Conveyal Analysis Documentation

Release v4.5.0

Conveyal

Aug 13, 2019

Setup

1 Contents

This manual will help you use Conveyal Analysis to edit land-use and transportation scenarios, and evaluate them in terms of accessibility.

If you are using the version hosted by Conveyal at analysis.conveyal.com, log in with the instructions sent via e-mail, then select a region and project to use. Once you have selected a project, you can edit and analyze scenarios.

Most users of analysis.conveyal.com will already have a project prepared when they first log in. If you don't see a region or a project, you'll first need to prepare a baseline network or contact your support team.

CHAPTER 1

Contents

1.1 Preparing baseline network

Start by gathering GTFS files for the transit agencies whose service will be included in your scenarios. Ensure any GTFS you upload follows requirements of the specification. Various validation tools are available. Common issues include:

- Missing required files
- Calendar dates that do not cover an intended date of analysis.
- Using values other than 0-7 in the route_type column of routes.txt

If there is no GTFS available for your region, as a workaround you can use a valid GTFS feed from somewhere else in the world, follow the steps below, then attempt to import route alignment shapefiles representing service in your region.

1.1.1 Setting up a new region

From the initial login page, set up a new region by clicking

If any regions have already been created, they will be shown in a list below this button.

When setting up a new region, enter a name and specify boundaries by moving the bounding box on the map. You must also upload an appropriate OpenStreetMap (OSM) extract in this view, which will serve as the road layer of the transport network. OSM extracts can be downloaded from services such as Geofabrik or Nextzen. Note that several formats exist for OSM data. We always use the PBF format because it is more compact and faster to process.

Filtering OSM data

The OSM database contains a lot of other data besides the roads, paths, and public transportation platform data we need for accessibility analysis. As of this writing, according to TagInfo 59% of the ways in OSM are buildings, and only 23% are roads or paths. Buildings frequently have more complex shapes than roads, and objects like waterways or political boundaries can be very large in size. It has been jokingly said that OSM should be renamed "OpenBuildingMap" rather than "OpenStreetMap".

Removing unneeded data will reduce the time and network bandwidth needed to the upload the file to Analysis, and will speed up the processing stages where the OSM data is converted into a routable street network. Several command line tools exist to filter OSM data. If you are familiar with the command line or comfortable experimenting with it, you may want to try Osmosis, Osmium-Tool, or OSMFilter. Osmium-Tool is extremely fast but is only straightforward to install on Linux and MacOS platforms. Osmosis is often slower at filtering but will also work on Windows as it's a multi-platform Java application. OSMFilter cannot work with PBF format files so we rarely use it. Below are some example commands for retaining only OSM data useful for accessibility analysis. You would need to replace `input.osm.pbf` with the OSM data file you downloaded.

Osmosis: `osmosis --rb input.osm.pbf --tf reject-ways building=* --tf reject-ways waterway=* --tf reject-ways landuse=* --tf reject-ways natural=* --used-node --wb filtered.osm.pbf`

Osmium-Tool: `osmium tags-filter input.osm.pbf w/highway w/public_transport=platform w/railway=platform w/park_ride=yes r/type=restriction -o filtered.osm.pbf`

Cropping OSM data

Services producing automated extracts of OSM data like Geofabrik or Nextzen are limited to predefined areas. You'll often need to download an extract for a country or region larger than your true analysis area, then cut it down to size.

Performing accessibility analysis with excessively large OSM data can lead to significant increases in computation time and complexity. Therefore we strongly recommend cropping the OSM data if they cover an area significantly larger than your transportation network or opportunity data. Several command line tools are also able to perform these cropping operations: Osmosis is a multi-platform Java tool that works on Windows, Linux, and MacOS but is relatively slow, OSMConvert is a fast tool pre-built for Windows and Linux and available on MacOS and Linux distributions as part of `osmctools` package. Osmium-Tool is a personal favorite that is extremely fast but only straightforward to install on Linux and MacOS platforms. Below are some example crop commands for these different tools:

Osmosis: `osmosis --rb input.osm.pbf --bounding-box left=4.34 right=5.84 bottom=43.10 top=43.97 --wb cropped.osm.pbf`

OsmConvert: `osmconvert input.osm.pbf -b=-77.255859375,38.77764022307335,-76.81365966796875,39.02345139405933 --complete-ways -o=cropped.osm.pbf`

Osmium: `osmium extract --strategy complete_ways --bbox 2.25,48.81,2.42,48.91 input.osm.pbf -o cropped.osm.pbf`

The latter two commands expect bounding boxes to be specified in the format `min_lon,min_lat,max_lon,max_lat`. We frequently find bounding boxes using the convenient Klokantech bounding box tool. Selecting the "CSV" format in the lower left will give exactly the format expected by these tools. You can also adapt the bounding box values shown in the region setup panel of Analysis.

When creating a region, the panel will show an osmconvert command pre-filled with the current regional bouding box. If you have osmconvert installed locally, you can paste this command into to your local command line and modify the filenames to crop your OSM data to regional boundaries before upload.

Note that files larger than 500MB may be rejected on upload. Please contact us if you genuinely need to upload a file of this size, or need assistance in cropping and filtering OSM data.

1.1.2 Uploading a GTFS bundle

On the main page for a region, upload your first bundle of GTFS feeds by clicking:

You can also click this icon on the sidebar to access GTFS Bundles:

This will take you to the GTFS Bundles page, where you can give the Bundle a name and choose .zip files to upload. If you have multiple GTFS feed .zip files, you can select them by shift-clicking, control-clicking or command-clicking (depending on your browser/operating system). Finally, click the create button to confirm.

Again, note that files larger than 500MB may be rejected on upload. The largest GTFS in regular use are below 400MB so a larger file may indicate a problem. Please contact us if you genuinely need to upload a file of this size.

1.1.3 Creating a Project

Uploading and processing a bundle may take several minutes. Once processing is complete, on the Projects page, click:

This will take you to the Create new Project page, where you can give the Project a name, select a bundle to which the project will be associated, and click the create button to confirm. You are now ready to move on to editing scenarios.

1.2 Preparing opportunity datasets

To measure access to spatially distributed opportunities (e.g. jobs, people, schools), you will need to ensure at least one **opportunity dataset** has been added to your project. To add or manage opportunity datasets, click this icon on the sidebar:

1.2.1 Uploading opportunity datasets

Opportunity datasets can be created by uploading shapefiles containing point features, shapefiles containing polygon features, or a CSV file with one point per row. In addition to the coordinates or geometries, uploaded files must have at least one numeric attribute or column specifying the opportunity count within each polygon or at each point. In CSV files with each row representing a single opportunity at a specific location, this numeric column should be filled with the number 1 (i.e. one opportunity at each point).

To start an upload, click:

Enter a name for the opportunity dataset source, then select the appropriate files.

If you are uploading a shapefile, it should not be zipped. Select all of the files in the Shapefile when uploading (at the very least, `.shp`, `.shx`, `.dbf` and `.prj`). How you select multiple files depends on your browser and operating system, but generally will involve shift-clicking, control-clicking or command-clicking.

If you select a CSV file (whose filename must end in `.csv`) two extra fields will appear in the interface, in which you must type the names of the latitude and longitude fields within the CSV. We currently only support CSV files which specify points in WGS 84 latitude/longitude coordinates. Many minor variants of the CSV format exist. Rather venturing a guess at which variant is being used, the system expects the file to adhere to a particular definition of CSV: fields should be separated by commas (rather than semicolons for example) and the first row should be a header row containing the names of the fields. The latitude and longitude field names you specify in the web UI should be detected in that header row.

Once you have done this, click the upload button to start the upload. Opportunity datasets will be saved with the source name you entered and the attribute/column names of the uploaded files.

After processing is complete, you can refresh the page and see dot-density maps of your datasets, converted to the analysis grid used in Conveyal Analysis.

1.2.2 Avoiding common errors

- Eliminate extraneous attributes/columns from your shapefile/csv before uploading.
- Ensure entries are numeric, not text values (e.g. "N/A", numbers stored as text). Only columns with exclusively numeric entries will be saved.

1.2.3 Managing opportunity datasets

Selecting an existing opportunity dataset from the dropdown menu will give you options to:

-
-
- (e.g. all attributes from a shapefile)

1.2.4 LODES import

For projects in the United States, Census block-level data on employment and workforce from LODES can be fetched by clicking:

1.3 Overview of editing mode

After logging into Conveyal Analysis and selecting a project, you will arrive at the screen below. Each project has an expandable list of numbered **scenarios** followed by a list of **modifications**. To prevent data conflicts, the system does not allow multiple users or browser tabs to edit the same project simultaneously. If you expect multiple people in your organization to be using Conveyal Analysis at the same time, you may want to create projects for each of them, as suggested *below*.

Each modification represents a single operation on the baseline transport network (for example adding a line, or adjusting the speed of an existing line) and can be *activated* in multiple scenarios. To add a modification, click

This will open a window allowing you to select the modification type and enter a name. After confirming these details, you will be taken to a modification detail panel that varies by modification type.

1.4 Basic example

To create a sample modification, follow this quick-start guide:

1. If you are not at the initial view in editing mode, with your project name at the top of the side panel, click this icon on the sidebar:
2. Select a project or add a new one
3. Click:
4. Leave "Add Trip" selected as the **Modification Type**, type "New Route Example" as the **Modification Name**, and confirm these options by clicking on the green button, which will create a modification and open the modification details panel for it
5. In the modification details panel, click
6. On the map, click to add stops for the new route. More details on editing route alignments are here.

7. In the modifications details panel, click:
8. Optionally, edit the default timetable parameters (e.g. set 5-minute headways for weekdays between 7 and 9 AM) and add additional timetables
9. To save your changes and return to the main list of Modifications, click this icon at the top of the modification details panel:
10. Add more modifications or proceed to analyze your scenario.

1.5 Usage suggestions and details

Modifications can be grouped by project and scenario, and different projects and scenarios can be compared against each other in analysis mode, giving you flexibility on how to use them. Depending on your use cases, different approaches may make sense.

If one user will be responsible for analyses in your region, involving a relatively small number of modifications, we recommend doing your work in one project and assessing the impact of different combinations of modifications by creating and using scenarios within that project.

If multiple users will be involved in editing scenarios, or if you want to assess more than 10 different combinations of modifications, which would make the list of scenarios annoyingly long, we recommend dividing the modifications among different projects. For example, one team member could code rail scenarios in Project A, another team member could code bus scenarios in Project B. Modifications can be *imported* between projects that use the same baseline GTFS bundle; in this example, modifications from the two projects could combined in a third Project C.

1.5.1 Toggling display of modifications on the map

In the list of modifications on the initial view in editing mode, clicking the title of a modification will open it and allow you to edit it. To control whether each modification is displayed on the map, click the visibility icon next to it (/)

Stops and segments representing modifications are displayed on the map, using different colors to indicate their state relative to the baseline GTFS:

- : Added
- : Removed
- : Changed (e.g. modified frequency, speed, or dwell time)
- : Unchanged

Projects start with only a Default scenario (plus a locked Baseline in which no modifications can be active). You can create additional scenarios expanding the list of scenarios, clicking the create button, and entering a name.

When the Scenario list is expanded, options next to each scenario allow you to: the modifications active in the scenario the scenario the scenario (not available for baseline or default scenario)

1.5.2 Activating modifications in scenarios

By default, each modification is active in all scenarios that exist when the modification is created. You can change which scenarios a modification is active in by using the checkboxes corresponding to scenario numbers at the bottom of the modification detail panel.

1.5.3 Importing modifications

To import modifications from another project or a shapefile, click

From another project

Occasionally, you may want to copy all of the modifications from one project into another. This may be useful to make a copy of a project, or to combine modifications developed by different team members into a single project (for instance, one team member working on rail changes and another on bus changes).

To do so, select a project in the upload/import panel and click

If you choose a project associated with the same GTFS bundle, all modifications will be imported; when there are multiple scenarios, the scenarios in the project being imported will be mapped directly to the scenarios in the receiving project (i.e. modifications in the first scenario will remain in the first scenario in the new project).

If you choose a project associated with a different GTFS, bundle, only add-trip modifications will be imported.

From Shapefiles

In general, it is best to create all modifications directly in Conveyal Analysis as it allows full control over all aspects of transit network design. However, on occasion, it may be desirable to import modifications from a GIS Shapefile. If you have a Shapefile containing lines, you can upload it to Conveyal Analysis and have it turned into a set of Add Trips modifications.

To do so from the upload/import panel, click

Then, after selecting and importing a zipped Shapefile, you will see the following:

There are several fields that must be filled in, corresponding to attributes (columns) in the Shapefile:

- Name of each modification (e.g. route id).
- Speed (in km/h)
- Headway (in minutes)

Finally, as Shapefiles only contain the route geometry and not the stop locations, stops can be created automatically at a specified spacing. The generated stop positions may be individually edited after import, for example to place a stop at a major transfer point.

1.5.4 Manually edit raw modifications (beta)

By clicking on “Customize modification” in the details pane for any modification, advanced users can copy, paste, and edit its raw JSON data.

1.6 Modification details

At the top of the modification details panel, there are multiple actions for each modification, including:

Clicking the small blue back arrow () saves your changes and take you back to the list of all modifications. Changes are also automatically saved every 10 seconds. Each type of modification has additional options available, as detailed below.

1.6.1 Add trips

The add trips modification allows you to add new trip patterns to your transport scenario. Generally one add-trip modification is used to model a new route, adding all of the trip patterns on that route. After creating the modification you will see this view:

To create an alignment for the modification (or to edit the alignment you've previously created), click

This will activate editing mode. In editing mode, click once on the map to place the first stop, then again to place the second stop, and so on. If you click on an existing stop (indicated by a small gray circle), the icon for the new stop will be black and the new transit service will stop at that existing stop. If you click in a place where there is not an existing stop, a new stop (in blue) will be created.

To insert a stop into the middle of an alignment, click any part of the alignment. Once created, any stop can be dragged to move it. Clicking on a stop gives you the option to delete it, or convert it to a *control point* through which the route will pass without stopping. Similarly, control points can be converted back to stops or deleted by clicking on them. It's important to get the alignment approximately correct so that the length of each segment is correct when used to calculate the travel times between stops.

Available options while editing an alignment include:

- **Snap to existing stops (beta)**: Experimental feature that adds stops from the baseline GTFS bundle to the new route. This feature adds stops within 20 meters of the alignment, but not more than one stop approximately every 80 meters.
- **Auto-create stops at set spacing**: Whether stops should be created automatically at a specified interval along the route.
- **Bidirectional**: If this checkbox is checked, vehicles will travel in both directions along the described geometry. If it is left unchecked, vehicles will only travel in the direction the line is drawn (which can be useful when there are couplets or other aspects of the route that don't follow the same alignment in both directions). You can choose whether stops should be created automatically at a specified interval along the route, or if you will create all stops manually.
- **Follow streets**: Make the route follow the streets. This only applies to segments that are actively being edited, and will not cause already drawn segments to follow the streets, allowing you to draw part of a route on street and part off-street.
- **Extend**: If this checkbox is checked, clicking on the map will extend the route by adding a new stop. If you wish to edit segments you already created, by adding stops or control points, it is often convenient to uncheck this option so that stray clicks do not extend the route from one if its termini.
- **Extend from end**: When "Extend" is enabled, this option allows you to specify whether new stops will be added moving forward from the last stop of the route or backward from the first stop of the route.

Once you have created an alignment, you need to specify when the routes run using a simplified timetable. You can do this by copying a previously created timetable, or by clicking:

1.6.2 Adjust dwell time

You may also want to adjust the dwell time along a route or at a particular stop, for example to model the effects of off-board fare collection, or the effects of increasing ridership at a particular stop. As with the remove-stops modification, you can select a feed, route and optionally patterns. You can then use the map to select the affected stops (if you skip this step, all stops will have their dwell times adjusted). You can then choose to either enter a new dwell time (in seconds), or scale the existing dwell times (for instance, entering 2 would double exiting dwell times).

Unfortunately, many source GTFS feeds do not contain any dwell time, meaning that this modification is of limited usefulness in some cases.

1.6.3 Adjust frequency

Often a scenario will include frequency changes to existing lines. We support this using the adjust frequency/convert to frequency modification. First, create a "convert to frequency" modification, and choose the feed and route you want to adjust:

You then create any number of frequency entries using simple timetables. Typically, there will be at least two entries (one for each direction). Each frequency entry will follow one template trip, which determines the stop-to-stop travel times of the trips that are created with the given frequency.

You then add details to each frequency entry. Repeat this process until you have created frequency entries for all the service you want to retain, in both directions.

You can choose to remove all existing trips on the route (the default) or choose to retain trips outside the time windows in which you specify frequencies, which is useful when you are changing the frequency for only part of the day (e.g. increased weekend frequency) and want to retain the existing scheduled service at other times. This is controlled using the "Retain existing scheduled trips at times without new frequencies specified" checkbox.

1.6.4 Adjust speed

Sometimes you will want to adjust the speed on a route, or a portion of it (for instance due to the addition of dedicated bus lanes, or an application of transit signal priority). As before, you will create the modification and select a feed, routes and patterns. If you want to modify only part of the route, you can use similar selection tools to those used in the remove stops modification (with new selection, add and remove buttons). The difference is that you are now selecting hops. The selected segment will be shown on the map in purple. Finally, enter a scale, which is the factor to multiply the speed by. For instance, if you enter 1.2, vehicles will travel 20% faster between stops (this modification does not affect dwell times; to model changes in dwell time, see the adjust dwell time modification below).

This modification can be applied to multiple routes, but only one route will be shown on the map.

This modification does not automatically increase frequency in response to the more efficient routes. However, it can be paired with an adjust frequency modification to model such a response.

1.6.5 Remove stops

It is also possible to remove some of the stops from a route, while leaving the rest of the route untouched. To do this, create a new Remove Stops modification, and select a feed, route, and patterns as you did when removing trips. You can then use the map to select which stops to remove. Under "Selection," click "new", "add to," or "remove from" to select new stops to remove, add to the existing selection, or remove from the existing selection. Stops that are selected for removal are listed at the bottom of the modification, as well as being highlighted in red on the map.

You can also specify that you wish to remove a certain amount of time at each removed stop (in addition to the dwell time specified in the original feed, which is automatically removed). This could be used to account for acceleration and deceleration, and can also be used when the original feed does not specify dwell time. This feature is useful when testing the effects of stop consolidation.

When removing the beginning of a route, the dwell times at each stop are removed, as is any time specified to be removed at each removed stop. Any remaining travel time is preserved as an offset from the start of the trip in the original GTFS to the start of trips at the new first stop. This is effectively as if the vehicles were leaving the original terminal at the same time but deadheading past all of the removed stops.

This modification does not automatically increase frequency in response to the more efficient routes. However, it can be paired with an adjust frequency modification to model such a response.

1.6.6 Remove trips

Another common modification is to remove trips. The most common use is to remove entire routes, but it is also possible to remove only specific patterns on a particular routes. In order to remove trips, create a new Remove Trips modification, and select a GTFS feed, route, and optionally the trip pattern of the trips to be removed. All trips on this route/pattern combination will be removed, and the route will be shown in red on the map. Note that the "active in variants" selector always specifies whether the modification is active, so in this case implies that the trips will be removed from the selected variants.

1.6.7 Reroute

This modification type can be used to represent detours, extensions, and curtailments. When creating a Reroute modification, you specify first select a feed, route, and patterns. Once patterns are selected, you then select a stop at which the reroute segments will start, or a stop at which the reroute segments will end, or both, by clicking

then clicking an existing stop on the baseline pattern.

Once a start or end stop is specified, you can add and modify segments by clicking

then clicking on the map. Editing behavior is similar to editing mode for *adding trip patterns*, with some options fixed:

- If only the "start of reroute/extension" is set, new stops and segments will be added extending *forward* from the selected stop on the baseline pattern ("Extend from end" turned on).
- If only the "end of reroute/extension" is set, new stops and segments will be added extending *backward* from the selected stop on the baseline pattern ("Extend from end" turned off).
- If both are set, the new segment between the stops cannot be extended, but it can be modified by clicking on it to add stops and control points ("Extend" turned off).

For example, consider a baseline pattern passing through stops A -> B -> C -> D:

- To curtail this pattern at stop C, eliminating service to stop D, select C as the "start of reroute/extension."
- To reroute/extend this pattern from C to another stop X instead of D, select C as the "start of reroute/extension," activate route editing, and click on stop X to add a segment from C -> X. Speeds and dwell times can be set on this added segment. Baseline speeds and dwell times between A and C are not affected.
- To extend this pattern backward, to originate at a stop Y, select A as the "end of reroute/extension," activate route editing, and click on stop Y to add a segment from Y -> A. Speeds and dwell times can be set on this new segment. Baseline speeds and dwell times between A and D are not affected.
- To detour this pattern so that it serves a stop Z between B and C, select B as the "start of reroute/extension", select C as the "end of reroute/extension", activate route editing, click on the new segment to add a stop, and drag the added stop to Z. Speeds and dwell times can be set on this new segment. Baseline speeds and dwell times between A and B, and between C and D, are not affected.

A reroute modification can apply to multiple patterns in a single direction as long as the patterns all contain the start and end stop in order; you will generally need to create one reroute modification for each direction of the route.

1.7 Timetables

Add trip and convert to frequency modifications require simple timetables. By default, a newly added timetable or frequency entry will specify trips running every 10 minutes from 7 AM to 10 PM, every day of the week.

Each timetable or frequency entry allows for the specification of days of service, span of service, and frequency. You can add as many timetables as you need to specify different frequencies or speeds at different times of days. Overlapping windows can be specified, but keep in mind that this means that trips on *both* entries will operate at the specified frequencies (e.g., if you have a ten-minute frequency and a 15-minute frequency overlapping, there will be one set of vehicles coming every ten minutes, and another, independent, set coming every 15).

For add trip modifications, speed and dwell time values can be set for each timetable, either at the segment level or as overall/default values. The user interface also displays travel times derived from these values. While segment-level running-time values can be modified, the speed values are what Conveyal Analysis actually saves and uses for calculation. Recalculated travel time values may differ slightly from explicitly entered values, due to rounding of speed values or if segment lengths change. Before analyzing scenarios, we recommend re-opening modifications with timetables and double checking that values reflect desired travel times.

For convert to frequency modifications, speed and dwell time values are copied from the template trip. Travel time often varies throughout the day due to varying traffic and passenger loads, so it makes sense to choose a template trip that is representative of the time window for which you are creating frequency service.

1.7.1 Exact Times

You can specify whether the timetable represents an assumed headway, or represents the exact schedule, using the "Times are exact" checkbox. The default setting, with this box unchecked, should be used when a trip pattern's frequency is known but an exact schedule has not yet been defined (e.g. for a new service still in the planning stages). For example, consider an entry specifying that a particular pattern runs every 15 minutes from 9 AM until 7 PM. With the checkbox unchecked, the routing engine knows that vehicles depart the first stop on the route every 15 minutes between 9 AM and 7 PM, but has no information as to exactly when that will happen. For example, vehicles might leave at 9:02, 9:17, 9:32, and so on, or they might leave at 9:10, 9:25, 9:40, etc.; many of these possibilities will be simulated in order to get a complete picture of how different possible schedules might perform. See methodology for more details.

When the complete schedule is defined, it is appropriate to activate the "Times are exact" checkbox. In this case, a single schedule will be created, with the first departure at the start time, and then additional departures with exactly the specified frequency until (but not including) the end time. For example, in the scenario given above, the vehicles would be scheduled to depart at exactly 9:00, 9:15, 9:30 until 6:45 (not at 7:00 because the end time is not included).

If the schedule is not known, but it is known that the schedules of two lines will be related (e.g. using timed transfers or pulsed schedules), the phasing feature may be enabled.

1.7.2 Copying Timetables

Timetable entries can be copied between add trip and frequency modifications.

Some users may find it convenient to use a single template add trip modification that specifies commonly used service windows and frequencies. For example, you could create a "Base Timetables" modification and deactivate it from all scenarios. You could then add multiple timetables to this template:

- AM Peak, Frequent Network: 7 AM to 9 AM, every 5 minutes, every day
- Midday, Frequent Network: 9 AM to 3 PM, every 10 minutes, every day
- PM Peak, Frequent Network: 3 PM to 6 PM, every 5 minutes, every day
- Base Weekday: 6 AM to 11 PM, every 30 minutes, Monday through Friday
- Base Weekend: 7 AM to 11 PM, every 60 minutes, Saturday and Sunday

When proceeding to add new routes with add trip patterns, the appropriate timetables could then be copied from this template by clicking:

1.8 Phasing

The phasing feature can be used to tie the schedules of two add trips or adjust-frequency modifications together. For example, if you are creating a pulsed system where buses run infrequently but are timed to meet at transfer points, you might want to specify that while you don't know the exact schedules of any of the lines, they will all meet at a central point at the same time. Alternately, you might have a branching service where two lines share part of their alignment but then branch. If each branch runs every 30 minutes, you might want to write the schedules such that they provide service every 15 minutes on the shared alignment, rather than both coming at the same time.

You can accomplish both of these things using the phasing settings. We implement this by allowing you to lock the departures on one timetable or frequency entry to those of another, saying that vehicles on one frequency entry depart a stop a certain number of minutes after vehicles on another frequency entry (generally on a different modification) depart a stop (the same one or a different, nearby one).

The image below shows creating a pulse between two lines in Atlanta. This line on Memorial Drive is phased at the stop "Memorial Drive SE at Moreland Ave SE" from the stop "Moreland Ave SE at Memorial Drive SE" on the timetable "Weekday" in the "Moreland" modification, with a phase of three minutes. This means that vehicles running on this timetable (7 AM-10 PM every day) will depart the stop "Memorial Drive SE" will depart "Memorial Drive SE at Moreland Ave SE" three minutes after vehicles on the "Weekday" timetable of the Moreland route depart the stop "Memorial Drive SE at Moreland Ave SE."

First, you select one of the stops on this line to phase at (the "phase at stop"). You then can select a modification (either an Add Trips modification or an Adjust Frequency modification) and frequency entry or timetable to phase from (the "phase from timetable"); the dropdown shows the name of the modification, as well as the name of the frequency entry and details about it. You can then choose the stop on the other modification where the phase should be applied (the "phase from stop").

Finally, you can specify the phase in minutes, which is how long after the other vehicle departs that this one should depart (at the last stop on either modification, the arrival time will be used in lieu of the departure time).

If you wish to create a pulse, generally you would want to specify a dwell time at the stop as well, to accommodate bidirectional transfers. Adjust frequency modifications may be paired with an adjust dwell time modification to accommodate this. There is not currently a way to set the dwell time at a specific stop in an add trips modification, but this feature is on the short-term development roadmap. The analysis engine requires at least a minute between alighting from one vehicle and boarding the next to make a connection, plus any walking time if the boarding and alighting do not occur at the same stop.

Pulsing will be disabled if either of the modifications involved is bidirectional (because we won't know how to properly phase the directions together), or if either of the frequency entries involved are specified using "exact times" (because the times are already set and can't be adjusted to match the other entry). It is possible to phase two frequency entries which do not have the same headway, although this should be used with caution. If one headway is a factor of the other, they will just be lined up so that they occur together when possible (for instance, vehicles on frequency entries with headways of 15 minutes and 30 minutes set up to pulse will arrive together every 30 minutes, with an additional trip from the 15 minute headway occurring in between). However, if they are not factors of each other, the results will not be as desired. For instance, phasing frequency entries with headways of 15 and 20 minutes will result in trips being aligned as desired once per hour, with other trips misaligned (for example, vehicles on the frequency entry with 20-minute headway might arrive at 7:00, 7:20, 7:40 and 8:00, while vehicles on the frequency entry with 15-minute headway might arrive at 7:00, 7:15, 7:30, 7:45 and 8:00).

1.9 Exporting modifications

To see options for exporting scenarios from the top of the editing panel, click

A panel will then be shown with multiple options to download or share the scenarios in your project:

1.10 Overview of analysis mode

The main analysis page is for generating isochrones (travel time contours) from selected origins. To enter analysis mode, click this icon on the sidebar:

To start an analysis, ensure a project and scenario are selected. On the rest of the page, isochrone and accessibility results corresponding to this scenario will be shown in blue. You may also select a comparison project and scenario, which will be shown in red. To retrieve results for the origin marker shown on the map, move the marker or click:

Once a compute cluster has initialized (which may take several minutes), several components will be enabled in the analysis mode.

1.10.1 Isochrone map

After the server computes results, the map will show a blue isochrone representing the area reachable from the origin marker within a given total travel time cutoff. The travel time cutoff is controlled by the slider in the left panel and initially defaults to 60 minutes. To change the origin of the analysis, simply drag the marker to a new location.

The modifications displayed on the map are controlled in editing mode.

If an opportunity dataset is selected in the drop-down menu in the settings panel, the map will show gray dots representing the density of opportunities. For instance, if your selected opportunity data are jobs, there will be tightly packed dots in areas of dense employment, and less tightly packed dots elsewhere. One dot represents one or multiple opportunities, and the scale may differ between zoom levels and opportunity datasets. For example, if at a given zoom level, one dot represents 4 jobs, at that same zoom level one dot might represent only two residents.

If multiple scenarios are being compared, the isochrone for the first scenario remains blue, while the isochrone for the second is red. Areas reachable under both scenarios are purple, areas reachable only under the first scenario are blue, and areas reachable only under the second scenario are red.

Clicking on the map will display the distribution of travel times from the origin to that location. For example, in the image below, the travel time varies between about 30 and 50 minutes depending on when one starts their trip.

1.10.2 Analysis panel

The left panel has controls for the analysis and displays the accessibility afforded by the scenario.

At the top of the panel, available projects, scenarios, and Opportunity Datasets are listed in drop-down menus. For example, you might be interested in how a given scenario provides access to jobs, or access to schools, or some other variable of interest represented in an Opportunity Dataset you uploaded.

Additional scenarios can be selected for comparison. A "Baseline" scenario with no modifications (i.e. the unmodified GTFS bundle you uploaded) is automatically available for every project.

Charts of accessibility results

Directly below the comparison controls are readouts of the accessibility (number of opportunities reachable) from the chosen origin under the scenario and (if applicable) any comparison scenario.

The main display of accessibility results is the stacked percentile plot. The right portion of the plot shows the distribution of cumulative accessibility, i.e. the number of opportunities reachable given varying travel time cutoffs. The graph is not a single line, because there is variation in transit travel time depending on when a user of the transport system starts their trip. Rather, the graph shows the number of opportunities given 95th, 75th, 50th, 25th, and 5th percentile travel time. The bottom of the shaded area is the number of opportunities which are almost always reachable, while the top is the number of opportunities that are reachable only in the best cases (e.g. when someone leaves their house at the perfect time and has no waiting time). The darkened line is the number of opportunities that are reachable at least half the time (i.e. have a median travel time of less than the travel time cutoff). For a more detailed explanation, see the methodology page.

The currently-selected travel time cutoff is indicated by the vertical line on the plot.

To the left of the Y axis labels is a box-and-whisker plot. This shows the same information as the cumulative plot, but only for the currently selected travel time cutoff. The lowest whisker shows the number of opportunities accessible given 95th percentile travel time, the box shows the number of opportunities accessible given 75th, 50th and 25th percentile travel time, and the top whisker shows the number of opportunities reachable given 5th percentile travel time.

When multiple scenarios are selected, the charts will be slightly different, because they will include information for both scenarios.

Two box plots will be displayed, in red and blue, to the left of the axis. The blue box plot is for the first scenario, while the red one is for the second scenario. Above the chart, there is a selector that allows you to select whether to view the cumulative curves for the first scenario, the second scenario, or both (in which case the plots will be simplified and only the bands between the 75th and 25th percentile travel times will be shown, for simplicity).

Downloading

There are multiple options for downloading single-point analyses:

- saves the isochrone currently shown on the map. The downloaded file can be converted to other formats using a tool like mapshaper. Note that these vector isochrones are interpolations of the underlying analysis grid. They can be useful for visualizing results in GIS, but additional steps may be needed to prepare them for geoprocessing.
- saves the underlying travel time surface, a raster of travel times (in minutes) from the selected origin to the rest of the region. This raster has five bands corresponding to time percentiles of 5, 25, 50, 75, and 95. For geoprocessing, we often suggest using band 3 (the 50th percentile travel times) of this raw output.

Analysis options

Below the accessibility charts, different parameters for the analysis can be set:

The first panel allows the creation and use of **bookmarks**, which store particular analysis settings (e.g. origin location, type of opportunity, departure date and time, travel time cutoff, etc.). Once you have a set of settings you would like save, click . Once that is done, you can select a bookmark from the dropdown box to automatically fill in all of the settings from that bookmark. Bookmarks are shared by all projects in a region.

Next are selectors for **access modes** and **transit modes**; you can choose to perform your analysis with or without transit, and using walking, biking or driving. For instance, in the image above, a combination of walking and transit has been chosen. Note that by default, traffic congestion is not taken into account in driving time estimates, though this may be a feature of a future release when more detailed datasets are available.

Next are the **date**, **from time**, and **to time**, which define the time period analyzed (i.e. the opportunities accessible by someone leaving the chosen origin point on the chosen date between the chosen times). The first time you open a project, these will default to the current date and 7:00 to 9:00. To avoid inadvertently introducing differences in results due to differences in service on different days, we recommend choosing a single date and using it for the duration of a project. You should check that the date chosen is sufficiently representative in the GTFS feeds you are using (e.g. a non-holiday weekday).

You will also need to select a **Routing engine** version, which should default to the highest available version of Conveyal R5.

The final option is the **Percentile of travel time**. In single-point analyses, this is rounded to one of five pre-defined values (5, 25, 50, 75, and 95). For more information, see methodology.

Advanced settings

Egress mode defaults to walking. Non-walk egress modes may require a lengthy initial computation step; contact your support team if you need assistance.

Walk speed, **Bike speed**, **Max walk time**, and **Max bike time** apply to each access, transfer, and egress leg of trips involving public transport (as of routing engine v4.6.0). For example, a 15 minute value for Max walk time would allow trips requiring a 15 minute walk to access initial public transport stops, 15 minute walks at each transfer, and a 15 minute walk egressing from public transport to destinations. These limits are not applied when public transport is disabled. Otherwise, the requested values will be applied for access legs; for transfer and egress legs, the requested values will be applied, up to a distance limit of 2 km for walk and 5 km for bicycle egress.

Simulated schedules controls the number of schedules simulated for sampling if your scenario includes frequency-based routes (either in the baseline GTFS or in modifications with exact times not selected). The sampling process introduces random uncertainty, so you may see results change slightly when you repeatedly request accessibility results. When comparing regional analyses that include frequency-based routes, you may see small unexpected increases or decreases attributable to this random noise. Final results will be more accurate when **simulated schedules** is set to higher values, but computation will take longer. For quick, interactive analysis, we recommend setting it to 200, whereas, for final analysis, we recommend setting it to 1000. For more information, see methodology.

If your scenario does not include frequency-based routes, there is no need to simulate schedules, so the requested number of simulated schedules is ignored. In other words, when departure times are explicitly specified for all trips in a scenario, only that single fully specified set of exact departure/arrival times needs to be tested, which speeds computation and eliminates random noise from sampling.

Maximum transfers is an upper limit on the number of transfers that will be considered when finding optimal trips.

Errors and warnings

Occasionally, analysis will fail because there is an error in a scenario. When this occurs, error messages will be displayed detailing the issues. Return to the scenario editing mode and fix any errors in the listed modifications (e.g. add-trip modifications without alignments or timetables).

In other cases, the scenario may generate a warning, for instance if you remove more time from a segment when speeding it up than the length of that segment. This is not necessarily an error, but may require attention.

Starting a regional analysis

The analysis interface also allows starting Regional Analyses, which involves repeating an accessibility calculation for every origin in a specified area. To start a regional analysis, first set the appropriate parameters using the controls in this view and fetch single-origin results. With results displayed for a single origin, the new regional analysis button will be enabled; click it after confirming that the isochrones and accessibility values are sensible.

You can also choose geographic bounds for your regional analysis in the Advanced settings. By default, the entire region is analyzed, but for efficiency it is also possible to analyze a smaller area. You can set the bounds of the analysis by dragging the pins on the map, or by selecting an existing regional analysis and using the same bounds. If you plan to compare two regional analyses, make sure they have the same bounds and routing engine version.

When you have configured all of these options, click at the top of the panel and enter a name.

After a few seconds, you will see your regional analysis appear in the list with a progress bar. Since Conveyal Analysis is computing accessibility from every origin in the region, it can take a few minutes for each regional analysis to complete. Once a regional analysis is complete, it can be viewed by selecting it from the drop-down menu, which will take you to the regional analysis view.

1.11 Regional analysis view

After a regional analysis has completed, you can access it by selecting it in the Regional Analysis view. Upon selecting a regional analysis, you will see a screen like the following:

The map shows the accessibility experienced at each location, with the legend to the left. This is the number of opportunities reachable from each location within the travel time cutoff specified when creating the regional analysis.

1.11.1 Downloading regional results

Using the download button, you can save regional analysis results in a raster format (GEOTIFF). These saved files can be opened in GIS to conduct additional analyses or create custom maps. In QGIS, you will likely want to style the accessibility layer with a singleband pseudocolor scheme. If you prefer to work with the results as a regular grid of vector points, you may find the "Raster values to points" tool in the QGIS processing toolbox helpful. Downloading results also allows you to see the raw grid cells used for analysis, rather than the smoother interpolated results shown in your browser.

1.11.2 Comparing regional analyses

You can also compare two regional analyses from different projects in the same region. The map will show the differences in accessibility between the two analyses, with blue areas showing increased accessibility, and red areas showing decreased accessibility, relative to the comparison analysis. Again, you can download raw results for the two analyses being compared for further styling and analysis in GIS.

1.11.3 Measuring aggregate accessibility

These regional analyses present a wealth of information, and maps of regional accessibility are frequently the best way to communicate the accessibility impacts of a transit plan. However, in some cases there is a need to summarize accessibility in a single metric for the purposes of setting measurable goals in planning practice. Conveyal Analysis allows aggregating the results of a regional analysis to a larger area, for example a neighborhood, city or region. The result of this aggregation is a histogram of the accessibility experienced by residents of the aggregation area, as well as quantiles of the level of accessibility experienced by the population (e.g. 80% of residents have access to at least 500,000 jobs within a 45 minute transit commute). This latter metric can be used a single number to set goals in transportation planning.

In order to accomplish this aggregation, you first need to choose a region and code it as a polygon Shapefile (unprojected WGS84, CRS 4326). The choice of region can have a significant impact on the final metric. If a very large region is chosen, where much of the region does not have transit service, there will be a large number of people with very low job access via transit, deflating the aggregate numbers. Conversely, if a small region is chosen, segments of the population that should be served by transit will be excluded from the aggregate metrics. Conveyal Analysis will not accept aggregation areas larger than 2 square degrees.

Once you have created a Shapefile of your aggregation area, you need to upload it to Conveyal Analysis. This can be done within the regional analysis view by selecting "Upload new aggregation area" under the "Aggregate to" heading:

You can then name your aggregation area and select the files to upload. Be sure to select all components of the Shapefile (i.e. .shp, .dbf, .shx, .prj, etc.). It may take some time to upload the files and process them, depending on their size and complexity. If there are multiple polygons in the input file, they will be merged into a single aggregation area.

Once the aggregation area is uploaded, you can perform the aggregation. You will select the area you want to aggregate to, as well as what you want to weight by. For example, if you select "Workers total,"" your histogram will represent how many workers experience different levels of accessibility. If instead you select "Workers with earnings $1250 per month or less," you will see how accessibility is distributed among low income workers. Any opportunity dataset you have uploaded is available for use as weights.

Once you have an aggregation area and weight selected, you will see a display similar to the one below, showing a histogram of how many of the units you weighted by experience a particular level of access.

The plot is a histogram of the number jobs accessible within the full opportunity dataset (not just Brooklyn) for workers residing in Brooklyn (since this is a regional analysis of access to jobs, aggregated to Brooklyn, and weighted by workers). We can see that the distribution is bimodal. There are a large number of workers with relatively lower accessibility values (the left peak), most likely residing in outer Brooklyn further from the subway and from job centers . There are also a number of workers with a higher level of accessibility, probably those residing in downtown Brooklyn and near Manhattan. This plot is conceptually similar to academic work on accessibility by population percentile (e.g. Grengs et al. 2010).

Below the histogram is a readout of the metric mentioned above: how many opportunities are accessible to a certain quantile of the population; in this case, 90% of workers residing in Brooklyn have access to more than 267,000 jobs. You can adjust the percentile by dragging the slider. The area of the histogram above the cutoff is highlighted. By setting it below 100%, you are effectively choosing what percentage of your region it is not practical to serve with transit, and not penalizing transit accessibility metrics for the lack of access in those areas.

The last metric is the weighted mean accessibility. This is a popular metric, and one used by Conveyal in the past. This represents the average accessibility experienced by all residents (or whatever unit you have weighted by) in the aggregation area. However, since it uses the mean, it is strongly affected by outliers, and is not representative of the full range of accessibility experienced. In the Brooklyn case, it falls between the two peaks, and does not reflect that many people have accessibility below that. Since aggregate accessibility frequently has a long right tail, with many residents with low to medium accessibility and few with very high accessibility, the mean is often higher than the accessibility experienced by a majority of the population. For these reasons, we do not recommend the use of this metric.

1.12 Developers Guide

1.12.1 Installing your own copy

Instructions on configuring and running a local copy of Conveyal Analysis are available here.

1.12.2 Updating this manual

If parts of this manual are unclear or confusing, we'd welcome your feedback. At the top of each page is a link to "Edit on GitHub." Clicking that link, when logged into GitHub, will allow you to edit the markdown files for this manual and propose changes by opening a pull request.

1.13 Frequently Asked Questions

1.13.1 How does Conveyal Analysis calculate travel times?

Conveyal Analysis calculates door-to-door total travel time, without any subjective impedance factors. Travel times are always computed by finding actual paths through a full street and (where applicable) public transport ("transit", in

American English) network. By default, Conveyal Analysis uses the centers of high-resolution grid cells as destinations.

For analyses with transit disabled, the total travel time from an origin to a destination includes time spent:

1. Walking from the selected origin to the nearest point on the street network
2. Traveling to the point on the street network nearest to the destination, using the selected direct mode (walk, bicycle, or car)
3. Walking from the street network to the destination

For analyses with transit enabled, the total travel time from an origin to a destination includes time spent:

1. Walking from the selected origin to the nearest point on the street network
2. Reaching nearby transit stops via the street network, using the selected access mode (walk, bicycle, or car)
3. Waiting to board transit (initially and at transfers)
4. Riding in transit vehicles
5. Walking via the street network between transit stops for transfers
6. Traveling from transit stops to the point on the street network nearest to the destination, using the selected egress mode
7. Walking from that point on the street network the directly to the center of the grid cell.

If it is faster to reach a destination directly, without using transit, the routing engine will replace the second step above with direct travel along the street network to the point on the street network nearest the to the destination, then skip to the final step. Public transport routing uses actual schedules from the imported GTFS feeds. For every origin, Conveyal Analysis finds a large number of travel times to every destination grid cell. Different travel times may be found for each departure time (each minute in the specified time window). If new transit routes have been added with frequencies but without specific departure times, many different possible schedules are also tested producing hundreds or thousands of possible travel times (according to the "simulated schedules" advanced parameter). All these different travel times imply a statistical distribution, from which a certain percentile of travel time, set in the user interface, can be read.

1.13.2 Why are travel times longer than expected?

Because Conveyal Analysis includes waiting time, which can vary greatly depending on when one departs, total travel times may be longer than you might initially expect. Varying the travel time percentile can help you determine what role service frequency plays in waiting times (and therefore total travel times) for your network. The fifth percentile usually reflects trips with close-to-minimal waiting times (e.g. when passengers consult schedules and adjust the start of their trips to minimize overall travel times).

Another potential explanation for unexpectedly long travel times is that origins, destinations, and stops are all linked to the nearest edge in a network's street layer. This linking behavior can lead to unexpected results, especially for stops, origins, or destinations in areas with sparse street or pedestrian networks. Consider these examples:

- You place the origin directly on a transit stop with fast, frequent service, but travel times using the service show an unexpected delay. Because total travel time includes walking from the origin to the nearest street or pedestrian path in the baseline street layer, then from the street layer (back) to the transit stop, there may be an unexpectedly long access time if the stop is far from a nearby street.
- You notice a very long transfer time between two nearby stops. If these stops are linked to different street edges, and the street edges are only connected via a long, circuitous path, the walking time for the transfer will be unexpectedly long.

To avoid such issues, we suggest placing stops close to streets or pedestrian paths, and snapping to stops that exist in the baseline transit layer when feasible.

Uploaded OpenStreetMap data with poorly connected subnetworks may also lead to issues. If you notice strangely non-contiguous isochrones, they may reflect destinations being linked to such a subnetwork (e.g. a network of walking paths in a park that only connects to the rest of the street network at a few locations).

1.13.3 Who can see and edit my projects?

All authorized users within an organization have access to that organization's regions, projects, and scenarios. Multiple users should not edit or analyze the same project concurrently. If multiple users try to edit the same modification simultaneously, or if you have Conveyal Analysis open in multiple browser tabs, you may see "data out of date" errors.

1.13.4 How long should it take to start a single-origin analysis?

Three steps take place when starting a new single-origin analysis.

First, the main Analysis server must request and initialize a compute cluster from Amazon Web Services. For scalability, we start a "worker" server for each transport network being analyzed. This means that even if you are already successfully fetching analysis results for a project, a new server will be needed if you switch to a project associated with a different GTFS bundle or region, or if you change the routing engine version.

Second, the worker server needs to set up a transport network. It first checks whether the required transport network is already built and available for download from Amazon S3. If it is, the server downloads it and proceeds to step 3. If a pre-built network cannot be downloaded, the server downloads the required input files (OSM extract and GTFS bundle). It then builds the transport network by combining the road and transit layers, which can be a lengthy process (on the order of 10 minutes for large regions, and an hour for very large regions with dense networks). To avoid having to repeat this step, the server will upload the built network to S3 for future use.

Third, once a transport network is downloaded or built, certain caching operations related to egress mode (e.g. walking or biking) need to be completed.

Recent routing engine versions provide status updates on these steps, including:

- *Starting routing server. Expect status updates within a few minutes.*
  - Trigger: analysis using a project that has not been analyzed within the last hour
  - Expected duration: 2-3 minutes
- *Building network…*
  - Trigger: analysis using a new GTFS bundle, scenario, or routing engine version
  - Expected duration: 5-50 minutes, depending on size of transit network
- *Linking grids to the street network and finding distances…*
  - Trigger: analysis using an updated egress mode or scenario
  - Expected duration: up to a few minutes, depending on extent of region
- *Performing analysis…*
  - Expected duration: a few seconds

By default, servers automatically shut down after one hour of inactivity. If you to override this default shutdown behavior for critical analyses, get in touch with your support team.

1.13.5 How long should each regional analysis take?

The time required to complete a regional analysis is a function of the size of the region, number of origins, and size and complexity of the transit network. Generally, computation is slower for routes specified as add-trip modifications than for routes specified in the baseline GTFS bundle. If frequency-based routes are present in the scenario's add-trip modifications or the base GTFS, compute time will also depend on the number of simulated schedules (Monte Carlo draws).

Additional servers start automatically once a results for few origins in a regional analysis have completed successfully. The number of additional servers is a function of the number of origins, with a default cap set to approximately 250. If you need a higher cap to complete a large batch of analyses quickly, contact your support team.

1.13.6 How do I model corridor upgrades where a new trunk is added and existing services are converted to feeder routes?

The new trunk service can be represented with an add-trip modification. Existing services can be curtailed using reroute modifications. You will need separate modifications for each direction of each curtailed route, setting the start/end stop to the stop at which the route will be curtailed as a feeder to the new trunk.

1.13.7 What new features is Conveyal working on?

Conveyal releases new features and improvements for the cloud-hosted version of Conveyal Analysis every few months. We regularly discuss with customers to understand how they use the system and identify features they would find useful. We create a roadmap containing features that we can realistically implement, considering long-term reliability and maintainability. If a customer wishes to pay for development effort or use development/support hours bundled in their contract to cover additional software development, features can be prioritized.

1.14 Methodology

1.14.1 Spatial resolution

As a shared geographic foundation for regions, opportunity datasets, and accessibility indicators, Conveyal Analysis uses a regular grid of cells. Each cell measures approximately 300 meters by 300 meters, depending on the latitude (with larger cells at the equator and smaller cells near the poles). These grid cells are not spaced at a round number of meters. Instead they are one-unit steps in the same global projection used for map display in our web interface. This helps accelerate map display, while eliminating the complexity of switching to different local projections. Large regions may contain more than a million such cells, reflecting a much finer resolution than typical regional travel demand models. Conveyal implemented this approach to counter the effects of the "modifiable areal unit problem" and in response to systematic bias we observed when using the center points of polygons defined by roads, we have made an intentional methodological choice to perform all measurement on regular grids whose geometry is independent of roads and land parcels.

Opportunity datasets from uploaded point or polygon files, as well as LODES imports, are resampled into this standardized regular grid. For example, if a large traffic analysis zone in an uploaded shapefile has 10 thousand jobs, those jobs are dispersed throughout the grid cells intersecting that zone, according to the areal proportion of the intersection of each cell with the zone.

1.14.2 Accounting for variability

Travel times by transit are often highly variable, depending on when travelers start their journeys and the timetables of routes they use. To account for this variability, we calculate the distribution of travel times experienced in a given departure window, then select specific values from this distribution according to a parameter we call the time percentile. This percentile ranges from 0 to 100 and represents how reliably a destination is reachable for travelers starting journeys in the selected departure window.

In general, this approach allows us to more appropriately characterize travel times between origin-destination pairs served by many alternative routes (e.g. a corridor with many overlapping bus services) than blanket half-headway assumptions. Note, however, that it assumes travelers have perfect knowledge of schedules in the network and act accordingly to minimize their travel time. In some cases, this assumption may not be appropriate. Travelers without access to complete schedule information may be inclined to board the first vehicle that arrives, even if others would allow them to arrive at their destination sooner.

We use the median or other percentile travel time, rather than the mean, because it can handle travel times that are infinite or undefined (for example, because the only route to a particular destination uses a bus that stops running before the end of the time window). For more details, please see Conway, Matthew Wigginton, Andrew Byrd, and Marco van der Linden (2017). "Evidence-Based Transit and Land Use Sketch Planning Using Interactive Accessibility Methods on Combined Schedule and Headway-Based Networks."

Others calculate the accessibility at each departure time and taking a mean of accessibility as is done by the University of Minnesota Accessibility Observatory. Conveyal Analysis does not use this approach because the travel time to each opportunity should be treated independently. Consider a situation of a small town situated between two major cities each with 500,000 jobs, with hourly train service to each city. Suppose that we're interested in the number of jobs reachable in one hour, given departure during a time window of 8:00 to 9:00 AM. Further suppose that, due to how the train schedules are written, it is possible to commute to all jobs in the first city in under an hour if you leave between 8:00 and 8:15, and all the jobs in the second city are accessible if you leave between 8:30 and 8:45, and at other times no jobs are accessible. This corresponds to hourly trains to each city, leaving at 8:15 in one direction and 8:45 in the other, and needing 45 minutes to travel to the respective city. Using the average of accessibility, this location would have an accessibility of 250,000, because ¼ of the time 500,000 jobs are accessible in the first city, ¼ of the time 500,000 jobs are accessible in the second city, and ½ of the time no jobs are accessible. Thus the accessibility value would be 250,000 even though there is no job that can be reached in an average travel time of less than 60 minutes.

1.14.3 Time percentile

Assuming service operates with perfect schedule adherence, the time percentile can be interpreted as how inclined travelers are to adjust their departure time based on transit schedules. Low time percentile values imply travelers are flexible and can start their journeys at times that minimize their waiting and overall travel time, which is appropriate for passengers accustomed to relying on schedules (e.g. commuter rail riders). Higher time percentile values are appropriate for passengers who expect "turn-up-and-go" service (e.g. users in dense areas with frequent service).

For most analyses, the default value of 50 is acceptable, though you may also want to consider 25th or 75th percentile travel times, depending on whether users are likely to use schedules or start trips randomly.

We assume passengers have perfect information about all schedules in the system and that they choose routes to minimize their total travel time. We also assume that passengers can board all vehicles, so we do not account for denied boardings due to vehicles or facilities that are inaccessible to people using wheelchairs, crowding, etc. Some routes may have frequencies/headways defined, but not explicit timetables, which can introduce uncertainty into results. Our routing engine (called R5) mitigates this uncertainty by simulating feasible timetables for all headway-based routes. For example, if the Red Line is set to depart Airport Station every ten minutes, without explicit timetables, one simulated timetable could include departures at 7:00, 7:10, 7:20…, and another simulated timetable could include departures at 7:02, 7:12, 7:22… The number of simulated schedules parameter in the analysis settings determines how many simulated timetables are used, rounding up to an integer number of schedules per minute in the departure window.

Example

Consider travelers with the following hypothetical journey:

- Walk 10 minutes from their origins to a stop served by a single route
- Wait at the stop
- Board the first vehicle of the route that arrives at the stop, and ride it for 30 minutes
- Alight directly at their destinations

These travelers have at least 40 minutes of travel time, plus a waiting time that varies depending on when they begin their journey with respect to the route's timetable.

Say these travelers want to begin their journeys sometime between 7:00 and 8:40 AM (a departure window of 100 minutes), and that they will only consider their destination reachable if their door-to-door travel time is less than 45 minutes. If the route departs the stop once per hour, at 7:00 and 8:00, there will only be five minutes of the departure window for which the destination is reachable. Travelers can start their journeys between 7:45 and 7:50, arriving at the station between 7:55 and 8:00 to board the 8:00 departure. The destination will only be considered reachable at time percentiles up to 5% (5 of the 100 possible departure minutes in the departure window). That level of reliability may be acceptable for travelers who are willing to structure their travel around schedules for services with low frequency.

If instead, the route departs the stop every 10 minutes, starting at 7:00, there will be fifty minutes of the departure window for which the destination is reachable (beginning trips between 7:05 and 7:10, or between 7:15 and 7:20, or between 7:25 and 7:30, etc.). The destination will be considered reachable at time percentiles up to 50%.

Finally, if the route departs every 5 minutes, the destination will be reachable within the 45-minute cutoff 100% of the time. Even if travelers just miss a vehicle, the next one will depart in 5 minutes, and they will arrive at their destination without exceeding the time cutoff.

1.15 Glossary

1.15.1 GTFS

General Transit Feed Specification, a format for transit network and schedule data. Most transit agencies produce GTFS feeds to power customer-facing trip planning applications, but they are also useful for analysis. Conveyal Analysis uses bundles of GTFS .zip files to build the transit layer of the baseline network.

1.15.2 routing engine

Conveyal R5 is the core computational software behind Conveyal Analysis. It performs one-to-many searches on multimodal (transit/bike/walk/car) transport networks.

1.15.3 transport network

A routable network with transit and road layers, built by a specific version of R5. The transit layer is built from a GTFS bundle and the road layer is built from the OpenStreetMap network associated with a region.

1.15.4 trip pattern

A sequence of stops visited by a transit vehicle. A trip pattern can have many trips, and a route consists of a one or more trip patterns.

1.15.5 trip

A single vehicle trip, representing a vehicle visiting the stops on a particular trip pattern at a particular time.

1.15.6 hop

A portion of a trip consisting of a transit vehicle traveling between two consecutive stops.