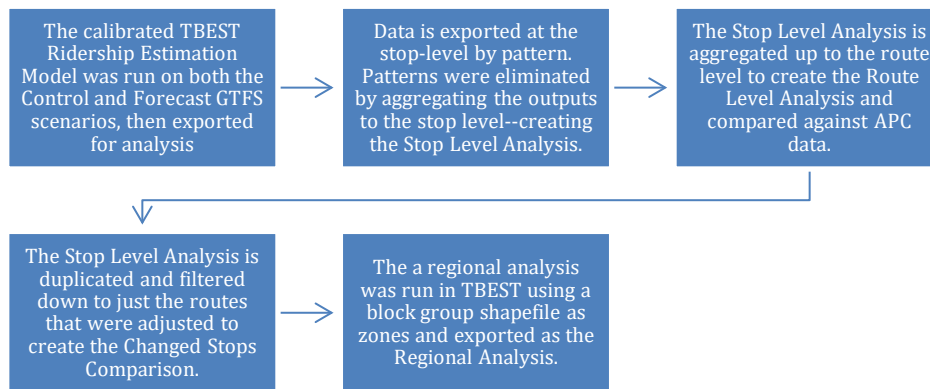
<sup>4</sup> Bunner, R., Catala, M., & Mistretta, M. (n.d.). TBEST 4.7 User Guide. *Martin Catala and Mark Mistretta Center for Urban Transportation Research (CUTR)*.

## Outcomes

The following lists data analysis products for comparing the forecast and control models:

- **TBEST Output (Control)** - Contains the raw output data from running the final model coefficients on the unmodified GTFS exported from Remix.
- **TBEST Output (Forecast)** - Contains the raw output data from running the final model coefficients on the modified GTFS that contained route adjustments.
- **Model Summary** - Outlines all model iterations with total ridership values compared to APC and a short description of what the model entailed.
- **Stop Level Analysis** - Select data from the TBEST Output Control and Forecast sheets, aggregated to the stop level (i.e., route patterns have been aggregated).
- **Changed Stops Comparison** - A concentrated version of the Stop Level Analysis in which only the Ridership values are shown and compared for only the routes that were modified.
- **Route Level Analysis** - Select data from the TBEST Output Control and Forecast sheets, aggregated to the route level (i.e., route patterns, directions, and stops have all been aggregated).
- **Regional Analysis** - Output of TBEST's "Regional Analysis" tool in which interzonal ridership is calculated based on the TIGER/Line 2019 New York Current Block Group shapefile.

Figure 8. Outcome Progression

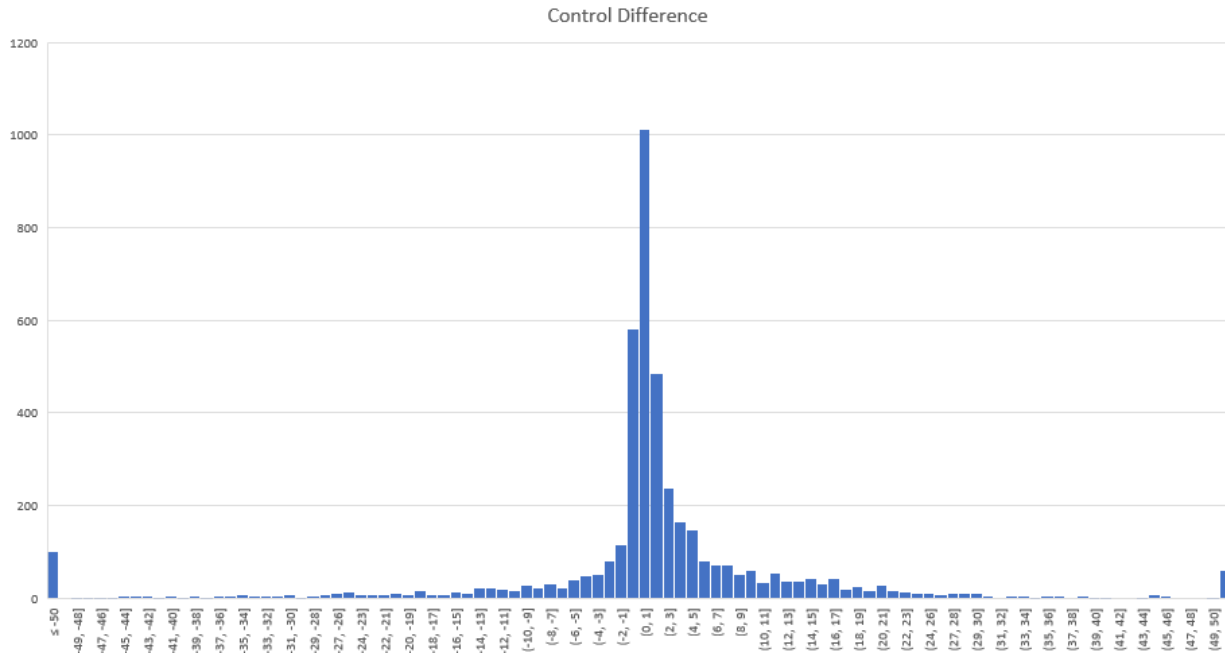


The Stop Level Analysis shown below was configured to evaluate and compare TBEST’s Ridership Estimations in both the Control (unmodified GTFS) and Forecast (modified GTFS) scenarios against the APC data. Individual stop ridership estimates are compared to identify differences from the APC data which are plotted in a histogram for high-level snapshot of the model outputs:

Figure 10. Stop Level Analysis

Route	Direction	Stop Description	Stop ID	APC - Observed Average		Forecast	Forecast / APC		Control / Forecast Difference	Control / Forecast Difference %
				Daily Boardings	Control		Difference	Difference %		
1	Eastbound	WOLF RD & COLONIE CENTER (00031)	31	106.43	21.10	-85.33	21.20	-85.23	0.10	0%
1	Eastbound	32 WOLF RD (BED BATH AND BEYOND) (00032)	32	56.29	19.00	-37.29	19.20	-37.09	0.20	1%
1	Eastbound	1010 CENTRAL AVE (00159)	159	43.29	17.50	-25.79	17.60	-25.69	0.10	1%
1	Eastbound	CENTRAL AVE & FULLER RD (00189)	189	48.29	10.60	-37.69	10.60	-37.69	0.00	0%
1	Eastbound	CENTRAL AVE & VAN BUREN AVE (00190)	190	13.86	8.90	-4.96	9.10	-4.76	0.20	2%
1	Eastbound	1160 CENTRAL AVE (SUNSET LANES) (00193)	193	21.00	8.30	-12.70	8.40	-12.60	0.10	1%
1	Eastbound	CENTRAL AVE & YARDBORO AVE (00195)	195	7.29	9.40	2.11	9.50	2.21	0.10	1%
1	Eastbound	CENTRAL AVE & HANNAFORD PLAZA - WEST MALL STATION (00198)	198	167.43	20.20	-147.23	20.30	-147.13	0.10	0%
1	Eastbound	709 CENTRAL AVE (SHOPRITE ALBANY) (00203)	203	3.71	21.20	17.49	21.40	17.69	0.20	1%
1	Eastbound	CENTRAL AVE & KING AVE (00205)	205	23.33	25.00	1.67	25.30	1.97	0.30	1%
1	Eastbound	Central Ave & N. Allen St - N. Allen Station (00207)	207	104.86	25.30	-79.56	25.50	-79.36	0.20	1%

Figure 9. Control/APC Difference Histogram



This histogram’s X axis are the difference values between the Control scenario’s estimated ridership and the APC data provided while the Y axis is the quantity of route/stop combinations with that value. The graph depicts a majority of the ridership estimations from the model were exactly the same (0) or slightly overestimated (1). There is a normal distribution of difference values with a slight skew towards the positive values indicating that the Control model is more likely to overestimate ridership at the stop level. The spikes on the far left and right are values that were considered outliers—greater than or less than 50



riders. By analyzing the stop locations that show up in these outliers, the Research Team determined that the model was overestimating shopping-related ridership and underestimating college ridership.

It is known that transit models assign ridership more accurately at the route level than at the stop level. Therefore, the Research Team aggregated the stop level data to the route level to better account for model gravity issues associated with stop level granularity. The table below shows some of the routes in the ecosystem with the modified routes highlighted yellow. The “Control/Forecast % Difference” column identifies the change in ridership according to the adjusted model. Some routes indicated a drop in ridership, while Route 80 was estimated to increase substantially likely due to a drastic increase in length and connectivity. Routes that were not directly edited either had no change or a small increase in ridership—attributed to an increase in accessibility from Route 80’s new service area.

Figure 11. Route Level Analysis

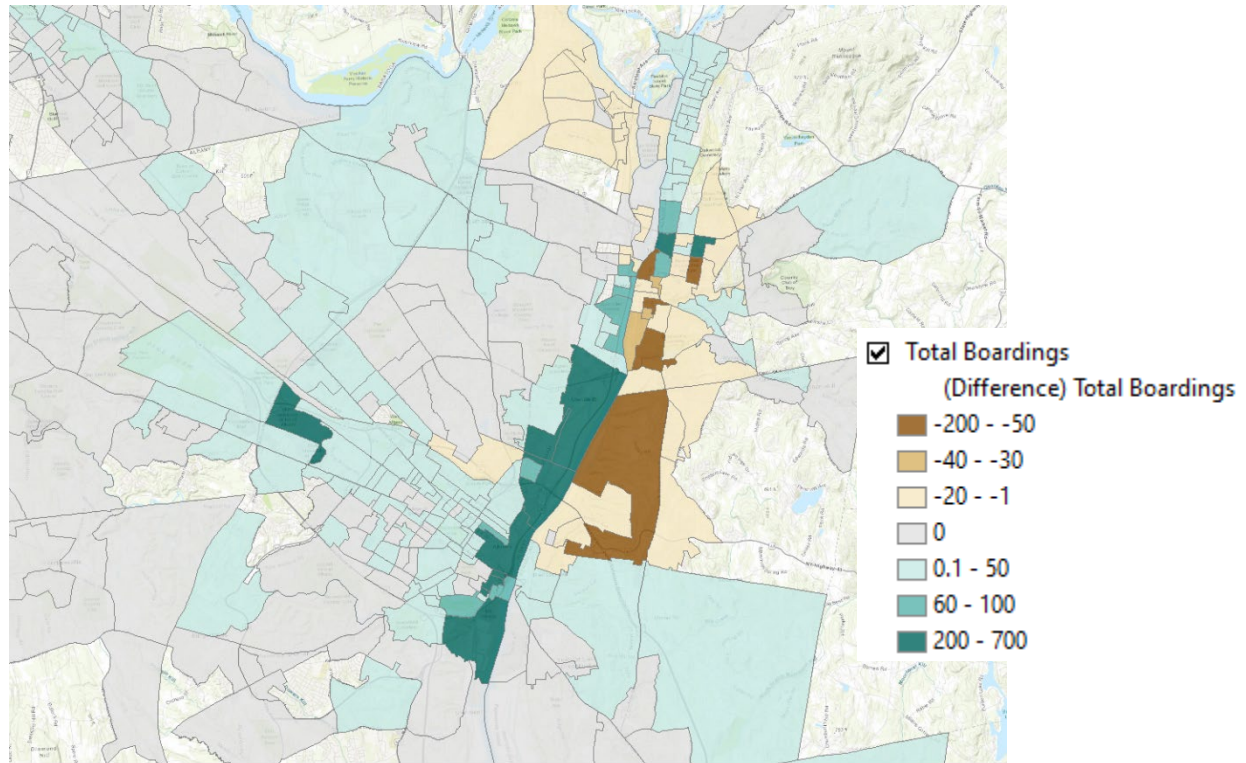
Route	Route Modifications	Observed Boardings (APC)	Predicted Boardings (Control)	APC/Control Difference	APC/Control % Difference	Predicted Boardings (Forecast)	Control/Forecast Difference	Control/Forecast % Difference
1		3077.62	2015.50	-1062.12	-35%	2033.60	18.10	1%
7		937.48	1228.40	290.92	31%	1286.50	58.10	5%
10		1938.76	2031.40	92.64	5%	2054.20	22.80	1%
11		821.95	770.90	-51.05	-6%	829.60	58.70	8%
12		5543.14	2149.70	-3393.44	-61%	2219.10	69.40	3%
13		1125.62	1534.90	409.28	36%	1547.50	12.60	1%
18		1278.10	2072.70	794.60	62%	2088.30	15.60	1%
22	x	2817.14	1815.10	-1002.04	-36%	2544.70	729.60	40%
80	x	686.46	812.40	125.94	18%	3485.40	2673.00	329%
85		1904.52	2116.00	211.48	11%	2246.20	130.20	6%
87	x	1283.67	1172.10	-111.57	-9%	874.00	-298.10	-25%
100		3052.95	2686.10	-366.85	-12%	2727.30	41.20	2%
114		1486.95	1716.10	229.15	15%	1784.50	68.40	4%
117		354.90	852.70	497.80	140%	861.10	8.40	1%
125		586.95	1796.60	1209.65	206%	1815.30	18.70	1%
138		746.38	1910.80	1164.42	156%	1931.00	20.20	1%
155		125.43	163.90	38.47	31%	166.60	2.70	2%
182		1299.10	2037.80	738.70	57%	2038.10	0.30	0%
214		518.33	1046.10	527.77	102%	1070.20	24.10	2%
224	x	1159.24	2069.80	910.56	79%	1269.20	-800.60	-39%
289	x	348.33	464.90	116.57	33%	574.60	109.70	24%
354		425.95	379.80	-46.15	-11%	380.90	1.10	0%
355		3412.05	1114.10	-2297.95	-67%	1116.90	2.80	0%

TBEST’s Regional Analysis function assesses interzonal relationships at a flexible geographic level depending on what geospatial dataset is used to determine zones. The Research Team utilized the TIGER/Line 2019 New York Current Block Group shapefile to perform the Regional Analysis on both the Control and Forecast scenarios. The Research Team combined the two outputs into a single dataset to calculate the difference in Total Boardings. The dataset was then imported into ArcMap to construct a map of the difference of Total Boardings between the Control and Forecast scenarios:

Figure 12 - Regional Analysis

GEOID	(Control) Direct Boardings	(Forecast) Direct Boardings	(Difference) Direct Boardings	(Control) Transfer Boardings	(Forecast) Transfer Boardings	(Difference) Transfer Boardings	(Control) Total Boardings	(Forecast) Total Boardings	(Difference) Total Boardings
360010001001	210	479	269	34	172	138	244	651	407
360010001002	114	151	37	10	43	33	124	194	70
360010002001	608	613	5	180	183	3	788	796	8
360010002002	113	114	1	16	16	0	129	130	1
360010002003	439	442	3	24	24	0	463	466	3
360010002004	981	1,031	50	107	120	13	1,088	1,151	63
360010003001	245	249	4	76	77	1	321	325	4
360010003002	126	127	1	33	33	0	159	160	1
360010003003	36	35	-1	11	11	0	47	46	-1
360010003004	622	627	5	95	95	0	718	722	4
360010004011	119	121	2	17	18	1	136	139	3
360010004031	165	168	3	68	69	1	232	236	4

Figure 13 - Difference in Total Boardings by Block Group



## Training

As part of this pilot process, staff at CDTA expressed interest in setting up TBEST to be used and assessed internally through a series of trainings. Four separate two-hour tech transfer sessions were scheduled and administered by the Research Team:



Figure 14. Training Progression

## Discussion

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### Limitations

Below are some of the of the methodological challenges and how the team addressed them:

- **TBEST Limitations**
  - The TBEST gravity model utilizes U.S. Census and employment data to estimate ridership at the stop-level. Due to the limitation in the U.S. Census around college populations, the model drastically underestimates college ridership. The model also overestimates state worker ridership likely due to how it clusters work sectors.
  - The TBEST model provides excellent boarding information at the stop-level but does not offer alighting data.
  - The Socio-Economic (SE) data package that TBEST uses to operate is either hosted by an entity or constructed manually from source downloads. The SE package construction is time-consuming and requires advanced technical understand. When the data is downloaded and stored locally, analysts would need to construct or buy new SE packages periodically or risk utilizing stale data.
  - Installation of the program was a complicated process due to potentially conflicting required dependencies and organization network permissions. It is currently only on one shared remote desktop computer. If CDTA wishes to institutionalize TBEST, additional installations could be time prohibitive.
- **Commute Estimates**
  - In accordance with the spirit of the open-source project, the Research Team decided to utilize the freely available CTPP data for journey to work origin-destination estimates. This data is only available at the census tract level, which is a higher aggregation level than desirable. In the future, the Research Team recommends using Replica data which is now available to the MPOs on a statewide contract.

### Lessons Learned

- **Initial Model Results**
  - Following the TBEST User Guidance workflow, the initial model run was validated against observed APC ridership data provided by CDTA on a stop-by-stop basis. The largest discrepancies between observed ridership were at universities and CBDs.
- **TBEST Validation**
  - The software utilizes a “validation” function for TBEST Ridership Models. This functionality allows the user to input Weekday, Saturday, and Sunday daily observed ridership values for all routes. The software compares the observed ridership values to the model estimations and calculates a Route Adjustment Factor that adjusts the model’s

ridership estimations to resemble the observed ridership for that route. This essentially snaps the ridership values to nearly exactly match the route-level observed ridership values. The Research Team viewed the validation step as a model override, undermining the efficacy of the underlying gravity model that TBEST uses. Once the Research Team discovered this function of the validation process, the Research Team decided to no longer implement that step in ridership modeling from that point forward.

- Model Calibration
  - When the validation process was removed from the TBEST Ridership Estimation Model, the results disagreed dramatically with CDTA's APC data. The invalidated model underestimated ridership by -212%. Analysis of stop-level results indicated that discrepancies predominately occurred at stops near universities and CBDs. The Research Team altered model coefficients, land use data, and assigned attracters systematically in an attempt to better align the model with observed ridership. The Research Team conducted a sensitivity analysis methodically changing one model component at a time essentially fine-tuning the TBEST gravity model to the CDTA Region. The model could use additional calibration to improve its efficacy.

### Replicability

This project is replicable in regions that have access to TBEST and its underlying socioeconomic data. CDTA was trained on how to replicate this project and appears able to do so. Regions that don't have familiarity with TBEST or lack the resources to set up the data environment are less likely to be able to replicate this project.

### Recommendations

The Research Team recommends that CDTA institutionalize the use of TBEST for market analyses and for testing proposed network changes. The training process was a success. There is one staff member at CDTA that is proficient with TBEST and others that have expressed interest. The Research Team recommends that CDTA update the SE package and calibrate the model to 2022 observed ridership. Hosting the SE data package at the state-level by either NYSDOT or NYSAMPO would dramatically reduce the friction for new users to begin performing analyses.

## Appendix A: Technical Design

This section outlines the technical analysis for the gap analysis, origin-destination analysis, and ridership modeling.

### 1. Gap Analysis

As described in the previous sections, the gap analysis was conducted to understand the transit service provision and transit demand within the City of Troy. To understand how transit service aligns with the demand and identify the service gaps, the team conducted a service provision analysis using ArcGIS and compared it to the Transit Propensity Index that was developed by CDTA. The technical steps are described below.

#### *CDTA TPI*

Identifying gaps between transit supply and demand required a clear understanding of the demand for public transit. In this pilot, CDTA's TPI was used to understand the transit demand in Troy. The TPI integrates multiple demographic and socioeconomic factors at the census block group level and applies weights to each of the factors. The factors include:

- Total population per square mile (ACS 2019, 5-Year Estimates)
- Population over 65+ per square mile (ACS 2019, 5-Year Estimates)
- Population below the poverty line per square mile (ACS 2019, 5-Year Estimates)
- Households with more workers than vehicles per mile (ACS 2019, 5-Year Estimates)
- 4-way intersection per previous TPI
- Mall / shopping plaza square footage per mile (Google maps)
- Students per square mile (Book of lists/Google)
- Hospital beds per square mile (American Hospital Directory)
- Jobs per square mile (LEHD 2019)
- Low-paying jobs per square mile (LEHD 2019)

#### *Service Provision Analysis*

Twelve CDTA bus routes served the City of Troy in 2019 and were included in this analysis:

- Route 22 Albany - Troy via Watervliet
- Route 80 – Troy/Fifth Avenue
- Route 85 – Fifth Avenue
- 87 – Hoosick St – RPI
- 182 – Troy – Albany via Cohoes and Latham
- 224 – Albany – Troy via I-90
- 286 – Troy/Wynantskill
- 289 – Griswold Heights – St. Mary's Hospital
- 370 – Troy/Schenectady
- 522 – Cohoes/Troy/Albany Express
- 809 – South Albany – Troy Shuttle
- 815 – Troy Shopping Bus

The bus stop locations served by the analyzed routes were imported, as a CSV file, into ArcGIS and visualized using the Display XY Data tool. Several shapefiles were used as a base in ArcGIS including CDTA bus routes (system-wide); Census block groups for Albany, Montgomery, Rensselaer, Saratoga, and Schenectady counties; the boundary for the City of Troy, and water bodies.

First, ¼-mile buffers were mapped around each bus stop to estimate the walkshed and the service area for each route. By only creating buffers around the stops this excluded no-stop segments of routes such as highways.

Next, the weekly scheduled revenue hours (weekdays, Saturdays, and Sundays) were calculated for each route using the 2019 service provision dataset.

Equation 1: Weekly Scheduled Revenue Hours Calculation

$$\text{Weekly Scheduled Revenue Hours} = (\text{Number of weekdays} * \text{weekday revenue hours}) + \text{Saturday revenue hours} + \text{Sunday revenue hours}$$

The weekly scheduled revenue hours for each route are shown in **Table 7**. The revenue hours were assigned to the buffer area of each route in ArcGIS to reflect the service provided, as shown in **Figure 15**. To determine the distribution of service, revenue hours per square mile of the buffered area were calculated.

Figure 15 - Service hours Allocation per Buffer Area in ArcGIS

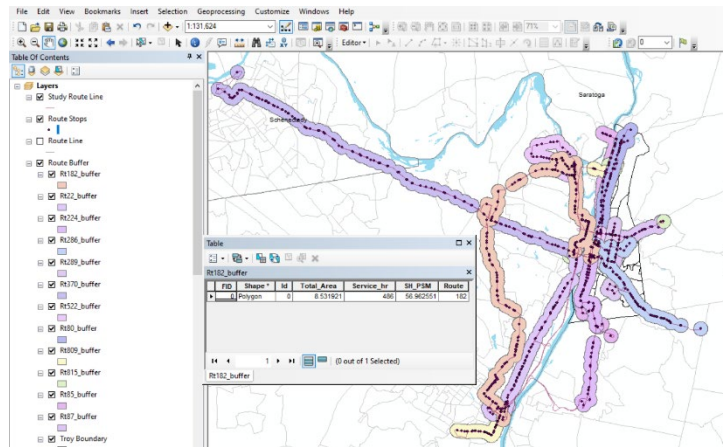


Table 7. Total Service Hours per route

Route	Scheduled Revenue Hours			Total
	Weekday	Saturday	Sunday	
22	128.0	68.8	49.7	759
80	40.4	25.8	10.7	239
85	74.7	48.5	26.2	448
87	52.2	38.3	21.7	321
182	82.9	42.9	28.0	486
224	62.1	0	0	311
286	18.1	15.6	0	107
289	16.0	16.0	0	96
370	79.6	55.1	31.8	485
522	9.0	0	0	45
809	1.9	0	0	10
815	2.5	0	0	13

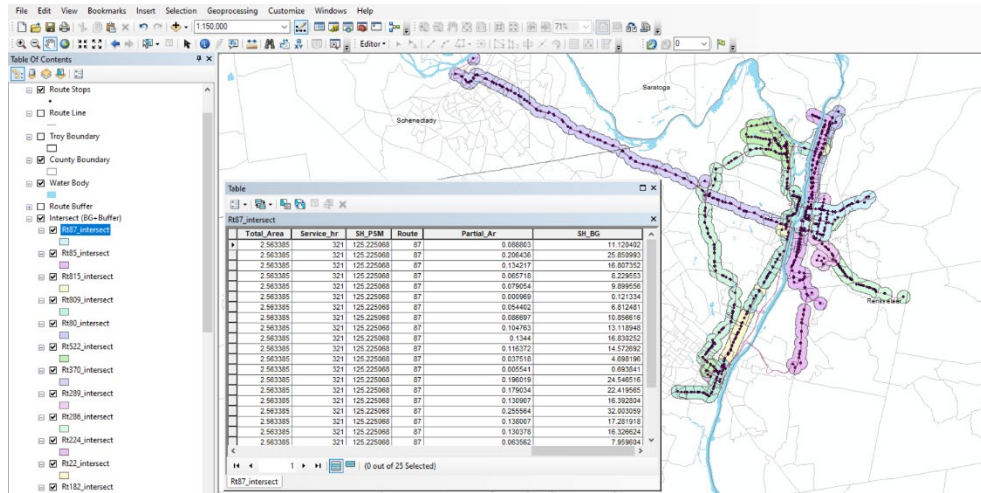
To calculate the portion of the buffer that falls within each census block group, the Intersect Tool was used with the input features as **individual** route buffers and census block groups, as shown in **Figure 16**. The partial area was calculated by creating a new column for each buffered zone. Within the same attribute table, another new column was created to calculate service hours in the block group by running a field calculator with the following equation:

Equation 2: Service hours per Census Block Group

$$\text{Service hours in the block group} = \text{partial area} * \text{service hours per sq mile}$$

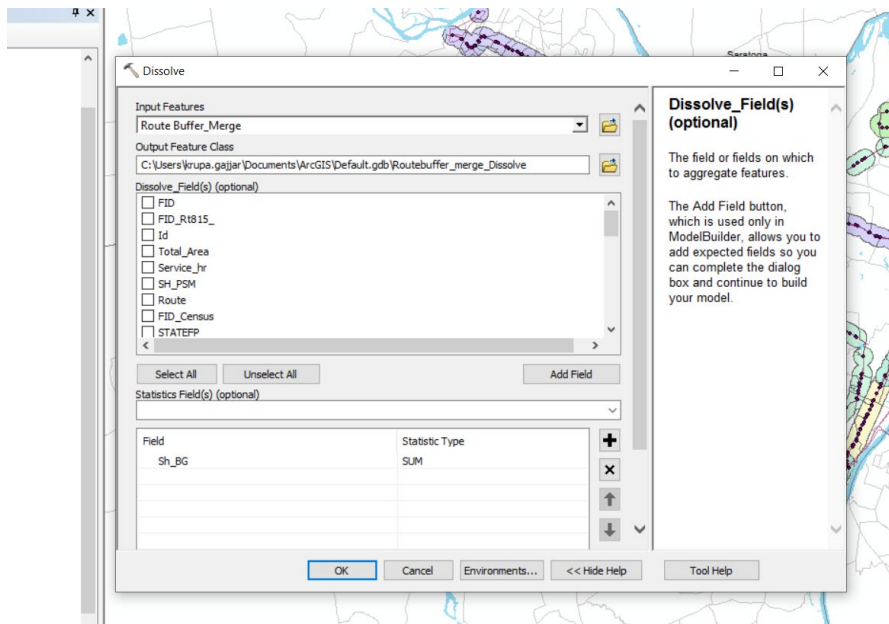


Figure 16 - Calculation of Service Hours per Census Block Groups in ArcGIS



To determine the combined service hours of all buffered areas within each census block group, the ArcGIS Merge tool was used on the route buffer. The Merge output layer was later dissolved by block group ID (using the Dissolve Tool) and summed based on the service hours in the block group column. A snapshot of the ArcGIS dissolve tool is shown in **Figure 17**.

Figure 17 - ArcGIS Dissolve Tool was used to determine the total buffer area within each census block group



Once the dissolve tool was run successfully, a new total area of the buffer was calculated. Since the Hudson River runs along the boundary of the City of Troy, some of the buffer areas overlapped with the river. To calculate the appropriate land area, the water body was clipped from the buffer, and the area was subtracted from the route buffer area. The partial final buffer area within each census block group was determined using the following equation:



Equation 3. Percent of Buffer Area

$$\text{Portion of buffer area} = \text{final buffer area} / \text{census block group area} * 100$$

As the final step in the service provision analysis, to generate a comparable indicator of transit service provision throughout the city, census block group scores were calculated by multiplying the total service hours in the block group by the portion of the buffer area. Scores were classified into five equal categories.

Equation 4. Transit Service Provision Score

$$\text{Total Score} = \text{percent of buffer area} * \text{service hours in the block group}$$

### Gap Analysis

The gap analysis was conducted based on the results from the transit supply analysis and CDTA’s TPI. It categorized the census block groups in Troy based on the differences between supply and demand and identified three sets of areas: (1) areas of oversupply, (2) areas where demand exceeds service supply, and (3) areas where the service level matches the demand. The gap analysis was conducted using ArcGIS and Microsoft Excel.

Using ArcGIS, the attribute table of the ‘total score’ for the Transit Supply and CDTA TPI layer were exported individually to analyze further in Excel. Taking the lower and upper boundaries of the five classes, each census block group was assigned a demand score and a supply score, ranked from one to five, as shown in **Figure 18**.

Figure 18 - Excel Workbook Showing Categorization

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	FID	STATEFP	COUNTYFP	TRACTCE	BLKGRPCE	GEOID	NAMELSAD	TotalScore	Class	Service Level		Lower boundary	Upper Boundary	Quantile	Level of Service	Count
2	5467	36	83	41300	2	360830413002	Block Group 2	0.283845863	1	Very Low		0	8.1	1	Very Low	9
3	6431	36	83	41400	2	360830414002	Block Group 2	0.464872335	1	Very Low		8.2	13.2	2	Low	10
4	5596	36	83	41200	1	360830412001	Block Group 1	2.536100646	1	Very Low		13.3	20.7	3	Medium	10
5	5597	36	83	41200	2	360830412002	Block Group 2	3.380207664	1	Very Low		20.8	31.1	4	High	10
6	8057	36	83	40500	1	360830405001	Block Group 1	3.794183957	1	Very Low		31.2	105.2	5	Very High	9
7	5598	36	83	41200	3	360830412003	Block Group 3	5.56890092	1	Very Low					TOTAL	48
8	5591	36	83	41100	3	360830411003	Block Group 3	6.191255581	1	Very Low						
9	5577	36	83	40900	4	360830409004	Block Group 4	7.495280501	1	Very Low						
10	14892	36	83	40200	6	360830402006	Block Group 6	8.089985741	1	Very Low						
11	5594	36	83	41100	1	360830411001	Block Group 1	8.645882493	2	Low						
12	14891	36	83	40200	3	360830402003	Block Group 3	8.879917903	2	Low						
13	5518	36	83	40100	3	360830401003	Block Group 3	10.06700167	2	Low						
14	5520	36	83	40200	5	360830402005	Block Group 5	10.24238491	2	Low						
15	5469	36	83	40100	5	360830401005	Block Group 5	10.47870588	2	Low						
16	5521	36	83	40300	1	360830403001	Block Group 1	12.00274956	2	Low						
17	8049	36	83	40200	2	360830402002	Block Group 2	12.07139602	2	Low						
18	13960	36	83	40900	3	360830409003	Block Group 3	12.4492254	2	Low						
19	5599	36	83	41200	4	360830412004	Block Group 4	12.89789266	2	Low						
20	5578	36	83	40900	2	360830409002	Block Group 2	13.1123187	2	Low						
21	2986	36	83	41400	1	360830414001	Block Group 1	13.42127131	3	Medium						
22	5595	36	83	41100	2	360830411002	Block Group 2	14.41141227	3	Medium						
23	5504	36	83	40600	2	360830406002	Block Group 2	15.0200695	3	Medium						
24	5517	36	83	40100	2	360830401002	Block Group 2	15.1043701	3	Medium						

The supply and demand levels were then compared to identify the gaps. Gap values were calculated based on the difference between the supply and demand ranking for each block group. **Table 8** shows the category distribution. The gap values ranged from -4 and 4. If the gap value for a given census block group was between -4 and -2, it was categorized as *high supply*, with more transit supply than demand. If the gap value was between -1 and 1, it was categorized as a *match*, meaning that the block group had equal

supply and demand. If the gap value was between 2 and 4, it was categorized as *high demand*, with more transit demand than supply. **Figure 19** shows the snapshot of the Excel analysis.

Table 8. Gap Analysis Category Distribution

Gap value	Gap Analysis Categorization
-4	GAP - high supply
-3	GAP - high supply
-2	GAP - high supply
-1	Match
0	Match
1	Match
2	GAP - high demand
3	GAP - high demand
4	GAP - high demand

Figure 19 - Excel Workbook Showing Categorization

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	STATEFP	COUNTYFP	TRACTCE	BLKGRPC	GEOID	NAMLSAD	Demand_Level	Service_Level	Delta	Gap	Delta value	Gap Analysis Distribution	Number of Block Groups	Percentage	
2	36	83	40900	4	360830409004	Block Group 4	5	1	4	GAP - high demand		-4 GAP - high supply	1	2%	
3	36	83	41300	4	360830413004	Block Group 4	5	4	1	Match		-3 GAP - high supply	3	6%	
4	36	83	40700	1	360830407001	Block Group 1	5	5	0	Match		-2 GAP - high supply	5	10%	
5	36	83	40800	1	360830408001	Block Group 1	5	5	0	Match		-1 Match	6	13%	
6	36	83	40600	1	360830406001	Block Group 1	5	3	2	GAP - high demand		0 Match	18	38%	
7	36	83	40700	2	360830407002	Block Group 2	5	5	0	Match		1 Match	5	10%	
8	36	83	40600	2	360830406002	Block Group 2	5	3	2	GAP - high demand		2 GAP - high demand	7	15%	
9	36	83	40200	2	360830402002	Block Group 2	5	2	3	GAP - high demand		3 GAP - high demand	2	4%	
10	36	83	40900	3	360830409003	Block Group 3	5	2	3	GAP - high demand		4 GAP - high demand	1	2%	
11	36	83	40200	3	360830402003	Block Group 3	4	2	2	GAP - high demand			48		
12	36	83	40100	3	360830401003	Block Group 3	4	2	2	GAP - high demand					
13	36	83	40700	4	360830407004	Block Group 4	4	5	-1	Match					
14	36	83	40100	5	360830401005	Block Group 5	4	2	2	GAP - high demand					
15	36	83	40300	1	360830403001	Block Group 1	4	2	2	GAP - high demand					
16	36	83	40200	5	360830402005	Block Group 5	4	2	2	GAP - high demand					
17	36	83	40200	1	360830402001	Block Group 1	4	3	1	Match					
18	36	83	40600	3	360830406003	Block Group 3	4	4	0	Match					
19	36	83	41300	5	360830413005	Block Group 5	4	4	0	Match					
20	36	83	40500	2	360830405002	Block Group 2	4	4	0	Match					
21	36	83	40400	1	360830404001	Block Group 1	3	4	-1	Match					
22	36	83	40800	2	360830408002	Block Group 2	3	4	-1	Match					
23	36	83	40700	4	360830407004	Block Group 4	2	3	0	Match					

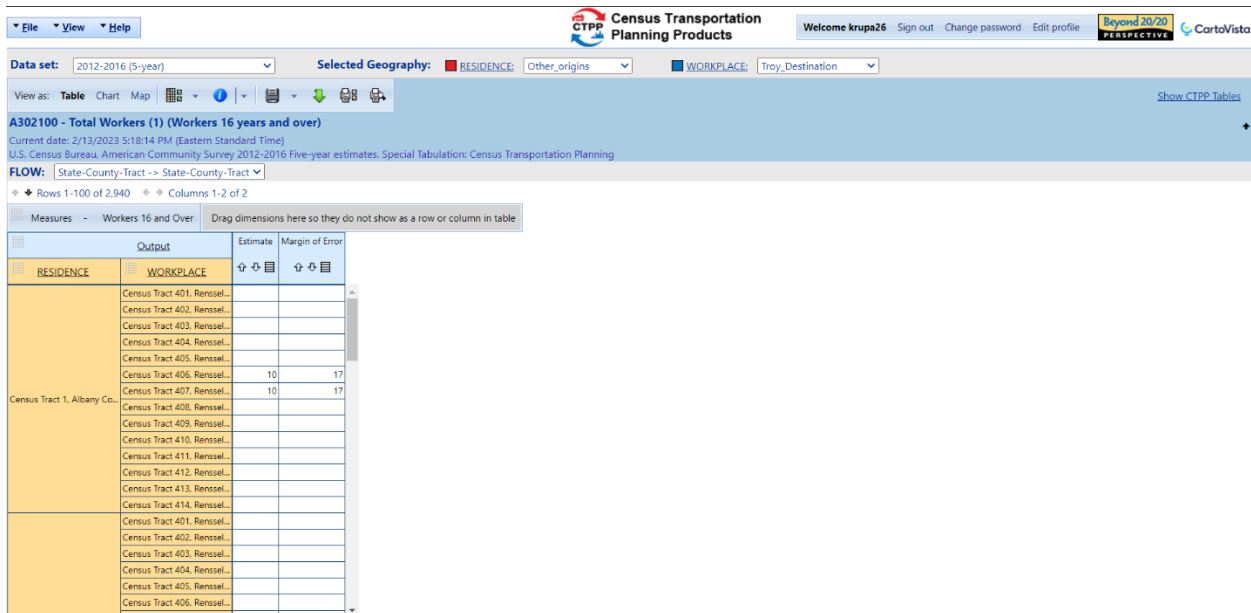
To visualize the gap analysis results, the CSV was imported into ArcGIS and joined to the Troy census block groups shapefile.

## 2. Origin-Destination Analysis

To determine the travel pattern of workers, an O/D analysis was conducted at the census tract level for all the workers over the age of 16 using CTPP data. Two datasets were gathered based on the place of residence and workplace, one for trips originating in Troy and one for trips destined for Troy.

CSV data tables and shapefiles were downloaded for Troy as the origin, 2019 Part 3: Flows; Table A302100 – Total Workers (1) (Workers 16 years and over), where selected geography was: residence = census tracts within City of Troy and workplace = all the census tracts within Albany, Schenectady, Saratoga, Rensselaer County. Similarly, for Troy as the destination, Table A302100 – Total Workers (1) (Workers 16 years and over) was used, where selected geography was: residence = all the census tracts within Albany, Schenectady, Saratoga, Rensselaer County, and workplace = census tracts within City of Troy. Then both the shapefiles were imported into ArcGIS for further analysis. **Figure 20** shows the snapshot of the CTPP website.

Figure 20 - Snapshot of CTPP website



In ArcGIS, the O/D pairs with Troy as the destination were visualized and broken into three categories (51–100, 101–150, and over 151). As the O/D data was analyzed to identify origin and destination hotspots for transit routes, O/D pairs with fewer than 50 trips were not considered in the analysis. The O/D map for all trips can in found in **Appendix B**. Similar steps were conducted to analyze the O/D pairs with Troy as the origin.

### 3. TBEST Ridership Analysis Tutorial

The TBEST Ridership Analysis utilizes the software’s ridership model estimation tool to generate ridership values and demographics based on demographics, connectivity, surrounding parcels, and a variety of other data. The following are the steps required to generate the ridership analysis after the software has been installed and setup according to the TBEST User Manual.

#### Scenario Creation

In the software’s “Explorer” tab, two scenarios are constructed by right clicking the “Scenarios” folder under the established Transit System. These two scenarios will be titled “Unmodified” and “Modified”, but otherwise be setup the same with the default data sources. For this analysis, the Mean Annual Wage was set to \$55,912, the average mean annual wage for all counties in the CDTA system at the time of this analysis. Annual Growth Rate was set to 0% as the scope of this analysis was not to forecast any data beyond the years of the datasets.

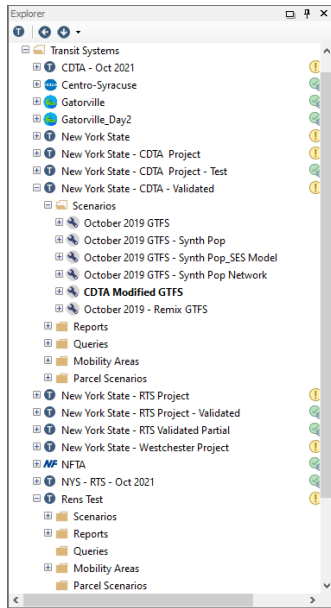


Figure 21 - Scenario Creation in TBEST

Next, both scenarios need to have their corresponding GTFS files imported. “GTFS Import/Export Tools” can be accessed by right clicking one of the newly created scenarios. Select “Import Routes from GTFS”. For this analysis, the Unmodified GTFS file from Remix was selected for the “Unmodified” scenario and the GTFS that has had route restructuring was selected for the “Modified” scenario. All GTFS Service Periods (Weekday, Saturday, Sunday) were selected from both GTFS files and imported.

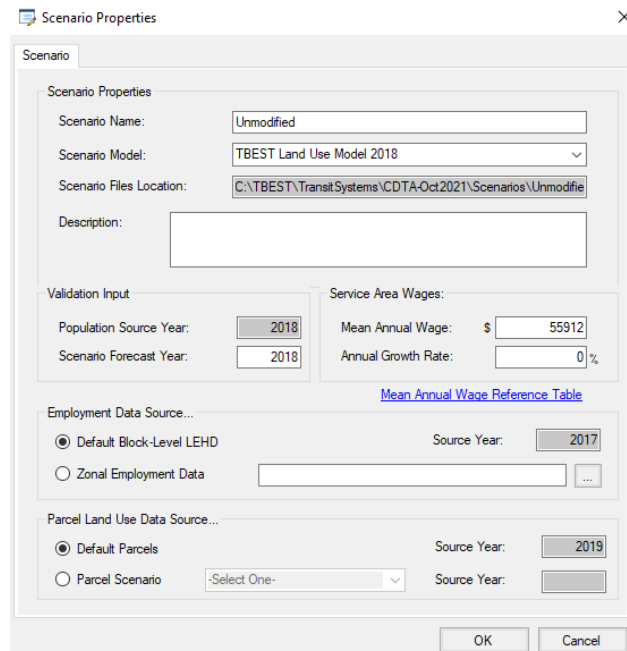
Right click and select “Set Socio-Economic Growth Rates...” and set all values to “0%” for both scenarios.

#### Editing and Running the Ridership Estimation Model

This pilot project explored the process of tweaking the model that the Ridership Estimation tool uses.

This process is **not** recommended by the software developer as the model required a significant process to construct.

Next, both scenarios need to have their corresponding GTFS files imported. “GTFS Import/Export Tools” can be accessed by right clicking one of the newly created scenarios. Select “Import Routes from GTFS”. For this analysis, the Unmodified GTFS file from Remix was selected for the “Unmodified” scenario and the GTFS that has had route restructuring was selected for the “Modified” scenario.



The first step in adjusting the TBEST model is to duplicate the original model to ensure that there is a back-up if reversion needed to be made.

In the “Explorer” panel, click the “+” button next to the “Models” folder to expand it and show all the models. Right click the “TBEST Land Use Model 2018” and click “Copy”. Enter the new model’s name as “Modified TBEST Model”.

Right click the “Modified TBEST Model” and click “Equation Coefficients” to adjust the coefficients of the model. Below is a list of changes made to the model during this pilot project:

Table 9. Altered Coefficients in TBEST Model

Equation	Category	Variable Description	Variable Key	AM PEAK	OFF PEAK	PM PEAK	NIGHT	SATURDAY	SUNDAY
Direct Boarding	Constant	Bus Constant	BUS-ONE	-6.242	-5.838	-6.555	-6.522	-2.424	-2.683
Direct Boarding	Employment	Share of Service Employment	SHARE_SERVEMP	0.25	0.25	0.25	0.25	0.25	0.25
Direct Boarding	Special Generators	Shopping Mall	MALLS	0.643	1.658	2.235	0	1.65	1.967
Direct Boarding	Special Generators	University	UNIVERSITY	2	2	2	2	2	2

With a new model available to use, update the model used by both scenarios by right clicking the scenario, selecting “Properties”, and choosing “Modified TBEST Model” from the “Scenario Model” drop-down menu. Click “Okay” to accept changes.

TBEST supports multiple scenario ridership estimation model runs which can be accessed by right clicking the “Scenarios” folder and clicking “Batch Model Run”. Check the box for both “Unmodified” and “Modified” scenarios and all time periods before clicking “Run Model”.

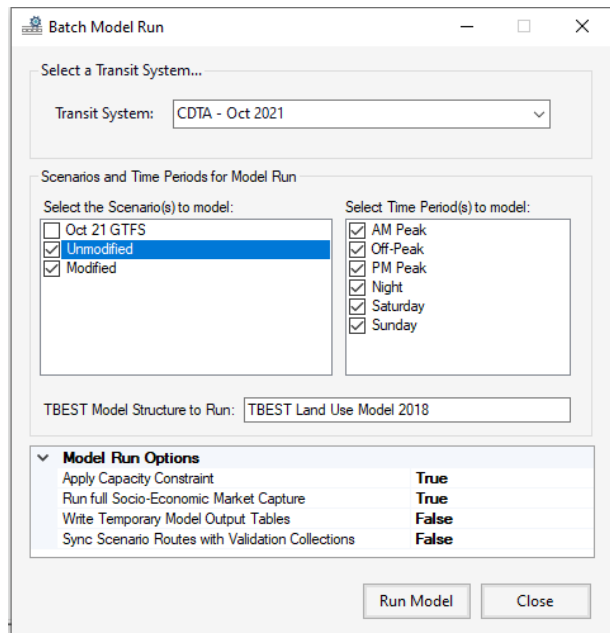


Figure 22 - TBEST Batch Model Run Window

### Exporting and Post-Processing the Ridership Estimations

TBEST’s Ad Hoc Query can be used to both access and export the Ridership Estimation Model results. For stop-level demographics, the Category is set to “Route Pattern Stops”, the “In-Service Results Only” box is unchecked, and the query statement is “1=1” to capture all of the entries. When the “Apply Query” button is pressed, the tool will select everything on the map and generate a table with all of the attributes of a stop by each pattern of each route. In the bottom-right of this tool, there is an Excel icon that exports the table to an Excel file.

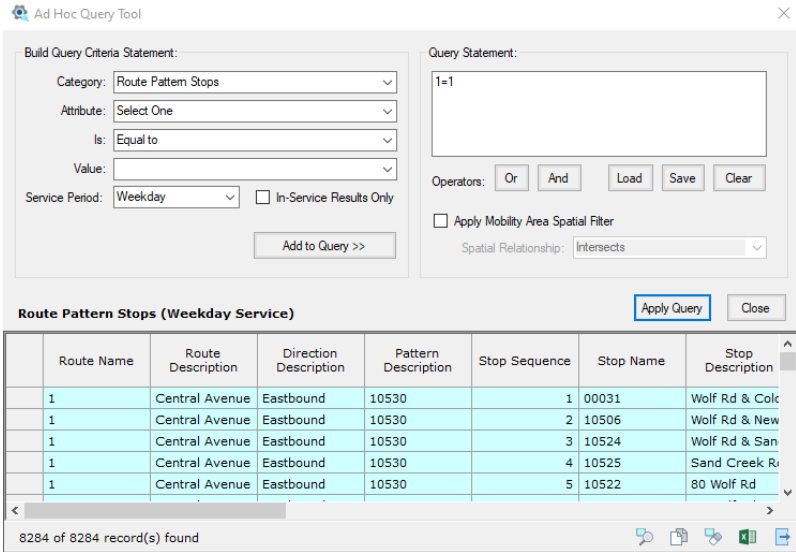


Figure 23 - TBEST Query Tool

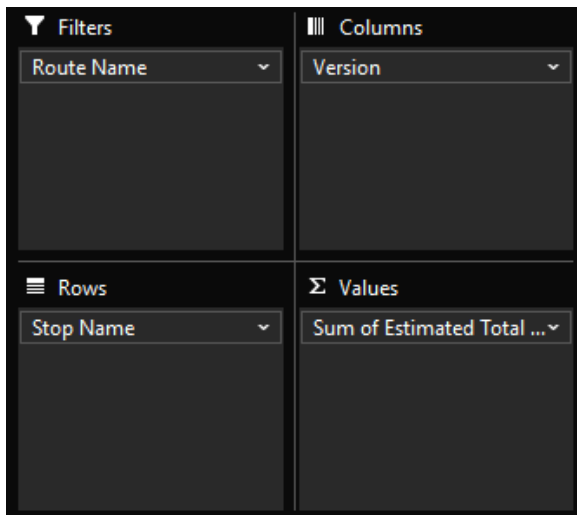


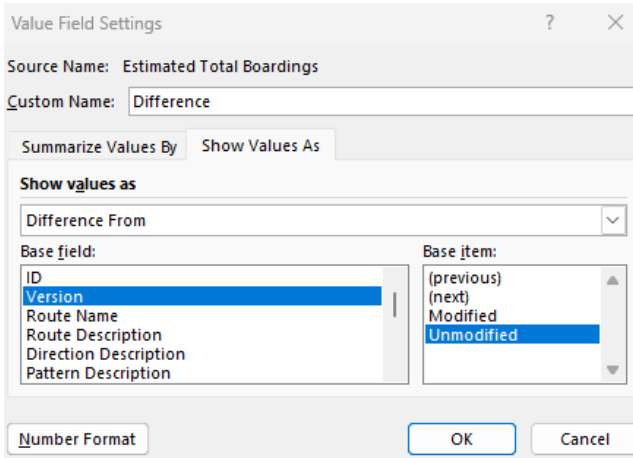
Figure 24 - Pivot Table Functions

Once in Excel format, the outputs can be formatted in several ways to compare the Unmodified and Modified ridership estimations. The TBEST export lends itself perfectly to Excel’s pivot table functionality. In both the Unmodified and Modified sheets, unhide all columns and insert a new column in the same location on both sheets with the header “Version”. In the first cell beneath the header, type “Unmodified” or “Modified”, then double click the green square in the bottom-right of the cell to duplicate that value for all entries in the sheets. Combine the sheets into one by pressing “Ctrl+A” and “Ctrl+C” to select and copy all of one sheet, then below the other sheet’s data, “Ctrl+V” to paste. Delete the duplicate header row. Press

“Ctrl+A” to select all data in the table, then Insert>PivotTable, and click “OK” to construct a new sheet in with Pivot Table functions on the right side:

Route-Level Ridership  
 Columns: Version  
 Rows: Route Name  
 Values: Sum of Estimated Total Boardings

Stop-Level Ridership  
 Filtering: Route Name  
 Rows: Stop Name  
 Values: Sum of Estimated Total Boardings



To create a difference table, drag “Estimated Total Boardings” to the “Values” section again. Click it and select “Value Field Settings” to open the configuration window. Change the Custom Name to “Difference”, click “Show Values As”, select the Base Field as “Version”, and the Base Item as “Unmodified”. Clicking “OK” will update your pivot table to include a column that calculates how ridership has changed from the Unmodified scenario.

Figure 25 - PivotTable Value Field Settings

### Performing a Regional Analysis

The TBEST Regional Analysis tool can be accessed in the “Reports” dropdown of the toolbar which brings up a configuration window. This project performed the Regional Analysis of weekday ridership total boarding estimates using the TIGER/Line 2019 New York Current Block Group shapefile<sup>5</sup>. The shapefile’s unique identifier for block groups in the attribute field is “GEOID” that needs to be converted to an integer using ArcGIS into a new field titled “GEOIDINT”. In the Configuration window, this attribute can be selected for the Area ID once it has been converted. Click “Apply” to generate the analysis.

GEOIDINT	Inbound Transfer Opportunities	Outbound Transfer Opportunities	Direct Boardings	Transfer Boardings	Total Boardings	Stop Arrivals
360010001001	165	168	210	34	244	1,235
360010001002	86	76	114	10	124	292
360010002001	1,864	1,871	608	180	787	1,501
360010002002	220	213	113	16	129	120
360010002003	349	309	438	24	462	253

Figure 26 - TBEST Regional Analysis

The Regional Analysis can be performed for both the Unmodified and Modified scenarios, exported, and combined into a single Excel document. Similarly to the previous post-processing, a difference column should be generated for “Total Boardings” between the two scenarios. This sheet was saved as a .CSV file and appended to the TIGER/Line 2019 New York Current Block Group shapefile’s attribute table in ArcMap.

In ArcMap, the block group shapes were recolored using Graduated Colors based on the Difference of Total Boardings between the two scenarios.

<sup>5</sup> TIGER/Line Shapefile, 2019, state, New York, Current Block Group State-based. (n.d.). [Data set]. Retrieved from <https://catalog.data.gov/dataset/tiger-line-shapefile-2019-state-new-york-current-block-group-state-based>

Appendix B

Figure 27 - All Trips Originating in Troy

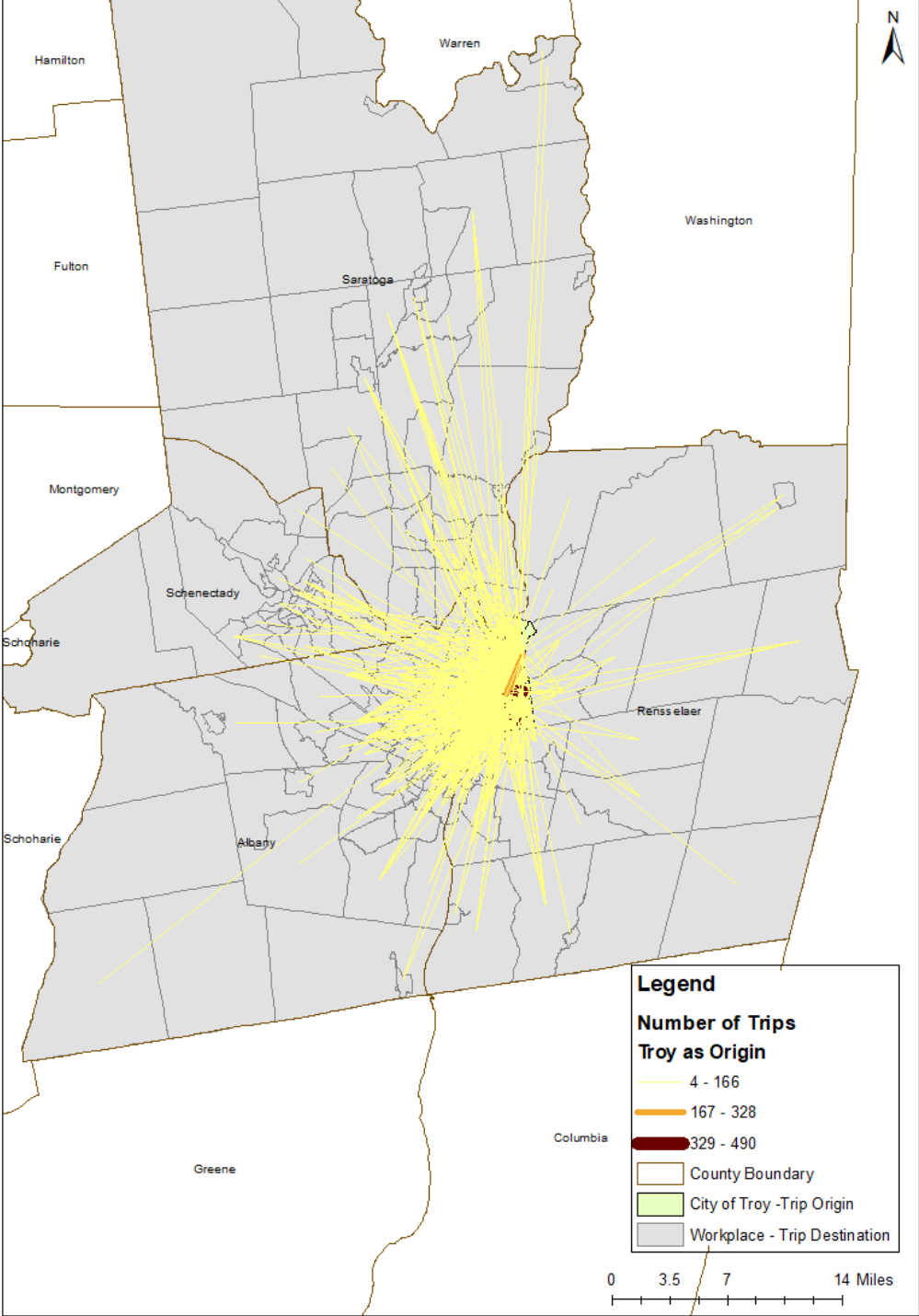
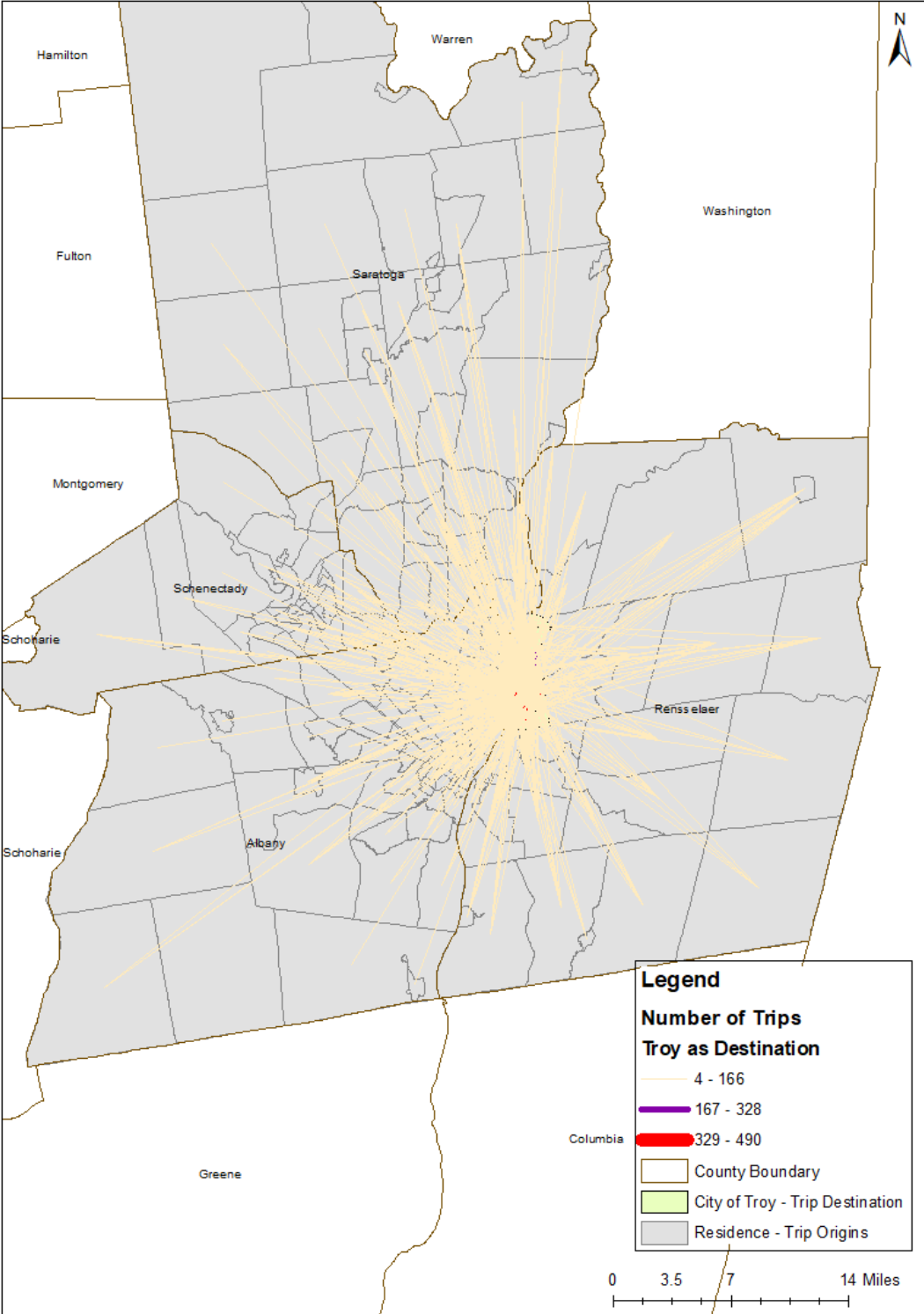




Figure 28 - All Trips Destined for Troy



## References

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### Dataset Data Sources

#### US Census Bureau Datasets

<https://www.census.gov/cqi-bin/geo/shapefiles/index.php>

- US Census Block Groups 2019: US Census Bureau Tiger/Line shapefiles 2019, Block Groups
- US Census Tracts 2019: US Census Bureau Tiger/Line shapefiles 2019, Census Tracts
- US Census County Boundary: US Census Bureau Tiger/Line shapefiles 2019, Counties (and equivalent)

#### New York State GIS Dataset

<https://gis.ny.gov/gisdata/inventories/details.cfm?DSID=928>

- Water Body: NYS Hydrography area shapefile

#### Census Transportation Planning Program (CTPP)

<https://ctpp.transportation.org/ctpp-data-set-information/>

- Troy As Origin: CTPP 2012-2016 (5-Year Estimate) Part 3: Flows; Table A302100 – Total Workers (1) (Workers 16 years and over), where Selected Geography: Residence = census tracts within City of Troy and Workplace = all the census tracts within Albany, Schenectady, Saratoga, Rensselaer County
- Troy As Destination: CTPP 2012-2016 (5-Year Estimate) Part 3: Flows; Table A302100 – Total Workers (1) (Workers 16 years and over), where Selected Geography: Residence = all the census tracts within Albany, Schenectady, Saratoga, Rensselaer County and Workplace = census tracts within City of Troy

#### CDTA

- Static GTFS database for Fall 2019
- Transit Propensity Index
- Weekly scheduled revenue hours, and route mileage by route, September 2019
- Transit Ridership by Stops, 2019