Final Report

NYSAMPO Shared Transit Service Planning and Analytics Initiative

June 2023

AVAIL transpogroup Sam Schwartz mca Marlene Connor Associates LLC

Table of Contents

Executive Summary

The Shared-Use Transit Software project was launched by the New York Association of Metropolitan Planning Organizations (NYSAMPO) to assess the transportation software landscape, perform a market analysis, and identify software viable for broader use by entities conducting transit mobility planning in New York State. The Research Team of AVAIL, Transpo Group, Sam Schwartz, and Marlene Connor Associates designed and implemented a program for evaluating a variety of software solutions for transit planning. Metropolitan Planning Organizations (MPOs) and Transit Agencies (TAs) were surveyed about their transit planning needs and about their important agency objectives. Agency needs were considered in the context of the technological environment and the design of analyses within it. Available software platforms were assessed through the lens of how each software could perform analysis in support of specific transit planning functions.

The Research Team solicited proposals for four pilot projects to test different transit planning software tools. Rochester's Regional Transit Service, Westchester County's Bee-Line Bus System, Central New York Regional Transportation Authority (CENTRO), and the Capital District Transportation Authority (CDTA) applied to the research program with case study project concepts. We reviewed a variety of software, both proprietary vendor software and available open-source modules, to determine which could be utilized for each pilot, with specific consideration for replicability of the pilot projects. **Remix, TBEST, Conveyal, Replica**, and **STOPS** were selected for the pilots. Each of the software were evaluated during the case studies for their potential in a statewide shared-use program, and for agency-specific use. Several other software packages were evaluated, but not used in a pilot project, and additional software, not specifically designed for transit were utilized in the pilots in support of the transit planning software.

This Final Report is the summarized culmination of multiple White Papers drafted throughout the project. The project information presented is thoroughly concentrated and substantially more detail can be found within its source documents;

- Market Analyses And Software Recommendations (December 8th, 2021)
- Case Study White Papers
    - Westchester Pilot Study (1/19/2023)
    - Regional Transit Service Pilot Study (3/14/2023)
    - CDTA Troy Transit Planning Pilot Study (3/14/2023)
    - Oswego Pilot Study (3/21/2023)
- Transit Recommendations (April 2023)

The final recommendations of this project include Technical Recommendations and Institutional Recommendations. The Technical Recommendations are software specific; each software is reviewed on the basis of its general usability as well as possible applicability for statewide deployment. The Institutional Recommendations outline important support considerations to ensure the success of future technological implementation and includes an example playbook for replicating this effort.

Background

Public transit has always been a key element of New York State's transportation network, and a new focus on technology-driven solutions has expanded what public transit can be, how far it can reach, and how agencies plan for it. Emerging technologies have also helped advance more traditional transit service by streamlining transit planning for agencies and improving the rider experience. This has been achieved through several strategies including more convenient fare payment options, real-time bus location information, more advanced scheduling software for demand-responsive and shared ride services, and an abundance of mobile trip planning applications.

Through this wide array of tactics, MPOs or TAs can augment long-term transportation goals with stepwise strategies. For example, the need for a new bus rapid transit (BRT) route may be identified in a rapidly growing area. During the time it takes to plan, design, and construct this expansion, shorter-term solutions could be implemented that temporarily bridge the identified gap. These solutions could use a combination of existing facilities and new mobility services to improve transit access at a faster pace than would otherwise be possible.

Advancements in public transit (through emerging technologies, policy changes, improved infrastructure, etc.) have increased the available options for implementation. With the many moving pieces that make up the transit planning industry, and the wide-ranging analytical needs and technical capacity of MPOs and TAs throughout New York State, it is imperative to understand which transit planning and analysis tools will be most effective in aiding agile, proactive, and intelligent transit planning. Through a targeted review and assessment of available tools, a unified transit toolbox can ultimately be deployed throughout the State that further empowers TAs and MPOs in their local and regional planning processes while integrating statewide methods and practices.

In tandem, the tools used to plan and analyze our transit networks have become more readily available and utilitarian. However, it is not always clear which options will best integrate with a region's system-wide transportation network and what tools can best aid in the development and evaluation of alternatives. In a quickly advancing, technology-driven industry, it is even more important to have the right tools to evaluate key transit components such as accessibility, future ridership demand, and operational scenario forecasting and choose the most efficient, equitable, and cost-effective solution. This requires the right combination of transit planning and analysis tools that can be utilized by the MPOs, TAs, and other planning partners who have a strong regional and local knowledge base.

Research Team

Albany Visualization and Informatics Laboratory (AVAIL)

AVAIL has a long history of providing cutting-edge web-based IT solutions for public sector transportation agencies. AVAIL specializes in utilizing the best in open source software to develop visually engaging, problem-specific, data science visualization suites. AVAIL's staff have more than 20 years of experience working in transportation planning and software development, having conducted a wide variety of projects for public transportation agencies in New York, New Jersey, Pennsylvania, Connecticut, Michigan, North Carolina, Ohio, and Texas, as well as the Metropolitan Transportation Authority, New Jersey Transit and FHWA.

Transpo Group

Transpo Group has a wide range of transit planning on-call expertise and know-how in leveraging new mobility products and services. Their team of professionals have evaluated first-and-last mile access to transit, performed transit oriented development site selection and conceptual design, provided transit policy guidance, and implemented innovative transit service delivery models. They have helped improve transit operations and efficient service delivery through multimodal integration, ridership forecasting and modeling, corridor analyses, and smart bus stop design. In addition, Transpo has collaborated with transit agencies in evaluating changes to improve the speed and reliability of transit service standard and assessing new transit technologies and capital improvements such as transit bypass lanes, queue jumps, transit signal priority, wireless access points and design, and transit access lanes.

Sam Schwartz

Sam Schwartz is a 130+ person transportation consulting firm with a diverse, talented team of professional planners, engineers, data scientists, and designers headquartered in New York City with offices in six other locations across the United States. Their service areas span multi-modal transportation planning and engineering, strategic planning, urban design, data analytics, community engagement, environmental and economic analysis, and civil engineering. With over 25 years of practice on a wide array of complex transportation issues, they have established a record of industry-leading projects that help communities reimagine their transportation systems in support of healthy, equitable, economically vibrant cities and regions.

Marlene Connor Associates

Establishing Marlene Connor Associates in 2015 has given them the ability to particularly focus on policy and planning projects that they believe are most important to the public transportation industry– providing one system mobility options for all persons. The pandemic clearly demonstrated that essential mobility is of primary importance for public transportation. It is also consistent with how MCA works with

customers and communities to advise on choices for each locale to communicate all opportunities, use technology to inform on options and recommend operating strategies, recognizing that ultimately it is the role of public transportation to ensure that services are available for all, ensuring full equity and inclusion.

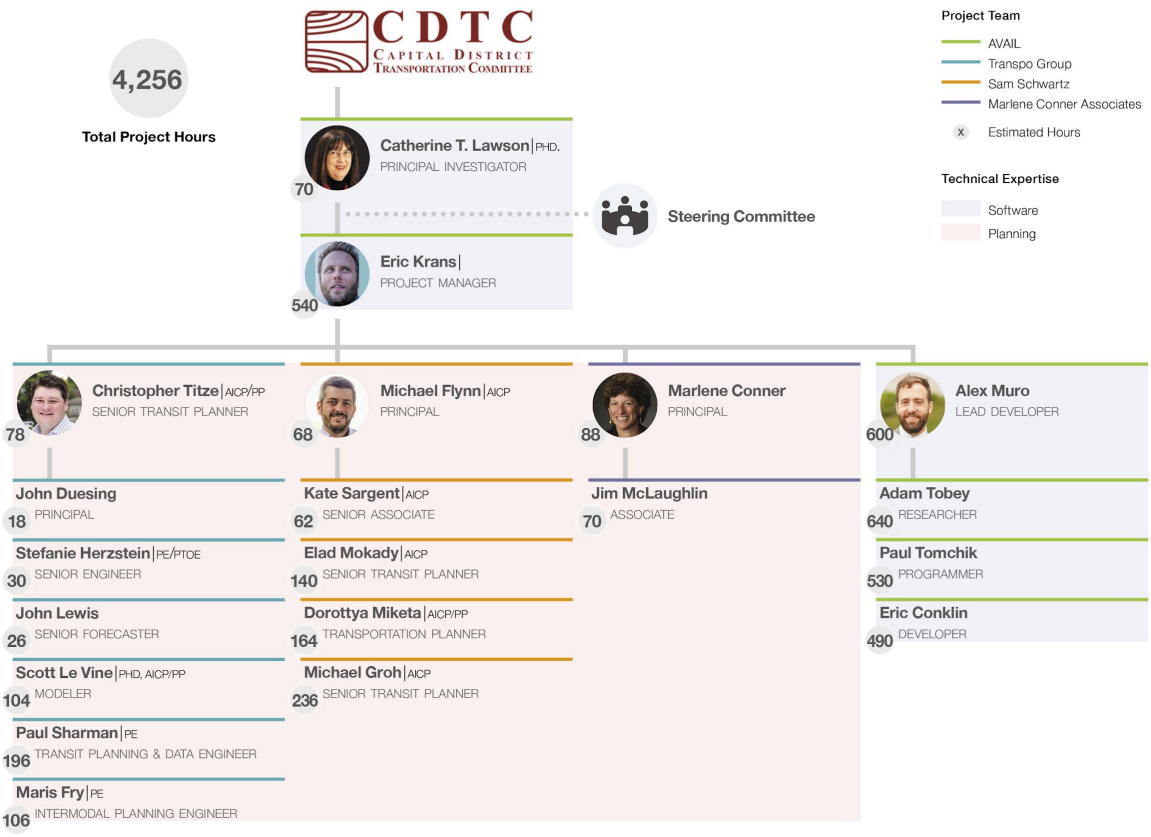


Figure 1 – Project Team Organization

Methodological Approach / Design

The approach used by the Research Team was designed to address the challenges of transit planning by soliciting information about practitioner needs and available software. The primary objectives were to identify and evaluate the available transit planning software, determine their compatibility with the needs of transit planning agencies, utilize select software on discrete analyses, and provide feedback about each selected software – particularly for replicability and potential use in a statewide shared-use program.

Market Analysis

To collect relevant information about transit planning needs and software tools currently used by transit planners, the Research Team distributed a *transit planning needs survey*. This survey was intended to assist the Research Team in:

- understanding the type of questions that transit planning agencies have about their networks;
- understanding what kinds of requirements they have to report on their network behavior to federal agencies; and
- identifying the critical features and functionalities that MPOs and TAs required in transit planning software.

The *software market analysis* was intended to assess the full software market and determine availability, applicability, and limitations of existing software tools for transit planners. The market analysis assessed software by license types, user experience, required user technical skills, the feature suite, and purposes. The Research Team designed the market analysis to result in recommendations for software to be tested in the case study portion of the program – and to inform the case study selection process.

Transit Planning Needs Survey

To assess the transit planning marketplace, the Research Team developed a survey to solicit information from MPOs and TAs. The survey was comprised of 25 multiple choice, ranked choice, and open-ended questions that focused on the agencies' experience with transit planning tools and data, the challenges in utilizing them, the analyses and tasks currently undertaken by the agencies using the tools, and the objective that agencies are looking to address in the future. Also included were basic questions about the responsibilities of the individual employee responding to the survey and their agency's roles related to transit services (supporting, planning, operations, etc.).

Hosted online and open for responses between September 27, 2021 and October 20, 2021, the survey was distributed through email messages to specific planning staff members of each MPO and selected TAs in New York State. Responses were received from 21 agencies including 12 MPOs, 8 TAs, and the NYS Department of Transportation (NYSDOT) Modal Grant Bureau. As part of this analysis, the MPOs

were further grouped into 3 categories based on their population size. NYSDOT Modal Grant Bureau was excluded from subsequent survey results due to its distinct functions and software needs.

Software Market Analysis

The software market analysis included a market scan of all transit planning software. The Research Team worked with the project Steering Committee and used the results of the *transit planning needs survey* to develop a comprehensive list of criteria, characteristics, and functions desired in a transit analysis software ecosystem. The Research Team reviewed and rated each software by characteristics such as cost (open source versus proprietary), ease of use, regional flexibility, integration of data sources, operational analysis, and others. Based on feedback from the Steering Committee, the Research Team recommended a set of software tools for use in standalone deployments or in a combinatory ecosystem.

For the transit planning software market assessment, the Research Team reviewed both proprietary vendor software and available free or open-source modules that met the following transit planning needs:

- Analysis of transit proximity to jobs, population, medical facilities, education institutions, and other services deemed essential during the COVID-19 pandemic by New York State
- Ridership demand forecasting and revenue projections
- Operational scenario planning:
    - Routing, frequency, and transfer analysis
    - Stop consolidation and relocation
    - Detour impact analysis
- On-time performance analysis
- Park and ride and transit center/ mobility hub market analysis
- First and Last mile connection analysis
- Title VI analysis

In addition to these functionalities, the software packages were assessed by a number of other measures that may impact MPOs or TAs and organized into two primary categories: agency resource needs and software considerations.

Case Studies

The purpose of the case study program was to determine the suitability of the selected software for future use by MPOs and TAs. The case studies were designed to test the capabilities of each software for use in agency specific work environments.

The pilot testing of the software was critical in generating user buy-in. The pilots were designed to assist practitioners in analyzing or solving one of the real-world problems they currently face. By choosing a specific goal for each pilot, the Research Team was able to measure the utility of the software tools in

their ability to answer the specific questions and also assess the friction that a practitioner faces in interfacing with a new workflow tool.

Solicitation

A statewide equitable solicitation of discrete technical analyses was used to select pilot projects and software. An open invitation was sent to all MPOs and TAs stakeholders encouraging applications with distinct current problems that may be solved with software solutions.

Selection

The pilot project applications were each reviewed against a rubric that weighed proposals based on compatibility with available software and reasonableness of the proposed scope of the pilot study. The review prioritized applicants in varied regions and sizes across the state to ensure that the methodology captured the diverse range of transit planning needs and maximized the number of software tested in the project.

Design

The Research Team developed distinct pilot projects based on applications received with input from the Steering Committee and the applicant. Some proposals had their scopes scaled to be pilotable and ensure that the workflows would be replicable using the selected software. Each pilot project was unique in software chosen, application of software tools, and output files generated:

- **Rochester's Regional Transit Service** - Used Remix and TBEST demographics outputs to determine which routes would most benefit their market area by an increase in frequency.
- **Westchester County** - Used Conveyal to determine the travel time impacts of removing or truncating a route.
- **Central New York Regional Transportation Authority** - Used STOPS and Replica to assess whether overall efficiency gains can be delivered by reorganizing the Oswego system without changes in staffing or revenue-vehicle resources.
- **Capital District Transportation Authority** - Used TBEST to analyze the current transit system and model potential changes to ridership based on service changes.

Analysis

Each case study was designed to be conducted by the Research Team independently from the MPOs and TAs. The Research Team held bi-weekly meetings with the representative(s) from each project's TA and regional MPO to report on progress and participate in the analysis design. The Research Team utilized an iterative approach with each pilot's software to adapt the research design based on initial results and workflows. Each pilot project analysis was consolidated into a white paper detailing the project and providing a deeper technical analysis.

Recommendations

The pilot project analyses each yielded technological recommendations for each software and its feasibility for a statewide shared use program. Both objective and subjective assessments were performed for each of the four transit pilot projects, including attributes about the software used, user experience with the software, and the results obtained. These individual assessments were compared to identify the strengths and weaknesses of each software. After holistically assessing software based on their efficiency of implementation, accuracy of results, ease of use, and necessary support for tech transfer, the most promising software were recommended for use in a statewide shared use program.

Additionally, the Research Team prepared Institutional Recommendations based on the findings of each Pilot Study, to ensure the success of any future investment in Transit Planning Software technology. The Institutional Recommendations take into consideration agency size and staffing capacity, statewide transit planning data needs, and tech transfer best practices.

Findings

This section provides a detailed overview of the outcomes of the market analysis, the four case studies, and the software assessment conducted by the Research Team. The market analysis consists of the initial survey results of MPO and TA current software uses, their future objectives, software challenges, and a potential project they would like to undertake aligning their long-term goals and software use. The Results for each of the case studies include an answer to the agency's question and an example of software applied for a solution. Additionally, the experience of the Research Team and the participating agency staff with each software solution provides the basis for best practices statewide.

Market Analysis

Survey Results

Twelve MPOs and eight TAs were surveyed about their transit planning software needs and their agency's priorities over the next five years. MPOs were categorized based on their population size: small (total population < 140k), medium (140k-200k), and large (>250k). The Research Team and the survey respondents identified twenty-five transit planning analysis types, of which the following software capabilities were identified as most important:

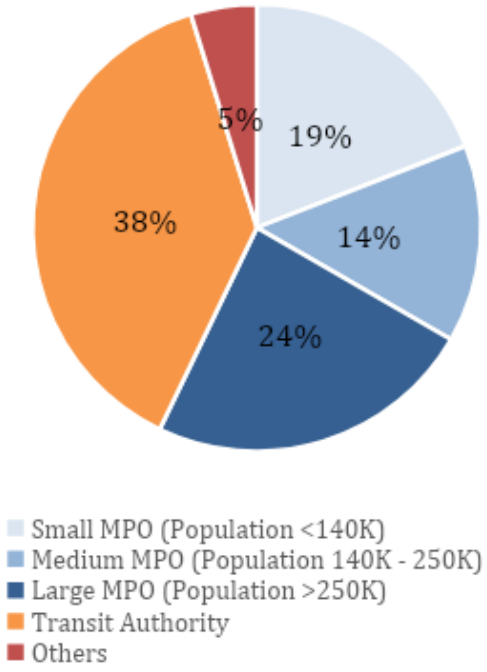


Figure 2 – Survey Respondents

Immediate Needs:

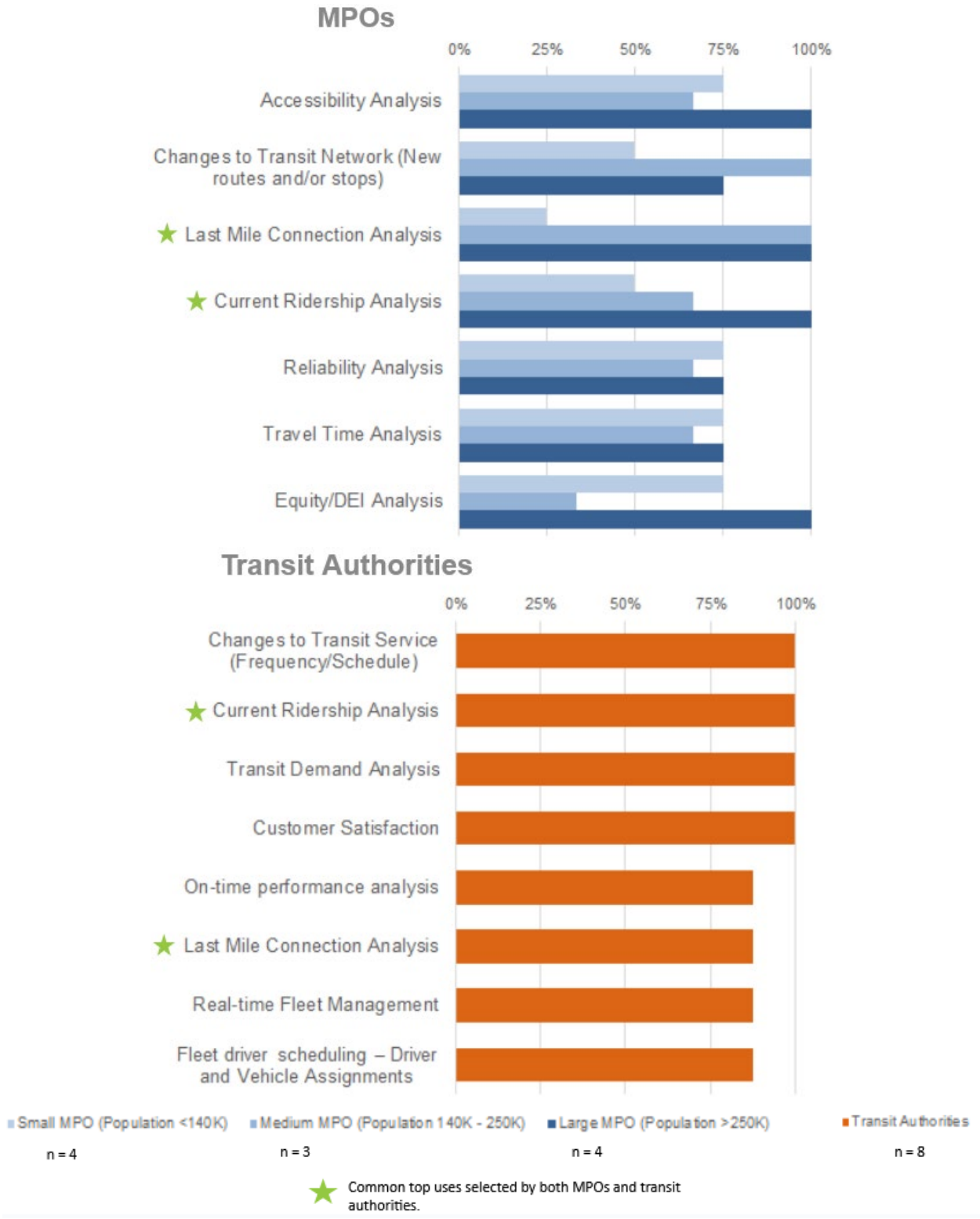


Figure 3 – Market Analysis Survey Results, "Market Analysis and Software Recommendations" White Paper

Many of the survey questions looked at transit related objectives that agencies anticipate they will focus on over the next five years. Participants were provided with a series of eighteen potential objectives and asked to rank the importance for their agency. MPOs identified increasing transit ridership, better serving disadvantaged groups, better serving choice riders, and improving access to employment as key out of possible eighteen choices. TA responses indicated that better serving disadvantaged groups, increasing transit ridership, and improving access to employment were the priorities. Both MPOs and TAs shared increasing transit ridership, better serving disadvantaged groups, improving access to employment, reducing journey times for transit riders, improving access to social services, and improving sustainability as important agency objectives over the next five years.

To better understand the challenges various agencies face, the survey included several questions on the constraints keeping agencies from achieving their objectives and their software needs. The most noticeable difficulties related to software use were personnel and resource constraints. Agencies noted that they faced limitations in staff bandwidth preventing agencies from performing more in-depth analyses. Agencies also responded that they lacked the specialized expertise to carry out these analyses. Additionally, several agencies indicated they faced difficulties in making the data they generated actionable.

Participants were asked to rank several software features by importance to their agency and to list any functions that the agency seeks in transit planning software packages. The roles of MPOs and TAs are distinct and the responses highlighted this difference in their software needs. While MPO's typically support transit planning in funding administration and regional data analysis, TAs are focused on planning, operating, and monitoring their provided services. Almost all MPO survey participants (eleven out of twelve) ranked software integration with the agency's existing GIS software and data as critically or very important. Software's technical support and user-friendliness were also highly ranked among all participants with eight TAs categorizing them as critically or very important. Software customization was ranked as highly important by seven of the agencies.

Available Software

The Market Research Survey Questionnaire responses indicated that staff expertise and time constraints played a critical role in the implementation of new software within their organization. These agency needs were considered when referring to the technological environment (computer hardware, network capabilities, robustness of IT department, etc.) necessary to operate a software and the difficulty of designing an analysis within it. Software was assessed by its data needs, user interface, complexity of analysis process, customizability, and support that was offered. Together these measures provided a metric for assessing the software landscape. The following software were reviewed by the Research Team:

Software Reviewed by the Research Team			
Open-Source / Free		**Commercial**	
Conveyal-Analysis	Route Trends	Conveyal (Commercial)	TransCAD
Conveyal-r5	STOPS	ESRI Public Transit Tools	Trapeze
Conveyal-Taui	TBEST	Hastus	TripSpark Transit
GTFS Editor	TNExT	Remix	
GTFS-R	Transitland	OptiBus	
OneBusAway	Transitr	RideConnect	
RidePilot		Spare Realize	

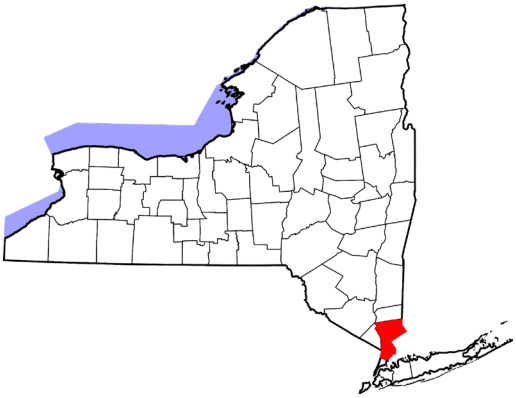
Table 1 – Software Reviewed by the Research Team

Due to their availability and the set of features offered by each software TBEST, STOPS, Conveyal, Remix, Replica, OpenTripPlanner and the ESRI Public Transit Network Analyst Tools were selected to be tested in four real-world use-cases in four case studies. ESRI Public Transit Tools and OpenTripPlanner were both assessed during the case study scoping processes and were dropped from further consideration due to intense labor requirements and analysis limitations, respectively.

Case Studies

The following section summarizes the four case studies. For more detailed information on each case visit the specific case study white paper. To replicate the case study or to utilize the methodology to solve similar problems visit the ***Transit Planning Analysis Playbook*** document.

The Bee-Line - Westchester: Analysis of Proposed Route Elimination



The Westchester project design tested the value of the BxM4C commuter express bus route. The project utilized origin-destination (O-D) matrices from a variety of open-source software tools to analyze travel time across a variety of service scenarios. The Research Team evaluated OpenTripPlanner (OTP) and Conveyal. Conveyal was chosen due to its ability to batch run and export detailed outputs in a format suitable for easy post-processing in MS Excel. The Research Team compared travel times from origins in Westchester County to destinations in Manhattan under three scenarios: current service conditions, truncated service, and no service.

The Research Team began the route analysis using OTP. However, OTP did not generate origin and destination matrices required for the project efficiently. To generate the matrices, the analyst would need to perform the same analysis for each O-D pair of interest and manually construct an output table. The Research Team instead opted to use Conveyal. Setting up an instance of Conveyal required an in-house software engineer to establish the web hosted instance and then guide the Research Team through the process of creating the transit network ecosystem. Then, the Research Team had to clone a GitHub repository constructed by the software engineer to their local machine. The setup process for both OTP and Conveyal is highly technical and would require dedicated support on-hand for a TA or MPO.

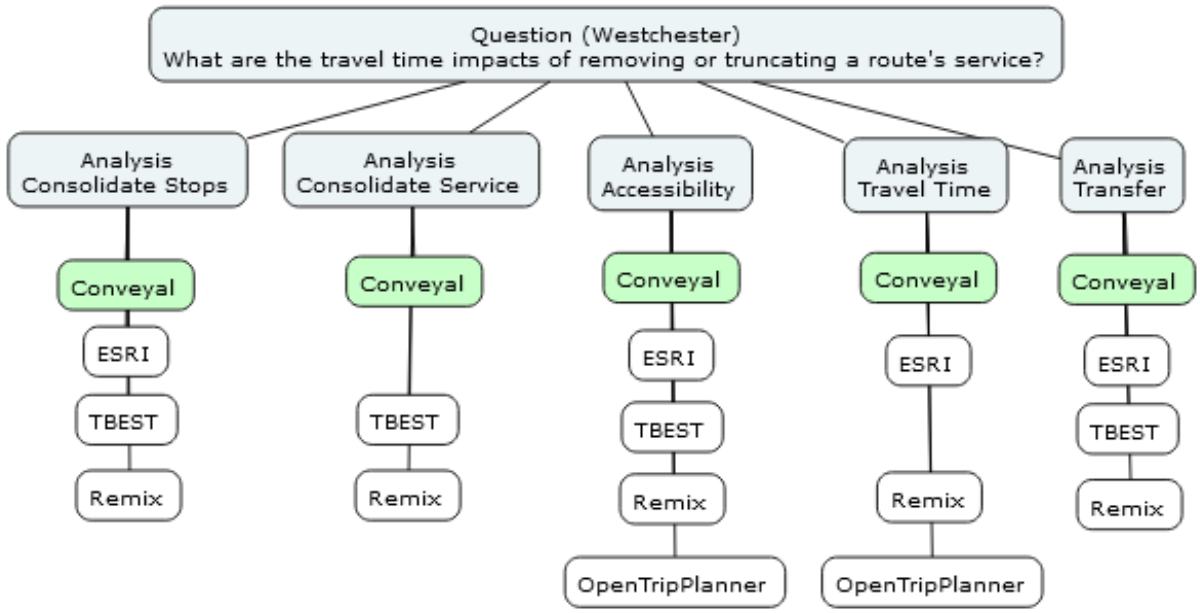


Figure 4 – Analysis Question and Software Selection, Westchester

Conveyal's user interface can be confusing and with repeated use, the workflow still remains unintuitive. Conveyal's strength is in its ability to provide flexibility when designing analyses. The user is able to customize major parameters that would be expected by an experienced analyst. Further customization is available through an integrated configuration component. This JSON editor allows the analyst to enter and define supported variables providing for further customization options.

After completing setup, Conveyal was able to generate travel times from origin locations on or near the BxM4C to select destinations within the ecosystem for each scenario. Conveyal's output provided the travel times for each O-D pairing and any transfers that a rider would need to take to get from destinations within Westchester County to Manhattan. Using Microsoft Excel, outputs from Conveyal were manually post-processed into matrices showing travel times (in minutes) from each origin to each destination. The BxM4C and No-BxM4C scenario matrices were compared to assess the impact the removal of service would have. Each of the truncation matrices were compared to each other to identify optimal locations for service truncation. The outcome was a series of matrices that could be analyzed independently or compared with each other.

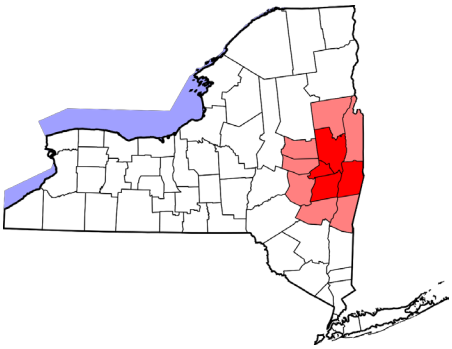
Using the matrices, the Research Team reviewed boarding and alighting data for the BxM4C. The Research Team added a list of origins and destinations which included all of the BxM4C stops and a collection of other locations that could be possible Westchester origins and possible high gravity locations in Manhattan and the Bronx. Boardings were high in lower Westchester County and alightings high along Central Park suggesting that the ridership of the BxM4C serves a consistent geographic and demographic group. Based on the outcomes of the analysis, the Research Team determined that removal of the BxM4C would most severely impact riders living in lower Westchester who work in upper Manhattan. Removal of the BxM4C would most severely impact this demographic by increasing inbound

travel times by anywhere from 20-50 minutes depending on commute start time and schedule optimization by those riders.

Conveyal was found to be a flexible transit planning tool that can be used effectively by planners to answer specific questions. It provides visually appealing isochrones, travel time analysis with origin-destination pairs, and is highly customizable. However, the user interface was found to be not intuitive and setup is difficult without dedicated support, making it challenging for application without external support by specialized staff with expertise using Conveyal on a recurring basis.

Software: *Conveyal*
Replicability: Replicating this project would likely require third party support to deliver desired outcomes with reasonable level of effort.

CDTA - Capital District Transportation Authority: Route Restructuring



The CDTA pilot project sought to identify and assess planning software that CDTA could utilize to perform route and ridership analysis in preparation for a comprehensive route restructuring. The City of Troy was selected as the project study area, limiting the analysis to the 12 CDTA bus routes that served the city. Latent demand was identified by analyzing gaps between the existing transit service and transit service demand within the Troy municipal area and origin-destination between Troy and other communities in the Capital District.

The Research Team developed a series of potential service modifications for CDTA's bus routes serving Troy, based on the gap analysis. However, the overarching goal of the pilot was to test a concise, reproducible methodology utilizing transit planning software. 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 the Florida Department of Transportation. Remix, a commercial, web-based transportation planning platform used for designing and evaluating transit routes, schedules, and service modifications, was also used as part of this analysis.

TBEST was chosen to run the ridership estimation model as it is a user-friendly, customizable transit ridership modeling software that supports multiple GTFS scenarios. TBEST provides a suite of tools for analyzing a transit network ecosystem. The most challenging component for utilizing the software was setup, but once it was completed, the software performs well.

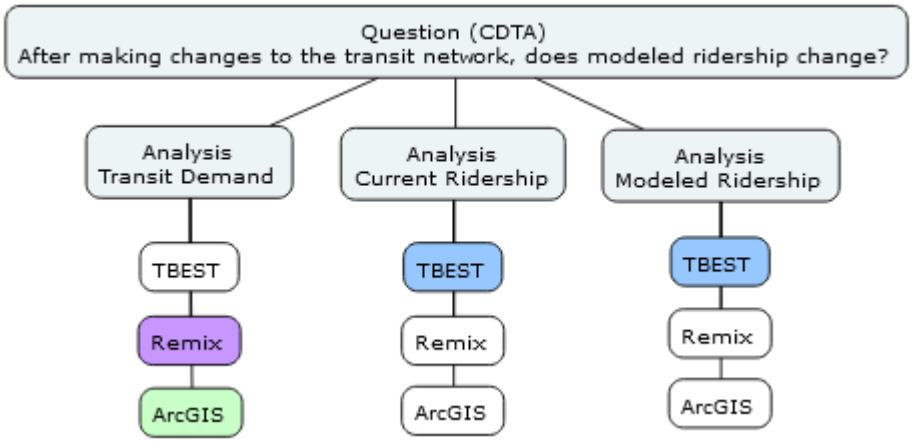


Figure 5 – Analysis Question and Software Selection, CDTA

The Research Team decided to utilize data from the Fall of 2019 as the analysis baseline due to the availability of both socio-economic data from US Census resources, and CDTA ridership data that reflect pre-pandemic conditions. CDTA's Transit Propensity Index (TPI), which incorporates multiple factors and weights, was used to assess demand for service.

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. TBEST provides output using a gravity model that utilizes American Community Survey 5-Year Estimates, Longitudinal Employer-Household Dynamics, Origin-Destination Employment Statistics (LODES), local parcel data, and a multi-linear regression model that provides coefficients for land uses.

An additional Socio-Economic Data Package product that was created previously by Service Edge Solutions and the New York State Department of Transportation for use in a separate project greatly simplified the TBEST setup. In the absence of the NYS specific data product, an analyst would be forced to manually build the package of data TBEST uses in its modeling. This process requires a high level of technical expertise and familiarity with multiple data sources, adding a high level of complexity to setup that may be prohibitive[1]. Additionally, TBEST has specific software dependencies which proved difficult to troubleshoot on a test computer–the issue may be exacerbated when put in use on a general-use agency computer.

In order to calibrate TBEST's model, CDTA provided observed ridership data via Automatic Passenger Count (APC). Compared to the APC data, TBEST overestimated the number of riders that used bus stops near the downtown Albany business district, which is known to be car commuting state workers. The model also underestimated college ridership, which was likely due to underrepresentation of transient college students in the census. The Research Team decided to forgo model validation in favor of calibration using model coefficients, land use data adjustments, and attractor designations via a

[1] Update: On 7/13/2023, the Florida Department of Transportation Public Transit Office announced a version update to TBEST. In this new version, the software now includes a new "Socio-Economic Data Configuration Tool" intended to expedite the process of creating base data.

sensitivity analysis process. The resulting calibrated model was found to be within a reasonable margin of error from the APC data.

The Research Team then designed a variety of service modifications to CDTA routes in the City of Troy through Remix. These modifications included adding a new route, restructuring select segments, and adjusting route schedules.

The model forecasted an increase in ridership throughout the market area as a result of the potential service modifications. While some routes indicated a slight drop in ridership, others were estimated to increase, 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.

Additionally, CDTA staff expressed an interest in setting up TBEST on a CDTA computer and training on its use. The Research Team conducted four separate two-hour training sessions covering initial setup through the replication of the analysis performed by the Research Team (see *Figure 4*).

TBEST was found to be a user-friendly software package that can be used to perform ridership market analyses and to forecast potential changes to transit networks–with caveats. Setup can become prohibitive in the absence of the premade socio-economic data package offered by ServiceEdge Solutions (SES) and NYSDOT and given TBEST's software dependencies.

Software: *TBEST*, *Remix*, and *ESRI ArcGIS*
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 successfully replicate this project with reasonable level-of-effort.

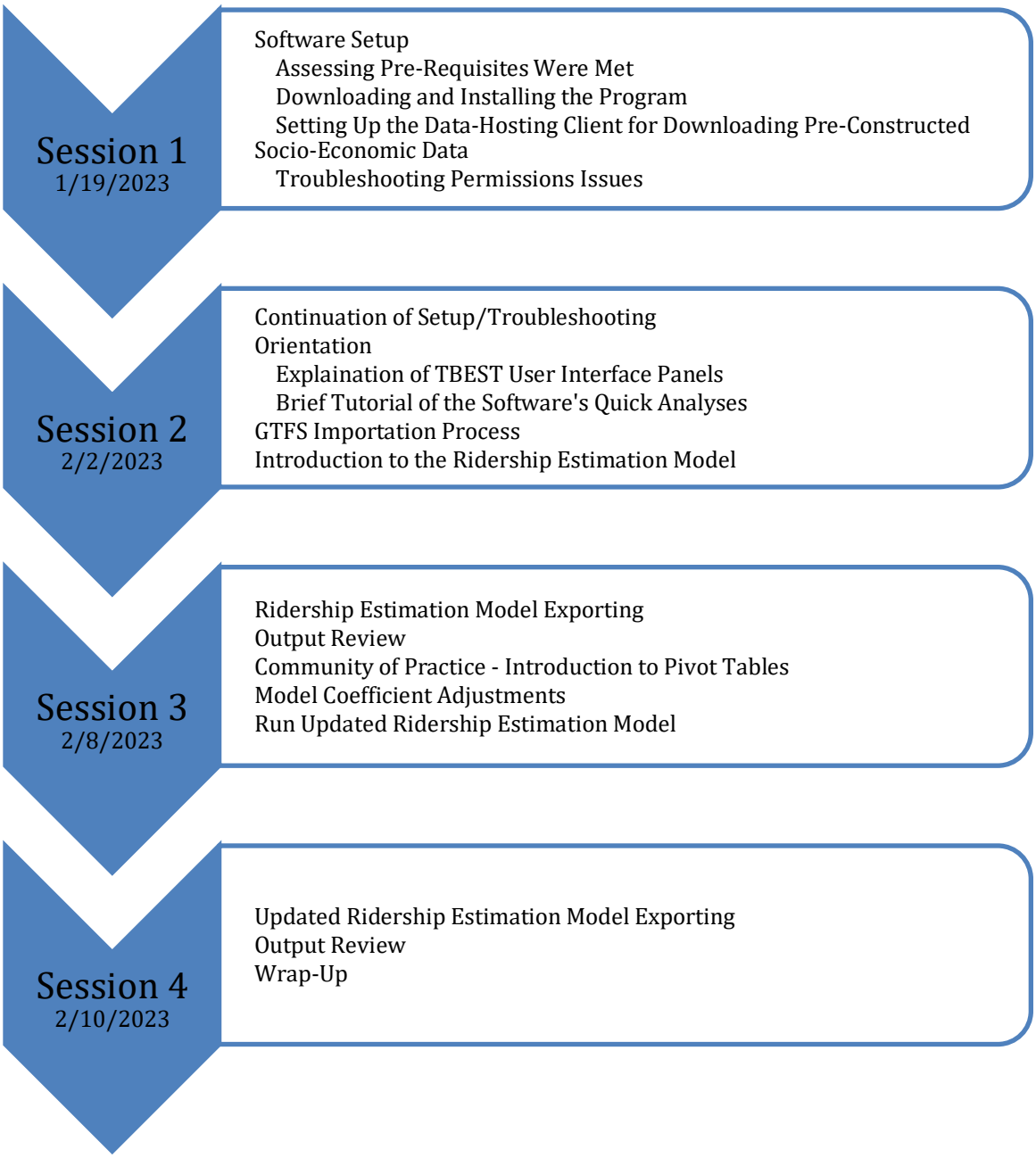
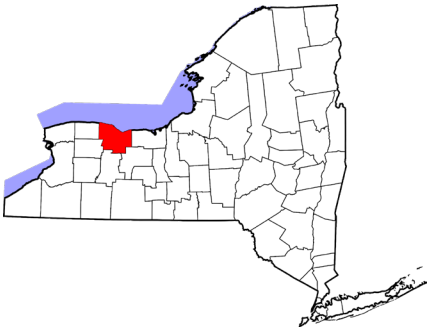


Figure 6 – CDTA Training Session Summary

RTS - Rochester: Increasing Employment Access through Increased Fixed-Route Frequency



The RTS pilot project was designed to produce 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 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. Both TBEST and Remix were selected for this project.

The project design utilized the export feature of both TBEST and Remix to generate potential ridership demographics and ACS 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. The design allowed 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.

The Research Team utilized TBEST's ridership estimation model export data for the first six months of the project. RTS and the Research Team gained access to Remix during the project which led to a parallel process based on the data products offered by 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. The Research Team reevaluated TBEST's export functionalities after Remix was able to provide comparable results.

Of the initially selected Routes of Interest, 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.

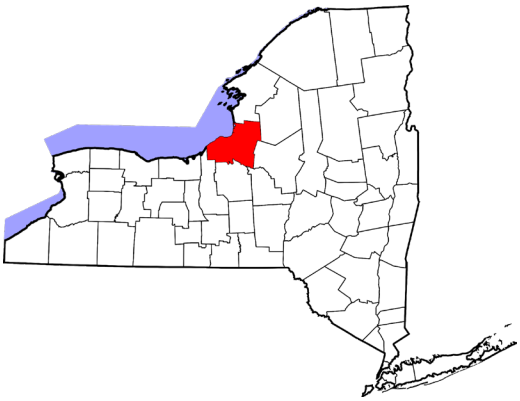
AVAIL trained staff at RTS on how to utilize the chosen software and the Excel composite score tool, as well as its underlying methodology, to rank any routes in their network. They were trained on how to update the composite score weighting factors and provided organizational tools for conducting sensitivity analyses on the adjusted demographic factors. 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. Though TBEST and Remix provided comparable outputs, 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.

Software: *Remix* and *TBEST*
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.

Oswego: Service Alignment Study

The objective of the Oswego project was to develop and then test a prospective redesign of Oswego's City Bus service by using two innovative travel demand analysis tools: Replica's synthetic origin-destination datasets and the Federal Transit Administration's Simplified Trips-on-Project Software (STOPS) open-access travel-demand modeling software package.



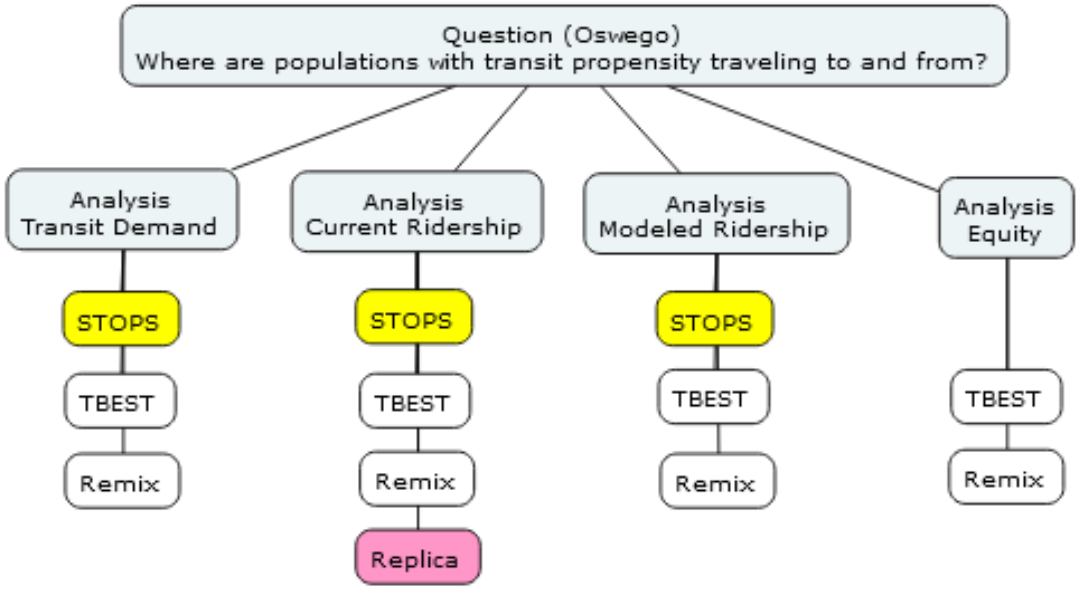


Figure 7 – Analysis Question 1 and Software Selection, Oswego

The focus of the project were Centro's City Routes, which were last critically evaluated decades ago. Centro operates three bus vehicles on the City Routes. Per discussions with Centro planning staff, the project aimed to use an evidence-based approach to propose a redesigned set of City Routes, and to then establish what the ridership impacts of redesigning the system would be. The starting point for the network redesign was an ambition to straighten and rationalize the City Routes, which currently follow indirect routings to serve various locations in the City of Oswego.

The project involved two work streams that were undertaken sequentially. The first involved preparing the proposed redesign of Oswego's City Routes to produce a service plan. Once the service plan was complete, the second task was to prepare ridership forecasts for the proposed system redesign. The objective was to quantify the impact of the service plan on ridership, as a key piece of decision-support information for Centro to consider.

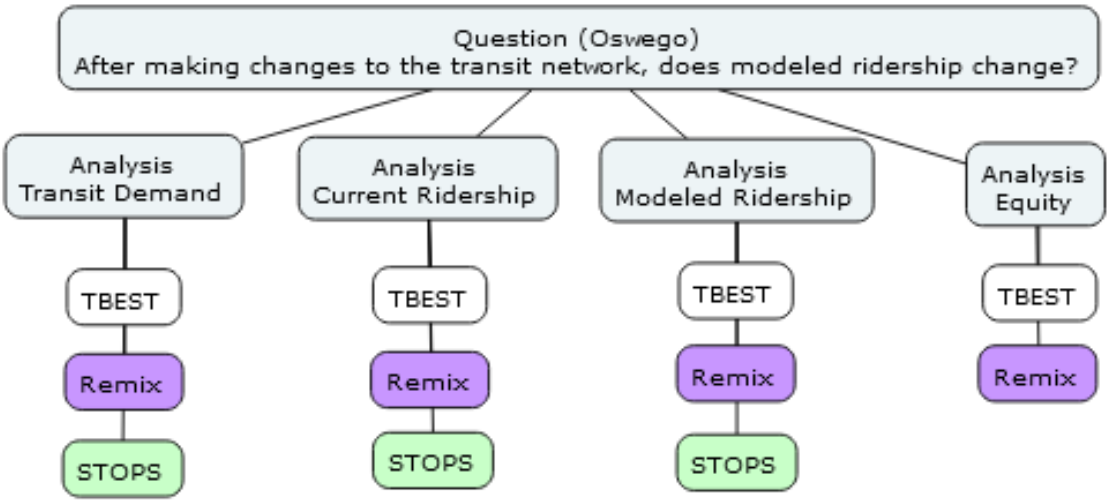


Figure 8 – Analysis Question 2 and Software Selection, Oswego

A traditional approach for evaluating candidate locations for increased (or decreased) transit service is to evaluate a Transit Propensity Index (TPI) for a small-area Census geography (Census blocks, block groups, or tracts). The Research Team drew on Replica data to perform an extended analysis of transit propensity. Replica data is a commercial data product to which all MPOs in New York State now have access through the vendor's online portal; with the paid-up access to Replica, there is no charge for each application of Replica data such as the queries in this pilot project. Replica data are synthetic and fused from a variety of sources. A major advantage of Replica is that it synthesizes the type of data that would normally come out of a custom regional travel survey, which does not exist in many parts of the country – including Oswego.

Replica data were employed to identify and prioritize among travel markets in Oswego. The prospective system redesign involved a primary east-west route along Rt. 104 (Bridge Street) and a secondary, less-frequent route to provide coverage to specific transit generators to the south of Bridge Street. It was found that the prospective redesign trades route-coverage for more service on the Rt 104 corridor, which would have negligible effects on ridership – in fact a decrease of 2.5% from 442 to 432 passenger-journeys per weekday. However, sensitivity analyses (which considered various combinations of routes, headways) show that 90% of the system's daily ridership could be served by operating only two bus vehicles along Rt 104, with the 3rd bus serving the off-corridor destinations providing much less productive service (in terms of ridership).

After developing prospective alignment and schedules, the operations of those changes to the Oswego city bus routes were coded into the GTFS data format which is the primary input needed for running STOPS software. STOPS is an open-access software (the application is open-access; note that the source code is not published), free-of-charge and accessible from FTA's website[2]. Users are advised that the website is not always maintained up-to-date, thus it is advisable to check with FTA's contacts identified on the website prior to beginning a STOPS assignment to confirm that the latest version of STOPS, documentation files, and associated CTPP data files will be used. STOPS training courses are regularly offered through the National Transit Institute.

STOPS was designed to generate ridership forecasts for major capital investments in mid-size and large transit systems. FTA confirmed to the Research Team that the application of STOPS in Oswego is towards the smaller scale of known STOPS applications nationally, and thus provides valuable insight into how STOPS works in small-scale cities with small transit systems.

The Replica data were found to be very easy to access and process into a usable Transit Propensity Index that was Origin-Destination based (which extends from standard practice using Census, travel surveys, and other spatial datasets). STOPS was found to provide credible forecasts in the context of this small-scale transit system, which is in contrast to the major capital investments in larger metro areas that STOPS was initially designed to model. A consistent theme was that specialized knowledge of travel demand modeling was key to this pilot study's success, meaning that ensuring knowledge-pooling/-sharing across NYS's planning agencies would be key to ensuring that the learning curve is as smooth as possible for staff and/or consultants.

Software: *STOPS* and *Replica*
Replicability: This project is replicable due to the statewide Replica license and the availability of STOPS, but STOPS has a steep learning curve and third party support might be essential to successful replication with reasonable level of effort. In contrast, Replica is more user-friendly (though provides very different functionality than STOPS).

[2] "STOPS - Documentation and Software | FTA." Accessed April 20, 2023. https://www.transit.dot.gov/funding/grant-programs/capital-investments/stops-documentation-and-software.

Recommendations

The results of the pilot studies indicate that a statewide program for software adoption will require a tailored approach in order to achieve the objectives that are sought by this study's stakeholders. There is no "one size fits all" software solution that would address all needs of every agency, thus there will be a need to both understand *how to operate the various software packages* and *how to select the most appropriate software package to address* a given need. Throughout the course of the pilot projects, two broad categories of recommendations emerged: technical and institutional.

Technical Recommendations

The analysis of the software market landscape and review of the case study requests from transit agencies focused empirical testing on select software. Each software has strengths and weaknesses in regards to their features and functions. Some are designed to perform very specific tasks and others are designed to perform a variety of tasks.

Additionally, software can either be open-source, freely available, or commercial. Open-source software is software which makes its code repositories available, allowing for end-users to modify them freely. Free software is freely available as-is, but cannot be modified by the end-user. Commercial software is obtained through a paid license or subscription.

The following software were thoroughly tested through the pilot projects and can be recommended for use in New York State:

Software	License Type
TBEST	Free (but requires ArcGIS license)
STOPS	Free (but requires ArcGIS or TransCAD license)
Conveyal	Open-Source
Remix	Commercial License
Replica	Commercial License, (Statewide Availability at the Time of Analysis)

Table 2 – Selected Software License Types

The Research Team focused on the area of specialization for each software as a means of understanding which kinds of transit planning analyses would pair well with each software. The software were analyzed on how well they met the transit planning needs identified by the survey.

Software	Specializations
TBEST	• Ridership Modeling • Scenario Comparison • Scheduling • Census/Land Use Data Integration • Market Demographics • Equity Analysis • Accessibility Analysis
STOPS	• Ridership Modeling • Scenario Comparison
Conveyal	• Accessibility Isochrones • Origin/Destination (O-D) Travel Times • Travel time matrices
Remix	• Ridership Modeling • Scenario Comparison • Scheduling • Census/Land Use Data Integration • Market Demographics • Equity Analysis • Accessibility Analysis
Replica	• O-D information with Demographic Information (e.g., Transit Propensity)

Table 3 – Selected Software Specializations

Software Assessment		
Software	**Strengths**	**Weaknesses**
Conveyal	• Visually Appealing Isochrones • Highly Adjustable Parameters • Cloud Based (No local User Machine Installation) • Open Source (Free)	• Difficult Setup Process • Unintuitive User Interface and Experience • Cloud Based (Requires Internal IT or Third-Party to Set Up and Host Instance)
Remix	• Cloud Based (No Installation) • Intuitive User Interface and Experience	• Limited Versatility • License Required
Replica	• Cloud Based (No Installation) • Well designed User Interface and Experience • Available to NYSDOT and MPOs via statewide license; no charge for querying Replica data as often as desired	• Complicated software • Modeled data, not observed • Not designed specifically for Transit Planning
STOPS	• Comprehensive Outputs • Open Source (Free; but source code is not published) • Integrates into ArcGIS	• Difficult Setup Process • Unintuitive Data Outputs (Large Text File) • Website not updated; outreach to FTA contact needed to ensure access to latest software version
TBEST	• Curated Reports • Flexible Analyses • Versatile Platform • Comprehensive Outputs • Open Source (Free)	• Difficult Setup Process • Complex User Interface and Experience • Not Open Source • Requires Construction of Socio-Economic Data Package to Operate[3]

Table 4 – Selected Software Strengths and Weaknesses

[3] Update: On 7/13/2023, the Florida Department of Transportation Public Transit Office announced a version update to TBEST. In this new version, the software now includes a new "Socio-Economic Data Configuration Tool" intended to expedite the process of creating base data.

Software Features					
	Conveyal	**Replica**	**Remix**	**STOPS**	**TBEST**
New Route	X		X	X	X
New Stop	X		X		X
Consolidate Stops	X		X		X
Consolidate Services	X		X		X
Frequency	X		X		X
Costs					X
Equity/Title VI Reporting			X		X
Accessibility Analysis	X		X		X
Equity Analysis		X	X		X
Land Use Market Analysis		X	X		X
O-D Travel Time Estimates	X		X		X
Reliability Analysis			X		
Travel Time Analysis	X	X	X		
Transfer Analysis	X	X	X		X
On-time performance analysis			X		X
Detour Analysis					X
Last Mile Connection Analysis					
Evacuation Analysis					
Current Ridership Analysis		X	X	X	X
Modeled Ridership Analysis			X	X	X
Transit Demand Analysis			X	X	X
Park and ride and transit center/ mobility hub market analysis	X				

Table 5 – Selected Software Features

Ease of setup and ease of use are similar metrics that tend toward subjectivity of the assessor. For a more holistic approach, the Research Team collaborated to develop a graph depicting these metrics relative to between the software;

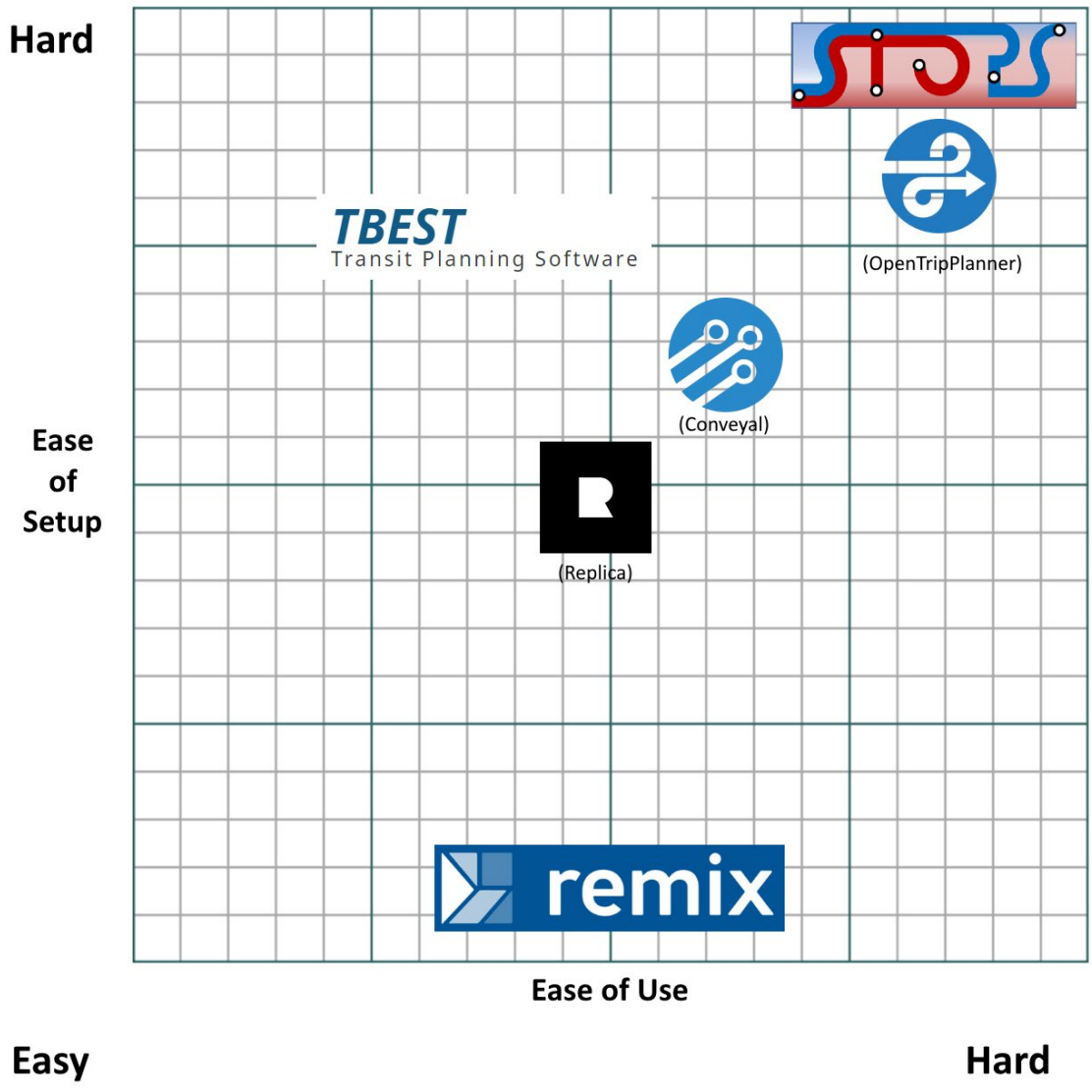


Figure 9 – Ease of Setup/Use Comparison

All software were explicitly assessed for their capacity to be deployed statewide and any features related to that. This analysis identified the strengths and weaknesses each software exhibited with regards to multiple users, collaborative functionality, data sharing, and software ecosystem. The table below summarizes these results:

Statewide Shared-Use		
Software	**Opportunities**	**Challenges**
TBEST	• Freely available • Data can be compiled and hosted by a third-party for statewide use • Can be a transit planning enterprise software, provides a variety of desired analysis features	• ESRI ArcGIS Dependency • Learning curve may be barrier to adoption, particularly for smaller agencies • Executable file must be installed on a local machine
Remix	• Web-hosted • Data is updated regularly • Very easy to use • Offers a variety of transit planning tools • Can serve both transit planning and operations • License is based on regional population which encourages shared license between TAs and MPOs/NYSDOT	• Requires a license • Limited set of features • Limited output • Requires support in order to setup networks based on different GTFS • Does not provide ridership modeling • Rudimentary transit demand analysis tools
STOPS	• Freely available • Industry standard tool for transit demand modeling	• Difficult to design and run analyses • Requires model data to operate • Limited set of features • Output format is prohibitively difficult to use • Requires GTFS editor to model network change scenarios
Conveyal	• Open-source software, available to be web-hosted by third-party • Provides unique set of features for analyzing transit accessibility • Provides limited GTFS editing tools • Could be used to create statewide data repository for transit accessibility	• Complicated software, may require support for most users • Setting up a hosted instance is complicated for software programmers, might be better served paying Conveyal for license/support. • Setting up the transit network ecosystem required to run analyses is complicated and requires technical data skills
Replica	• Provides useful origin/destination and home/work data • Provides Useful demographic data • Provides Public Transit Propensity index • Currently available to NYSDOT and the New York State MPOs via a statewide license • Supports use of STOPS model	• Modeled data, not observed • Not designed as a transit planning tool, limited transit planning features. • No transit demand modeling of network change scenarios

Table 6 – Selected Software Shared-Use Potential

Scalability

Practitioner feedback during the *Case Studies and Software Tools Open Forum* section of the project workshop provided a critical insight that requires additional attention and further research. Transit planning practitioners expressed interest in scaling up the analyses conducted in each of the four case studies. However, some transit planning analyses are not conducive to scaling. Therefore a distinction must be made between two primary transit planning analysis types - discrete and systemic - as a means of making statewide deployment recommendations:

- Discrete analyses are targeted processes that attempt to provide concise and specific insights (i.e., identifying how many additional riders may be served by adding a new bus stop).
- Systemic analyses intend to quantify the impact of one or more changes on all components of a system (i.e., identifying how ridership on all routes changes with the removal of a whole route).

Generally, scalability is dictated by software functionality like data inputs accepted, geographic selection options within the interface, types of analysis a software is capable of, and analysis processing time. Future efforts should provide guidance on how to scale analyses into larger network redesign efforts and also make recommendations on when analyses have the potential for scaling up to statewide data products.

As guidance for future efforts, the Research Team provides this brief scalability assessment of the software used in each of the case studies:

- **The Bee-Line - Westchester: Analysis of Proposed Route Elimination**
    - Conveyal was used in this case study to perform the discrete analysis but has a strong capacity for systemic analyses. The software supports bundling of multi-modal GTFS files, user-defined geography boundaries, macro area analyses, and offline data processing allows for scaling specific functions into statewide data processing and potentially statewide transit data measures.
- **CDTA - Capital District Transportation Authority: Route Restructuring**
    - TBEST has a robust feature set with the capacity for both systemic analyses and discrete analyses.
- **RTS - Rochester: Increasing Employment Access through Increased Fixed-Route Frequency**
    - Remix has the capacity for both discrete and systemic analyses. Establishing a large geographic boundary may require the assistance of Remix staff. Remix should also be urged to provide data export at the stop-level to improve its capacity for discrete analysis.
- **Oswego: Service Alignment Study**
    - Replica was used in a discrete analysis. In terms of transit, it is unknown whether Replica provides useful systemic analysis features.
    - STOPS is very strong as a systemic modeling tool capable of forecasting cascading impacts to discrete changes to the system but its output hinders it’s capacity for discrete analyses.

Institutional Recommendations

The following Institutional Recommendations are designed to ensure the success of any future public investment in NYS in Transit Planning Software technology. These recommendations are, in essence, a formalized program that replicates the best practices of this research project, and builds upon the opportunities identified herein.

The four pilot studies highlighted the varying needs of small and large transit agencies when it comes to technical analyses and software functionality. Smaller agencies, such as Westchester County, have limited bandwidth and resources to perform these analyses, which puts them at a disadvantage compared to larger agencies, such as RTS and CDTA, that have the staffing and capacity to replicate analyses and learn new software.

All MPOs and TAs that participated in the pilot projects were offered training sessions to assist with integration of the software within their organization. Centro and Westchester, despite the software and workflows being valuable, had staff resource limitations that prohibited learning the software. Conversely, RTS and CDTA both had the capacity to engage in training sessions with the Research Team to understand the software. However, both RTS and CDTA could benefit from additional support in order to integrate the new software into workflows.

To address the technical capacity gap among agencies, and to encourage the workflow integration step of tech-transfer, the Research Team recommends the establishment of a Transit Planning Community of Practice (CoP) that fosters collaboration and knowledge sharing along with technical support. The Transit Planning CoP may require a lead agency to act as a champion in spearheading its development and maintenance. The lead agency should document its role and assess its function annually. Figure 6 describes a three-part CoP framework wherein a state-level entity can provide varying degrees of assistance tailored to the needs of the MPOs and TAs.

Technical Analysis Support for Small Agencies	The overarching entity could directly perform technical analyses on behalf of MPOs and smaller TAs that lack the resources and expertise to conduct them on their own. This would ensure that all MPOs and TAs have access to critical technical analyses to inform their planning and decision-making.
Technical Data Processing and Software Support for All Agencies	The entity could provide data processing and technical skill development to mid-sized and larger agencies to help them integrate new tools into workflows– helping these agencies improve their technical analysis capacity.
Community of Practice Including Agency Needs Assessments, Presentations, and	The entity could foster a larger-scale CoP where practitioners can engage with each other and develop technical skills. Technical data and analysis needs from the CoP could better identify and address the most pressing technical challenges facing all members. This would create a positive feedback loop to tailor technical analyses to the needs of its members and generate more like-

Playbook Development	kind analyses for the next round of work.

Table 7 – Potential CoP Framework

Investing in software is often seen as a solution to improve technical capacity, but the pilot studies suggest that investing in a tech-transfer focused CoP may be a more effective approach. A Community of Practice would enable NYSDOT, MPOs, and TAs to work together to identify their specific technical needs and develop a shared understanding of the most effective tools and methods prior to investing in a specific software–enabling all parties to make more informed decisions.

Prior to expending any additional resources on software or support, partners should consider beginning to establish a Community of Practice by surveying the agencies for their needs, capacities, and interest. This would be the most cost-effective next step to advance the findings of this study, and it would inform decision making about a statewide program.

Transit Planning Community of Practice

The Research Team provides the following vision for the establishment of an interagency transit planning cooperative community of practice that supports transit planning in New York State by providing technical analysis support, presentations, and documentation.

The benefits of using any software in a community of practice are extensive. MPOs and TAs can collaborate to identify common goals and prioritize projects that serve the broader transportation network. This will allow them to coordinate their efforts and leverage their resources to achieve a more comprehensive and efficient transportation system.

The Community of Practice and/or its champion(s) would be responsible for the following;

1. Collect technical analysis case studies and best practices into a playbook which would be a living document (catalog of practices and technologies) that is maintained by the champion and/or the community of practice. The playbook would include:
    a. Frequently asked questions, frequently needed analyses,
    b. Analysis methodologies,
    c. Problem identification,
    d. How to assess the value of an analysis, and
    e. Provide crosswalks of problems/questions/analyses to software tools.
2. Support small technical transit planning tasks at the NYSDOT Regions, MPOs, and TAs by soliciting case studies and framing problems for spot analysis.
3. Schedule technical presentations and working sessions for sharing case studies, tech transfer, data analysis training, and planning accreditation credits.
4. Conduct regular research scans and provide literature reviews of best practices.
5. Annually solicit case studies that are meant to enhance the playbook.

Potential Community of Practice Champions include;

- NYSDOT
    - NYSDOT's rural transit efforts already provide some of the support outlined in this document to small rural transit agencies. NYSDOT could utilize this existing effort to support a statewide community for technology sharing.
    - NYSDOT's developing mobility policy and support capabilities provide an opportunity for transit planning as a potential organizing effort to implement the recommendations of the Shared-Use Transit Project.
    - MTA's Replica license demonstrated that a shared purchase for statewide data tools is possible.
- NYSAMPO
    - NYSAMPO's role in a statewide community of practice is as a participant in the technical analyses performed by their specific partner transit agencies. The MPOs were active participants in the case studies for this project which demonstrates the viability of a community of practice.
    - The Transit Working Group could serve as an information dissemination mechanism.
- NYPTA
    - NYPTA could be a partner in organizing the Transit Planning Community of Practice. They might utilize their existing efforts in support of Transit Operations to organize a statewide interagency Transit Planning effort through outreach, advocacy, training, sharing, and assistance in locating funding.

Transit Planning Playbook

To support the establishment of a transit planning Community of Practice, the Research Team recommends developing a product for collecting and sharing best practices for transit planners at all levels. This is best facilitated by the creation of a Transit Planning Playbook that would serve as an institutional starting point for the Community of Practice. The Playbook would be a collaborative effort, collecting and curating institutional knowledge with each iteration. The Playbook would serve the dual role of collecting and disseminating information for the Community of Practice. A champion would regularly update and share the Playbook. The established workflow and any technical documents would be collected for each new update.

Each collected case study added to the Playbook would feature a similar workflow. First, a problem or need would be identified. In order to address this problem or need, the case study would determine which questions need to be asked. From there, an analysis (or analyses) would be constructed to provide answers to the questions. Software would be evaluated to pair appropriate features with the needed analysis. Finally, the outputs, their interpretation and how to organize them would be determined. This process would form the standard for all case studies solicited through the Community of Practice for the Playbook.

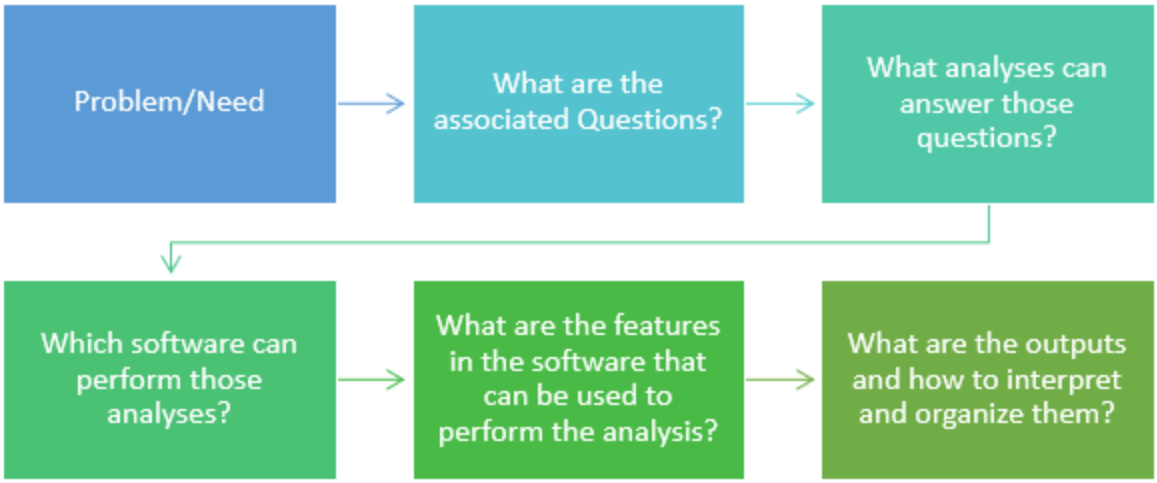


Figure 10 – Transit Planning Workflow

How to Update the Playbook

The Community of Practice would need to have a lead entity regularly interviewing transit planners across the state to learn about their technical planning needs. This entity, or champion, would be responsible for soliciting case studies for the Playbook and assisting with the design and implementation of analysis as outlined in the transit planning Playbook workflow above. Regular meetings with the Community of Practice would be held by the champion in order to present case studies for feedback, comments, and discussion.

Each case study collected for the Playbook would document the designed workflow in the form of a diagram and a narrative. The Playbook itself could take many forms, including a wiki or a github repository to facilitate sharing and ease of update. The narrative would follow the workflow diagram above. Any technical documents produced for the case study would be included as an appendix in the Playbook. Any technical documents collected this way need to be sure to include the date of the case study and the specific software versions used to perform the analysis. Deprecated analyses would be updated and replaced each time a new and relevant case study was conducted to answer a similar question or need as a previous case study.

Example Playbook

A draft Transit Planning Playbook is provided as an appendix to this Final Report. The playbook provides high level workflow information about each of the case studies undertaken in this project and also provides the detailed Technical Design documents associated with each case study. Transit planners should be able to consult the playbook to conduct comparable transit planning analyses.

Conclusion and Next Steps

The project was successful in drawing conclusions about how to provide statewide technical and institutional transit planning assistance. The technical recommendations focused on each software's capabilities in design, functionality, and shared-use potential. While some software were more flexible than others, none were capable of completely spanning agency needs as an enterprise software. Subsequently, multiple software solutions should be considered, taking into account the specific requirements and staffing of each agency. Software adoption is a nuanced process that involves the integration of technical expertise with institutional capabilities and pairing different software tools with each agency's institutional capabilities may require outside technical assistance.

Therefore The Research Team also makes Institutional Recommendations with the goal of establishing an effective software integration into statewide practice. The Research Team recommends replicating and building upon the methodology of this research. The market assessment could be updated annually with an accompanying literature scan. An agency-needs solicitation would also be a valuable annual practice, and some form of technical assistance is needed to help agencies design and conduct actionable analyses. In addition, it is recommended that a peer-to-peer sharing of experiences and "lessons learned" is developed to build an institutional framework that supports software adoption. The Transit Planning Playbook is an example of a possible decision support product that could serve to cohere an institutional framework. The Playbook summates the case study projects into replicable planning processes and provides a method for updating that

Each software solution could be useful statewide, provided that it is matched with the appropriate institutional capabilities and analysis design. The Playbook provides a framework for agencies capable of investing staff resources in utilizing the softwares to replicate the case studies. However, it is much more likely that the adoption of the solutions outlined herein requires an institutional framework - the establishment of a transit analytics tech transfer community of practice - to provide technical assistance and peer-to-peer sharing of experiences and lessons learned. This community of practice would facilitate the adoption of software solutions by agencies across the state and ensure that each agency is able to access the software tools that meet its specific needs.

Future Research

The project was limited in its scope by access to software and by the costs of each case study design. The scope of the software market analysis also didn't take into account software that is not specifically designed for transit planning. There are many planning software that can be useful in transit planning that were not reviewed and the Research Team has heard from planners about their interest in understanding more about how to utilize those in their planning practice. Future research should consider reviewing land-use planning software and other kinds of modeling software for how they might support near and long term transit planning.

The software market is a constantly evolving landscape that requires continuous attention. As of the finalization of this project, two key market changes capable of impacting the results of this study occurred and should be addressed:

1. On 7/13/2023, the Florida Department of Transportation Public Transit Office announced a version update to TBEST. In this new version, the software now includes a new "Socio-Economic Data Configuration Tool" intended to expedite the process of creating base data. Configuration of Socio-Economic data was a technical challenge that was noted as a potential hindrance for agency software adoption. Though this new feature remains untested by the Research Team, its implementation aims to address the primary shortcoming of the software identified and indicates that developers are receptive to industry needs.
2. On 7/13/2023, The developers responsible for PTV Visum, PTV Group, announced the release of a new public transport service planning software called "PTV Lines". The software is untested by the Research Team, but initial insights indicate that it is a web-based tool for service planning that interoperates with PTV Visum. Promotional documentation suggest that the software is a strategic spatial and temporal planning and analysis software with multi-modal support.

References

"ArcGIS Network Analyst | Vehicle Routing Problem & Spatial Network Analysis." Accessed December 23, 2022. https://www.esri.com/en-us/arcgis/products/arcgis-network-analyst/overview.

"Bee-Line Bus Schedules and Maps." Accessed December 22, 2022. https://transportation.westchestergov.com/bee-line-bus/index.php?option=com_content&view=article&id=1176&Itemid=123.

Bunner, Rodney. "TBEST Socio-Economic Data Configuration," February 2021.

Bunner, Rodney, Martin Catala, and Mark Mistretta. "TBEST 4.7 User Guide." *Martin Catala and Mark Mistretta Center for Urban Transportation Research (CUTR)*, n.d.

"Conveyal - Evaluate Changes to Your Public Transportation System." Accessed December 23, 2022. https://conveyal.com/.

"Deprecated Tools | Public Transit in ArcGIS." Accessed April 20, 2023. http://esri.github.io/public-transit-tools/DeprecatedTools.html.

Google Developers. "Google Transit." Accessed December 23, 2022. https://developers.google.com/transit.

"Home | Public Transit in ArcGIS." Accessed April 20, 2023. http://esri.github.io/public-transit-tools/index.html.

Lahoorpoor, Bahman, and David M. Levinson. "The Transit Travel Time Machine: Comparing Three Different Tools for Travel Time Estimation." Working Paper, November 12, 2019. https://ses.library.usyd.edu.au/handle/2123/21351.

"OpenTripPlanner 2." Accessed December 23, 2022. https://docs.opentripplanner.org/en/v2.2.0/.

"Public Transportation Planning Software | Remix." Accessed April 20, 2023. https://www.remix.com/solutions/transit.

"Remix - TransitWiki." Accessed February 3, 2023. https://www.transitwiki.org/TransitWiki/index.php/Remix.

"Replica: Data to Drive Decisions about the Built Environment." Accessed April 20, 2023. https://www.replicahq.com/.

"ServiceEdge TBEST Hosting Subscription Add-In – ServiceEdge Solutions." Accessed December 29, 2022. https://ses-transport.com/index.php/serviceedge-tbest-hosting-subscription-add-in/.

"STOPS - Documentation and Software | FTA." Accessed April 20, 2023. https://www.transit.dot.gov/funding/grant-programs/capital-investments/stops-documentation-and-software.

"TIGER/Line Shapefile, 2019, State, New York, Current Block Group State-Based." Unknown. Accessed March 2, 2023. https://catalog.data.gov/dataset/tiger-line-shapefile-2019-state-new-york-current-block-group-state-based.

UserBenchmark. "UserBenchmark: AMD Ryzen 7 5800X 100-100000063WOF." Accessed December 23, 2022. https://cpu.userbenchmark.com/AMD-Ryzen-7-5800X/Rating/4085.

Westchester. "Westchester Mobility." Accessed December 22, 2022. https://www.westchestermobility.org.