



Rochester: Increasing Employment Access through Increased Fixed-Route Frequency

NYSAMPO Shared Transit Service Planning and Analytics Initiative
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■ Executive Summary

The Research Team was tasked with developing an impact score for ranking low-frequency, local routes based on ridership demographics, income, and employment to provide RTS with an evidence-based approach for adjusting the frequency of routes within their system.

The project design used TBEST and Remix to generate and collect potential ridership demographics for all routes in the RTS transit network ecosystem. The Research Team utilized Excel to post-process and create a value-add research product that synthesizes the various demographics attributes. Routes 2 and 9 continuously had the highest rankings of the Routes Of Interest (ROI). The methodology utilized by the Research Team exceeded the anticipated scope of work by analyzing all routes in the GTFS network at the same time—not just the ROI. After reviewing the expanded data, RTS identified additional low-frequency local routes, beyond the selected ROI, that ranked towards the top of the list with high impact scores.

AVAIL trained staff at RTS on how to utilize the chosen software and the Excel composite score tool, as well as its underlying methodology, to rank any routes in their network. They were trained on how to update the composite score weighting factors and provided organizational tools for conducting sensitivity analyses on the adjusted demographic factors. The training was designed to assist RTS in adopting the software as a data export tool and integrate the Excel composite score tool as an impact scoring product that can be customized to best meet their organizational needs.

■ Problem Statement

The Rochester-Genesee Regional Transportation Authority's Regional Transit Service (RTS) sought assistance in developing an impact score that would account for a variety of ridership demographics; specifically including poverty and employment related attributes. The intent was to provide RTS with an evidence-based approach for adjusting the frequency of routes within their system to balance service and operational efficiency. Based on practitioner knowledge, RTS identified several of their low-frequency, local routes as potential Routes of Interest (ROI) to investigate on which route(s) an increase in frequency would be the most impactful. Based on their initial assessment, RTS selected a subset of these low-frequency, local routes for AVAIL to perform an impact analysis on.

 **Solution**

Design

The project design utilized the export feature of both TBEST and Remix to generate potential ridership demographics and American Community Survey variables for all routes in the RTS transit network ecosystem. Relevant variables were selected for a route impact score and then post-processed by normalizing all values onto a 1-10 scale. The normalized values were combined to create a composite score for each route, which were then ranked. Two mechanisms were developed to increase the relevance of the composite score:

- A weighting mechanism was constructed that allows the analysts to adjust multipliers for all variables which updates the ranks in real-time.
- A toggle switch was created that allows the scores to be switched between total and a length-adjusted values.

The design allows RTS to generate custom impact scores for all routes in the network that account for a variety of variables with adjustable weights to accommodate evolving agency needs.

Selection of Open-Source Software

This pilot was organized and implemented through the NYSAMPO Shared Transit project which tasked the Research Team with testing open-source software for transit network analysis. “Open-source” is a designation for software whose original source code is freely available for users to view, modify, or redistribute. These software are often free to use or modify, and do not contain proprietary components that cannot be accessed.

The Research Team performed a market assessment of open-source transit software that identified a viable candidate for this analysis—the Transit Boardings Estimation and Simulation Tool (TBEST). Early on, RTS indicated that they, and the Research Team, may gain access to Remix, a proprietary web-based software. The Research Team utilized TBEST’s ridership estimation model export data for the first six months of the project. Once access to Remix was granted, the Research Team created a parallel process based on the data products offered by Remix. The Research Team reevaluated TBEST’s export functionalities after Remix was able to provide comparable results.

The Research Team identified several pros and cons of using the open-source TBEST software versus the proprietary Remix software:

- Since Remix is a web-based subscription software, the setup process is negligible, and users can begin analyzing quickly. TBEST requires an onsite--or third-party--analyst to create and update the Socio-Economic (SE) data package required to run TBEST. Remix offers that as part of their subscription, which RTS already pays for.

- Though TBEST’s setup is substantially more time-consuming, the outputs are generated faster, and its attributes are provided as direct values, as opposed to percentages from Remix. Remix requires users to spend more time post-processing data, giving TBEST an edge in time efficiency.
- TBEST can provide stop-level ridership estimation based on a variety of datasets that may allow analysts to better target more specific potential rider demographics. Remix depicts the distribution of demographics in a user-prescribed radius around a route’s bus stops and length, which provide geospatial demographic context.
- The TBEST user interface and experience is more customizable and feature-rich, but more challenging to master. Remix has a more streamlined user experience but lacks some of the advanced features TBEST offers.

Though the two software are comparable, the Research Team determined Remix would be the better product for RTS’ workflow—especially considering that RTS already maintains a subscription to the software and uses it for other planning purposes.

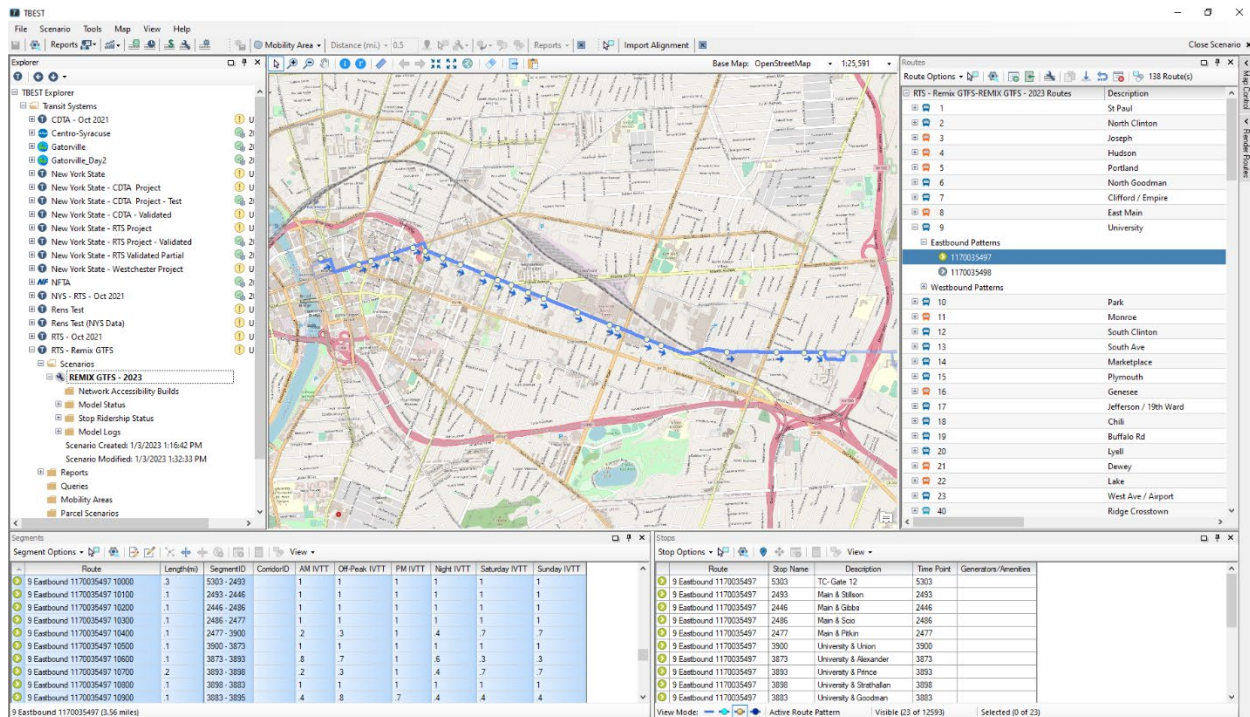


Figure 1 - TBEST User Interface

TBEST

Analysts on the Research Team had minimal experience with TBEST, so when the software was selected for this analysis, the workflow required trial and error. Previous experience with TBEST had been to use the tool to generate a ridership model with stop-level demographics data. TBEST’s Ridership Estimation 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.¹ The model generates ridership based on coefficients, demographics, and land use data within a quarter mile (0.25 mi) buffer around stops and/or segments then assigns the riders to bus stops based on attractors. Ridership demographics at the stop-level can be exported to a .CSV file for post-processing and analysis within Microsoft Excel.² The TBEST model provided the Research Team with a set of forecasted ridership data for the month of October in 2019 in RTS based on the SE data products previously created by Service Edge Solutions and the New York State Department of Transportation.

Remix

Remix is a web-based transportation software that utilizes the OpenStreetMap road network, LEHD, ACS and Census demographics, and user-provided GTFS data to generate a transit network ecosystem. The software captures demographics and employment attributes in a specified (0.25mi default) buffer zone that surrounds routes while providing users with high-level route metrics like mileage and operating costs. Additionally, Remix includes an isochronal generation tool to visualize network accessibility by time and location. Outputs can be exported to a variety of file types including shapefiles, .CSV, and GTFS.³

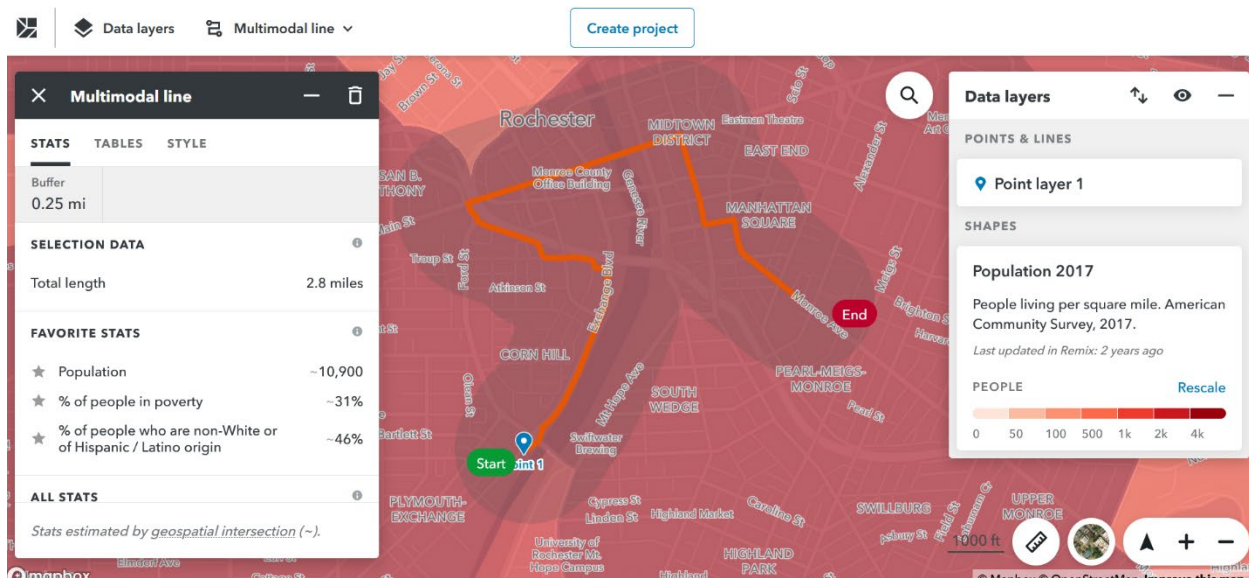


Figure 2 - Remix User Interface

¹ Bunner, R. (2021). *TBEST Socio-Economic Data Configuration*.

² Bunner, R., Catala, M., & Mistretta, M. (n.d.). *TBEST 4.7 User Guide*. Martin Catala and Mark Mistretta Center for Urban Transportation Research (CUTR).

³ *Remix—TransitWiki*. (n.d.). Retrieved February 3, 2023, from <https://www.transitwiki.org/TransitWiki/index.php/Remix>

Case Study Methodology

The Research Team used both TBEST and Remix to export transit network service and market area demographics within a 0.25-mile buffer around ROI. The primary ROI selected at the beginning of this project were **routes 2, 9, 14, 19, 23, 24, 37, 40, and 41**. Both software were used to collect its demographics values specific to that software for each ROI. Once each output was exported, the Research Team utilized Excel to post-process and create a value-add research product that synthesizes the various demographics attributes.

Remix exports attributes as percentages of the whole buffer geography—if there are 1000 people within the 0.25-mile buffer of a route and 100 of them are zero-vehicle households, then the Remix output will be “10%”. All data attributes required Excel post-processing to convert values for the number of people, households, and jobs from the percentages. This was achieved by multiplying the percentages by the corresponding root variable: total population, total households, and total employment. These root variables each have a substantial difference of magnitude and need to be normalized for comparison. The Research Team normalized all chosen attributes to a scale of 1-10 and a composite weighting tool was constructed to apply and change a multiplier for each variable to weight as the analyst sees fit. These post-processed and analyst-weighted demographics sheets were used to create route-level composite scores to rank the routes and create RTS’ desired impact score.

One route remained an outlier in all metrics and RTS noted that it was the longest route, thus introducing a length bias by having a larger service area coverage. RTS recommended that the Research Team apply a length divisor to each value to remove the length bias. Once completed, the composite score indicated that of the initially selected ROI, routes 2 and 9 were leading with the highest impact score.

REMIX				TBEST		
Line	Composite Score	Composite Score Normalized	Rank	Composite Score Normalized	Composite Score	Line
753 19th Ward-Plym-City SE / Monroe - Pattern A	866.8	100.0	1	100.00	847.9	753 19th Ward-Plym-City SE / Monroe - Pattern A
450 N Goodman-Portland / Genesee - Pattern A	852.8	98.3	2	98.27	833.9	450 N Goodman-Portland / Genesee - Pattern A
443 Joseph-Hudson / Genesee - Pattern A	851.7	98.2	3	97.89	830.9	443 Joseph-Hudson / Genesee - Pattern A
436 City SE / Norton - Pattern A	844.0	97.2	4	96.16	816.9	768 N Win Vill-Beechwood / Monroe - Pattern A
784 19th Ward NW-Plymouth / Lake - Pattern A	825.8	95.1	5	96.15	816.8	785 City SE / Lake - Pattern A
635 Plym-Jef-19thNE / Fernwood Park - Pattern A	825.4	95.0	6	95.98	815.5	436 City SE / Norton - Pattern A
785 City SE / Lake - Pattern A	820.0	94.3	7	95.97	815.3	635 Plym-Jef-19thNE / Fernwood Park - Pattern A
368 City SE / Colfax - Pattern A	815.6	93.8	8	95.58	812.2	784 19th Ward NW-Plymouth / Lake - Pattern A
276 19th Ward SE / Prince - Pattern A	815.3	93.8	9	94.93	807.0	368 City SE / Colfax - Pattern A
447 City SE / Genesee - Pattern A	810.6	93.2	10	93.68	796.9	276 19th Ward SE / Prince - Pattern A

Figure 3 - Impact Score Tool Rankings (Preliminary)

The Research Team provided RTS with a tool (Figure 4) and training allowing them to run a sensitivity analysis on the composite score to test the impact of each demographic in the score. This tool allows RTS to compare the demographic outputs from TBEST and Remix.

Composite Score Builder		
TBEST Variable	Remix Variable	Score Modifier
In Poverty by Mile Normalized	people in poverty normalized	1
Zero Vehicle by Mile Normalized	households that are car free normalized	1
Disabled by Mile Normalized	people living with a disability normalized	1
	workers who take public transit to work normalized	20
Service by Mile Normalized	essential jobs (work) normalized	20
\$20K-\$24.9K by Mile Normalized	people within 125% of the poverty threshold normalized	1
\$25K-\$29.9k by Mile Normalized	people within 150% of the poverty threshold normalized	1
\$30K-\$34.9K by Mile Normalized	people within 185% of the poverty threshold normalized	1
\$35K-\$39.9K by Mile Normalized	people within 200% of the poverty threshold normalized	1
	public housing buildings	1
	hospitals	10
	urgent care facilities	10
	nursing homes	10
	pharmacies	10
	Schools: Childcare and K-12	10
	colleges / universities	0
	supplemental colleges	0
	SNAP Retailer Supermarkets 2020	10
Commercial by Mile Normalized		0

Figure 5 - Impact Score Tool Weight Modifier Interface

Line	Composite Score	Composite Score Normalized	Composite Score Ranked	AVG Length	population	jobs (work)	% of people in poverty	people in poverty	people in poverty normalized
1 St Paul - Pattern A	366	39.51262065	112	5.1	13,310	4,791	29%	822	5.46368715
2 North Clinton - Pattern A	480	53.3306178	76	4.7	15,412	6,892	26%	954	6.20111732
3 Joseph - Pattern A	536	59.98973531	61	3.6	14,226	4,916	39%	1570	9.64245810
4 Hudson - Pattern A	537	60.12310845	60	4.1	16,133	7,127	36%	1394	8.65921788
5 Portland - Pattern A	496	55.22104523	70	4.9	16,498	7,956	30%	1010	6.51396648
6 North Goodman - Pattern A	420	46.00923006	98	5.0	17,336	10,015	30%	1098	7.00558659
7 Clifford / Empire - Pattern A	484	53.74266824	73	7.5	18,124	7,904	26%	646	4.48044693
8 East Main - Pattern A	299	31.42198501	121	4.2	12,776	9,585	25%	856	5.65363128
9 University - Pattern A	396	43.11792577	103	3.6	12,163	12,781	22%	762	5.12849162
10 Park - Pattern A	423	46.3578121	96	4.2	15,774	10,878	17%	715	4.86592179
11 Monroe - Pattern A	312	32.99338949	119	9.5	20,513	17,957	15%	321	2.66480447
12 South Clinton - Pattern A	315	33.32446621	117	6.1	12,762	11,039	22%	494	3.63128492
13 South Ave - Pattern A	418	45.75671433	99	6.1	12,650	22,462	24%	557	3.98324022
14 Marketplace - Pattern A	323	34.25444521	114	10.2	13,185	30,555	27%	349	2.82122905
15 Plymouth - Pattern A	615	69.59959393	44	4.8	17,662	33,730	38%	1463	9.04469274
16 Genesee - Pattern A	668	76.02663424	30	4.7	18,002	31,960	35%	1406	8.72625698
17 Jefferson / 19th Ward - Pattern A	740	84.65813451	17	9.5	30,493	34,412	31%	1084	6.92737430
18 Chili - Pattern A	417	45.65166868	100	9.7	17,947	11,334	23%	501	3.67039106
19 Buffalo Rd - Pattern A	291	30.4387169	122	8.2	12,238	9,856	38%	585	4.13966480
20 Lyell - Pattern A	467	51.70573427	78	8.4	14,381	16,262	27%	503	3.68156425

Figure 4 - Post-Processed Remix Output

■ Outcomes

Of the initially selected ROIs, routes 2 and 9 continuously had the highest rankings in the first pass of the work. The methodology utilized by the Research Team exceeded the anticipated scope of work by analyzing all routes in the GTFS network at the same time—not just the ROI. After reviewing the expanded data, RTS identified additional low-frequency local routes, beyond the selected ROI, that ranked towards the top of the list with high impact scores.

AVAIL trained staff at RTS on how to utilize the chosen software and the Excel composite score tool, as well as its underlying methodology, to rank any routes in their network. They were trained on how to update the composite score weighting factors and provided organizational tools for conducting sensitivity analyses on the adjusted demographic factors. AVAIL provided a user guidance document on how to update the Remix data inside of the tools. The technical section further in this document provides guidance on how to export from TBEST and the TBEST User Guide document provides detailed information on further use of the tool.

The training was designed to assist RTS in adopting the software as a data export tool and integrate the Excel composite score tool as an impact scoring product that can be customized to best meet their organizational needs. RTS now has the tools and knowledge necessary for fine-tuning the impact score and expanding upon the process to find all applicable analysis needs.

Software Assessment

Remix - The web-based software required limited local setup to begin using immediately. The platform's user interface was simple and intuitive. The data export from Remix formatted attributes as percentages—requiring significant post processing.

TBEST - The desktop software required substantial setup on the local machine to begin using. The platform's user interface is complex, but intuitive after a moderate learning curve. The data export from TBEST formatted attributes as values—requiring less post processing.



Output Data Post-Processing and Analysis

Remix - Export Attributes were percentages of a whole. For example, "Car Free Households" is exported as a "31%" for Route 1. To get a value of that, the 31% is multiplied by the "Total Households" value. Post-processing required this, and all other percentage attributes, to be calculated this way.

Both Software's exports were processed by normalized to create a singular score between 1 and 10. All relevant scores were aggregated to create a composite score. The composite scores were normalized as a 1 to 100 value. This normalized composite score was ranked from highest to lowest.



Training and Integration

RTS staff were given a thorough walkthrough of the data-processing techniques, including building the equations used for both normalization and ranking. The step-by-step instructions on the construction of the Impact Score Tool sheet was drafted as a tutorial document (included in this report).

Discussion

Limitations

- TBEST documentation recommends performing a “Validation” step that entails entering Weekday, Saturday, and Sunday observed ridership data like Automatic Passenger Counts (APC) for each route in the network. The software then uses that data to generate a “Route Adjustment Factor (RAF)” that modifies the outputs of the software’s Ridership Estimation Model. Application of this validation step “snaps” the Ridership Estimation Model data to the total ridership of the APC data effectively overriding the gravity model’s coefficients making the outcomes questionable. In one of the other case studies of this Shared Transit project (see CDTA Report), AVAIL removed the TBEST validation step and changed the coefficients in the model to calibrate it more closely to the region—a process recommended by this Research Team.
- TBEST’s export process for data at the route level, without running a ridership estimation model, organized variables into different categories requiring the analyst to export multiple iterations and combine them for a dataset consisting of all available variables.
- Remix cannot export data at the stop-level, only at a 0.25-mile (adjustable) buffer around the route.
- Remix data export lacked immediate usefulness for analyses without post-processing to convert attribute percentages to values. There may be an opportunity for Remix to adjust their export product or functionality for maximum usability like TBEST which offers a toggle for users to select between exporting percentages or values.
- Remix’s and TBEST’s route-level tools, as used in this analysis, have a geographic spatial vicinity that is not picking up 0.25-miles around the bus stop but by 0.25-miles along the entire route.

Lessons Learned

- The Research Team identified several pros and cons of using the open-source TBEST software versus the proprietary Remix software:
 - Since Remix is a web-based subscription software, the setup process is negligible, and users can begin analyzing quickly. TBEST requires an onsite, or third-party, analyst to create and update the Socio-Economic (SE) data package required to run TBEST. Remix offers that as part of their subscription which RTS already pays for.
 - Though TBEST’s setup is substantially more time-consuming, the outputs are generated faster and its attributes are provided as direct values, as opposed to percentages from

- Remix. Subsequently, the reduced analysis generation duration and post-processing efforts give TBEST an edge in time efficiency.
- TBEST can provide stop-level ridership estimation based on a variety of datasets that may allow analysts to better target more specific potential rider demographics. Remix depicts the distribution of demographics around bus stops which provide geospatial demographic context.
 - The TBEST user interface and experience is more customizable and feature-rich, but more challenging to master. Remix has a more streamlined user experience that lacks some of the advanced features.
- Avoid the TBEST Validation Process
 - The TBEST Ridership Model validation process is not optimal for data export analysis. By “snapping” model outputs to user-entered APC (or other Observed Ridership data), it undermines the value of the coefficients and obfuscates the efficacy of the underlying gravity model within the software.
 - Excel/TBEST Processing—Hardware Matters
 - When performing analyses with local software (desktop programs installed on the computer being used), a significant quantity of calculations are performed to process data taking more time based on the quantity, complexity, and functionality of the formulae. Larger datasets, like stop-level by pattern demographics data, exacerbate the processing time required to perform these calculations.
 - Route length normalization is a complex issue that needs further analysis.
 - Not normalizing data attributes introduces a length bias where longer routes have a larger services area but normalizing the data attributes by route length penalizes longer routes which may go through lower population areas that have city sections counterbalancing the data.
 - Additional research is needed to assess the impact of length, number of stops, and population served on the route impact composite score methodology developed in this project.

Replicability

This project could be replicated easily by anyone with access to Remix. Replicating it with TBEST is somewhat more complicated due to the setup requirements associated with TBEST.

Recommendations

Based on the experiences in this project, the Research Team makes the following recommendations:

1. Though the two software, Remix and TBEST, are extremely comparable, the Research Team determined Remix would be the better product for RTS' workflow—especially considering that RTS already maintains a subscription to the software.
2. RTS should perform a sensitivity analysis by assigning different variable weights to the composite score calculation and record to outcomes using the organizational tools provided. This sensitivity analysis can be used to adjust the weighting mechanism to better reflect RTS' organizational needs.
3. Contact administrators of Remix and TBEST software to request a feature implementation allowing users to export demographics data as values at the stop-level.
4. Develop better mechanisms to account for length issues—this may be accomplishable using a stops-per-mile, stops-per-route, or a combination score for routes.

References

Bunner, R. (2021). *TBEST Socio-Economic Data Configuration*.

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from <https://ses-transport.com/index.php/serviceedge-tbest-hosting-subscription-add-in/>

Appendix A: Technical Design

Introduction

The purpose of this tutorial is to provide instructions on how to create a composite scoring spreadsheet to compare multiple routes in a transit system using the data available in Remix. A composite score is a single variable that represents a combination of information from multiple variables. Creating a composite score for each route in the user's transit system will allow them to rank the routes based on information the user deems to be most valuable.

This tutorial will teach the user how to use Remix to add routes for comparison and then download the standard socio-economic data from Remix for post processing in Excel. Data will be converted from percentages to values and then normalized and ranked. To analyze the outputs, a sheet to summarize the data will be constructed allowing the user to weight each variable within the composite score calculation and automatically update the route rankings. At the end of this tutorial, the user will know how to use Remix to access data for multiple transit routes, post-process the outputs, create composite scores, and produce a spreadsheet suitable for use as an analysis tool.

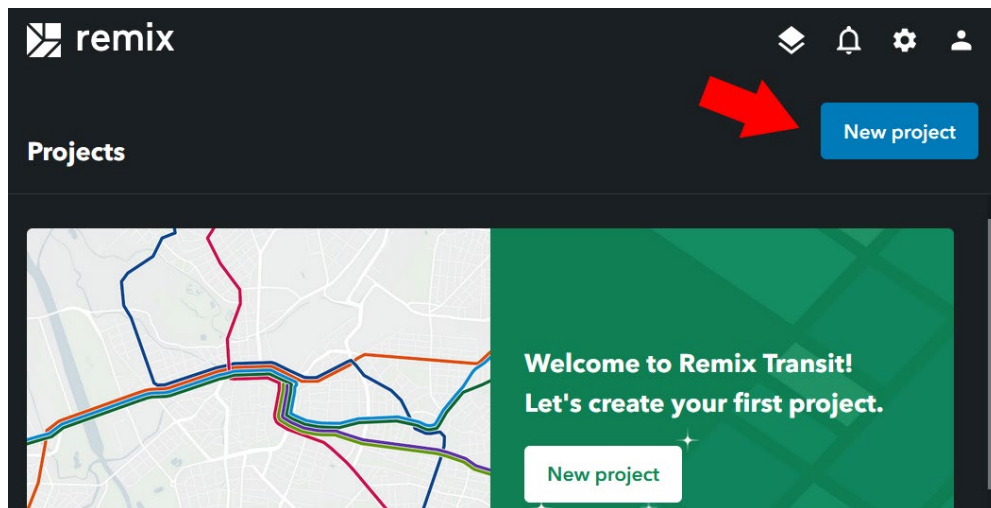


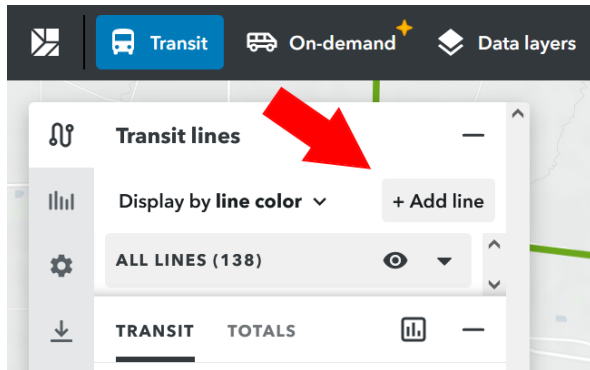
Figure 6 - Remix New Project Button

Navigating Remix

Once logged into Remix, the user will be taken to the **Projects** screen. All current projects, containing individual or groups of transit routes, are found here—an existing project can be selected, or a new project can be created here.

For this tutorial, we will create a new project that will contain all routes in the transit system. Click on the blue **New project** button towards the top center of the screen. Name your new project, provide an optional description, and click **Create**.

The user will be taken to the **Remix Explorer** screen which provides the user with a graphical view of their region, transit lines, and various data layers. From this screen, we will be adding all routes in the transit system, selecting a quarter-mile radius around each stop, and downloading the socio-economic data to work with.



Start by clicking on the **+ Add line** button. You will see a list of all lines in your transit system. If the list is collapsed, click on the black arrow to expand the list of routes. Click on the three dots next to the black arrow and select **Import all lines**. Once done, the lines will begin to show up on the map with each route in the list having a blue checkmark displayed next to it. Click the arrow next to **Add Lines** to go back to the transit lines screen.

Figure 7 - Remix Add Line Button

At the transit lines screen, specify the desired mile radius around each stop to collect data from by clicking on the number displayed. For this tutorial we will use the default (0.25 mi). Once the value is set, click on the eye icon, the last icon next to it, to display the transparent radii buffers around each stop on the map. *Note: The buffers may not be visible when zoomed out.*

Now that the routes and radii around each stop have been selected, the data is ready to be downloaded. Click on the **Exports** icon to open the exports tab and under **Export Map Data**, select **Line attributes (Excel)** to begin the download of the data. This will download the spreadsheet that will be post-processed and analyzed. Take note of the folder where the spreadsheet was downloaded to. Navigate to that folder and open the spreadsheet.

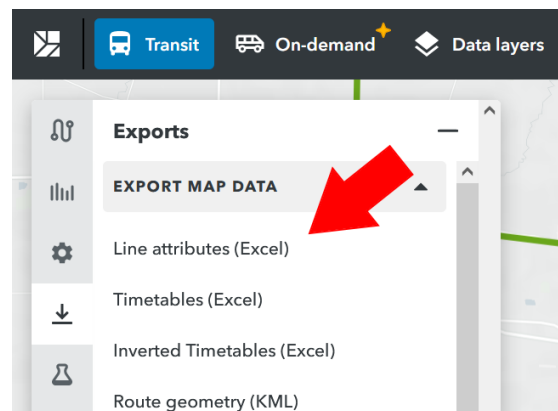


Figure 8 - Remix Line Attributes Button

Navigating TBEST

TBEST’s software setup can be a significant process requiring a variety of datasets to be downloaded and formatted to create a socio-economic data package. For more information, this process is detailed in the TBEST User Guide and TBEST Socio-Economic Data Configuration guide. This section assumes the user has:

- Installed TBEST
- Constructed or Downloaded the Relevant Socio-Economic Data Package(s)
- Imported the Relevant GTFS File(s)

With the desired regional GTFS open in TBEST, the user can select all routes in the right-side “Routes” panel by clicking the route at the top of the list, holding the shift key, and clicking the route at the bottom of the list. With all the routes highlighted (selected), right click on any route to open a context menu. From this context menu select the “Route Socio-Economic Reporting...” option.

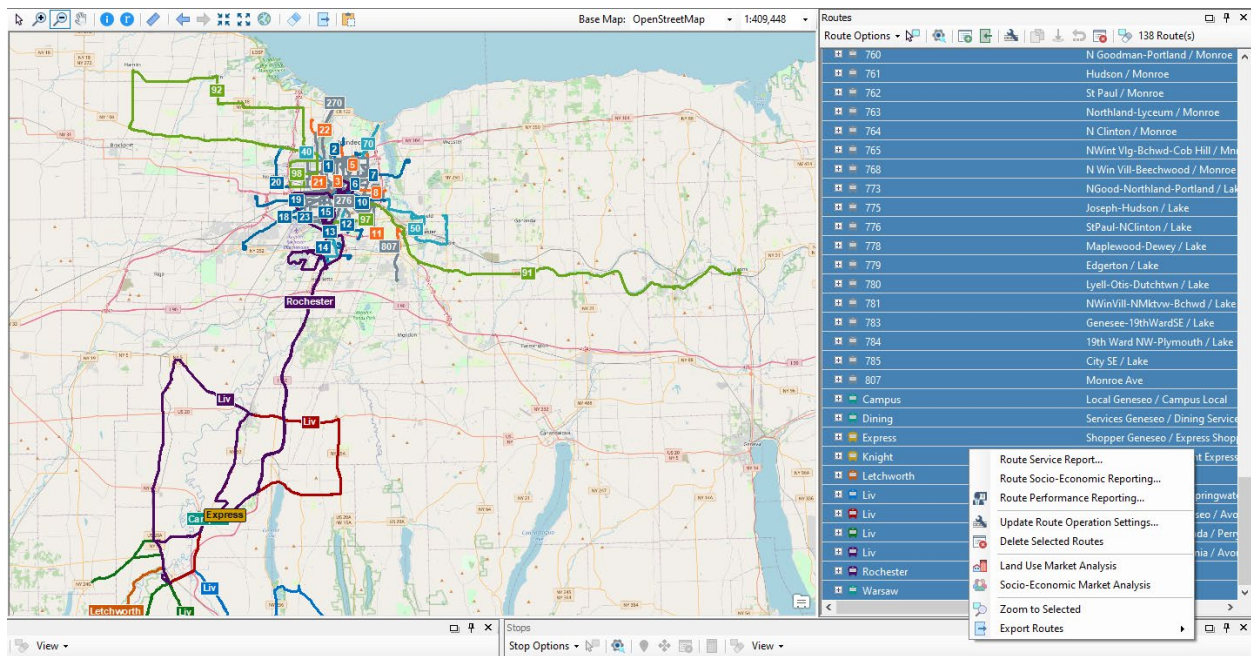


Figure 9 - TBEST Routes Context Menu

The Route Socio-Economic Report has several configuration options available. The report options were set to best resemble the data format exported from Remix to make the datasets comparable to each other. Since Remix captures Census data from a 0.25-mile buffer around the entire routes, the Service Period was set to “Weekday”, Walk Access Distance was set to “0.25 miles”, and Walk Access From: was set to “Segments”.

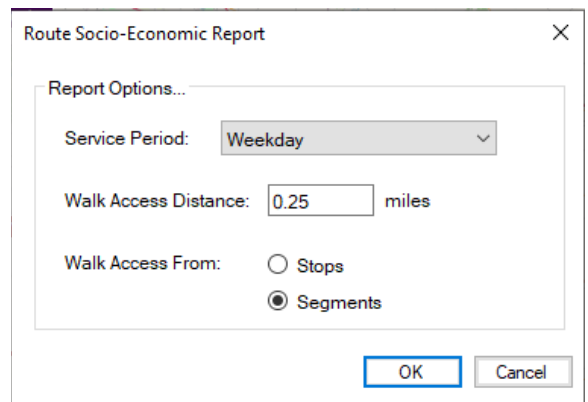


Figure 10 - TBEST Route Socio-Economic Report Configuration

The Route Socio-Economic Summary Report captures the census variables from the 0.25-mile route buffer selected on in the previous configuration window. By default, these values are displayed as percentages. To minimize post-processing, check the “Show Demographics Counts” box at the bottom of the window turn the percentages into values.

The screenshot shows a window titled "Route Socio-Economic Summary Report" with a dropdown menu open for "Profile". The dropdown menu lists: Default, Population, Household Employment, Title VI, Race/Ethnicity, Auto Ownership, Education Level, Population Age, Primary Language, Household Income, and Aggregate Income. The table below shows data for 20 routes, with columns for Route, Population, Population Density, Minority, Hispanic, Limited English Proficiency, Over 65, Under 18, Households, Low Income, Zero Vehicle, One Vehicle, Jobs, Job Density, Service, and Comments. At the bottom, there is a checkbox for "Show Demographic Counts" and buttons for "Export to Excel" and "Close".

Figure 11 - TBEST Route Socio-Economic Summary Report

Each “Profile” contains different variable attributes and will have to be exported to multiple Excel documents. Use the “Export to Excel” button to create and save the file generated for each relevant Profile. In this analysis, the Research Team exported the Default, Population, and Household profiles. These three sheets should be combined into one sheet that contains all the unique variables from each.

Spreadsheet Setup

Before scores can be calculated, the data will need to be processed in preparation. The downloaded spreadsheet from Remix contains Summary, Demographics, and Stops sheets, as well as a sheet for each of the lines selected in Remix. To prepare, we will need data from the Summary and Demographics sheets to make calculations based on route length. It is important to *not* sort any of the data in any of the sheets before beginning and to remember to save your work frequently. It is also recommended that a copy of the original spreadsheet is saved.

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D
1	Routes--Tutorial			
2	https://platform.remix.com/map/ec963c32			
3				
4	Within	0.25	mi of stops	
5				
6		population (Cens	population	jobs (work)
7	SYSTEM STATS	325,199	300,715	180,195
8	1 St Paul	14,339	13,314	4,791
9	2 North Clinton	17,454	15,412	6,892
10	3 Joseph	14,615	14,226	4,916

First, select the **Demographics** sheet and remove the top five rows. This will leave each column with a header. In cell A1—currently blank—enter in “Route”. Row 2 displays the aggregate data for the entire system and must be deleted or it will cause the composite scores and their ranking to be unsuitable for analysis.

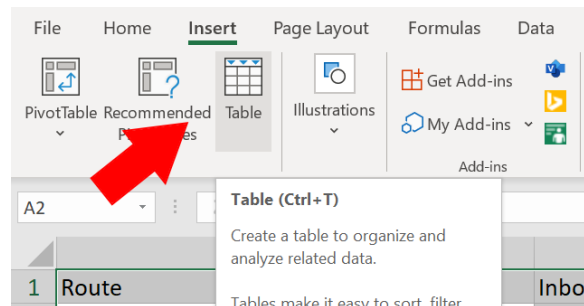
Figure 12 - Remix Output

Next, insert two new columns next to the Route column which will be used to paste inbound and outbound miles data from the **Summary** sheet. Do this by right-clicking on column B and clicking “Insert” to create one new column, and then repeat the step to create a second. Go to the **Summary** sheet and scroll down to row 53 where mileage, vehicle, and cost data per line is found. Using your mouse, select the “Inbound (mi)” and scroll down the list of lines until the very end. Then, holding shift, left click on the very last number in column C. Press CTRL+C on your keyboard to copy the data and then switch back to the **Demographics** sheet. Selecting the first cell in column B, press CTRL+V to paste the miles data into the **Demographics** sheet. It is important to make sure to have *not* sorted any of the data in either sheet before doing this otherwise the inbound and outbound miles will not match up with the routes.

	A	B	C
49	Trip hours / sun	568	
50	Layover hours / sun		
51	Miles / sun	8,241	
52			
53	Line	Inbound (mi)	Outbound (mi)
54	1 St Paul - Pattern A	5.2	5.1
55	2 North Clinton - Pattern A	4.7	4.8
56	3 Joseph - Pattern A	3.5	3.7
57	4 Hudson - Pattern A	4.1	4.2
58	5 Portland - Pattern A	4.8	5.0
59	6 North Goodman - Pattern A	5.0	5.0
60	7 Clifford / Empire - Pattern A	7.6	7.5
61	8 East Main - Pattern A	4.3	4.2
62	9 University - Pattern A	3.6	3.7
63	10 Park - Pattern A	4.1	4.2
64	11 Monroe - Pattern A	9.6	9.3
65	12 South Clinton - Pattern A	6.2	6.0

Figure 13 - Excel Inbound/Outbound Data

The last step to setting up the spreadsheet is to put all the Demographics data into a table. With the **Demographics** sheet selected, press CTRL+A to select all and click on the **Insert** ribbon at the top of the



Excel window. Click on “Table” to put all the selected data into a table. Once this is completed, the cells in the sheet should be filled in various shades of blue. Check to ensure that the table has correctly included everything before moving on. Please note that this table is named **Table1** for reference in the creation of a **Composite Score Summary** sheet later.

Figure 14 - Excel Insert Table

Data preparation

The data is now prepared for manipulation. Remix provides multiple variables as percentages of a total rather than the raw numbers which will need to be calculated before they can be used for score. Similarly, to rank scores by mile, the average length of a route needs to be calculated using the inbound and outbound variables.

The user will need to choose which variables they would like to use to create their score. For the purposes of this tutorial, we will be using:

- % of people in poverty.
- % households that are car free
- % people living with a disability
- % workers who take public transit to work
- % essential jobs (work)
- % people within 200% of the poverty threshold

Each of these variables will need to have a raw number calculated from the percentage using the population variable on the same row. This will allow the user to create normalized scores for each chosen variable, and then add them together to create a composite score.

To create an average length for each route, right click the column next to “Outbound (mi)” and insert a new column. Then name it “AVG Length.” In the cell below, use the following formula:

$$=([\text{Outbound (mi)}]+[\text{Inbound (mi)}])/2$$

This will add the outbound and inbound miles together and divide them by two to get the average. The rest of the column will be automatically updated with the formula for each row.

	A	B	C	D
1	Route	Inbound (mi)	Outbound (mi)	AVG Length
2	1 St Paul	5.2	5.1	5.15
3	2 North Clinton	4.7	4.8	4.75

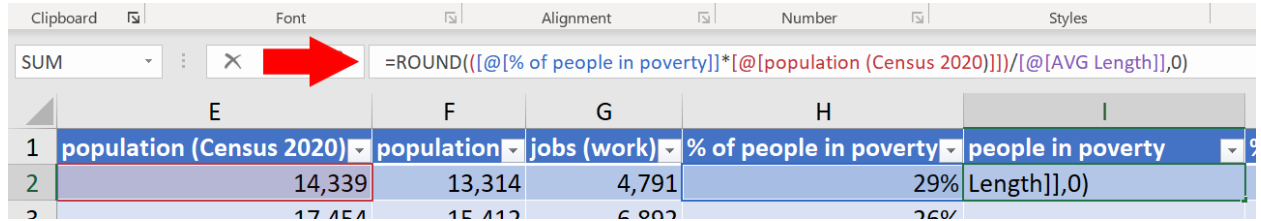
Figure 15 - AVG Length Equation

This new AVG Length column can be copied and pasted into the TBEST export sheet so those attributes can be calculated using the same length values.

Now it is time to create raw numbers from the percentages offered from the Remix data for each of the variables listed above, and then divide the value by the average length of the route. Each variable will need a new column to be inserted next to it to calculate the raw number. Name the column after the variable selected, but drop the “%” (e.g., “% of people in poverty” would have a new column next to it named “people in poverty”).

Using “% of people in poverty” as an example, use the following formula:

=ROUND(([@[% of people in poverty]]*[@[population (Census 2020)]])/[@[AVG Length]],0)



	E	F	G	H	I
1	population (Census 2020)	population	jobs (work)	% of people in poverty	people in poverty
2	14,339	13,314	4,791	29%	Length]],0)
3	17,454	15,412	5,992	26%	Length]],0)

Figure 16 - Percent to Value Conversion

This will round the total of the “% of people in poverty” multiplied by the “population (Census 2020)” and divide the result by the inbound miles to get the approximate amount of people in the quarter-mile radius around the route. Do this for each variable selected.

Alternatively, the formulas for each variable can be set up to allow for the division by the average length to be toggled on and off using the summary sheet to be created later in the tutorial. To do so, the formulas need to be set up for each variable like the following example:

=IF('Composite Score Sheet'!\$A\$25<>"", ROUND(([@[% of people in poverty]]*[@[population (Census 2020)]])/[@[AVG Length]],0), ROUND(([@[% of people in poverty]]*[@[population (Census 2020)]]),0)

This formula adds an “IF” that will cause Excel to evaluate whether the condition following it is true or false, and then either perform one calculation, or the one the follows it in the formula. In this case, the formula will check cell A25 on the Composite Score Sheet (which will be created later in the tutorial) to see if it has any text values. If it does, it will then perform the first calculation which divides the number of people in poverty by the average length of the route, else it will just use the number of people in poverty without dividing it by the average length.

Please note that not all calculations should be made with the “Population (Census 2020)” variable. For instance, when trying to calculate the number of jobs (“% essential jobs (work)”), use the “jobs (work)” variable. Similarly, when trying to calculate the number of households that are car free, use the “households” variable in place of “Population (Census 2020).”

These would look like: =ROUND(([@[% essential jobs (work)]]*[@[jobs (work)]])/[@[AVG Length]],0)

And

=ROUND(([@[% of households that are car free]]*[@[households]])/[@[AVG Length]],0), respectively.

For each of these new variables created, the values must be normalized before they can be added together to create a composite score. To do so, create a new column next to the raw number variables and name it so it contains a normalized variable (e.g., “people within 200% of the poverty threshold” would have a new column next to it named “people within 200% of the poverty threshold normalized”).

This tutorial will be using a normalized range of 1-10—10 will represent the top-end of the values, with 1 representing the low-end.

In the newly created column, use the following formula with “BN:BN” being the column of the variable being normalized:

$$=1+9*(([@[people within 200% of the poverty threshold]]-MIN(BN:BN))/(MAX(BN:BN)-MIN(BN:BN)))$$

This will create a value based on the 1-10 range considering the range of values for the variable selected. Repeat this step for each of the variables chosen.

The TBEST export will need to be post-processed by following similar steps above, excluding the percentage to value conversion equation. On the TBEST export, the following variable columns will require similar post-processing:

- In Poverty
- Zero Vehicle
- Disabled
- Service
- Commercial
- \$20K - \$24.9K
- \$25K - \$29.9K
- \$30K - \$34.9K
- \$35K - \$39.9K

Each variable should have two new columns created for it—Proxy and Normalized. The Proxy columns introduce the IF statement required for the per-mile toggle switch and use the equation:

$$=IF('Composite Score Sheet'!A25<>"", [@[Zero Vehicle]]/[@[AVG Length]], [@[Zero Vehicle]])$$

This expression says that if the toggle switch cell has any value in it, divide the attribute value by the route length, but if there is no value in the toggle switch cell, use the original value.

Follow the normalization steps noted for the Remix sheet above in each new Normalized column created in the TBEST output, normalizing the new Proxy Column:

$$=1+9*((@[Zero Vehicle Proxy]]-MIN(K:K))/(MAX(K:K)-MIN(K:K)))$$

Once completed, the user should have normalized scores for all the variables they wish to use in their composite score.

The formula bar shows: $=1+9*((@[people\ within\ 200\% \ of\ the\ poverty\ threshold]) - MIN(BM:BM)) / ((MAX(BM:BM) - MIN(BM:BM)))$

	BJ	BK	BL	BM	BN	BO	BP	BQ	BR
1	people within 185% of the poverty threshold	people within 185% of the poverty threshold normalized	% of people within 200% of the poverty threshold	people within 200% of the poverty threshold	people within 200% of the poverty threshold normalized	% of people who are 65+	people who are 65+	% of people who are 17+	people who are 17+
2	1699	10	63%	1774	MIN(BM:BM)	14%	623	26%	10
3	1656	10	63%	1731	10	14%	584	26%	10
4	1558	9	62%	1645	9	10%	382	30%	10

Figure 17 - Normalization Calculation

Calculating scores

With the data prepared, the user can now create their composite scores. First, a new blank sheet must be created that will be referenced later titled “Composite Score Sheet”. Return to the Remix output sheet to continue. A total score must be created by adding together all the normalized scores created in the preceding step. Then, those scores must be normalized using a 1-100 range. Afterwards, the scores can be ranked and a score per mile value created.

On the **Remix Demographics** sheet, next to the “Route” column and the **TBEST export** sheet, create three new columns. Name these “Composite Score”, “Composite Score Normalized”, and “Composite Score Ranked” to set up the columns necessary.

	B	C	D
	Composite Score	Composite Score Normalized	Composite Score Ranked

Figure 18 - Composite Score-Related Columns

First, create the composite score by adding together all the selected normalized variables. Use the following formula in the “Composite Score” column **for Remix**:

=([@[people in poverty normalized]]*'Composite Score Sheet'!\$C\$4)+([@[households that are car free normalized]]*'Composite Score Sheet'!\$C\$5)+([@[people living with a disability normalized]]*'Composite Score Sheet'!\$C\$6)+([@[workers who take public transit to work normalized]]*'Composite Score Sheet'!\$C\$7)+([@[essential jobs (work) normalized]]*'Composite Score Sheet'!\$C\$8)+([@[people within 125% of the poverty threshold normalized]]*'Composite Score Sheet'!\$C\$9)+([@[people within 150% of the poverty threshold normalized]]*'Composite Score Sheet'!\$C\$10)+([@[% of people within 185% of the poverty threshold]]*'Composite Score Sheet'!\$C\$11)+([@[people within 200% of the poverty threshold normalized]]*'Composite Score Sheet'!\$C\$12)+([@[public housing buildings]]*'Composite Score Sheet'!\$C\$13)+([@[hospitals]]*'Composite Score Sheet'!\$C\$14)+([@[urgent care facilities]]*'Composite Score Sheet'!\$C\$15)+([@[nursing homes]]*'Composite Score Sheet'!\$C\$16)+([@[pharmacies]]*'Composite Score Sheet'!\$C\$17)+([@[Schools: Childcare and K-12]]*'Composite Score Sheet'!\$C\$18)+([@[colleges / universities]]*'Composite Score Sheet'!\$C\$19)+([@[supplemental colleges]]*'Composite Score Sheet'!\$C\$20)+([@[SNAP Retailer Supermarkets 2020]]*'Composite Score Sheet'!\$C\$21)+(Table14[@[Commercial by Mile Normalized]]*'Composite Score Sheet'!\$C\$22)

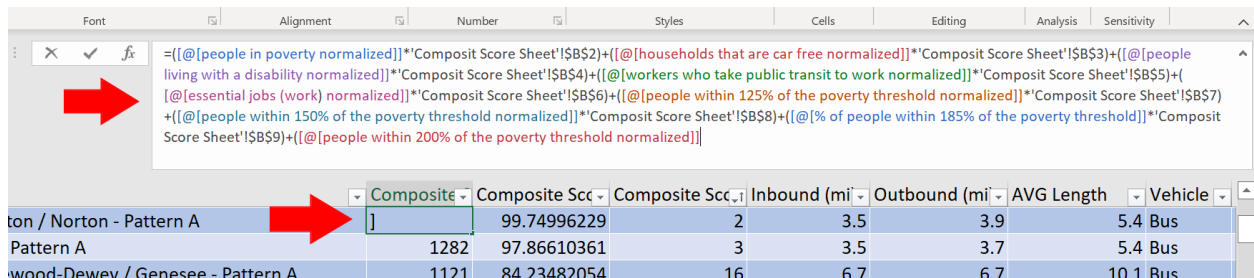


Figure 19 - Composite Score Calculation

For TBEST:

=([@[In Poverty Normalized]]*'Composite Score Sheet'!\$C\$4)+([@[Zero Vehicle Normalized]]*'Composite Score Sheet'!\$C\$5)+([@[Disabled Normalized]]*'Composite Score Sheet'!\$C\$6)+(Table13[@[workers who take public transit to work normalized]]*'Composite Score Sheet'!\$C\$7)+([@[Service Normalized]]*'Composite Score Sheet'!\$C\$8)+([@[\$20K-\$24.9K Normalized]]*'Composite Score Sheet'!\$C\$9)+([@[\$25K-\$29.9k Normalized]]*'Composite Score Sheet'!\$C\$10)+([@[\$30K-\$34.9K Normalized]]*'Composite Score Sheet'!\$C\$11)+([@[\$35K-\$39.9K Normalized]]*'Composite Score Sheet'!\$C\$12)+(Table13[@[public housing buildings]]*'Composite Score Sheet'!\$C\$13)+(Table13[@[hospitals]]*'Composite Score Sheet'!\$C\$14)+(Table13[@[urgent care facilities]]*'Composite Score Sheet'!\$C\$15)+(Table13[@[nursing homes]]*'Composite Score Sheet'!\$C\$16)+(Table13[@[pharmacies]]*'Composite Score Sheet'!\$C\$17)+(Table13[@[Schools: Childcare and K-12]]*'Composite Score Sheet'!\$C\$18)+(Table13[@[colleges / universities]]*'Composite Score Sheet'!\$C\$19)

Sheet'!\$C\$19)+(Table13[@[supplemental colleges]]*'Composite Score Sheet'!\$C\$20)+(Table13[@[SNAP Retailer Supermarkets 2020]]*'Composite Score Sheet'!\$C\$21)+([@[Commercial Normalized]]*'Composite Score Sheet'!\$C\$22)

This will add together all the normalized scores, creating one composite score. To get a handle on what seems to be a complex formula, it is important to understand that it is a series of arguments repeated for each variable being used in the composite scoring. The formula is composed of a variable in Table1 multiplied by its corresponding modifier on the score sheet:

([@[people in poverty normalized]]*'Composite Score Sheet'!\$C\$3)

The first part references the header labeled “people in poverty normalized” on the current sheet (Table1) which it then multiplies by the value found on the **Composite Score Sheet** found at **column C, row 3**. The dollar sign (\$) in front of the “C” and “3” ensures that the formula always links back to the same cell down the entire column rather than allowing Excel to automatically update the formula relative to each row. Add a plus sign and repeat for each variable being used in the composite scoring and the finished formula will look like the previous full formula. Double check that each reference to a cell on the score sheet (e.g., !\$C\$3) matches with the variable it should and that all parenthesis open and close where they should, then paste the full formula into the cell in Table1.

Next, these values need to be normalized using the following formula in the “Composite Score Normalized” column with “B:B” being the corresponding column:

=1+99*(((@[Composite Score]))-MIN(B:B))/(MAX(B:B)-MIN(B:B))

This will normalize the composite scores using a 1-100 range. Afterwards, in the “Composite Score Ranked” column, use the following formula:

=RANK([@[Composite Score Normalized]],B:B,0)

With all of this completed on both Remix and TBEST sheets, the user can now create composite scores, normalize the scores, and rank them. The next section explains the process of constructing a composite score summary sheet where each variable can be weighted differently, with calculations and rankings updated automatically.

Composite Score Summary Sheet

In the previous section, composite scores created and ranked but the variables used were all unweighted. Weighting variables differently is a good way to tailor your composite score to focus on different characteristics of interest. To do this, a new sheet must be created that will reference the table created earlier and allow the user an easy to view place to see the data summarized and change the

variable weights. Once the new sheet has been setup, the composite score column on the previous sheet will need to be edited to take the weighting from the new sheets into account by updating the composite score formula.

Create a new sheet and name it “Composite Score Sheet.” This sheet will contain two columns to list the variables used in the composite scoring from the previous sheet and display the score weights. Additional columns will be used to display route ranking, route name, route composite score, and the normalized composite score. As the weights are updated, the scores for each route will update and be reranked in real-time on this sheet.

In the **A** and **B** columns, enter the relevant variables associated with TBEST and Remix, respectively as shown in the figure to the right. The **C** column will be the score modifiers associated with each variable calculation. The variable columns will have a row for each variable included within the composite score while the “Score Modifier” column will contain the value used to weight each variable. Enter in the weights desired under the “Score Modifier” column (e.g., “10” for “people in poverty normalized” or “5” for “workers who take public transit to work normalized”). These can be adjusted as desired later. With this completed, make note of each variable used in the composite scoring on the previous sheet. This tutorial uses the following:

	A	B	C
1	Composite Score Builder		
2			
3	TBEST Variable	Remix Variable	Score Modifier
4	In Poverty Normalized	people in poverty normalized	1
5	Zero Vehicle Normalized	households that are car free normalized	1
6	Disabled Normalized	people living with a disability normalized	1
7		workers who take public transit to work normalized	20
8	Service Normalized	essential jobs (work) normalized	20
9	\$20K-\$24.9K Normalized	people within 125% of the poverty threshold normalized	1
10	\$25K-\$29.9K Normalized	people within 150% of the poverty threshold normalized	1
11	\$30K-\$34.9K Normalized	people within 185% of the poverty threshold normalized	1
12	\$35K-\$39.9K Normalized	people within 200% of the poverty threshold normalized	1
13		public housing buildings	1
14		hospitals	10
15		urgent care facilities	10
16		nursing homes	10
17		pharmacies	10
18		Schools: Childcare and K-12	10
19		colleges / universities	0
20		supplemental colleges	0
21		SNAP Retailer Supermarkets 2020	10
22	Commercial Normalized		0

Figure 20 - Variables for Score Weighting

- TBEST
 - In Poverty
 - Zero Vehicle
 - Disabled
 - Service
 - Commercial
 - \$20K - \$24.9K
 - \$25K - \$29.9K
 - \$30K - \$34.9K
 - \$35K - \$39.9K
- Remix
 - people in poverty normalized
 - households that are car free normalized
 - people living with a disability normalized

- workers who take public transit to work normalized
- essential jobs (work) normalized
- people within 200% of the poverty threshold normalized

Below the “Variable” and “Score Modifier” columns is where the toggle for whether to divide values by their route’s

24	By Mile Toggle
25	X

Figure 21 - By Mile Toggle

average length should be created. Above, cell A25 was used, so label cell A24 “Calculate per Mile?” to mark the toggle on the sheet. If any text is entered into cell A25 (e.g., “Y”), then the formulas will divide by the average route length.

Next, skip column **D** and Enter Remix in E1:G1 and TBEST in I1:K1 and “Line”, “Composite Score”, and “Composite Score Normalized”, “Rank”, “Composite Score Normalized”, “Composite Score”, and “Line” in **row 3** of **columns E through K**, respectively—as shown in the figure below.

REMIX			TBEST			
Line	Composite Score	Composite Score Normalized	Rank	Composite Score Normalized	Composite Score	Line
753 19th Ward-Plym-City SE / Monroe - Pattern A	866.8	100.0	1	100.00	847.9	753 19th Ward-Plym-City SE / Monroe - Pattern A
450 N Goodman-Portland / Genesee - Pattern A	852.8	98.3	2	98.27	833.9	450 N Goodman-Portland / Genesee - Pattern A
443 Joseph-Hudson / Genesee - Pattern A	851.7	98.2	3	97.89	830.9	443 Joseph-Hudson / Genesee - Pattern A
436 City SE / Norton - Pattern A	844.0	97.2	4	96.16	816.9	768 N Win Vill-Beechwood / Monroe - Pattern A

Figure 22 - Score Ranking Layout

In the “Rank” column, enter “1” into **row 3** and drag down to create as many ranks as there are routes in the data acquired from Remix—this tutorial has 138 routes and thus will have 138 ranks.

The next three columns will use formulas to pull route names, scores, and normalized scores from the previous sheet. These three columns will automatically update as the user makes changes to the score modifiers to weight variables, allowing for dynamic rescoring and ranking. Like the “Variable” column, data must be pulled from the previous sheet. The following three formulas should be pasted into the first row beneath the “Route”, “Composite Score”, and “Composite Score Normalized” columns:

=INDEX(Table1[Line], MATCH('Composite Score Sheet'!D2, Table1[Composite Score Ranked],0))

And

=INDEX(Table1[Composite Score], MATCH('Composite Score Sheet'!D2, Table1[Composite Score Ranked],0))

And

=INDEX(Table1[Composite Score Normalized], MATCH('Composite Score Sheet'!D2, Table1[Composite Score Ranked],0))

Each of these will reference back to **Table1** (or whichever table number references the Remix **Demographics** sheet) or Table2 (or whichever table number references the TBEST sheet) and pull the data pointed to. Copy these down each respective column down to rank 138 in **columns E and K** so that every route will be covered.

The table should automatically update the entire column with the new formula. The scores should have automatically updated based on the weights put into the score modifier column on the score sheet. Switch to the score sheet and then change a variable weight to see the rankings change in real time.

With this additional step, the user can make a more nuanced analysis based on the data they have access to, and with a minimal amount of Excel work for additional variables or analyses.

Sensitivity Analysis

A sensitivity analysis is performed to determine how different variables affect a dependent variable. In this case, we will be performing iterative analyses to determine how different variables affect the route composite scores. Changes will be made to the variables from the **Composite Score Summary** sheet and the results of those changes recorded on a separate sheet, with one row for each iteration.

To do this, a new sheet will need to be created to record the values for the variables used to calculate the composite scores for each iteration and new columns created on the score sheet to record the score changes for each. Create a new sheet named **Sensitivity Analysis Parameters**. Select and copy all the variables from the **Composite Score Summary** sheet under the “Composite Score Builder” that are used to calculate the composite scores, and right click and select “transpose” to paste them in as column headers rather than rows. Insert two new columns next to **A1** and name them “Run” and “Notes” to record each iteration of analysis performed and notes on what the goal of the analysis was.

In the **Sensitivity Analysis Parameters** sheet, enter in the desired values for each modifier variable and then select all, copy them, and do a “transpose” to paste them in to the “Composite Score Builder” section of the sheet. The scores will automatically update. Make a copy of the **Demographics** sheet, and remove all the variables except for “Line”, “Composite Score”, “Composite Score Against All Routes”, and “Network Rankings”. Name the new sheet **Sensitivity Analysis Outcomes**. Next, add three new columns and name them “Run 1 Composite Score”, “Run 1 Composite Score Against All Routes”, and “Run 1 Network Rankings.” Rename the original composite score and rankings headers to include “Current” (e.g., Composite Score becomes Current Composite Score). Next to “Current Composite Score,” add a new column and name it “Average Rank of All Runs”.

On the **Sensitivity Analysis Outcomes** sheet, copy the values in the cells for the “Composite Score”, “Composite Score Against All Routes”, and “Network Rankings” columns and right click and select “Paste Values” under the new “Run 1” columns. Using this method, the user can record each set of scores and rankings as they change with each iteration of modifier changes.

The workflow should be adding a new row for a new run to the **Sensitivity Analysis Parameters** sheet, copying the values and pasting them using transpose to the “Composite Score Builder” on the **Composite Score Sheet**, then creating three new columns on the **Sensitivity Analysis Outcomes** sheet to record the values for that run. Each successive run should build on the previous until the user desires to perform a different analysis focusing on different modifiers.