TransitCenter Equity Dashboard:

Technical Documentation

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Table of Contents

1. Introduction

The purpose of this project is to provide timely indicators of public transit system performance via a publicly available web dashboard. The focus of the dashboard is to track the equity of transit service over time in seven US regions. The dashboard facilitates visualization and assessment of changes in accessibility (measured as access to various opportunities with and without a fare constraint), transit service intensity, and transit reliability (delay) and their varying effects on different neighborhoods and populations.

The dashboard includes summary charts, customizable maps, and data downloads. These features allow users to visualize and understand how transit service levels have changed, and how they have impacted how riders experience transit since the Covid-19 pandemic began through the present (with periodic updates moving forward). Ultimately, we expect that the dashboard and its underlying data and analysis will support TransitCenter and the public's need for robust and timely information on public transit performance during and following this challenging time.

The analysis behind the dashboard uses emerging data sources to better reflect actual public transit service delivery in the US and how service meets demands of different riders. It uses a novel fare calculator to represent the opportunities that are reachable for less than a set fare amount. The analysis uses reproducible and open-source methods for calculating and analyzing access to opportunities in major US regions with an emphasis on comparing conditions faced by different socioeconomic and ethnic groups. In this technical memorandum, we describe our data and analysis approach.

The TransitCenter Equity Dashboard is available at dashboard.transitcenter.org. All code used to generate the dashboard is available on the dashboard's "How it Works" page.

2. Dashboard overview

The dashboard's landing page allows users to navigate to information for each of seven regions, with options for a map viewer, story page with charts, and data downloads. Users also have the option of navigating to a "How it Works" page.

When users navigate to the maps page, the menu on the left side of the screen includes instructions for how to use the map tool, user-defined parameters that can be used to tailor the map (Table 1), a shareable link to the current map view, and a data download button.

The story page includes an introduction describing the context of the pandemic and its effects on transit. Users can also navigate to explanatory text and charts illustrating five critical transit-equity-related themes.

Table 1: Dashboard map parameters and user options.

Parameter			Options
Analysis boundary			metropolitan statistical area (MSA) economic activity region urban core equity neighborhoods
Performance measure	Accessibility	Travel mode	transit ratio of transit to auto
		Destination type	jobs low-wage jobs grocery stores and supermarkets hospitals urgent care pharmacies parks and greenspace colleges and universities transit service intensity[1]
		Measure type	Depends on destination type: cumulative opportunities in X minutes minimum time to reach X facilities gravity measure (data download only)
		Fare	Fare limited No fare limit
		Time of day/week	weekday morning (7 to 9 am) weekday night (10 pm to 12 am) weekend day (Saturday 10 am to 12 pm)
	Equity	Population overlay	Asian and Pacific Islander Black Hispanic/Latinx White Living at or below poverty level Essential workers (at their place of residence) Single-mother households No car households
Date slider			~monthly 2/20 to 2/21, less frequently 2/21 onward
Units			Percentiles Transit:Auto ratio

[1] Transit service intensity represents the opportunity to access transit itself. We group it with accessibility in the map menu for simplicity although it differs from measures of access to specific destinations.

3. Data and analysis

3.1. Scope

3.1.1. Spatial areas

The analysis includes the following seven study regions:

1. Boston
2. Chicago
3. Los Angeles
4. New York City
5. Philadelphia
6. San Francisco-Oakland
7. Washington, D.C.

For each region, accessibility and transit service intensity scores are computed for the entire region and then summarized for four analysis boundaries, defined as follows.

1. **Metropolitan statistical area (MSA**): This region consists of a high-density urban center and its suburbs, and is defined by the U.S. Census Bureau.
2. **Economic region***:* This region consists of a high-density urban center plus surrounding counties with high exchange of economic activity and travel, and is defined by TransitCenter. This region includes counties that meet at least one of the following criteria, based on LEHD data: where at least 3% of the people who work in the central city live; where at least 3% of the people who work in the MSA live; where at least 3% of residents of the central city work; and/or where at least 3% of residents of the MSA work.
3. **Urban core**: This is a contiguous area with the highest existing transit use and/or highest potential for transit use in the region. TransitCenter defined this area based on the following conditions: workflow to and from the central city (using LEHD data), population density, household incomes, race and ethnicity, and presence of high-frequency and high-quality transit (using GTFS feeds from transit.land[2] and the CNT AllTransit tool[3]). Local transit advocates gave input on the definitions.
4. **Equity neighborhoods***:* Areas that local transit advocates and TransitCenter identified as meriting additional resources for transit improvements because of past disinvestments or marginalization in planning decisions.

The entire region used to perform the analysis includes the union of all four analysis boundaries, which is equivalent to the union of the economic region and the MSA. The entire region is used

[2] https://www.transit.land/
[3] https://alltransit.cnt.org/

to generate the summary statistics on the story page. Viewing data for the entire region is not an option on the map.

Most analyses use census block groups as the base unit with the exception of the reliability measures.

3.1.2. Time periods

The dashboard provides snapshots of accessibility, transit service intensity, and transit reliability over time. These snapshots are estimated approximately monthly from February 23, 2020 (immediately preceding pandemic lockdowns) through February 21, 2021. From February 2021 onward, estimates are provided less frequently depending on the uses of the dashboard and the frequency of service changes.

3.2. Accessibility

Accessibility combines land use and travel characteristics to quantify how easily people can reach destinations in terms of impedance (e.g. travel time, distance, or cost) from different starting locations throughout a region. This section describes the time periods of interest, our approach to calculating travel times by public transit and automobile, the data used to locate different types of destinations, and the methods used to estimate fares. Finally, we describe how these data sources are combined to arrive at our accessibility measures.

3.2.1. Time periods

Measures of transit access are estimated for three times during the week, including weekday mornings (7am to 9am), weekday nights (10pm to 12am), and weekends (Saturdays 10am to 12pm).

3.2.2. Transit travel times

We use open-source, reproducible approaches to transit travel time measurement that rely on publicly available data.

The spatial scale of our travel time analysis is the census block group. We use centers of population, as defined by the US Census Bureau based on the 2010 decennial census, as the origin and destination (OD) points within each block group polygon. These points represent the population-weighted mean center of each polygon.

We use OpenTripPlanner (OTP), an open source multi-modal transportation routing engine, to compute accurate public transit travel time estimates between block group centroids. OTP considers all components of the door-to-door transit trip: walking to a stop, waiting for a vehicle, in-vehicle travel time, transfer time (if necessary), and walking from the departing stop to one's final destination. The pedestrian networks used in OTP are sourced from OpenStreetMap (OSM). OSM provides extensive coverage of walking (i.e. non-auto) paths

compared to other street network data sources, and has been used extensively in previous transit accessibility studies (*1*, *2*).

OSM data are downloaded based on the geographic extents for each study region. The transit components of the network are built using schedule-based General Transit Feed Specification (GTFS) data. GTFS is a standardized format for public transit route and schedule data, associated geography, and agency information. We use TransitLand[4] for DC and SF-Oakland and OpenMobilityData[5] (formerly TransitFeeds) for all other regions to source and download GTFS data for agencies. Transit agencies and their associated GTFS data are included for each region if a stop lies within the geographic extents for each study region. GTFS and OSM data are combined within OTP to generate multi-modal network "graphs" for each study region. Once these graphs are built, we compute origin-destination travel time matrices between all block groups. Travel times are capped at 90 minutes.

The inputs for generating these transit trip itineraries are the OD coordinates (block group centroids), travel modes, departure date, and time of day. Since there are minute-by-minute variations in travel times by public transit, accuracy can be improved by computing travel times for multiple departure times (e.g. not only at 8 am for the morning commute period). To strike a balance between computational burden and accounting for temporal schedule variations, we compute two travel times across each of the two-hour time periods noted above. These travel times are randomly selected from two 30-minute time blocks (e.g. 7:30 to 8:00 and 8:00 to 8:30). We then compute accessibility for both departure times and average the result.

3.2.3. Automobile travel times

We compute OD travel times for automobile travel using ArcGIS Network Analyst (ArcGIS Pro 2.7) and the ESRI Streetmap Premium network based on HERE[6] data. The Streetmap Premium network contains link-level travel time impendance and driving restrictions for the entire US. Importantly, the impendences and restrictions are temporally dynamic, and based on historically recorded and averaged conditions experienced in the real world. This means that automobile travel times can be calculated according to average conditions on roads at specific times of day and days of the week. This feature is used to generate OD matrices of travel times between all block group centroids in each study region for our three time periods.

Only one departure time is selected to represent each period: a typical pre-pandemic Tuesday at 8am and 11pm, and Saturday at 11am. Because the focus of the dashboard is on changes in transit service and access over time, pre-pandemic auto travel times are used as a point of comparison to transit travel times. We present time-varying transit travel times as a ratio to fixed auto travel time estimates in each snapshot shown in the dashboard.

[4] https://transit.land/
[5] https://transitfeeds.com/
[6] https://www.here.com/

3.2.4. Destinations

We consider five categories of destinations: employment, grocery stores and supermarkets, healthcare, parks and green space, and higher education. Each destination type and data source is described in Table 2.

Table 2: Destination types and data sources used in the accessibility analysis.

Destination type	Description	Data source
Employment	Finding and retaining employment is paramount to economic independence, poverty reduction, and overall well-being. We use US Census LEHD data to measure access to all jobs in a region, as well low-wage jobs ($1250/month or less).	2017 LEHD data: https://lehd.ces.census.gov/data/
Grocery stores & supermarkets	Access to affordable, healthy food is essential for well-being. Because of the equity focus of our study, our grocery store dataset includes those that are part of the Supplemental Nutrition Assistance Program (SNAP, previously called Food Stamps).	https://github.com/jshannon75/snap_retailers
Healthcare	This category includes hospitals, urgent care facilities, and pharmacies (each presented separately). These are critical essential services. All urgent care facilities in this dataset must provide emergency care, surgery, and recuperative care.	Hospitals: https://hifld-geoplatform.opendata.arcgis.com/datasets/6ac5e325468c4cb9b905f1728d6fbf0f_0?geometry=91.417%2C-16.829%2C-122.333%2C72.120 Urgent Care Facilities: https://hifld-geoplatform.opendata.arcgis.com/datasets/urgent-care-facilities Pharmacies: https://rxopen.org/
Parks & green space	Access to green space is beneficial for health and well-being. We measure access to parks and other green space (cemeteries, school yards, etc.) in our study regions based on OpenStreetMap data.	OSM: https://www.openstreetmap.org queried with https://wiki.openstreetmap.org/wiki/Overpass_API to extract parks and green space.
Higher education	This category includes colleges and Universities. Education is a fundamental means for achieving social mobility, and these institutions are also centers for jobs, community resources, and social and cultural events.	https://hifld-geoplatform.opendata.arcgis.com/datasets/colleges-and-universities https://hifld-geoplatform.opendata.arcgis.com/datasets/supplemental-colleges/data

The employment data are provided at the block level based on all jobs included in the LEHD data. These are aggregated up to block groups based on their unique identifiers. All other data

are aggregated to block groups based on spatial overlay. For the points corresponding to grocery stores, health care facilities, and higher education, we conduct a spatial join, counting the number of each that fall within each block group.

For parks, since these are area data, we conduct a spatial intersection of green space polygons and block group polygons and then compute the total area within each block group classified as green space based on this intersection. We represent park acreage as a point at the population-weighted centroid of the zone. Note that when calculating intrazonal travel times (access within the same zone), we use the "radius" of the zone divided by walking speed. This is a typical practice that approximates walking access in small urban zones and larger rural zones, however for large urban zones (e.g. a large park such as the National Mall in Washington D.C.) it can lead to strange results in the affected zone and in adjacent zones when it results in a relatively long internal walk time that does not capture the ability to reach part of the park within a shorter amount of time. It may also lead to edge effects when representing access to park space from adjacent zones that result from the location of the centroid of each zone.

fixed auto travel time estimates in each snapshot shown in the dashboard.

3.2.5. Fare data, fare rules and fare analysis

The cost to take transit -- the transit fare -- is rarely accounted for as a travel constraint in accessibility analyses. More commonly, shortest-path travel times are computed and combined with opportunity data to compute accessibility scores. Fares introduce an additional level of complexity. Because of the way that shortest-path algorithms work, if we impose a fare constraint ahead of time (e.g., $5 total fare budget) we may encounter a situation where a route with a lower cost but longer travel time is not generated by the path builder. Imposing a fare constraint on a network of shortest-path travel times could inappropriately reduce a location's apparent accessibility. Although there are methods to simultaneously optimize on fare and travel time (*3*), they are not readily incorporated into existing analysis tools.

In this analysis we take a heuristic approach to fare analysis. Specifically, in each region we define two different transit networks whose fare costs we expect to differ:

1. low-cost modes (local bus plus comparable-cost modes), and
2. all modes.

Low-cost modes are defined to capture transit options with fare expenses similar to local buses (e.g., streetcar, light rail, flat subway fares) while excluding "premium" modes that are more expensive (e.g. commuter rail, private commuter bus, extra-fare express buses, distance-based subway fares). The low-cost network is created in OTP by inputting a list of premium routes/modes/transit agencies on which to restrict travel. Any trip using the low-cost network will not involve a route, mode, or transit agency that is restricted.

We then use OTP to generate travel times and fares separately for each of these networks. The output from OTP is a JSON file containing information for the itinerary pertaining to the trip that returns the most easily traveled route between the origins and destinations given the specified departure time. The selection of the most easily traveled route is a function of the shortest travel time and other factors that are built into OTP, which we refer to as the shortest path route for simplicity. This output itinerary includes information regarding the agency, modes, distance, and routes used for the trip which feed into our fare calculations. Because generating itineraries in OTP is computationally intensive, we use census tract centroids as origins and destinations. OTP is run twice (once for the all modes network, and once for the low-cost mode network) in each region using a weekday morning departure time. Like the travel time calculation, trips are restricted to a 90-minute travel time threshold.

The next step is to estimate the cost of traveling between each OD pair on both the low-cost and the all modes transit networks. Most agencies do not provide fare data and fare attribute data in their GTFS data. Because fare calculations are not often undertaken, there are few established processes for easily generating out-of-pocket costs for many OD pairs at once. Therefore we have developed a fare calculator to automate this.

The cost of a ride depends on the number of transfers, fare medium, routes, and modes of transit taken. The number of transfers and modes are available from each OD trip itinerary generated by OTP. The fare calculator estimates the cost of each itinerary based on a database of manually calibrated rules representing fare information from each transit operator's website. These fare rules include the cost of transfers within and between agencies. For agencies with very complex fares, such as WMATA, NJ Transit, and SEPTA, it is necessary to use a simplified representation of fares. Additional detail about the fare rules used is included in Appendix B.

The few agencies that provide fare data and fare attribute data in their GTFS data generally only consider cash payment while ignoring rules for inter-agency payment agreements. The problem with using a cash fare is that it is likely to overestimate the costs per trip since many transit riders will have some type of pass that reduces their total fare. We assume that transit travelers pay for a one-way ride with an intermediate purchase choice that is less expensive than cash, such as a ticket or card. We do not include discounted fares like student or senior fares or options that require a large up-front purchase like monthly or weekly passes. In regions where we cannot define an intermediate choice, we use cash fares.

Our fare calculator for the Boston metropolitan region provides an example of our analytical approach. There, we selected a payment medium representing an intermediate ticket choice in terms of cost and transfer rules: the Charlie Ticket. Figure 1 illustrates our process for calculating fares. In the first step, OTP generates trip itineraries for all OD pairs that can be reached within 90 minutes on the transit network. The output is a JSON file with detailed trip attributes including duration, mode, stop name, agency name, and route for each leg of a journey.

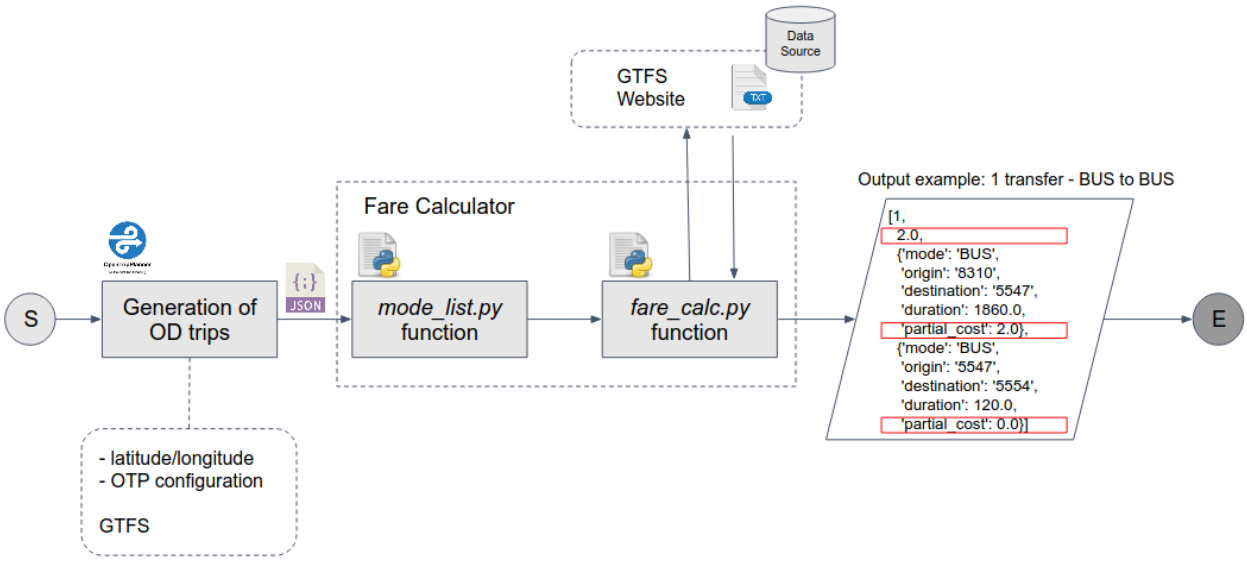

Figure 1: Process to calculate fares for each itinerary. The output example represents a local bus to local bus transfer on the Massachusetts Bay Transportation Authority (MBTA) and a Charlie Ticket.

This information is passed to the fare calculator, which contains two functions developed in Python. The mode_list.py is a "field aggregator." It outputs a list with the fields necessary to model fare rules and a record of each itinerary leg. Fare rules are collected from transit agency websites and documentation. These rules get recorded and applied in the fare_calc.py function. The fare calculator also manages transfer rules subject to maximum trip duration and a maximum number of free or discounted transfers to reproduce real fare systems.

For every itinerary generated in OTP, we calculate the cost per leg, named "partial_cost" in our dictionary structure. Figure 1 also shows an example of a transfer between local bus routes (in the "output example" there are two trips, each with 'mode': 'BUS'). In this case, the fare rule mapped is "With a CharlieCard or CharlieTicket, 1 free transfer to Local Bus within 2 hours of the first tap."[7] For the output example, the first local bus has a partial cost of $2, and the second is free due to transfer rules, so the total trip cost is $2.

Appendix B includes a more detailed description of the fare calculator, transit agencies and premium modes, and built-in fare assumptions.

The fare calculations are performed for three time periods (weekday morning peak, weekday evening, and weekend morning) for both the low cost and the all modes network. The resulting fare cost between each tract-based OD pair on each network during each time period is then disaggregated to the corresponding block-based OD pairs. This information is passed to the accessibility calculator, which generates fare-constrained travel times and accessibility for each date estimated on the dashboard as described in the next section.

[7] https://www.mbta.com/fares/transfers

Note that the tract-level fare estimates are estimated based on GTFS feeds for February 2020 and fare information posted on agency websites in 2020. Fare estimates are assumed to be constant, while the travel times used to estimate the accessibility measures are re-estimated for each date evaluated.

3.2.6. Evaluating accessibility

Accessibility is generally understood as the ease of reaching destinations. Measuring accessibility is a combination of travel costs (i.e. the ease) and the relative locations of destinations. For this analysis we consider travel costs to be travel times required to reach destinations at different times of the day. For frequent travel destinations (employment and higher education) we also consider fare thresholds.

Once we have destination data and travel times between all block groups, we can measure accessibility. The most common way to measure accessibility uses the following equation:

$$A_i = \sum_j O_j f(c_{i,j}) \quad [1]$$

Where A_i is the measure of accessibility for block group i, O_j is the number of opportunities, or destinations (e.g. jobs, pharmacies, etc.) in block group j, and $c_{i,j}$ is the travel cost from i to j. $f(c_{i,j})$ is an impedance function that weights locations that have a lower travel cost more than those that have a greater travel cost.

For our study, the travel cost is first based only on centroid to centroid travel times. For destination types that are widely available (such as jobs and parks), we measure accessibility using primal cumulative opportunity measures with travel time thresholds (e.g. the number of jobs reachable in 45 minutes, total area of green space reachable in 15 minutes). These accessibility estimates can be represented as

$$A_{i,m} = \sum_j O_j f(t_{i,j}, t_{m,}) \quad [2]$$

Where $t_{i,j}$ is the travel time from i to j by transit, t_m is the travel time threshold, and the impedance function $f(t_{i,j}, t_{m,})$ returns 0 if the travel time exceeds the travel time threshold ($t_{i,j} > t_m$) and 1 if the travel time is less than or equal to the threshold ($t_{i,j} \leq t_m$).

Cumulative measures are relatively intuitive, but they are limited by their binary definition (e.g. for a 45-minute threshold, a job that is one minute away has the same consideration as one that is 44 minutes away, but a job that is 46 minutes away is not counted). Accordingly, we evaluate cumulative measures using several thresholds. For example, when evaluating access to jobs we evaluate 30, 45, and 60 minutes, while for access to parks we evaluate access to park acreage within 15 and 30 minutes.

We also evaluate accessibility using a measure that is based on continuous distance decay function using a gravity formulation. This gravity measure is not included in the dashboard map but is included in the data download. Impedance functions are based on a negative exponential

decay function where the output is in the range of 0 to 1 and a travel time of 30 minutes returns a value of 0.5. This is based on a 30-minute trip being approximately equal to the median travel time across all study regions based on data from the National Household Travel Survey. This accessibility measures uses equation [1] with the impedance function formulated as follows:

$$f(t_{ij}) = e^{-0.0231 t_{ij}} \quad [3]$$

Cumulative and gravity accessibility measures are a primal measure of accessibility, representing the number of destinations that can be reached within a given impedance. For destination types that are sparser, we use a dual measure, which reflects the time needed to reach the nearest destination(s). These dual measures can be conceptualized as the reciprocal of the primal form of accessibility (*4*). Instead of estimating the total number of opportunities reachable based on travel time, we estimate the minimum travel cost to reach a certain number of opportunities. In other words, we estimate how long it takes to reach *n* opportunities from origin *i* (e.g., the minimum travel time required to access three grocery stores).

We use dual measures for grocery stores, health facilities, and higher education. As with cumulative measures, the dual measures represent a threshold that can yield arbitrary differences. We include more than one dual measure for each destination type. For each destination type evaluated using dual measures, we evaluate the travel time from one's home to one destination (representing the minimum time needed to reach the destination) as well as the minimum travel time needed to reach three destinations from one's home (representing the travel time needed to access a variety of options), potentially improving outcomes for the traveler (the closest destination to home may not always meet one's needs for example if there is a mismatch in terms of the cost or type of goods or services provided.)

We also estimate cumulative accessibility to jobs and low-wage jobs additionally using a fare constraint, which requires considering the cost of each trip's fare relative to a fare threshold. For this measure, we estimate the shortest transit travel times between each pair of block groups in the region for the two transit networks evaluated by the fare calculator: one that includes only low-cost modes (local bus plus comparable-cost modes) and the other including all modes (all available public transit options). If a trip from i to j meets both the fare and time constraints, then opportunities at j are counted as part of the accessibility score for i.

Cumulative accessibility measures that impose a fare constraint can be represented by expanding equation [2] as follows:

$$A_{i,m,n} = \sum_j O_j \max_{k \in K} \{ f(t_{i,j,k}, t_{m,}) f(c_{i,j,k}, c_n) \} \quad [4]$$

Where $t_{i,j,k}$ is the travel time from i to j on network k, $c_{i,j,k}$ is the estimated transit fare cost for the trip on network k, and c_n is the fare cost threshold. Similar to [2], $f\left(t_{i,j,k}, t_{m,}\right)$ represents the travel time impedance function, returning 0 if the travel time exceeds the travel time threshold ($t_{i,j,k} > t_m$) and 1 if the travel time is less than or equal to the threshold $t_{i,j,k} \leq t_m$.

$f(c_n, c_{i,j})$ represents the fare cost impedance function, returning a 0 if the fare exceeds the fare threshold ($c_{i,j,k} > c_n$) and 1 if the fare is less than or equal to the threshold $c_{i,j,k} \leq c_n$.

For example, suppose we are evaluating accessibility with a $5 fare constraint and a 45-minute time constraint. The fastest trip between an OD pair on the all modes network is a trip involving commuter rail that costs $20 and takes 20 minutes. A slower trip between the same OD pair on the low-cost network using only local buses costs $2.50 and takes 43 minutes due to the additional transfers and slower vehicle travel speed. The all-modes network will not capture the slower trip, but the low-cost network will. Our accessibility estimate will eliminate the commuter rail trip because it exceeds the fare threshold, replacing it with the local bus trip. Using both networks together gives us a reasonable sense of the different travel times required to travel between OD pairs for riders on a budget in our study regions.

The fare constraints used in each region are determined based on the cost of living and base transit fares. They are set at $4 for a one-way trip in Chicago, Los Angeles, and Philadelphia and $5 in Boston, the District of Columbia, New York City, and San Francisco-Oakland.

Finally, we estimate a fare-constrained version of the dual measure of access to higher education. Similar to above, we use the low-cost and all mode network fare information from the fare calculator to return the fastest trip between each OD that also meets the fare constraint. This information is then used to create fare-constrained dual measures of access that represent the time required to reach the nearest and 3rd nearest higher education destinations without exceeding the fare threshold.

Table 3 summarizes the destination types and accessibility measures that are estimated. Each of these are computed for both auto and transit modes, and for three time periods defined above (weekday morning peak, weekday night, and weekend).

Table 3: Destination types and accessibility measures.

Destination type	Measure Type	Thresholds	Fare Constraint
Employment	Primal (cumulative)	Jobs within 30, 45, 60 min	Yes
Low-wage employment	Primal (cumulative)	Jobs within 30, 45, 60 min	Yes
Grocery stores & supermarkets	Dual	Minimum time to 1, 3 destinations	No
Healthcare	Dual	Minimum time to 1, 3 destinations	No
Parks & green space	Primal (cumulative)	Acres reachable in 15, 30 min	No
Colleges and universities	Dual	Minimum time to 1, 3 destinations	Yes

3.3. Transit service analysis

In addition to measures of accessibility, the dashboard includes two measures of transit service: intensity and reliability.

3.3.1. Transit service intensity

Using static GTFS feeds, which represent transit schedules, we estimate the total number of unique transit trips that visit stops within 200m (1/8 mile) of a block group per hour. This distance is based on the range of distances that transit riders have been observed to walk to reach transit (*5*). This is estimated for a weekday and for a Saturday. For each block group, this is computed by creating a 200m buffer around the block group boundary, selecting all stops that fall within the buffered block group, counting all trips that stop at these stops during a single service day without double counting any trip that stops at more than one stop within the same block group, and dividing the count by 24 to present the result as a per hour metric.

3.3.2. Transit reliability

Most measures of accessibility calculate travel times based on expected public transit schedules but in practice delivered service can deviate substantially from the schedule. Our analysis also includes performance measures based on real-time information about public transit service delivery where available.

Delivering reliable transit service requires maintaining or creating consistent conditions in which to operate transit. Service consistency can be affected in two key ways, including during the Covid-19 pandemic:

1. Transit agencies adjust service levels as ridership, costs, and staff availability change (as often occurred during the Covid-19 pandemic), and
2. Trip patterns both at the traffic level and the passenger demand level shift, which may affect how buses move around a region.

The dashboard captures transit service reliability for a select number of transit operators that provide sufficient information in their real-time GTFS feeds. When a GTFS-real-time feed is queried, it provides a snapshot of conditions at the moment of the query. Where GTFS-real-time feeds provide direct reports about the status of delay of every bus (e.g., minutes early or late for the next stop) we use these reported values to generate reliability estimates.

Headway-based measures require continuous sampling of real-time GTFS feeds, including downloading and archiving of real-time-GTFS data over a period of a week or more which is too onerous in terms of the available data as well as computation and data storage that would be required. The delay measures we calculate represent schedule adherence and are not headway based. Our delay measure strikes a middle ground between information density and computational tractability.

To capture real-time reliability, available GTFS-real-time and NextBus transit feeds across all regions are sampled on approximately an hourly basis (with exact times randomly picked from each hour). We calculate the average delay of all buses, the average schedule deviation of early buses (more than 1 min early) and the average delay of all late buses (more than 5 min late) across all vehicles captured in a given query. This reliability analysis is not spatially detailed, but is summarized for each transit operator.

3.4. Equity analysis

The dashboard's Story page includes key equity indicators, including population-weighted accessibility and transit service intensity for people of color (based on race and ethnicity)[8], people from households living below the poverty level, essential workers at their place of residence,[9] and female single-parent households. The location of each of these populations is also available as a demographic overlay in the map view. Block group demographic summaries are also included in the data download. Demographic data are obtained from the 2018 five-year American Community Survey data from the US Census. We also evaluate transit accessibility

[8] Including White, Black/African American, Hispanic/Latinx, and Asian/Pacific Islander.

[9] These are estimated for 2-digit NAICS codes based on 4-digit essential NAICS codes and shares in each 2-digit sector using LEHD Census data, as estimated by TransitCenter and shown in Appendix A. For more on how essential work is defined, see TransitCenter's original analysis on essential workers: https://transitcenter.org/2-8-million-u-s-essential-workers-ride-transit-to-their-jobs/.

measures relative to car access to provide an indication of differences in access for different mode users.

4. Web framework and database

4.1. Conceptual design

Four individual components make up the final web application and ongoing analysis portion of the project, as shown in Figure 2.

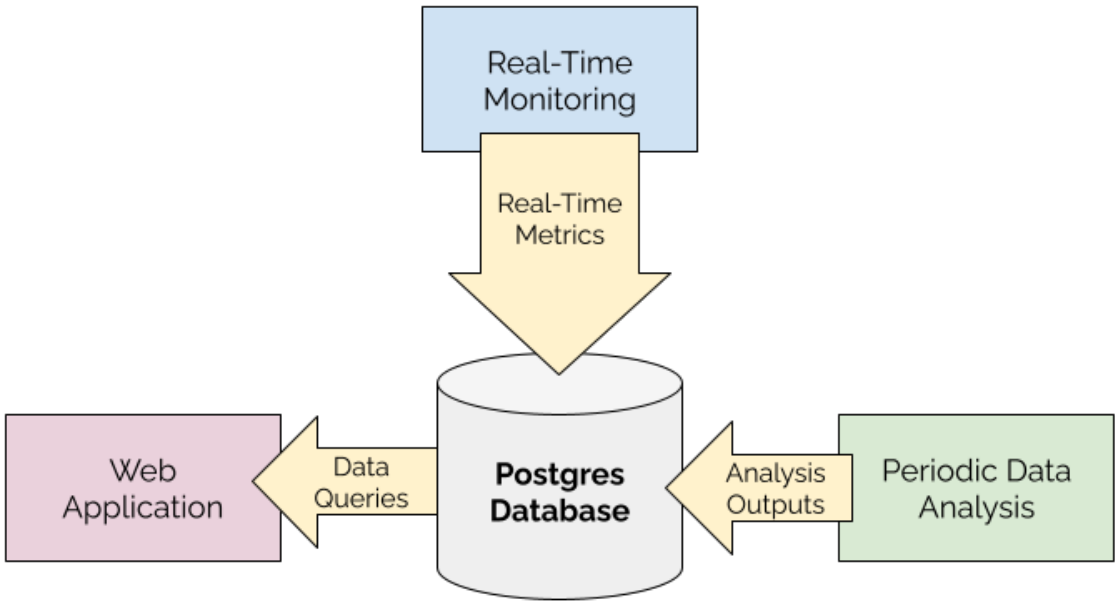

Figure 2: Web application components.

The web application, built using the Flask framework, does the work of visualizing the results of analysis, and allowing users to build highly customized and nuanced queries for regions and view geospatial summaries. The real-time monitoring component monitors the real-time transit feeds of available agencies and collects basic on-time performance data. The periodic data analysis consists of running transit travel time calculations using updated transit feeds, and computes updated accessibility measures based on those travel times. These values, along with the real-time data, are written to a central data repository (a Postgres Database), which is in turn queried by the web application for display and download.

4.2. Code structure

The web application code structure is divided into three parts, across three repositories: `equity-pulse-web` holds the code for the web application and visualization, including the backend Python Flask application, and the JavaScript used for the application. `equity-pulse-db` contains the database object relational mapping (ORM) code and some database utility functions such as definitions and creation/loading scripts. `equity-pulse-realtime` contains the code used for the gathering and analysis of real-time data and insertion into the database.

Both the realtime and web code require the presence of the database application code. The best approach is to download the db repository next to the web or realtime code, as they are designed to look for neighboring folders for the appropriate code.

Requests to the database are made through helper functions attached to the ORM definitions inside the db.py file. Database connection information can be found in the dbconfig.py file, which is not stored in the repository for security reasons.

4.3. Web application

The web application is a custom-designed Python application making extensive use of Flask, a lightweight web framework, and numerous JavaScript libraries. The web application handles requests from visitors to display various sets of geospatial data by querying the centralized database and attaching the resulting data into a mapping application. Users can choose from a large combination of measures and filters which are in turn fetched from the centralized database (Figure 3).

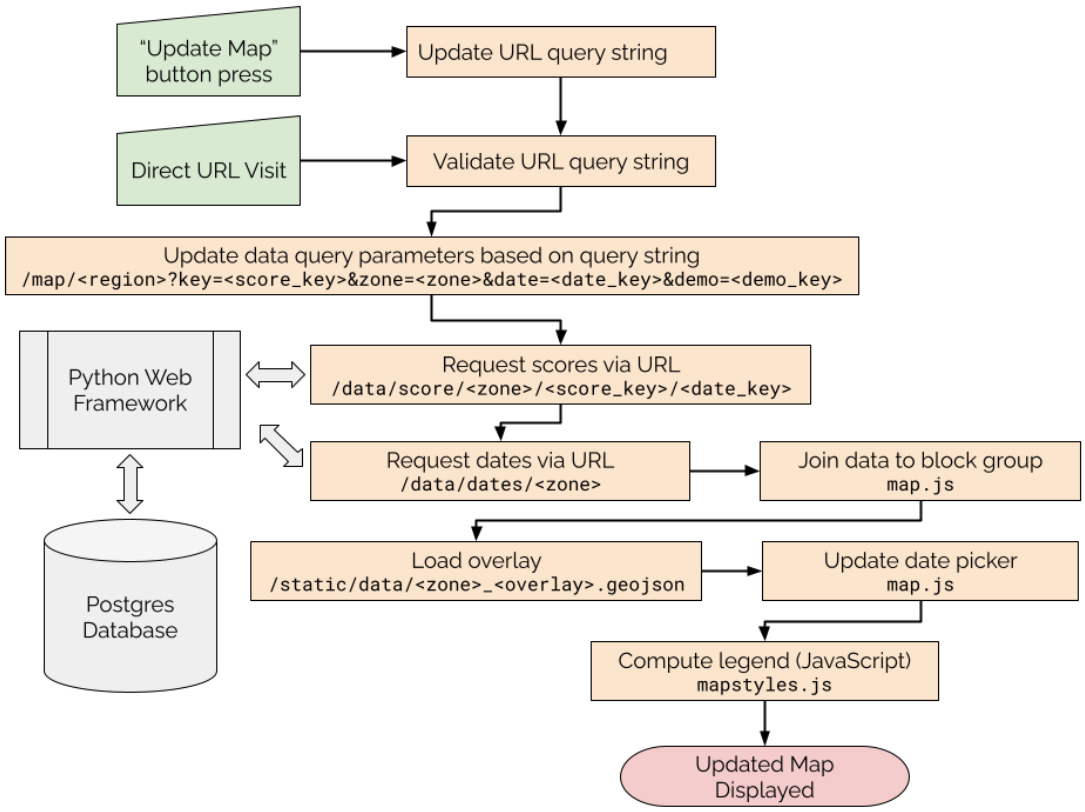

Figure 3: Web application design.

4.4. URL structure

For the mapping application, the information that is loaded is based on the construction of the query string, which is the information that follows a question mark (?) in common URLs and consists of a set of key-value pairs separated by ampersands (&). The structure of the URL before the ampersand is fixed, with the exception of the <region>, which is a lower-case tag associated with each region. The query string should contain the following keys:

- **key** is a multi-part string separated by underscores (_) that indicate the type of data and the measures to query. This key is unique for each score type, parameter choice, and time period of analysis.

- **zone** indicates what subset of the entire region to display. This is one of the following options:

    - **er** - Economic region
    - **msa** - Metropolitan statistical area
    - **urban** - The 'urban core' region
    - **equity** - Equity neighborhoods

- **date** is the date of analysis for display. It must be one of the key dates or the application will default to the most recent date. Date keys must be in YYYY-MM-DD format.

- **demo** indicates whether to display a demographic overlay as part of the map rendering. This demographic overlay key must be one of the following:

    - **pop_asiapacific** displays 1 dot for every 100 Asian/Pacific Islander people.
    - **pop_black** displays 1 dot for every 100 Black people.
    - **pop_hispanic** displays 1 dot for every 100 Hispanic and/or Latinx people.
    - **pop_white** displays 1 dot for every 100 White people.
    - **pop_poverty** displays 1 dot for every 100 people below the poverty line
    - **hhld_single_mother** displays 1 dot for every 50 female single-parent households
    - **workers_essential** displays 1 dot for every 50 essential workers.

This query string allows for direct sharing of individual map configurations. Query strings are validated before data loading takes place, and any missing data is set to default parameters.

4.5. Backend data queries

4.5.1. Score queries

After a URL string is validated and loaded, the appropriate data must be queried for display to the user. This is done by a URL request that contains the required information. For block-group level data, the URL request is as follows:

/data/score/<zone>/<score_key>/<date_key>

- **score_key** is a multi-part string separated by underscores (_) that indicate the type of data and the measures to query. This key is unique for each score type, parameter choice, and time period of analysis.

- **zone** indicates what subset of the entire region to display. This is one of the following options:

    - **er** - Economic region
    - **msa** - Metropolitan statistical area
    - **urban** - The 'urban core' region
    - **equity** - Equity neighborhoods

- **date_key** is the date of analysis for display. It must be one of the key dates or the application will default to the most recent date. Date keys must be in YYYY-MM-DD format.

Sending a request to this URL will return a JSON file that contains block group IDs and scores. These scores are then joined to the loaded GeoJSON block groups.

4.5.2. Date queries

To display available dates in the bottom right date picker, a query of the available dates must be made via a similar URL request:

/data/dates/<zone>

- **zone** indicates what subset of the entire region to display. This is one of the following options:
    - **er** - Economic region
    - **msa** - Metropolitan statistical area
    - **urban** - The 'urban core' region
    - **equity** - Equity Neighborhoods

4.6. Database

The database design is structured to allow for varied, dynamic queries of the score data. All tables are given a unique primary key ID (always named **id**) in addition to columns used for the application.

block_group: GEOID information for block groups in all regions.	
geoid (varchar(12))	The 12-digit code for the block group

block_group_tag: A many-to-many table containing tag information for each block group.	
block_group_id (varchar(12))	The 12-digit GEOID code for the block group. Foreign keyed to block_group.geoid
tag_id (int)	The ID of the tag used. Foreign key to tag.id

log: A running log capturing ongoing and one-off data events	
timestamp (timestamp)	The timestamp of the event
flag (text)	Flag for severity. One of (INFO, DEBUG, ERROR)
function (text)	Service/function logging the event: ● reliability logs information about the collection of

	realtime data. ● setup-region logs information about a region setup ● load-static-data logs information about static data loads and updates.
message (text)	The log message

population: Population and sociodemographic data for each block group	
block_group_id (varchar(12))	The 12-digit code for the block group. Foreign keyed to block_group.geoid
population_type_id (int)	Reference for the population type being stored. Foreign key to population_type.id
value (float)	The population value being stored

population_type: Population and sociodemographic data for each block group	
name (text)	The reference name for the population demographic group.
description (text)	Reserved for a description for the group referenced if needed. Typically blank.

realtime: Statistics collected from realtime information feeds from all regions	
timestamp (timestamp)	Timestamp of measurement.
region (text)	Code for the region that is being measured. One of boston, chicago, la, nyc, philadelphia, sf, dc
agency (text)	The agency being summarized
mode (text)	The mode being summarized. One of Bus or Rail
delay_abs (float)	The average delay in seconds across all measurements
delay_late (float)	The average delay in seconds across all late vehicles (>300)

delay_early (float)	The average delay in seconds across all early vehicles (<-60)
otp (float)	The on-time performance across all vehicles. This is the total number of vehicles which are not early and not late, divided by the total number of vehicles measured.
fraction (float)	The fraction of realtime vehicles which provided a delay measurement.

region: Region metadata for visualization purposes.	
name (text)	The proper name of the region
description (text)	A brief tagline for the region used on the front page.
tag (text)	Code for the region used through the application. One of boston, chicago, la, nyc, philadelphia, sf, dc
county (text)	The main county of the region. Used for displaying Coronavirus statistics.
state (text)	The state the region is in. Used for Coronavirus statistics.
lat (float)	The latitude of the central visual point of the region. Used for loading the map and centering the user on the region.
lon (float)	The longitude of the central visual point of the region. Used for loading the map and centering the user on the region.
zoom (float)	The zoom of the starting point of the region load for the user.
agencies (text)	A partial sentence describing the agencies used in the analysis in a given region.
live (bool)	Whether the region is visible on the main page and can be accessed by URL or not.

run: A tabulation of the data runs made for each region.	
region (text)	Code for the region used through the application. One of boston, chicago, la, nyc, philadelphia, sf, dc

date (date)	Date of data run
live (bool)	Whether the data for the run is available or not (False during data loading)
note (text)	A note to display alongside the run on the data download page.

score: All scores (accessibility or service intensity) for all regions across all runs.	
block_group_id (varchar(12))	The 12-digit code for the block group. Foreign keyed to block_group.geoid
score_type_id (int)	ID of score type measured. Foreign keyed to score_type.id
score (float)	Value of the particular score.

score_type: Specific keys and dates used for scores	
key (text)	A multi-part string, separated by underscores, which defines the various variables of measurement as described in the"How it Works" page.
date (date)	Date of the measurement
description (text)	Reserved for a description for the measurement if needed (typically blank)

summary: Area summaries of various population-weighted metrics	
zone (text)	The code for the zone within a region. One of msa, urban.
date (date)	Date of the measurement
description (text)	Sociodemographic/population code.
score_key (text)	The score being summarized
value (float)	The summary value for the region

tag: Region tags denoting different geographies within a region	
name (text)	The name of the tag, constructed as region-subset
region (date)	Code for the region used through the application. One of boston, chicago, la, nyc, philadelphia, sf, dc
subset (text)	The code for the zone within a region. One of all, msa, er, urban, equity.

4.7. Updating the dashboard

To provide up-to-date estimates of performance measures, the transit service data collection and analysis process can be repeated periodically. This update process includes checking for updates to GTFS feeds across all regions and calculating updated measures. The randomized hourly real-time transit data collection (used to estimate delay and missed trips) can also be repeated. These measures are added to the database supporting the web application so that new data can be displayed as it is calculated.

Other data sources (auto travel times, demographics, destinations, fare calculator) will not be updated automatically, but can be adjusted periodically as inputs to the analysis using the open-source code that will accompany this project.

5. References

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3. Conway, M. W., and A. F. Stewart. Getting Charlie off the MTA: A Multiobjective Optimization Method to Account for Cost Constraints in Public Transit Accessibility Metrics. *International Journal of Geographical Information Science*, Vol. 33, No. 9, 2019, pp. 1759–1787. https://doi.org/10.1080/13658816.2019.1605075.

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5. Kittelson & Associates, Inc., P. Brinckerhoff, KFH Group, Inc., Texas A&M Transportation Institute, Arup, Transit Cooperative Research Program, Transportation Research Board, and National Academies of Sciences, Engineering, and Medicine. *Transit Capacity and Quality of Service Manual, Third Edition*. Transportation Research Board, Washington, D.C., 2013.

Appendix A: Definition of essential workers

Region	LEHD Job type	NAICS sector	% who are essential workers
Bos	CNS01	11 (Agriculture, Forestry, Fishing, Hunting)	87.2%
	CNS02	21 (Mining, Quarrying, and Oil and Gas Extraction)	15.7%
	CNS03	22 (Utilities)	99.1%
	CNS04	23 (Construction)	0.0%
	CNS05	31 - 33 (Manufacturing)	45.5%
	CNS06	42 (Wholesale Trade)	73.5%
	CNS07	44 - 45 (Retail Trade)	49.7%
	CNS08	48 - 49 (Transportation and Warehousing)	84.1%
	CNS09	51 (Information)	39.9%
	CNS10	52 (Finance and Insurance)	35.7%
	CNS11	53 (Real Estate and Rental and Leasing)	10.8%
	CNS12	54 (Professional, Scientific, and Technical Services)	14.7%
	CNS13	55 (Management of Companies and Enterprises)	0.0%
	CNS14	56 (Administrative and Support and Waste Management and Remediation Services)	61.7%
	CNS15	61 (Educational Services)	0.0%
	CNS16	62 (Health Care and Social Assistance)	91.7%
	CNS17	71 (Arts, Entertainment, and Recreation)	0.0%
	CNS18	72 (Accommodation and Food Services)	98.7%
	CNS19	81 (Other Services [except Public Administration])	23.1%
	CNS20	92 (Public Administration)	59.1%
Chic	CNS01	11 (Agriculture, Forestry, Fishing, Hunting)	83.4%
	CNS02	21 (Mining, Quarrying, and Oil and Gas Extraction)	13.7%

	CNS03	22 (Utilities)	98.4%
	CNS04	23 (Construction)	0.0%
	CNS05	31 - 33 (Manufacturing)	42.7%
	CNS06	42 (Wholesale Trade)	75.2%
	CNS07	44 - 45 (Retail Trade)	49.7%
	CNS08	48 - 49 (Transportation and Warehousing)	86.1%
	CNS09	51 (Information)	48.4%
	CNS10	52 (Finance and Insurance)	41.8%
	CNS11	53 (Real Estate and Rental and Leasing)	13.0%
	CNS12	54 (Professional, Scientific, and Technical Services)	6.1%
	CNS13	55 (Management of Companies and Enterprises)	0.0%
	CNS14	56 (Administrative and Support and Waste Management and Remediation Services)	63.3%
	CNS15	61 (Educational Services)	0.0%
	CNS16	62 (Health Care and Social Assistance)	91.8%
	CNS17	71 (Arts, Entertainment, and Recreation)	0.0%
	CNS18	72 (Accommodation and Food Services)	97.8%
	CNS19	81 (Other Services [except Public Administration])	27.5%
	CNS20	92 (Public Administration)	68.7%
DC	CNS01	11 (Agriculture, Forestry, Fishing, Hunting)	80.8%
	CNS02	21 (Mining, Quarrying, and Oil and Gas Extraction)	12.9%
	CNS03	22 (Utilities)	98.7%
	CNS04	23 (Construction)	0.0%
	CNS05	31 - 33 (Manufacturing)	38.9%
	CNS06	42 (Wholesale Trade)	71.8%
	CNS07	44 - 45 (Retail Trade)	48.4%
	CNS08	48 - 49 (Transportation and Warehousing)	85.7%

	CNS09	51 (Information)	51.8%
	CNS10	52 (Finance and Insurance)	54.5%
	CNS11	53 (Real Estate and Rental and Leasing)	17.0%
	CNS12	54 (Professional, Scientific, and Technical Services)	12.4%
	CNS13	55 (Management of Companies and Enterprises)	0.0%
	CNS14	56 (Administrative and Support and Waste Management and Remediation Services)	66.3%
	CNS15	61 (Educational Services)	0.0%
	CNS16	62 (Health Care and Social Assistance)	87.4%
	CNS17	71 (Arts, Entertainment, and Recreation)	0.0%
	CNS18	72 (Accommodation and Food Services)	99.0%
	CNS19	81 (Other Services [except Public Administration])	15.5%
	CNS20	92 (Public Administration)	36.2%
LA	CNS01	11 (Agriculture, Forestry, Fishing, Hunting)	84.0%
	CNS02	21 (Mining, Quarrying, and Oil and Gas Extraction)	21.4%
	CNS03	22 (Utilities)	97.5%
	CNS04	23 (Construction)	0.0%
	CNS05	31 - 33 (Manufacturing)	31.1%
	CNS06	42 (Wholesale Trade)	60.7%
	CNS07	44 - 45 (Retail Trade)	42.5%
	CNS08	48 - 49 (Transportation and Warehousing)	80.1%
	CNS09	51 (Information)	30.9%
	CNS10	52 (Finance and Insurance)	46.2%
	CNS11	53 (Real Estate and Rental and Leasing)	13.2%
	CNS12	54 (Professional, Scientific, and Technical Services)	6.7%
	CNS13	55 (Management of Companies and Enterprises)	0.0%
	CNS14	56 (Administrative and Support and Waste Management	62.3%

		and Remediation Services)	
	CNS15	61 (Educational Services)	0.0%
	CNS16	62 (Health Care and Social Assistance)	92.2%
	CNS17	71 (Arts, Entertainment, and Recreation)	0.0%
	CNS18	72 (Accommodation and Food Services)	98.6%
	CNS19	81 (Other Services [except Public Administration])	25.8%
	CNS20	92 (Public Administration)	57.8%
NY	CNS01	11 (Agriculture, Forestry, Fishing, Hunting)	90.9%
	CNS02	21 (Mining, Quarrying, and Oil and Gas Extraction)	8.4%
	CNS03	22 (Utilities)	98.0%
	CNS04	23 (Construction)	0.0%
	CNS05	31 - 33 (Manufacturing)	45.4%
	CNS06	42 (Wholesale Trade)	63.3%
	CNS07	44 - 45 (Retail Trade)	44.1%
	CNS08	48 - 49 (Transportation and Warehousing)	87.0%
	CNS09	51 (Information)	44.8%
	CNS10	52 (Finance and Insurance)	45.0%
	CNS11	53 (Real Estate and Rental and Leasing)	7.3%
	CNS12	54 (Professional, Scientific, and Technical Services)	5.9%
	CNS13	55 (Management of Companies and Enterprises)	0.0%
	CNS14	56 (Administrative and Support and Waste Management and Remediation Services)	67.7%
	CNS15	61 (Educational Services)	0.0%
	CNS16	62 (Health Care and Social Assistance)	91.0%
	CNS17	71 (Arts, Entertainment, and Recreation)	0.0%
	CNS18	72 (Accommodation and Food Services)	98.0%
	CNS19	81 (Other Services [except Public Administration])	23.1%

	CNS20	92 (Public Administration)	65.2%
Phil	CNS01	11 (Agriculture, Forestry, Fishing, Hunting)	89.8%
	CNS02	21 (Mining, Quarrying, and Oil and Gas Extraction)	14.7%
	CNS03	22 (Utilities)	98.0%
	CNS04	23 (Construction)	0.0%
	CNS05	31 - 33 (Manufacturing)	51.9%
	CNS06	42 (Wholesale Trade)	74.0%
	CNS07	44 - 45 (Retail Trade)	51.0%
	CNS08	48 - 49 (Transportation and Warehousing)	86.1%
	CNS09	51 (Information)	55.1%
	CNS10	52 (Finance and Insurance)	44.7%
	CNS11	53 (Real Estate and Rental and Leasing)	15.2%
	CNS12	54 (Professional, Scientific, and Technical Services)	9.6%
	CNS13	55 (Management of Companies and Enterprises)	0.0%
	CNS14	56 (Administrative and Support and Waste Management and Remediation Services)	61.3%
	CNS15	61 (Educational Services)	0.0%
	CNS16	62 (Health Care and Social Assistance)	92.1%
	CNS17	71 (Arts, Entertainment, and Recreation)	0.0%
	CNS18	72 (Accommodation and Food Services)	97.9%
	CNS19	81 (Other Services [except Public Administration])	26.4%
	CNS20	92 (Public Administration)	58.7%
SF-Oak	CNS01	11 (Agriculture, Forestry, Fishing, Hunting)	86.4%
	CNS02	21 (Mining, Quarrying, and Oil and Gas Extraction)	48.0%
	CNS03	22 (Utilities)	98.1%
	CNS04	23 (Construction)	0.0%
	CNS05	31 - 33 (Manufacturing)	43.7%

CNS06	42 (Wholesale Trade)	71.5%
CNS07	44 - 45 (Retail Trade)	43.2%
CNS08	48 - 49 (Transportation and Warehousing)	83.6%
CNS09	51 (Information)	29.0%
CNS10	52 (Finance and Insurance)	46.5%
CNS11	53 (Real Estate and Rental and Leasing)	11.9%
CNS12	54 (Professional, Scientific, and Technical Services)	11.0%
CNS13	55 (Management of Companies and Enterprises)	0.0%
CNS14	56 (Administrative and Support and Waste Management and Remediation Services)	62.4%
CNS15	61 (Educational Services)	0.0%
CNS16	62 (Health Care and Social Assistance)	91.2%
CNS17	71 (Arts, Entertainment, and Recreation)	0.0%
CNS18	72 (Accommodation and Food Services)	97.8%
CNS19	81 (Other Services [except Public Administration])	22.7%
CNS20	92 (Public Administration)	57.8%

Appendix B: Fare calculations and assumptions

Fare Calculator

Client	Transit Center
Project	Accessibility analysis to determine transit equity in major U.S. cities
Date 1st version	Mar/2020
Last update	Apr/2021
Last Version Modified by:	Mitchell Robinson
Technical Review	Diego Silva

Table of Contents

1. Functional Requirements

This document is a description of business requirements and technical design for Fare Calculator.

1.1. Project Scope

Develop and conduct an accessibility analysis that uses real-time transit data and other sources to measure how transit connects people to destinations in several major U.S. regions. Comparisons of access for groups of people within an area will be used to measure transit equity. The Fare Calculator is a function to compute the user cost in public transit across seven pre-defined regions: New York, Boston, Bay Area, Los Angeles, Chicago, Philadelphia, and Washington D.C.

1.2. Fare Cost

This document refers to paragraph: "*This analysis will also advance industry practice for measuring equity and access, improving upon existing standards' simplistic models and parameters, by:*
(...)

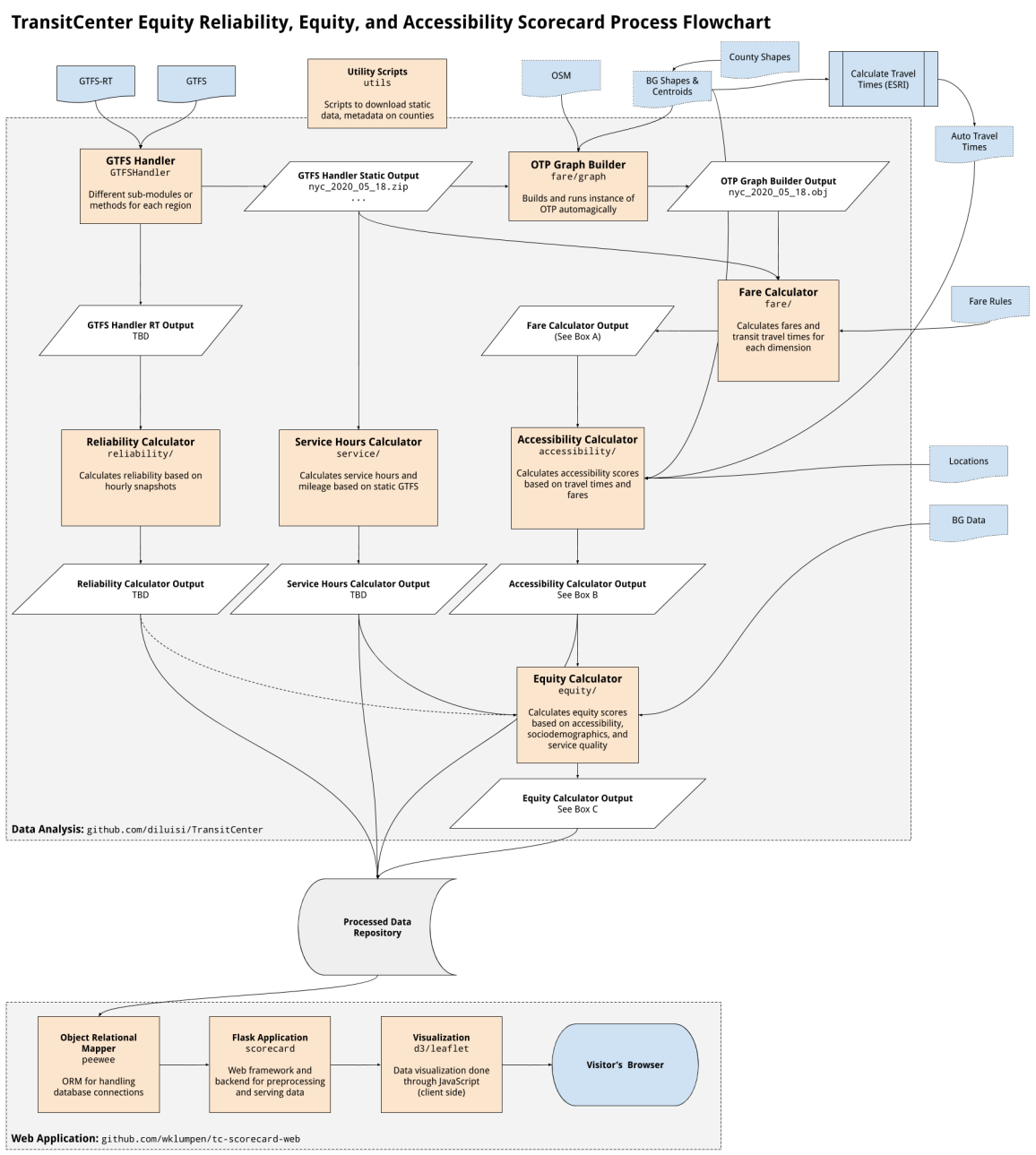
- *Building travel time & cost constraints that reflect transit riders' experiences – using reliability, frequency, fare, ADA, and span of service data from GTFS and real-time feeds – rather than peak service schedule data alone."*

1.3. Data Collection and Privacy

The data was collected in accordance with our mission in this study. The risk has been assessed and addressed by an appropriate combination of excision, anonymization, and/or agreements. The release to appropriate legitimate researchers will further our mission and is endorsed by leadership. The data will be shared with the

Transit Center. The data will be processed on Transit Center owned systems meeting security policies, which include password-controlled access, regular applications, or system updates. Authorized access to the data will be limited to personnel working as part of this effort.

2. Technical Design: Architecture

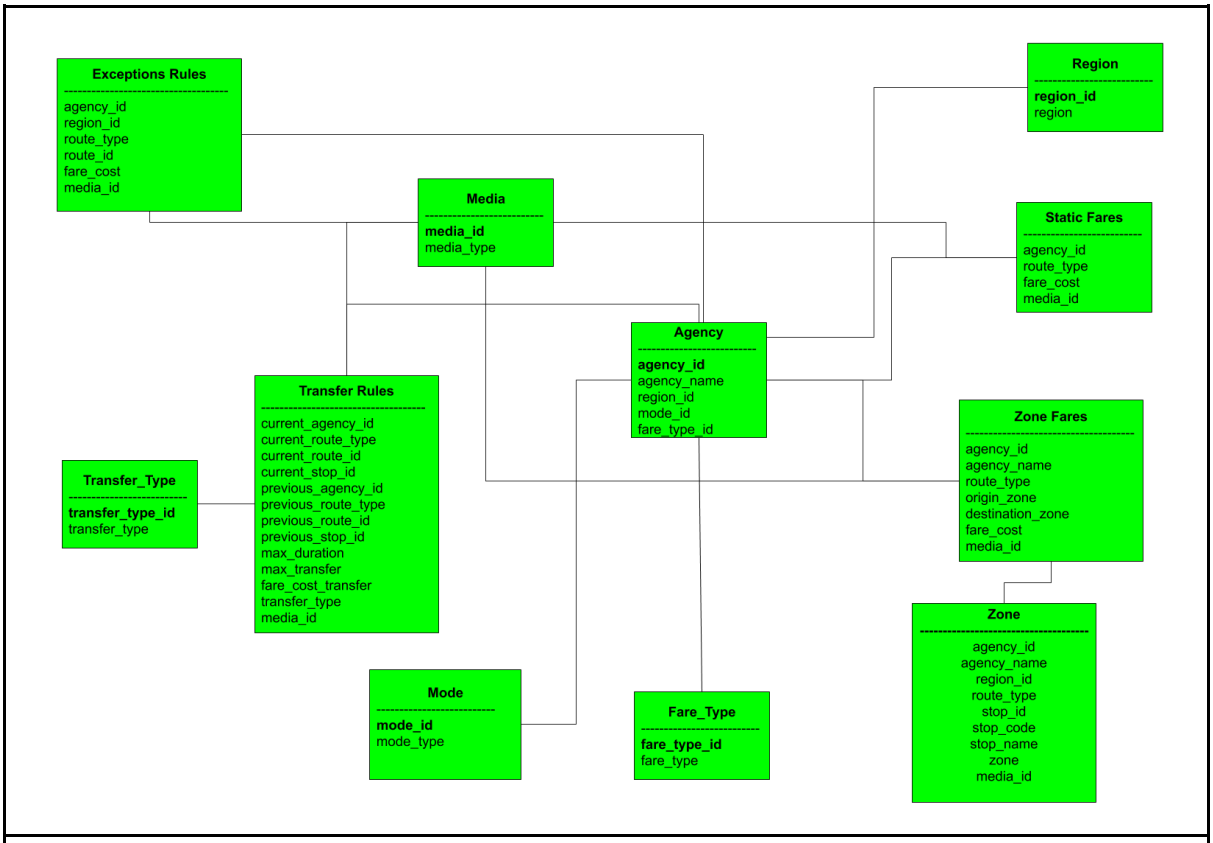


Data Architecture

The Fare Calculator receives input from two sources: GTFS-static and the transit agencies' website. Although GTFS-static has a file *fare.txt* describing the fare structure, the file is optional, and most transit agencies' feeds do not include it. Consequently, the primary

source to collect fare costs and transfer rules agreements between agencies was to gather the information from their websites. To deal with the complex fare mapping, we modeled a database to manage the information collected. The description of each table is given below:

- **Agency**: Transit agencies separated by mode and region.
- **Media**: Payment media (card, cash, ticket).
- **Transfer Type**: Transfer level (stop-stop, route-route, agency-agency, mode-mode)
- **Mode**: Type of mode (bus, train, subway)
- **Fare Type**: Type of fare (Flat fare, zonal fare, distance-based, non-profit)
- **Region**: New York, Boston, Bay Area, Los Angeles, Chicago, Philadelphia, and Washington D.C.
- **Static Fares**: Flat cost per transit agency, mode, and region.
- **Exception rules**: Duplicated modes with a different cost (express buses)
- **Transfer rules**: Transfer rules agreements between agencies in four different levels: agency, mode, route, and stops.
- **Zone:** Zone ID for each station in a zonal-based fare
- **Zone Fares**: Zonal cost



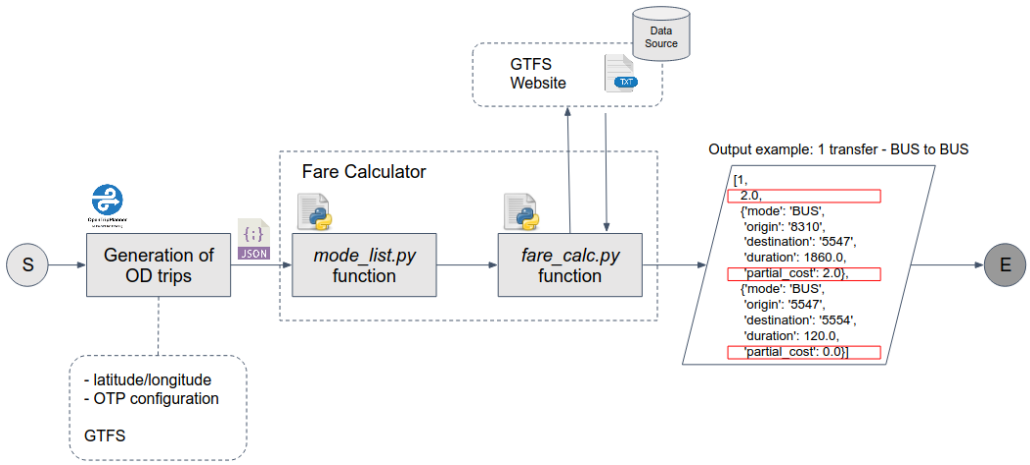
Data base model

2.1 Code implementation glossary

Name	Type	Description
FareDB.db	sqlite3	Database model
EXCP	list	List of transit agencies using National Transit Database 2018 https://www.transit.dot.gov/ntd/data-product/2018-metrics
MISSING_AGENCY_ID	list	Transit agencies without Agency ID field in GTFS
list_mode(json_trip)	function	WALK mode exclusion Return: the ID of each trip leg
query_exceptions(agency_id ,region_id,route_type,route_i	function	Search for route/mode exception cost in Exception

d)		Table Return: Fare
query_agency(agency_id,agency_name,region_id,route_type)	function	Search transit agency in Agency Table Return: Fare type id
query_zone_fare(agency_id,agency_name,region_id,route_type,origin_zone,destination_zone)	function	Search fare based on station zone in Zone Fare Table Return: Fare
query_zone(agency_id,agency_name,region_id,route_type,stop_id)	function	Search zones based on station (stop ID) in Zone Table Return: zone id
query_region(region)	function	Search region based on name parameter in REgion Table Return: region id
query_static_fare(agency_id,route_type,region_id,agency_name)	function	Search static fares based on agency parameters in Static Fare Table Return: Fare
query_transfer_rules(current_agency_id,current_route_type,current_route_id,current_stop_id,previous_agency_id,previous_route_type,previous_route_id,previous_stop_id,region_id,current_agency_name,previous_agency_name)	function	Search transfer rules in Transfer Rule Table based on pairs of trip legs (current and previous). Return: List of valid transfer rules
lookup_transfer(current_agency_id,current_route_type,current_route_id,current_stop_id,previous_agency_id,previous_route_type,previous_route_id,previous_stop_id,region_id,current_agency_name,previous_agency_name)	function	Search transfer rules for each level: agency, route, mode, and stops. Return: List of transfer rules
rule_beautifier(leg_item,transfer_rules, transfer_list, rule_id_true)	function	Transfer rule tracker (duration and number of transfers used) Return: Transfer list, valid rules, rules selected
transfer_update(rules_id_tru	function	Transfer update based on

e,leg_item,leg_duration,flag, transfer_list,current_agency_id,current_route_type,current_route_id,current_stop_id, previous_agency_id,previous_route_type,previous_route_id,previous_stop_id,region_id,current_agency_name,previous_agency_name)		maximum transfer and maximum duration. Return: Transfer list, flag (0=rule not used, 1=rule used), valid rules
fare(jsn, region)	function	Calculate fare based on OTP trip and region Return: Fare

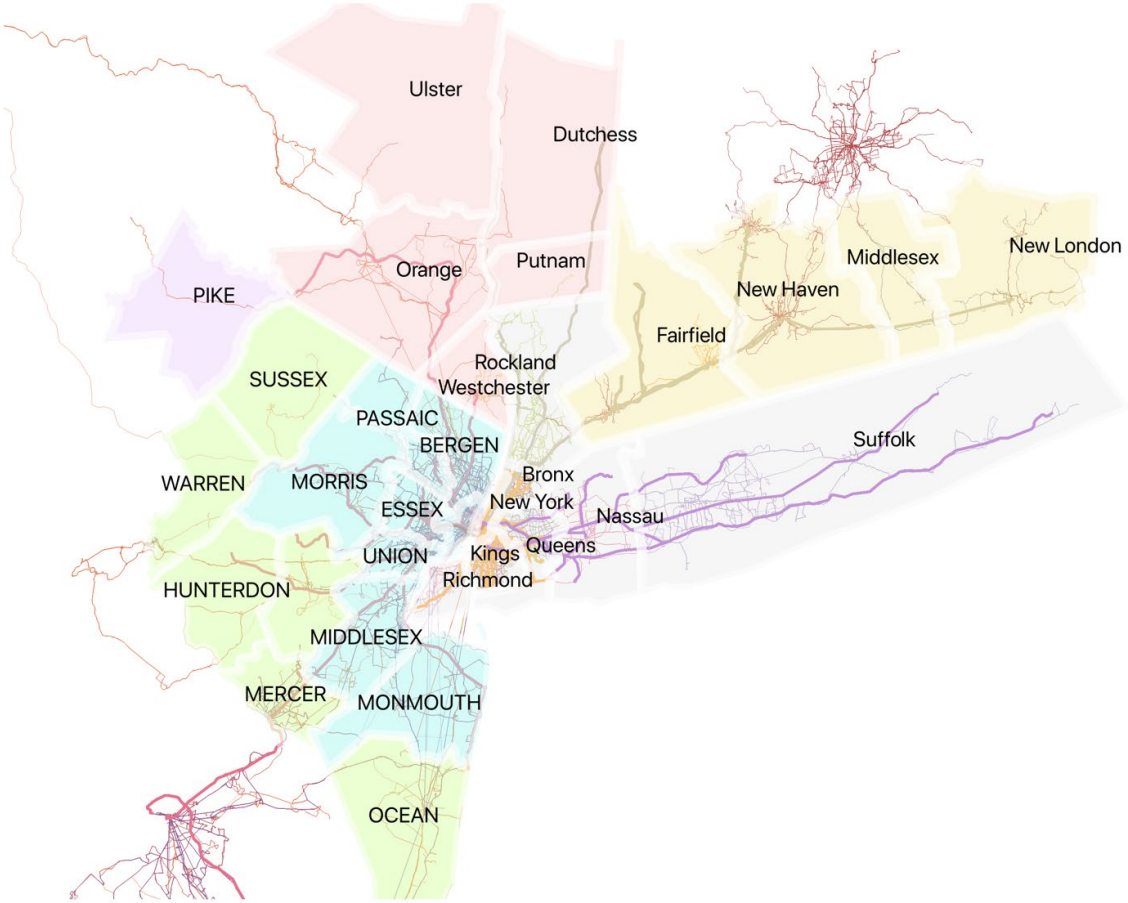


Basic representation of Fare Calculator E2E
S=start/E=end

3. Fare Assumptions per Region

3.1 The New York Region

Public Transit in the New York Metropolitan Area



Grey – NY Counties in Study Area
Light Blue – NJ Counties in Study Area
Red – NY Counties Out of Study Area
Green – NJ Counties Out of Study Area
Yellow – CT Counties Out of Study Area
Purple – PA Counties Out of Study Area

Agency Name	MTA
Fare URL	https://new.mta.info/fares
Accessed in	12/09/2020
Fare Media	ticket
Fare cost, transfers, and exceptions	

Single Ride Ticket: $3.00
These are only available at ticket machines, useful if you don't want to put the $5.50 minimum on a pay-per-ride card.
Cannot transfer between the subway and the bus with this fare. Only bus to bus.
Note: Passengers can't transfer to an express bus.
MTA Staten Island, MTA Queens, NYC Subway, MTA Manhattan, NYC Bus Company, NYC Subway Supplemented, NYC Ferry, MTA Bronx, MTA Brooklyn

Agency Name	JFK Airtrain
Fare URL	https://www.jfkairport.com/to-from-airport/air-train
Accessed in	20/04/2021
Fare Media	card
Fare cost, transfers, and exceptions	
AirTrain is free unless you start or end your journey at Jamaica and Howard Beach Stations. There, the fee is $7.75 USD, payable only by Metrocard. There are Metrocard machines located at both Jamaica and Howard Beach Stations. We considered free cost for all three routes: 2877 - Air Terminal, 2878 - Jamaica, and 2879 - Howard Beach.	

Agency Name	NJ Transit
Fare URL	https://www.njtransit.com/tickets/light-rail-tickets
Accessed in	20/04/2021
Fare Media	ticket
Fare cost, transfers, and exceptions	
• Bus: New Jersey Transit Bus and Light Rail We estimated a cost/km based on the National Transit Dataset 2018 (column Cost per Passenger Mile and Mode MB) = US$0.49/passenger.km https://www.transit.dot.gov/ntd/data-product/2018-metrics Transfers (2-hour timeframe) - Transfers are available for use by one-way full-fare-paying riders whose complete	

trip must be made using two buses within New Jersey only. The transfer must be purchased at the time of boarding. Customers pay the regular fare to the transfer location, plus the transfer charge. The transfer will be accepted on the connecting bus for a one-zone ride. Riders going beyond one zone must pay an additional fare.

- Rail:

  We estimated a cost/km based on the National Transit Dataset 2018 (column Cost per Passenger Mile and Mode CR) = US$0.30/passenger.km

  https://www.transit.dot.gov/ntd/data-product/2018-metrics

  Transfer
- One zone bus transfer: $0.75 from Hudson-Bergen tram
- One zone bus transfer: $0.75 from Newark tram
- One zone bus transfer: $0.70 from River Line tram

Agency Name	Bee-Line Bus
Fare URL	https://transportation.westchestergov.com/bee-line/fares-and-metrocard
Accessed in	12/09/2020
Fare Media	ticket
Fare cost, transfers, and exceptions	
Westchester County Department of Transportation All Routes except BxM4C/Rte28 Westchester-Manhattan Express: $2.75 **Transfers** One ride with one free paper transfer to Bee-Line buses, NYC buses. **BxM4C/Rte28 Westchester-Manhattan Express: $7.50** There are no free transfers available between the BxM4C and any Bee-Line local bus or NYC bus or subway.	

Agency Name	Suffolk County Transit
Fare URL	https://www.sct-bus.org/fares.html
Accessed in	12/09/2020
Fare Media	ticket
Fare cost, transfers, and exceptions	

Full Fare - $2.25, All Suffolk County Transit Bus Routes
Transfers:

- 25 cents
- Available on request when paying fare.
- Good for two (2) connecting buses.
- Valid for two (2) hours from time received.

Agency Name	New York City Department of Transportation
Fare URL	https://www1.nyc.gov/html/dot/html/ferrybus/sif-traveler-info.shtml
Accessed in	12/09/2020
Fare Media	ticket
Fare cost, transfers, and exceptions	
The Staten Island Ferry is free.	

Agency Name	Southeast Area Transit District
Fare URL	https://www.southeastareatransitdistrict.com/fares-info/
Accessed in	12/09/2020
Fare Media	ticket
Fare cost, transfers, and exceptions	

Fare cost: $2.00

- Transfers allow customers to complete a one-way trip which requires multiple buses without additional fare payment. Transfers cannot be used to make a round trip. Transfers are issued upon request, and are time-limited, and are only accepted at designated Transfer Points:

Norwich Transportation Center, Lisbon Landing, Mohegan Sun, New London/Water Street, New London Shopping Center, Eugene O'Neill & State Street Shelter, Groton Square, Groton Plaza Court, I-95/Route 2 Commuter Lot (North Stonington), and Olde Mistick Village.

Agency Name	Port Authority Trans-Hudson Corporation
Fare URL	https://www.panynj.gov/path/en/fares.html
Accessed in	12/09/2020
Fare Media	ticket
Fare cost, transfers, and exceptions	
PATH SingleRide Ticket costs $2.75 No transfers	

Agency Name	NYC Ferry
Fare URL	https://www.ferry.nyc/ticketing-info/
Accessed in	12/09/2020
Fare Media	ticket
Fare cost, transfers, and exceptions	
Fare cost: $2.75 At the St George terminal, customers can make connections with Staten Island Ferry service to Manhattan	

Agency Name	Connecticut Transit Shore Line East
Fare URL	https://shorelineeast.com/tickets-and-fares/fares
Accessed in	20/04/2021
Fare Media	cash
Fare cost, transfers, and exceptions	

To/From New Haven	One-Way
Branford	$3.25
Guilford	$4.25
Madison	$5.00
Clinton	$5.75
Westbrook	$6.50
Old Saybrook	$7.25
New London	$10.25

Interzone fares

Between any two stations within ONE Zone:

Within ZONE 2: Branford, Guilford and Madison – OR – within ZONE 3: Clinton, Westbrook, and Old Saybrook.

Fare: US$3.25

Between Zone 2 and Zone 3 – OR – between Zone 3 and Zone 4:

Between ZONE 2: Branford, Guilford and Madison – AND – ZONE 3: Clinton, Westbrook, and Old Saybrook

Between ZONE 3: Clinton, Westbrook, and Old Saybrook – AND – Zone 4: New London

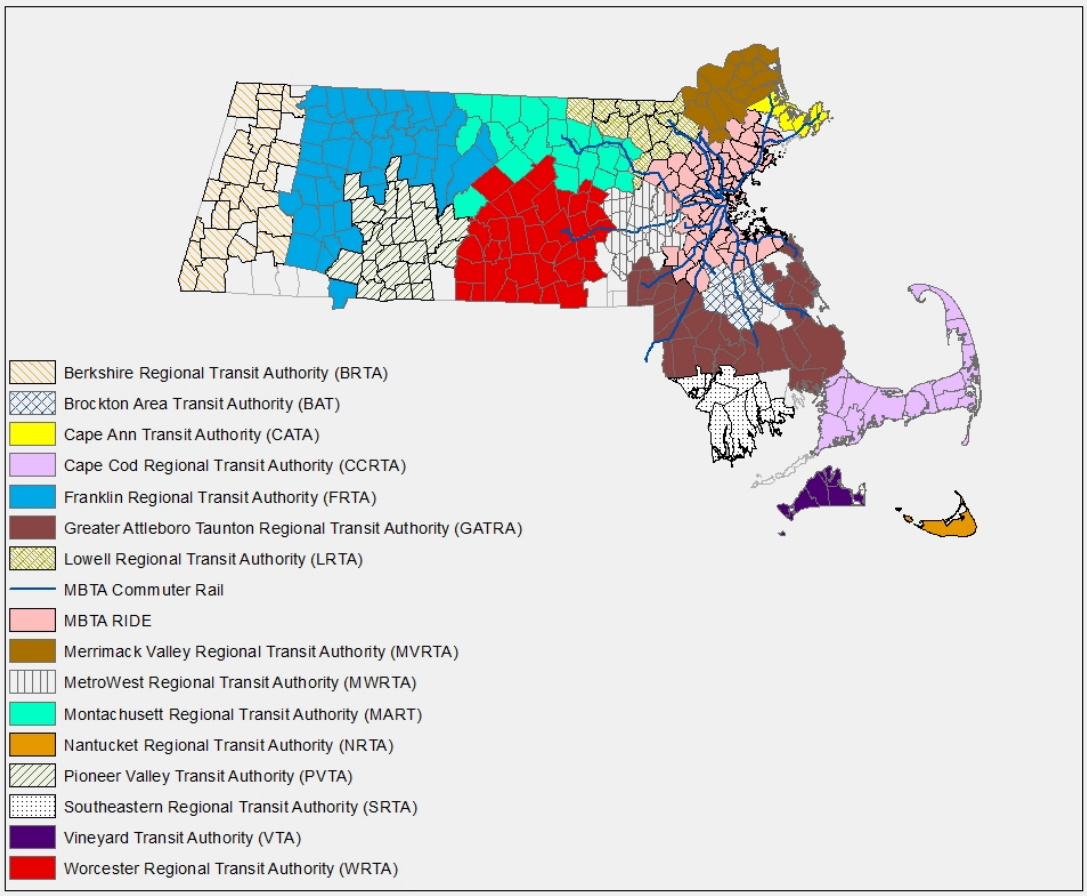
Fare: US$4.25

Between ZONE 2 and ZONE 4:

Within ZONE 2: Branford, Guilford and Madison – AND – Zone 4: New London

Fare: US$7.25

3.2 The Boston Region



The map (and list below) show which cities and towns are within the service areas of each Regional Transit Authority, as well as which cities and towns are served by the MBTA. Source: https://www.mass.gov/info-details/public-transportation-in-massachusetts

Agency Name	Yankee Line
Fare URL	https://yankeeline.betterez.com/cart/5804fd27175fde200b007b97/reservation/5804fd27175fde200b007b98
Accessed in	02/07/2020

Fare Media	Web tickets
Fare cost, transfers, and exceptions	
Yankee Line operates in three different routes: - Acton - Boston - Concord Fare cost is flat: $12.00 one-way for all destinations. Verified in “BOOK TICKETS” button at the Yankee website. No information about transfers or exceptions.	

Agency Name	WRTA
Fare URL	https://www.therta.com/fare/
Accessed in	02/07/2020
Fare Media	Charlie Card
Fare cost, transfers, and exceptions	
Areas served by WRTA fixed route service include: - Auburn - Brookfield - Charlton - East Brookfield - Leicester - Millbury - Oxford - Shrewsbury - Southbridge - Spencer - Webster - West Boylston - Worcester - Grafton - Northbridge - Westborough Fare cost is flat: $1.75 one-way for all destinations. No information about transfers or exceptions.	

Agency Name	Martha's Vineyard Transit Authority
Fare URL	https://www.vineyardtransit.com/fares-passes
Accessed in	02/07/2020
Fare Media	Cash

Fare cost, transfers, and exceptions

According to the MVTA website, its fleet is composed of eight routes.

Fare cost for MVTA buses is based on zones and the calculation is shown below:

Fare cost = # cities traversed * $1.25

We classified MVTA as a “Specific Fare” because it is a small agency that operates on the Island of Martha’s Vineyard. link

MVTA has two Fare Cost tables for peak and off-peak season. We considered the off-peak season as a reference because it contemplates Fall/Winter/Spring, and set fare cost by Origin/Destination according to the route name.

Town to Town Fares

	Aquinnah	Chilmark	Edgartown	Oak Bluffs	Tisbury	West Tisbury
Aquinnah	$1.25	$2.50	$5.00	$6.25	$5.00	$3.75
Chilmark	$2.50	$1.25	$3.75	$5.00	$3.75	$2.50
Edgartown	$5.00	$3.75	$1.25	$2.50	$3.75	$2.50
Oak Bluffs	$6.25	$5.00	$2.50	$1.25	$2.50	$3.75
Tisbury	$5.00	$3.75	$3.75	$2.50	$1.25	$2.50
West Tisbury	$3.75	$2.50	$2.50	$3.75	$2.50	$1.25

Off peak

Town to Town Fares

	Aquinnah	Chilmark	Edgartown	Oak Bluffs	Tisbury	West Tisbury
Aquinnah	$2.00	$4.00	$8.00	$10.00	$8.00	$6.00
Chilmark	$4.00	$2.00	$6.00	$8.00	$6.00	$4.00
Edgartown	$8.00	$6.00	$2.00	$4.00	$6.00	$4.00
Oak Bluffs	$10.00	$8.00	$4.00	$2.00	$4.00	$6.00
Tisbury	$8.00	$6.00	$6.00	$4.00	$2.00	$4.00
West Tisbury	$6.00	$4.00	$4.00	$6.00	$4.00	$2.00

Peak

No information about transfers or exceptions.

Agency Name	Martha's Vineyard Transit Authority
Fare URL	https://www.vineyardfastferry.com/land_tran

	sportation.htm#
Accessed in	02/07/2020
Fare Media	Pass
Fare cost, transfers, and exceptions	
Martha's Vineyard Transit Authority is a ferry service to Island of Martha's Vineyard. Fare cost is flat: $56.00 one-way off-peak No information about transfers or exceptions.	

Agency Name	Southeastern Regional Transit Authority
Fare URL	https://srtabus.com/fares http://www.srtabus.com/wp-content/uploads/SRTA-is-Implementing-a-New-Fare-Collection-System_compressed_UPDATED.pdf
Accessed in	02/07/2020
Fare Media	Ticket
Fare cost, transfers, and exceptions	
The Southeastern Regional Transit Authority (SRTA) provides fixed route and demand response service to residents of Acushnet, Dartmouth, Fairhaven, Fall River, Freetown, Mattapoisett, New Bedford, Somerset, Swansea, and Westport. Fare cost is flat: $1.50 one-way off-peak	

Agency Name	Southeast Area Transit District
Fare URL	https://southeastareatransitdistrict.com/fares-info/
Accessed in	02/07/2020
Fare Media	Ticket
Fare cost, transfers, and exceptions	

SEAT is a transit district, created by local towns in New London county as authorized by the General Statues of CT (Chapter 103A). Fare cost is flat: $2.00 one-way

Agency Name	Seastreak Ferries
Fare URL	https://seastreak.com/
Accessed in	02/07/2020
Fare Media	Ticket
Fare cost, transfers, and exceptions	
Ferry boat service: - New York, Massachusetts, and New Jersey Fare cost is per route: - Route 272: $50.00 one-way - Route 270: $40.00 one-way - Route 211: $28.00 one-way	

Agency Name	RIPTA
Fare URL	https://www.ripta.com/wp-content/uploads/2020/05/ride_guide_eng_v2_lores.pdf
Accessed in	02/07/2020
Fare Media	Ticket
Fare cost, transfers, and exceptions	
Rhode Island Public Transit Authority Fare cost is flat: $2.00 one-way Transfer: +$1.00 - Unlimited travel for two hours	

Agency Name	Pioneer Valley Transit Authority
Fare URL	http://www.pvta.com/faresPassesBus.php
Accessed in	02/07/2020

Fare Media	Ticket
Fare cost, transfers, and exceptions	
The Pioneer Valley Transit Authority - Massachusetts Fare cost is flat: $1.50 one-way Transfer: - +$0.25 - Unlimited travel for two hours - The transfer time is 90 minutes. - A transfer cannot be used on the same route. - One transfer per ride.	

Agency Name	Montachusett Regional Transit Authority (MART)
Fare URL	http://www.mrta.us/farespasses http://www.mrta.us/sites/default/files/pdf/TStyleSystemMap_bigger.pdf
Accessed in	02/07/2020
Fare Media	Ticket
Fare cost, transfers, and exceptions	
Ashburnham, Ashby, Athol, Ayer, Bolton, Boxborough, Fitchburg, Gardner, Hardwick, Harvard, Hubbardston, Lancaster, Leominster, Littleton, Lunenburg, Royalston, Shirley, Sterling, Stow, Templeton, Westminster, Winchendon Categorized as an exception fare. For each route a fare cost obtained at the website.	

Agency Name	Middle West Regional Transit Authority (MWRTA)
Fare URL	https://www.mwrta.com/routes/rates-and-fares https://mwrta.com/application/files/1014/3222/5852/Youth_Brochure_2014.pdf
Accessed in	02/07/2020

Fare Media	Ticket
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.50 one-way MBTA Charlie Tickets are not honored on the MWRTA system. MWRTA buses only accept the plastic CharlieCards. Transfer**:** - coupons are available on all buses and are good for transfers between all MWRTA buses. Riders wishing to transfer from one route to another must ask the driver for a transfer coupon and present it to the next driver within 90 minutes. Transfers are free of charge.	

Agency Name	Merrimack Valley Regional Transit Authority (MVRTA)
Fare URL	http://www.mvrta.com/fares/
Accessed in	02/07/2020
Fare Media	Ticket
Fare cost, transfers, and exceptions	

Fixed Route Fares:
- Full Fare: $1.25
- Beach Bus Fares:
  - To/From Salisbury Beach:$2.00
  - To/From Hampton Beach:$3.00
- Boston Shuttle Service: $6.00
Transfer**:**
- coupons are available on all buses and are good for transfers between all MWRTA buses. Riders wishing to transfer from one route to another must ask the driver for a transfer coupon and present it to the next driver within 90 minutes. Transfers are free of charge.
Exceptions:
Starting Monday, September 9, 2019, the following routes will be FREE OF CHARGE:
 	
● Route 34 (Prospect Hill)
● Route 37 (Beacon Street)
● Route 85 (Lawrence Downtown Shuttle)	

Agency Name	Massachusetts Bay Transit Authority

	(MBTA)
Fare URL	https://www.mbta.com/fares https://www.mbta.com/fares/transfers
Accessed in	02/07/2020
Fare Media	Charlie Ticket
Fare cost, transfers, and exceptions	

Bus (https://www.mbta.com/fares/bus-fares):
- Local Bus Fare: $2.00
- Inner Express: $5.25
- Outer Express: $7.00

Subway(https://www.mbta.com/fares/subway-fares):
- Fare: $2.90

Ferry:
- Fare: $3.70 (Charlestown)
- Fare: $9.75 other destinations

Commuter Rail:

Transfers:

Generally, your trip includes 1 free transfer to a mode that costs the same or less than your first fare payment. For example, your subway fare includes 1 free transfer to a Local Bus route within 2 hours of your first trip.

- **Subway to Local Bus:**
  - With a CharlieTicket, 1 free transfer to SL4 or SL5 from a nearby subway stop within 2 hours
  - No free or discounted transfers with a CharlieTicket or cash
- Local Bus to Subway:
  - No free or discounted transfers with a CharlieTicket or cash
- **Local Bus to Local Bus:**
  - With a CharlieCard or CharlieTicket, 1 free transfer to Local Bus within 2 hours of first tap
- Subway to Subway:
  - Transfers at subway stations are free
- Subway or Local Bus to Commuter Rail:
  - Cash value CharlieCards and CharlieTickets not valid on Commuter Rail
- Commuter Rail to Subway or Local Bus:
  - No free or discounted transfers to subway or bus with 1-way tickets or cash

Charlie Ticket transfers:

CharlieTickets loaded with cash value include 1 free Local Bus to Local Bus transfer within 2 hours of the first fare payment.

Transfers between the Silver Line and subway are available on a limited basis with a CharlieTicket:

- **Between SL3 and Blue Line at Airport Station**
- **To SL4/SL5 from nearby subway stops**

Transfers between the Red Line and Mattapan Trolley are available at Ashmont Station with a CharlieTicket.

For all other combinations, you will pay the full CharlieTicket fare for each mode you travel on.

Exceptions:

- **SL1, SL2, and SL3 are subway fares, while the SL4 and SL5 are Local Bus fares.**

Agency Name	Coach Company
Fare URL	https://coachco.com/schedules/
Accessed in	12/18/2020
Fare Media	Ticket
Fare cost, transfers, and exceptions	
Fare cost is specific - Hooksett NH/Manchester NH/ Nashua NH/Lowell MA run: $35.00 - Portsmouth/Newburyport/South Lawrence run: $40.00 - Commuter H run: $15.00	

Agency Name	Peter Pan Bonanza Division Peter Pan Bus Lines
Fare URL	https://www.cttransit.com/fares
Accessed in	12/18/2020
Fare Media	Cash
Fare cost, transfers, and exceptions	

The Peter Pan Lines operate under CT Transit.

Peter pan Bonanza Division operates the local routes and are fixed: $1.75. The single fare ticket is valid for 2-hours and includes unlimited FREE local service transfers for the 2-hour duration.

Peter Pan Bus Lines
Flattened to fixed cost of $4.58 by averaging the zone costs.

Fare Category	Fare
2 Zones	$3.20
3 Zones	$4.10
4 Zones	$5.00
5 Zones	$6.00

Transfers:

- Local routes provide 2-hour unlimited local to local transfers.Additional fare payment required on Express services.
- Express 2-Hour passes retain the full value of the original zone fare paid, providing unlimited local and express rides for the number of zones paid. Travel on a route that charges a higher zone fare would require additional payment. Because the average fare cost by zone was used

Agency Name	The Greater Attleboro Taunton Regional Transit Authority
Fare URL	http://www.gatra.org/index.php/fares-passes/
Accessed in	1/5/21
Fare Media	Cash
Fare cost, transfers, and exceptions	

Fare cost is fixed: $1.50 one-way

Exceptions:

- Foxborough MBTA Commuter: Free
- Wareham/Middleborough/Lakeville Train Connector: $2.00
- Middleborough-Taunton Connection (weighted average taken): $2.33
- Downtown Middleborough Shuttle: $1.00
- Wareham Plymouth Connection (weighted average taken): $1.22

Transfers:

- Free transfers within 1 town. No limits described on time frame or number of transfers. It's therefore assumed that there are unlimited transfers within a 2-hour timeframe.

Agency Name	Brockton Area Transit Authority
Fare URL	https://www.ridebat.com/
Accessed in	1/5/21
Fare Media	Charlie Card
Fare cost, transfers, and exceptions	
Fare cost is fixed: $1.35 one-way (Charlie card, cash is $1.50) Exceptions: - Ashmont routes are $2.10 with Charlie card (cash is $2.25). This includes routes 3219, 2948, 3220, 3221, 3222, 3223. Transfers: - Free transfers between routes except route 3219. One transfer within 1-hour.	

Agency Name	128 Business Council
Fare URL	https://128bc.org/riders/
Accessed in	1/5/2021
Fare Media	Free
Fare cost, transfers, and exceptions	
Fare cost is free due to COVID19. This will likely change in the future according to their website: "A**ll 128BC/The Grid services will be fare-free until further notice.** We are working on developing contact-free methods of fare payment that will be safe for our riders and operators."	

Agency Name	1. Massport 2. Logan Express
Fare URL	http://www.massport.com/logan-airport/to-from-logan/transportation-options/logan-express/

Accessed in	1/5/2021
Fare Media	Ticket for Logan Express
Fare cost, transfers, and exceptions	
1. Routes listed under the Massport agency are free “ON-AIRPORT shuttles”. 2. Routes listed under Logan Express are buses to the airport and have specific costs: - Braintree, Framingham, Peabody and Woburn are $12.00 - Back Bay is free when traveling from Logan Airport to Back Bay, but $3.00 when traveling from Back Bay to Logan Airport. A round trip average is assumed and cost is set at $1.50	

Agency Name	Lowell Regional Transit Authority
Fare URL	http://lrta.com/fare/
Accessed in	1/7/2021
Fare Media	Charlie Card
Fare cost, transfers, and exceptions	
LRTA has 2 separate fares: $1.25 for urban/city/local and $1.85 for suburban. Most routes extend within the two zones, with no clear distinction on when different fares apply. Therefore, an average of the 2 fares was applied as a fixed fare cost across all routes: $1.55. Transfers are only issued on inbound routes and accepted on outbound routes. They therefore apply to round trip and are not included for the one-way fare cost calculation.	

Agency Name	Cape Ann Transportation
Fare URL	http://canntran.com/fares.cfm
Accessed in	1/5/2021
Fare Media	Charlie Card
Fare cost, transfers, and exceptions	
Fare cost is both fixed and zonal, depending on the route. There are also exceptions. The fixed routes are $1.00 and the zonal routes are either $1.00 or $1.25. The exceptions are $3.00. Because of the small fare difference between zonal and fixed, the weighted	

average was taken for zonal routes ($1.17) Exceptions: - Route 3241: $0.50 - Route 2846: $3.00 - Route 2843: $1.00 - Route 2856: $1.00

Agency Name	Boston Harbor Islands National and State Park
Fare URL	https://www.bostonharborislands.org/ferry-information/
Accessed in	1/5/2021
Fare Media	Ticket
Fare cost, transfers, and exceptions	
Fare cost is fixed: $24.95 round-trip	

Agency Name	Plymouth & Brockton Street Railway Co.
Fare URL	http://www.pvta.com/faresPassesBus.php
Accessed in	02/07/2020
Fare Media	Ticket
Fare cost, transfers, and exceptions	
UPDATE (MKR): As of 1/5/2021, service still suspended due to COVID19. It serves Cape Cod and the South Shore, that involves Kingston, Sagamore, Harwich, Truro, Rockland, Plymouth, Barnstable, Harwich, Hyannis, Orleans, Wellfleet, and Orleans. No information due to COVID19 "801","Plymouth & Brockton Street Railway Co.","https://www.p-b.com/buy-bus-tickets/","Boston",3,1	

Agency Name	Middlesex 3 TMA

Fare URL	http://www.middlesex3tma.com/SERVICES/SHUTTLES
Accessed in	02/07/2020
Fare Media	-
Fare cost, transfers, and exceptions	
The Middlesex 3 Transportation Management Association (TMA) has been formed by the Middlesex 3 Coalition to address transportation issues in the region which includes the communities of Bedford, Billerica, Burlington, Chelmsford, Lowell, Tewksbury, Tyngsborough, and Westford Massachusetts. The Middlesex 3 Coalition has made the TMA a 501c (6) Massachusetts non-profit corporation.	

3.3 Bay Area

Agency Name	WestCAT (Western Contra Costa)
Fare URL	https://www.westcat.org/home/FaresAll
Accessed in	10/9/2020
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.75 Exceptions - LYNX Transbay Bus: $5.00 Transfer Rules - To WestCAT fixed Route Buses From BART, SolTrans, AC Transit, FAST, and Golden Gate Transit: $1.00 - From WestCAT Local Fixed Route Buses to WestCAT LYNX: $3.25 - From WestCAT Local Bus to another WestCAT Local Bus: FREE with transfer slip at shared bus stops only. - 90 minute transfer time from WestCat to WestCat. Another section mentions 60 minute transfer time. 90 minute was used. - 120 minute transfer time using Clipper Card with inter-agency transfers.	

Agency Name	Union City Transit
Fare URL	www.uctransit.org
Accessed in	10/7/2020
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.00 one-way for all destinations. Transfers - Union City Transit Transfer: 1 FREE transfer (90 minutes) - BART-to-Bus Transfers (at Union City BART Station only): $0.50 - AC Transit/Dumbarton Express Transfers (at shared stops): $0.25 Union City Transit transfers are issued only at time fare is paid. Clipper Card automatically issues a transfer on the card, no paper transfer will be issued. Union City Transit transfers are valid for one transfer within 90 minutes of issue.	

Agency Name	Tri Delta Transit
Fare URL	http://trideltatransit.com/fares.aspx
Accessed in	10/9/2020
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.00 one-way for all destinations. Exceptions for routes 200/201: fare cost of $2.50 Transfer times subject to Clipper Card rules: 120 minutes Transfers - Bart Transfer (to or from BART): $1.25 - Transferring to/from a County Connection Bus at shared stops: FREE - Transfer slips are no longer issued on Tri Delta Transit buses. To do so you must have a valid Day Pass, a valid 31-Day Pass, a valid Clipper Card or pay an additional single ride fare.	

Agency Name	Tideline Water Taxi
Fare URL	https://tidelinetickets.com/
Accessed in	10/9/2020
Fare Media	
Fare cost, transfers, and exceptions	
Services are currently suspended due to Covid-19 and no information is available.	

Agency Name	Stanford Marguerite Shuttle
Fare URL	https://transportation.stanford.edu/marguerite/about-the-marguerite
Accessed in	10/9/2020
Fare Media	N/A
Fare cost, transfers, and exceptions	

Marguerite is free and open to the public – no ID required.

Agency Name	Sonoma County Airport Express
Fare URL	https://airportexpressinc.com/schedule.php
Accessed in	10/8/2020
Fare Media	Ticket
Fare cost, transfers, and exceptions	
Premium Network Fares to/from Sonoma County one way: $38.00 Fares to/from Marin County / San Rafael one way: $30.00 (entered as exception)	

Agency Name	SolTrans (Solano County Transit)
Fare URL	https://soltrans.org/fares/
Accessed in	10/13/2020
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Note that SolTrans and FAST operate cooperatively and list shared routes/fares Fare cost is flat $2.00 one-way for all destinations Valid for travel within Vallejo and Benicia on SolTrans Local fixed routes* and local trips on SolanoExpress fixed routes. Extra surcharge for SolanoExpress travel outside Vallejo and Benicia. Exceptions: Solano County Express Travel: $2.75 Valid for travel within Solano County on SolanoExpress fixed routes and on SolTrans and FAST (Fairfield and Suisun Transit) Local fixed routes. (Note: This fare was input for FAST, as it appears it's the FAST flat rate and not as an exception for SolTrans). Outside County Express: $5.00 Valid for travel both outside and within Solano County on SolanoExpress fixed routes and SolTrans and FAST Local fixed routes. Route 82: $10.00	

Extra surcharge on SolanoExpress Route 82 to the San Francisco Ferry terminal and on SolanoExpress Green Express operated by FAST. Transfers: **If you are paying with cash or a pass and use more than one bus, you must present a fare each time you board a different bus.**

Agency Name	FAST (Fairfield and Suisun Transit)
Fare URL	https://fasttransit.org/schedules-maps/solanoexpress-intercity-routes/
Accessed in	10/13/2020
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Note that SolTrans and FAST operate cooperatively and list shared routes/fares Fare cost is flat: $2.75 for all one-way Travel within Solano County on Blue, Yellow, and Red Lines. Valid on FAST local service and SolTrans local service. Exceptions: Outside Solano County (Blue, Yellow, Red): $5.00 Travel on Blue, Yellow, and Red Lines. Valid on FAST local service and SolTrans local service. All SolanoExpress Lines (Green Express - GX): $5.75 Transfers: **If you are paying with cash or a pass and use more than one bus, you must present a fare each time you board a different bus.**	

Agency Name	SMART (Sonoma Marin Area Rail Transit)
Fare URL	http://www.sonomamarintrain.org/fares
Accessed in	10/13/2020
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Zonal Fares with 5 zones: Travel within 1 zone $3.50 Travel within 2 zones $5.50	

Travel within 3 zones $7.50
Travel within 4 zones $ 9.50
Travel within 5 zones $11.50

Daily maximum for all trips on SMART $23.00

Transfers:
SMART passengers who pay with Clipper receive a $1.50 discount when transferring to Golden Gate Transit, Marin Transit, Petaluma Transit, Santa Rosa CityBus or Sonoma County Transit. The same discount applies when you transfer from one of these public transit providers to SMART and pay with cash value.

Agency Name	Santa Cruz Metropolitan Transit District
Fare URL	http://www.scmtd.com/en/fares
Accessed in	10/13/2020
Fare Media	Ticket or Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.00 for all one-way Exceptions: Highway 17 Express Bus: $7.00	

Agency Name	VTA (Santa Clara Valley Transportation Authority)
Fare URL	https://www.vta.org/go/fares
Accessed in	10/13/2020
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.50 for all one-way - same for light rail and bus Exceptions: - Express Bus: $5.00 Transfers - 2 hour transfer time - free transfers across rail and bus - Local to Express: pay local to express fare difference of $2.50	

Regional Transfers
- ACE passengers holding any valid ACE ticket or pass may ride free on all VTA bus and Light Rail service.
- Adults using Clipper who board VTA within one hour of exiting the BART station will receive a fare credit of $0.50.
- AC Transit riders using Clipper who transfer within 2 hours of first boarding and tagging on an AC Transit bus receive one local fare credit valid on a VTA Light Rail or non-Express bus.
- Riders using Clipper who transfer within two hours of tagging on the Dumbarton Express receive one local fare credit.
- Capitol Corridor transfers are accepted as a one-time local single-ride fare on VTA Light Rail and non-Express buses. Assumed 2-hour transfer time

Note that transfers between VTA and AC Transit were only performed at the mode level due to an extremely high number of combinations at the route level.

Agency Name	SamTrans (San Mateo County Transit District
Fare URL	https://www.samtrans.com/fares/farechart.html
Accessed in	10/13/2020
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.05 for all one-way using Clipper ($2.25 for cash or mobile app) Exceptions: - Express Bus: $4.00 using clipper - $4.50 using cash or mobile app - Routes: FCX Commuter Express Transfers - 2 hour transfer time - free transfers (Fare upgrade will be required when transferring to Express Route). - Unlimited transfers for 2 hours from initial fare paid.	

Agency Name	SJRTD (San Joaquin Regional Transit District; RTD)
Fare URL	http://sanjoaquinrtd.com
Accessed in	10/13/2020
Fare Media	Cash

Fare cost, transfers, and exceptions
Fare cost is flat: $1.50 for all one-way Exceptions: - Commuter Route 150 (BART 150) – Stockton $7.00 - Commuter Route 150 (BART 150) – Lathrop $7.00 - Commuter Route 150 (BART 150) – Tracy $7.00 - Commuter Route 152 (Livermore Labs LLNL) – Stockton $7.00 - Commuter Route 152 (Livermore Labs LLNL) – Lathrop $7.00 - Commuter Route 163 (Sacramento) – Stockton $7.00 - Commuter Route 163 (Sacramento) – Lodi $7.00 No Transfer rules outlined.

Agency Name	SFMTA (San Francisco Municipal Transport Agency
Fare URL	https://www.sfmta.com/getting-around/muni/fares
Accessed in	10/14/2020
Fare Media	Clipper Card

Fare cost, transfers, and exceptions

Fare cost is flat: $2.50 Clipper Card/MuniMobile ($3.00 cash or ticket)
* Note that cable cars are not operational at the time the data was compiled.
* Clipper card fare used in fare cost
 	
SFMTA Transfers for buses and light-rail.
- 2 hour transfers: Free
- no transfers for cable cars
 	
Inter-Agency Transfers (no timeframe described. Applied the 2-hour transfer time)
- The SFMTA provides a fifty-cent discount off an adult single ride for customers transferring to Muni from the agencies listed below when using a Clipper card (does not apply to Cable Car service)
  - AC Transit
  - BART
  - Caltrain (zone 1)
  - Golden Gate Ferry
  - Golden Gate Transit
  - SamTrans
  - San Francisco Bay Ferry
- Daly City BART station (4341) to Muni
  - You are eligible for two free rides on the 14R, 28, 54 and 57 Muni routes when transferring from the Daly City BART Station and paying your fare

using Clipper. The first trip must be taken within 23 hours after exiting BART and the second within 24 hours after exiting BART for the free fares to apply.
- Route 57 is suspended, so route ID was not available in the GTFS. It has therefore not been added to the transfer rules as of 10/14/20.

Agency Name	San Francisco Bay Ferry
Fare URL	https://sanfranciscobayferry.com/fares-and-tickets
Accessed in	10/16/2020
Fare Media	Clipper Card

Fare cost, transfers, and exceptions

Fare cost is specific to route
- Oracle Park to Alameda or Oakland:
  - $9.60 (no Clipper at Oracle Park)
- Between Alameda or Oakland and San Francisco Ferry Building or Pier 41:
  - $7.20 Cash, $5.40 Clipper (Set as static fare)
- Between Harbor Bay and San Francisco
  - $7.50 Cash, $5.60 Clipper
- Between Richmond and San Francisco Ferry Building
  - $9.30 Cash, $7.00 Clipper
- Weekday Service between South San Francisco and the East Bay (Alameda/Oakland)
  - $9.40 Cash, $8.10 Clipper
- Weekday Service between South San Francisco and the Harbor Bay
  - $9.40 Cash, $8.10 Clipper
- Between Vallejo and San Francisco Ferry Building or Pier 41
  - $15.10 Cash, $11.30 Clipper

Roundtrip fare cost between Vallejo and Oracle Park: $15.90 (Not available in GTFS feed, so not included.)

Exceptions (Routes not available in the GTFS feed, so were not included):

- Short Hop: one-way between Oakland and Alameda $1.70
- Short Hop: one-way between SF Ferry building and Pier 41 $1.70

Transfers:
- From MUNI (SFMTA): $0.50 discount when paying with Clipper.
- To or From AC Transit: $2.25 discount when paying with Clipper.

Agency Name	San Benito County Express
Fare URL	http://www.sanbenitocountyexpress.org/fares.html

Accessed in	10/16/2020
Fare Media	Ticket or Cash
Fare cost, transfers, and exceptions	
Fare cost is flat for one-way local routes: $1.00 Exceptions: Intercounty (Gilroy) one-way - 4 routes: $2.00 Transfer - free for local buses - 2-hour transfer time	

Agency Name	Rio Vista Delta Breeze
Fare URL	http://riovistacity.com/fares/
Accessed in	10/16/2020
Fare Media	Cash or Ticket
Fare cost, transfers, and exceptions	
Fare cost is flat for one-way local routes: $2.00 Exceptions: - Intercity one-way: $6.00 *Only routes 50 and 52 available in GTFS Transfer - free between Rio Vista buses - must be redeemed on next available bus	

Agency Name	Mountain View Transportation Management Association
Fare URL	https://mvgo.org/
Accessed in	10/16/2020
Fare Media	Cash or Ticket
Fare cost, transfers, and exceptions	

Service suspended due to Covid. No fare information is available and agency not added.

Agency Name	Marin County Transit District
Fare URL	https://marintransit.org/fares
Accessed in	10/16/2020
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Fare cost is flat for one-way trips: $1.80 Clipper, $2.00 cash (Clipper fare used) Transfers - 2 free transfers on all Marin Transit and Golden Gate Transit buses within Marin County - 2 hour transfer time	

Agency Name	Livermore Amador Valley Transit Authority
Fare URL	https://www.wheelsbus.com/fares/
Accessed in	10/16/2020
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Fare cost is flat for one-way trips: $2.00 Transfers - 1 free transfer within 2 hours of fare payment using Clipper - $1.00 fare credit from BART with Clipper - Free transfer to/from ACE (Altamont Corridor Express)	

Agency Name	Golden Gate Transit
Fare URL	https://www.goldengate.org/bus/bus-fares-payment/
Accessed in	10/16/2020
Fare Media	Clipper Card

Fare cost, transfers, and exceptions

Fare cost is zonal. Cash fares are higher, depending on zone (intercounty travel: 20%, Marin County: 10% discount). Prices here represent Clipper Card fares.

For riders ages 19 to 64.	San Francisco	Marin County			Sonoma County		East Bay
Zone (See Zone Map)	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
Zone 1 *(San Francisco)*	$3.80*	$6.00	$6.20	$7.20	$10.80	$10.80	$3.50
Zone 2 *(Sausalito, Marin City, Mill Valley, Tiburon, Belvedere)*	$6.00	$1.80			$7.20	$7.60	$5.20
Zone 3 *(Corte Madera, Larkspur, Greenbrae, Kentfield, Ross, San Anselmo, Fairfax, Manor, San Rafael, Santa Venetia, Terra Linda, Marinwood, Lucas Valley)*	$6.20				$7.00	$7.20	
Zone 4 *(Ignacio, Hamilton, Novato, San Marin)*	$7.20				$5.80	$5.80	
Zone 5 *(Petaluma, Cotati, Rohnert Park)*	$10.80	$7.20	$7.00	$5.80	$3.80*		$9.80
Zone 6 *(Santa Rosa)*	$10.80	$7.60	$7.20	$5.80			
Zone 7 *(Richmond, El Cerrito Del Norte BART Station)*	$3.50	$5.20			$9.80		$2.00

* A discount fare is not available when traveling within San Francisco or within Sonoma County.

Transfers.

- Within the Golden Gate system:
  - 3 transfers within 2 hours
  - Full bus fare and ferry fare required if using both modes.
- To/From SF MUNI (SFMTA)
  - $0.50 fare credit for Clipper only. 2-hour transfer time.
- To/From SMART Train
  - $1.50 fare credit for Clipper only. No timeframe specified, 2-hour assumed.

Agency Name	Golden Gate Ferry
Fare URL	https://www.goldengate.org/ferry/ferry-fares-payment/
Accessed in	10/20/20
Fare Media	Clipper Card

Fare cost, transfers, and exceptions

Fare cost is flat for one-way trips: cost differs by fare media
- cash $13.50, Clipper $7.25 to Sausalito and Tiburon (Clipper fare used)

Exceptions
- cash $13.00, Clipper $8.25 to Larkspur

Trips to Oracle Park and Chase center for special events are available from Larkspur for $14.50 cash only, but no route information is available and these were not included.

Transfers:
- Full bus fare and ferry fare required if using both modes
- To/From SF MUNI (SFMTA)
    - $0.50 fare credit for Clipper only. 2-hour transfer time
- To/From SMART Train
    - $1.50 fare credit for Clipper only. No timeframe specified, 2-hour assumed.

Agency Name	Dumbarton Express Consortium
Fare URL	https://dumbartonexpress.com/db_fares/
Accessed in	10/20/20
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	

Fare cost is flat for one-way trips: cost differs by fare media
- cash $2.50, Clipper $2.25 (Clipper fare used)
- Dumbarton Express is a partner company of AC Transit. The only routes Dumbarton appears to operate are the Transbay routes (DB and DB1), which are exceptions.

Exceptions:
- Transbay: $6.00
    - Must pay the additional $3.75 difference between local and Transbay when transferring from local to Transbay

Transfers:
- Local-to-Transbay: Free within 1.5 hours, but must pay $3.75 upgrade difference
- Transbay-to-local: Free within 1.5 hours
    - Local are considered AC Transit local routes because no local routes are defined for Dumbarton.
- To SamTrans (2-hour) or VTA (2.5 hours): Free with Clipper
- To Union City Transit: $0.25 (no time stated, 2-hour applied)

Agency Name	County Connection
Fare URL	https://countyconnection.com/fares/fare-types-prices/

Accessed in	10/20/20
Fare Media	Clipper Card
Fare cost, transfers, and exceptions	
Fare cost is flat for one-way trips: $2.00 Clipper ($2.50 cash fare, Clipper fares/rules used) Exceptions - Express routes $2.25 Transfers (2-hour transfer time used if no time was defined): - BART-to-bus transfer: $1.00 - Bus-to-Bus: Free (2-hour time) - County Connection accepts transfers as full fare payment at designated bus stops which are served by neighboring transit systems, and include WestCAT, SolTrans, FAST, and Capital Corridor trains in Martinez. - Free transfers from Tri Delta Transit and Wheels are only available using Clipper. - ACE train passengers can ride Route 92X free with pre-purchased ACE train tickets.	

Agency Name	Capitol Corridor Joint Powers Authority
Fare URL	https://images.capitolcorridor.org/wp-content/uploads/2019/08/Student_Fare_Chart.pdf
Accessed in	10/21/20
Fare Media	Clipper Card

Fare cost, transfers, and exceptions

Fare cost is zonal: Single ride fare chart for train based trips. Costs for connecting bus trips are not included in the table. Bus trips are considered an extension of the train route and no cost transfer is permitted with a paid train fare.

	ARN	RLN	RSV	SAC	DAV	FFV	SUI	MTZ	RIC	BKY	EMY	OKJ	OAC	HAY	FMT	GAC	SCC
RLN	9.50																
RSV	11	8.50															
SAC	16	12	11														
DAV	18	16	14	9													
FFV	24	22	19	15	13												
SUI	26	24	20	16	14	11											
MTZ	31	29	27	19	16	13	12										
RIC	35	31	31	27	23	17	16	12									
BRK	35	31	31	29	24	19	18	13	9								
EMY	35	32	32	29	27	20	19	13	9	7.50							
SFC	39	36	36	33	31	24	22	17	13	11.50							
OKJ	35	35	32	29	27	21	19	14	10	9	7						
OAC	35	35	32	29	27	21	19	16	12	10	9	7.50					
HAY	39	35	35	31	29	25	24	18	13	12	12	10	9				
FMT	43	39	39	35	31	27	26	20	16	15	14	13	12	10			
GAC	43	43	41	36	33	30	29	24	19	18	18	16	15	13	10		
SCC	43	43	42	37	35	32	31	25	20	19	19	17	16	14	11	6	
SJC	43	43	43	40	35	32	31	27	20	19	19	17	16	15	12	8.50	6

Transfers: Up to 2 free transfers across many agencies. A 3-hour timeframe was considered.

- To AC Transit - Bus connections at Richmond, Berkeley, Emeryville, Oakland, Hayward and Fremont stations.
- The County Connection - Bus connections at Martinez station.
- FAST (Fairfield and Suisun Transit) - Bus connections at Suisun, Vacaville and Sacramento stations.
- Tri Delta Transit - Bus connections at Martinez station
- VTA (Santa Clara Valley Transportation Authority) - Bus connections at the Santa Clara University, Great America and San Jose Diridon stations and to nearby VTA light rail.
- WestCAT - Bus connections at the Martinez station

Agency Name	Commute.org Shuttles
Fare URL	http://www.commute.org

Accessed in	10/21/20
Fare Media	Most are free: Shuttle pass required on paid shuttles
Fare cost, transfers, and exceptions	

Most Commute.org shuttles are free and open to the public. However, there are a few in Brisbane and South San Francisco that require a shuttle pass.
 	
Exceptions:
- Passes are required for paid shuttles and are purchased at a minimum 1-month pass at $50 cost. Assuming 2 trips/day Monday-Friday, that results in 10 trips/week and 40 per month. So a fare cost of $1.25 was applied to the following routes
  - Brisbane: Crocker Park BART
  - South San Francisco: Oyster Point BART, Oyster Point Caltrain, Utah-Grand BART, Utah-Grand Caltrain	

Agency Name	Commute.org Shuttles of San Mateo County
Fare URL	https://www.commute.org/
Accessed in	10/21/20
Fare Media	Free
Fare cost, transfers, and exceptions	
Service is free and open to the public.	

Agency Name	City of Palo Alto Shuttle
Fare URL	https://www.cityofpaloalto.org/gov/depts/trn/palo_alto_shuttle/default.asp
Accessed in	10/21/20
Fare Media	Free
Fare cost, transfers, and exceptions	
Service is free and open to the public, but currently suspended due to Covid-19	

Agency Name	Caltrain

Fare URL	https://www.caltrain.com/Fares/farechart.html
Accessed in	10/21/20
Fare Media	Clipper
Fare cost, transfers, and exceptions	

Fares are zonal:

Ticket Type*	How to Buy	Travel within					
		1 Zone	2 Zones	3 Zones	4 Zones	5 Zones	6 Zones
One Way	Ticket Machine	$3.75	$6.00	$8.25	$10.50	$12.75	$15.00
	Clipper Card	$3.20	$5.45	$7.70	$9.95	$12.20	$14.45
Day Pass+	Ticket Machine	$7.50	$12.00	$16.50	$21.00	$25.50	$30.00
Zone Upgrade	Ticket Machine	$2.25 per zone					
Monthly Pass++	Clipper Card	$96.00	$163.50	$231.00	$298.50	$366.00	$433.50

Agency Name	Blue & Gold Fleet
Fare URL	https://www.blueandgoldfleet.com/
Accessed in	10/21/20
Fare Media	Ticket
Fare cost, transfers, and exceptions	

Fares are route specific and represent one-way costs
- Angel Island: $9.75
- Tiburon: $13.00
- Sausalito:$13.00

Agency Name	BART (Bay Area Rapid Transit)
Fare URL	https://www.bart.gov/tickets/calculator
Accessed in	10/21/20

Fare Media	Clipper
Fare cost, transfers, and exceptions	
Fares are zonal. There is a $0.50 surcharge for paper tickets over clipper card prices. This surcharge was not applied to the fare costs as Clipper was prioritized.	

Agency Name	Angel Island Tiburon Ferry
Fare URL	https://angelislandferry.com/tickets-fares/
Accessed in	10/21/20
Fare Media	Ticket
Fare cost, transfers, and exceptions	
Fare cost is flat: $7.50 for one-way	

Agency Name	AC Transit (Alameda-Contra Costa Transit)
Fare URL	http://www.actransit.org/actrealtime/fares-tickets-passes/
Accessed in	10/21/20
Fare Media	Clipper
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.25 for one-way Exceptions - Transbay routes: $6.00 - Must pay the additional $3.75 difference between local and Transbay when transferring from local to Transbay Transfers: - Transbay-to-local: Free within 1.5 hours Inter-Agency Transfers To AC Transit - BART-to-bus: $0.50 discount on first local bus away from BART - From Union City Transit: One free transfer to AC Transit local routes or one discounted transfer to AC Transit Transbay routes within 1-1/2 hours of boarding Union City Transit. - From Capitol Corridor: One free transfer to AC Transit local routes, or fare credit for Transbay service:Transbay upgrade fare paid in cash	

- From FAST: One free transfer to AC Transit local routes (cash).
- From Golden Gate Transit: One free transfer to AC Transit local routes or one discounted transfer to AC Transit Transbay routes within 2.5 hours of tagging off on Golden Gate Transit (Clipper).
- From San Francisco Bay Ferry: One free transfer to AC Transit local routes or one discounted transfer to AC Transit Transbay routes within 1-1/2 hours of tagging off
- From WestCAT: One free transfer to AC Transit local routes within 1 hour of boarding WestCAT

Inter-Agency Transfers From AC Transit

- To SamTrans (2-hour) or VTA (2-hour): Free local fare with Clipper
- To Golden Gate Transit: Good in the East Bay only; one discounted fare when tagging with Clipper card ($2.25 value)
- To San Francisco Bay Ferry: One discounted ride within 90 minutes: $2.25 discount for Adult
- To Union City Transit: One local fare credit within 2 hours.
- To WestCAT: $1.00 discount within 2 hours.

Agency Name	ACE (Altamont Corridor Express)
Fare URL	https://acerail.com/schedules/
Accessed in	10/22/20
Fare Media	Paper Ticket/Mobile Ticket
Fare cost, transfers, and exceptions	

Fare cost is zonal. See fare URL for fare matrix.

Transfers:

- ACE passengers holding any valid ACE ticket or pass may ride free on all VTA bus and Light Rail service.
- ACE passengers may present a valid ticket for free transfer to/from Wheels/Rapid buses.
- ACE train passengers can ride County Connection Route 92X free with pre-purchased ACE train tickets.

3.4 Los Angeles Region

In the Los Angeles region, there are 25 agencies that coordinate interagency transfers for a cost of $0.50 when using TAP only. The transfer fee differs where noted. Not all agencies defined a transfer time, but some describe a 2.5 hour timeframe. 2.5 hours was therefore used for all participating agencies. These agencies are:

- Culver CityBus
- Glendale Beeline
- LA County Department of Public Works
- Long Beach Transit
- Metro
- Norwalk Transit
- Palos Verdes Peninsula Transit Authority
- Pasadena Transit
- Santa Monica Big Blue Bus
- Torrance Transit System ($0.40)

Note that only agencies considered in the network were used, resulting in the 11 agencies above.

Agency Name	Airport Valet Express
Fare URL	https://airportvaletexpress.hudsonltd.net/res
Accessed in	10/27/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
No fare information is currently available. Likely a premium service and fare type set to specific. No fare information was input.	

Agency Name	ART (Anaheim Resort Transportation)
Fare URL	https://rideart.org/fares-and-passes/
Accessed in	10/27/20
Fare Media	Cash or Ticket/Ticketing App
Fare cost, transfers, and exceptions	
Fare cost is flat: $4.00 for one-way. No exceptions or transfer rules.	

Agency Name	Avalon Transit
Fare URL	http://www.cityofavalon.com/transit
Accessed in	10/27/20
Fare Media	Ticket/Ticketing App
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.00 for one-way. No exceptions or transfer rules.	

Agency Name	Big Blue Bus
Fare URL	https://www.bigbluebus.com/Fares/Fare-Information.aspx
Accessed in	10/27/20
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.10 for one-way using TAP. ($1.25 cash; TAP fare used) Exceptions - Rapid 10 route: $2.10 Transfers: 1 transfer, 2.5 hour timeframe - Must pay full fare with each BBB bus used. No free/reduced fare transfers. - From BBB to Metro or Muni Bus: $0.50 - From BBB to Metro Rail: $0.50 - To BBB from Metro or Muni Bus: $0.50 - To BBB from Metro Rail: $ 0.50	

Agency Name	Corona Cruiser
Fare URL	http://www.coronaca.gov/government/departments-divisions/public-works/public-transit/corona-cruiser
Accessed in	10/28/20
Fare Media	Cash

Fare cost, transfers, and exceptions
Fare cost is flat: $1.50 one-way Transfers: - From Metrolink to Corona Cruiser: free transfer (2-hour assumed) - Between RTA and Corona: Transfers only for day pass or 31-day pass, so not included in transfer rules.

Agency Name	Culver CityBus
Fare URL	https://www.culvercity.org/how-do-i/find/culver-city-bus/fares
Accessed in	10/28/20
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.00 one-way Transfers: - Culver CityBus to CityBus: $0.25, 1 transfer, 2-hour timeframe	

Agency Name	Duarte Transit
Fare URL	http://foothilltransit.org/fares/fares-and-passes/
Accessed in	10/28/20
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.50 one-way (TAP), $1.75 cash. TAP fares used. Transfers: - Participates in the TAP interagency transfers. - No transfers within agency.	

Agency Name	El Monte Transit
Fare URL	http://www.ci.el-monte.ca.us/327/Trolleys
Accessed in	10/28/20

Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $0.50 one-way Transfers: - No transfers between El Monte buses - Free fare with ticket from Metrolink Rail. Connects via shuttle routes at the El Monte Metrolink Station (no transfer time stated, 2-hour assumed).	

Agency Name	Foothill Transit
Fare URL	http://foothilltransit.org/fares/fares-and-passes/
Accessed in	10/28/20
Fare Media	TAP
Fare cost, transfers, and exceptions	

Fare cost is flat: $1.50 one-way using TAP ($1.75 using cash)
 	
Exceptions
- Silver Streak Line: $2.75 TAP ($3.00 cash)
- Commuter Express: $5.50
  - Lines 490, 493, 495, 498, 499, 699
 	
Transfers (For local Foothill buses):
- Participates in the TAP interagency transfers
- No transfers between Foothill buses.
- Orange County Transportation Authority (OCTA):
  - To OCTA at Beach and La Habra and at the Brea Mall (Applied at the agency level, 2-hour, Free).
- Omnitrans:
  - FREE transfer from Foothill Transit to Omnitrans at Pomona Transit Center and Montclair Transit Center only.
  - Omnitrans passes as a FREE transfer to Foothill at Pomona Transit Center and Montclair Transit Center only.
  - **Note: due to the complexity of these rules, they were omitted. It was determined there would be a lesser impact on fares to omit than add at the agency level, especially for Foothill express buses.**
- Transfers to Foothill Transit Express routes (TAP interagency transfers, and Omnitrans, OCTA):
  - To Silver Streak route: $1.25
  - Commuter Express (same for Metrolink): $4.00 (Lines 490, 493, 495, 498, 499, 699)
  - **Note: due to the complexity of these rules, they were omitted. It was**	

determined there would be a lesser impact on fares to omit than add at the agency level. Route level was not feasible given the time constraints.

- Metrolink tickets are worth $1.25

Agency Name	Glendale Beeline
Fare URL	https://www.glendaletransit.com/tools/cash-fares-passes
Accessed in	10/29/20
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.00 one-way Exceptions - Express Routes 11-12: $2.00 Transfers: - Beeline to Beeline: $0.25 (1 transfer, 2-hours)	

Agency Name	Gold Coast Transit
Fare URL	http://www.goldcoasttransit.org/fares
Accessed in	10/29/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.50 one-way Transfers: - 1 free transfer between GCT buses, 2-hour timeframe	

Agency Name	Kern Transit
Fare URL	https://kerntransit.org/fares/?referrer=gtfs
Accessed in	10/29/20
Fare Media	Token Transit (Mobile App)

Fare cost, transfers, and exceptions

Fare cost is flat: $2.00 one-way
 	
Exceptions
- Intercommunity routes: $3.00
  - 100,110,115,120,130,150,227,230,240,250
- Cross-county routes: $5.00
  - These routes are technically zonal. They are routes 100 and 130 that pass through Tehachapi and Frazier Park. Their fares were flattened using the weighted average, which results in a fare of $4.00

Agency Name	LA Go Bus
Fare URL	https://dpw.lacounty.gov/transit/Shuttles.aspx#pageTitle
Accessed in	10/29/20
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $0.25 one-way Exceptions - Topanga Canyon Beach Bus: $1.00 - Action & Agua Dulce Shuttle: $1.00 - Edmund D. Edelman Children's Court Shuttle: Free - Sunshine Shuttle Route C: Free - Wellness Center Shuttle: Free - The Link - King Medical Center: Free	

Agency Name	LA Metro Bus
Fare URL	https://www.metro.net/riding/fares/
Accessed in	10/29/20
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.75 one-way Exceptions - Silver line and Express bus lines: $2.50	

Transfers
- Payment with TAP includes 2-hours of unlimited transfers to Metro rail and Metro bus in one direction.
- Participates in the TAP interagency transfers

Agency Name	LA Metro Rail
Fare URL	https://www.metro.net/riding/fares/
Accessed in	10/29/20
Fare Media	TAP
Fare cost, transfers, and exceptions	

Fare cost is flat: $1.75 one-way

Transfers
- Payment with TAP includes 2-hours of unlimited transfers to Metro rail and Metro bus in one direction.
- Participates in the TAP interagency transfers

Agency Name	LADOT
Fare URL	https://www.ladottransit.com/comexp/index.html
Accessed in	10/29/20
Fare Media	TAP

Fare cost, transfers, and exceptions

Fare cost for local bus routes (DASH) is flat: $0.50 one-way

Exceptions

- Commuter Express routes are zonal. For routes operating in only 1 zone, the fare cost for that zone is used. For routes operating across multiple zones, the weighted average was calculated based on the number of routes in each zone. The calculated fare cost is $2.72
- Note: the wrong table is listed for route 422 so it's not included in the calculation. The flattened fare of $2.72 was used for route 422.

Zone	Fare	142	409	419	431	534	573	574	US/BH	422	437	448	549	438	423	439
Base	$1.50	X	X	X			X	X	X						X	
Zone 1	$2.50		X		X	X	X				X	X	X	X	X	X
Zone 2	$3.00		X									X	X		X	
Zone 3	$3.75							X				X			X	
Zone 4	$4.25			X											X	

Transfers

- Transfers can be made to other Commuter Express routes and to/from most other fixed route transit services in LA County by buying a $0.25 Interagency Transfer when you pay your Commuter Express fare.
- Interagency Transfers are not valid on DASH

Note: Because interagency transfers are only valid on Express routes, LADOT transfers were not included. The effect should be negligible due to the weighted average being used and only a $0.25 transfer cost.

Agency Name	Lawndale Beat
Fare URL	http://www.lawndalecity.org/html/DEPTHTML/CSD/Beat.htm
Accessed in	10/29/20
Fare Media	Cash

Fare cost, transfers, and exceptions

Fare cost is flat: $0.75 one-way Transfers (60 minutes) - Free between Lawndale buses

Agency Name	LBT (Long Beach Transit)
Fare URL	https://ridelbt.com/fares/
Accessed in	10/29/2020
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.25 one-way Transfers - Participates in the TAP interagency transfers - LBT to OCTA: $0.50	

Agency Name	Metrolink Trains
Fare URL	https://metrolinktrains.com/ticketsOverview/ticket-info/ticket-types/
Accessed in	10/29/20
Fare Media	Ticket
Fare cost, transfers, and exceptions	
Fare cost is zonal for train and bus routes. Transfers - Free from Metrolink to the following services (LA County) - LA Metro Bus - LA Metro Rail - Antelope Valley Transit Authority - City of Baldwin Park Pumpkin and Teal shuttles - Burbank Bus - City of Commerce - Culver CityBus - El Monte Transit - Foothill Transit - Gardena Municipal Bus - Glendale Beeline	

- Glendora Minibus
- LADOT/DASH
- Long Beach Transit
- LA Go Bus
- Montebello Bus Lines
- Monterey Park Spirit Bus
- Norwalk Transit
- North County TRANSporter Bus
- Pasadena ARTS
- Santa Clarita Transit
- Torrance MAX
- Torrance Transit

- Orange County
  - OCTA: Free to local routes
  - OCTA: $2.00 credit to OC express routes 206 and 213
- Free from Metrolink to the following services (Riverside County)
  - Riverside Transit Agency (RTA)
- San Bernardino County
  - Free to Omnitrans
- Free from Metrolink to the following services (San Diego County)
  - NCTD Breeze/Sprinter
- Free from Metrolink to the following services (Ventura County)
  - Gold Coast Transit
  - Ventura County Transportation Intercity Service (VISTA)
  - Moorpark City Transit

Agency Name	Mountain Transit
Fare URL	http://mountaintransit.org/fares-and-tickets/
Accessed in	10/30/20
Fare Media	Cash
Fare cost, transfers, and exceptions	

Fare cost is flat: $1.50 for one-way on buses
Fare cost is flat: Cable Trams (Routes 7 and 8): $5.00

Exceptions
All exceptions are zonal. Zonal coverage differs, and fares were flattened for each route.
- Route 5: Flattened fare of $5.83
- Routes 2 and 4: Flattened fare of $2.25
- Route 6: Flattened fare of $4.10

Agency Name	Norwalk Transit System (NTS)
Fare URL	https://www.norwalk.org/city-hall/departments/norwalk-

	transit-system-nts/fares-schedules
Accessed in	10/30/20
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.25 one-way Transfers - NTS bus to NTS bus: $0.50 - Participates in the TAP interagency transfers	

Agency Name	OCTA (Orange County Transportation Authority)
Fare URL	http://www.octa.net/Bus/Fares-and-Passes/Overview/
Accessed in	10/30/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.00 one-way Exceptions - OC Express fares - OC Express buses travel within Orange County: $4.00 - Express fares - Express buses travel between Orange County and neighboring counties: $7.00 Transfers - No local transfers issued - Transfer from Local OCTA to OC Express: Pay $2.00 fare difference - Transfer from Local to Express: Pay $5.00 fare difference	

Agency Name	OmniTrans
Fare URL	https://omnitrans.org/buy-a-pass/fares/
Accessed in	10/30/20
Fare Media	Cash
Fare cost, transfers, and exceptions	

Fare cost is flat: $2.00 one-way

Transfers
- You may use your Omnitrans pass as a free transfer to Foothill Transit at the Montclair Transit Center and the Pomona Transit Center.
- Omnitrans will accept a valid TAP card as a transfer from Foothill Transit at two locations only: the Montclair and Pomona Transit Centers.
- OmniTrans to RTA: Free
- From Municipal transit agencies: Passengers using a TAP card can receive a free transfer onto an Omnitrans bus only at the Montclair and Pomona Transit Center. (This rule is currently ignored due to the complexity of linking different agency routes by 1 single stop).
- Metrolink to OmniTrans: Free

Agency Name	Palo Verde Valley Transit Agency
Fare URL	https://pvvta.com/fares/
Accessed in	10/30/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.75 one-way Exceptions - Route 3 Express: $3.50 flat fare - Wellness Express (BWE): $10.00 one-way	

Agency Name	Pasadena Transit
Fare URL	https://www.cityofpasadena.net/pasadena-transit/fares/#fares
Accessed in	10/30/20
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $0.75 one-way Transfers - Pasadena Transit to Pasadena Transit: unlimited free transfers using TAP for 2.5 hours	

- LA Metro Bus, LA Metro Rail (Gold Line), Foothill Transit, LADOT Commuter Express to Pasadena Transit: $0.25

Agency Name	PASS Transit
Fare URL	https://www.beaumontca.gov/DocumentCenter/View/31274/Fare-Schedule
Accessed in	11/5/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.25 one-way Exceptions - Commuter Link fares are flat: $3.50 one-way	

Agency Name	PVPTA (Palos Verdes Peninsula Transit Authority)
Fare URL	http://www.palosverdes.com/pvtransit/index.cfm?pg=passes
Accessed in	11/5/20
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.50 one-way Transfers - Participates in the TAP interagency transfers - It is not clear if this applies for PVPTA to PVPTA transfers, but is assumed to.	

Agency Name	RTA (Riverside Transit Agency)
Fare URL	https://www.riversidetransit.com/index.php/fares-a-passes/fares-a-passes
Accessed in	11/5/20
Fare Media	Cash
Fare cost, transfers, and exceptions	

Fare cost is flat: $1.75 one-way

Exceptions
- Commuter Link fares are $3.50 one-way

Transfers
- RTA will accept valid Metrolink passes for the full fare on routes that serve Metrolink stations for customers traveling to or from a Metrolink station.
  - No stated time, 2-hour assumed.
  - Travel from “RTA to Metrolink” using a Metrolink ticket is not accounted for and is always a paid trip when RTA is the first leg.

Agency Name	Simi Valley Transit
Fare URL	http://www.simivalley.org/departments/community-services/simi-valley-transit/bus-fares-and-passes
Accessed in	11/6/20
Fare Media	Cash

Fare cost, transfers, and exceptions

Fare cost is flat: $1.50 one-way

Transfers
- To Ventura County Transportation Commission InterCity Bus: Free
  - Assumed 2-hour time

Agency Name	Spirit Bus
Fare URL	http://www.montereypark.ca.gov/549/Spirit-Bus
Accessed in	11/6/20
Fare Media	TAP

Fare cost, transfers, and exceptions

Fare cost is flat: $0.25 one-way

Exceptions
- Route 5 and LINK Shuttle: $0.50 one-way

Transfers
- 1 free transfer between Spirit Buses on routes 1 - 5. No transfers with LINK Shuttle.

- Metrolink ticket accepted as fare on Route 5.
- 2-hour transfer time assumed.

Agency Name	Ventura County Transportation Commission
Fare URL	https://www.goventura.org/vctc-transit/fares-passes/
Accessed in	11/6/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is zonal but flattened: Within Ventura County is $1.75, Outside of Ventura county is $4.00. Taking the weighted average between the 2 zones, the flattened fare cost is $2.68. Transfers - VCTC to VCTC: 1 free transfer, 1.5-hour	

Agency Name	SunLine Transit Agency
Fare URL	https://www.sunline.org/riding-sunline/pricing
Accessed in	11/6/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.00 one-way Exceptions - Commuter Link 220 is zonal. There are 2 zones, and travel within 1 zone is $3.00 and travel within 2 zones is $6.00. To flatten the fare, the weighted average based on the number of buses within each zone was calculated. Because it's only 1 bus traveling between zones, the flattened fare used is $4.50 Transfers - SunLine to SunLine transfers: $0.25, 2-hours of unlimited rides for local routes only. Commuter Link 220 service fare must be paid to use. - Metrolink tickets are valid for use on Commuter Link 220 zone 1. An additional $3.00 fare is required for zone 2. Due to fare flattening, the metrolink ticket is considered valid over the entire route.	

Agency Name	Thousand Oaks Transit

Fare URL	ttp://www.toaks.org/departments/public-works/transit/fares-prepaid-passes
Accessed in	11/9/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.00 one-way Exceptions - Summer Beach Busf: $3.00 Transfers - 90 minute transfer time - Free transfers between Thousand Oaks buses - Free transfers between Ventura County Transportation Commission intercity buses	

Agency Name	Torrance Transit System
Fare URL	https://transit.torranceca.gov/fares
Accessed in	11/9/20
Fare Media	TAP
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.00 one-way Exceptions - Express routes: $2.00 Transfers - Participates in the TAP interagency transfers: $0.40	

Agency Name	Victor Valley Transit Authority
Fare URL	http://vvta.org/fares/
Accessed in	11/9/20
Fare Media	TouchPass (Pass)

Fare cost, transfers, and exceptions
Fare cost is flat: $1.50 one-way on local routes Exceptions - County Route Fare on routes 21P, 21W, 22, 23, 28, 29 are zonal, where local trips have the local fare, but county trips are $2.50. The fare was flattened using taking the weighted average of $2.00 for these routes. - B-V Link Fares: The VVTA Route 15 B-V Link features one-way fare charged per segment with two available segments: Barstow to Victor Valley, and Victor Valley to San Bernardino Valley. Cost is $6.50 per segment (Route currently omitted) - Route 200: $13.00 Transfers - Those with valid Omnitrans fare media receive a $1.00 discount when paying B-V Link fare from stops departing San Bernardino Valley on the same day of travel.

3.5 Chicago Region

Agency Name	Chicago Transit Authority
Fare URL	https://www.transitchicago.com/fares/
Accessed in	11/11/20
Fare Media	Ventra Card
Fare cost, transfers, and exceptions	
Fare cost is flat for subway: $2.50 one-way Fare cost is flat for bus: $2.25 one-way Transfers - Up to 2 transfers within CTA, 2-hour timeframe: $0.25	

Agency Name	Metra
Fare URL	https://metrarail.com/tickets/ticket-options#One-Way-Ticket
Accessed in	11/11/20
Fare Media	Ticket
Fare cost, transfers, and exceptions	

Fare cost is zonal. There are many operators under Metra, but the fare costs don't change between operators.

Zone	A	B	C	D	E	F	G	H	I	J
A	$4.00									
B	$4.25	$4.00								
C	$5.50	$4.25	$4.00							
D	$6.25	$5.50	$4.25	$4.00						
E	$6.75	$6.25	$5.50	$4.25	$4.00					
F	$7.25	$6.75	$6.25	$5.50	$4.25	$4.00				
G	$7.75	$7.25	$6.75	$6.25	$5.50	$4.25	$4.00			

H	$8.25	$7.75	$7.25	$6.75	$6.25	$5.50	$4.25	$4.00		
I	$9.00	$8.25	$7.75	$7.25	$6.75	$6.25	$5.50	$4.25	$4.00	
J	$9.50	$9.00	$8.25	$7.75	$7.25	$6.75	$6.25	$5.50	$4.25	$4.00

Agency Name	Pace Bus
Fare URL	https://www.pacebus.com/fares
Accessed in	11/12/20
Fare Media	Ventra

Fare cost, transfers, and exceptions

Fare cost is flat: $2.00 one-way ($2.25 cash, Ventra prioritized)

Note that not all routes were in the GTFS, and route id's for backdated GTFS files are not the same as the most up-to-date feed. Therefore, only routes in the current GTFS were considered.

Exceptions
- Several bus routes have a free fare
- Premium routes are $4.50

Transfers
2-hours, 2 transfers. Rules below apply to the first transfer. The second transfer is always free.
- From Regular fixed route
    - To Regular route: $0.30
    - To Premium route: $2.80
    - To Local route: $0.00
- From Local fixed route
    - To Regular route: $0.30
    - To Premium route: $2.80
    - To Local route: $0.00
- From Shuttle Bug routes
    - To Regular route: $0.30
    - To Premium route: $2.80
    - To Local route: $0.00
- From Premium routes
    - To Regular route: $0.30
    - To Premium route: $0.30
    - To Local route: $0.00
- From Free fare routes
    - To Regular route: $2.00
    - To Premium route: $4.50
    - To Local route: $2.00

With the accessibility threshold of $4.00 for Chicago, transfer rules were simplified to be as accurate as possible while minimizing any impact on accessibility scores.

1. Free route to local/regular route: 2 transfers, $1.00 cost per transfer
2. Free route to Premium route: 2 transfer, $4.50 cost.
3. Local/Regular to Premium: 2 transfer, $2.80 cost
4. Local to Local: 2 transfers, $0.15 cost per transfer.
5. Premium to Premium: 2 transfers, $0.15 cost per transfer.

Note: Shuttle Bug falls under local/regular rules.

Agency Name	Northern Indiana Commuter Transportation District
Fare URL	https://www.mysouthshoreline.com/images/Copy-of-Y2018Increase-FINAL.PDF
Accessed in	11/12/20
Fare Media	Ticket
Fare cost, transfers, and exceptions	
Fare cost is zonal and the zone fares can be found in the table at https://www.mysouthshoreline.com/images/Copy-of-Y2018Increase-FINAL.PDF	

3.6 Philadelphia Region

Agency Name	Cecil Transit
Fare URL	http://www.ccgov.org/government/community-services/cecil-transit
Accessed in	11/12/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.00 one-way	

Agency Name	NJ Transit
Fare URL	https://www.njtransit.com/tickets/light-rail-tickets
Accessed in	20/04/2021
Fare Media	ticket
Fare cost, transfers, and exceptions	

- Bus: New Jersey Transit Bus and Light Rail

  We estimated a cost/km based on the National Transit Dataset 2018 (column Cost per Passenger Mile and Mode MB) = US$0.49/passenger.km

  https://www.transit.dot.gov/ntd/data-product/2018-metrics

  Transfers (2-hour timeframe)
- Transfers are available for use by one-way full-fare-paying riders whose complete trip must be made using two buses within New Jersey only. The transfer must be purchased at the time of boarding. Customers pay the regular fare to the transfer location, plus the transfer charge. The transfer will be accepted on the connecting bus for a one-zone ride. Riders going beyond one zone must pay an additional fare.

- Rail:

  We estimated a cost/km based on the National Transit Dataset 2018 (column Cost

per Passenger Mile and Mode CR) = US$0.30/passenger.km

https://www.transit.dot.gov/ntd/data-product/2018-metrics

Transfer
- One zone bus transfer: $0.75 from Hudson-Bergen tram
- One zone bus transfer: $0.75 from Newark tram
- One zone bus transfer: $0.70 from River Line tram

Agency Name	Port Authority Transit Corporation
Fare URL	http://www.ridepatco.org/schedules/fares.html
Accessed in	11/13/20
Fare Media	Ticket
Fare cost, transfers, and exceptions	

Fare cost is zonal

From:	To:	One-way:
Lindenwold, Ashland & Woodcrest	Philadelphia	$3.00
Haddonfield, Westmont & Collingswood	Philadelphia	$2.60
Ferry Avenue (Camden)	Philadelphia	$2.25
Any New Jersey station (except between Broadway and City Hall)	Any New Jersey station	$1.60
Broadway (Camden)	City Hall (Camden)	$1.40
Broadway & City Hall (Camden)	Philadelphia	$1.40
Any Philadelphia Station	Any Philadelphia Station	$1.40

Agency Name	SEPTA Bus
Fare URL	http://www.septa.org/fares/index.html
Accessed in	11/13/20
Fare Media	SEPTA Key
Fare cost, transfers, and exceptions	
Fare cost on bus and tram routes are flat: $2.50 one-way	

Transfers (Only available with Key Card)
- 2-hour transfer time
- First transfer is Free
- Second transfer is $1.00

Applied as 2 transfers of $0.50

Agency Name	SEPTA Rail
Fare URL	http://www.septa.org/fares/new/index.html
Accessed in	11/13/20
Fare Media	SEPTA Key
Fare cost, transfers, and exceptions	

Fare cost on regional rail is zonal.

The Market-Frankford, Broad St. and Norristown High Speed lines are considered base fare ($2.50). The following web url is a clickable map that defines the fare zone and connecting service of each stop: http://www.septa.org/maps/system/

Transfers (Only with Key): only apply to Market-Frankford, Broad St., and Norristown High Speed Lines.
- 2-hour transfer time
- First transfer is Free
- Second transfer is $1.00

These rules were applied as 2 transfers, $0.50 each.

Note: the high speed lines (subway) are in the bus GTFS. Septa Rail only references the regional rail lines.

3.7 Washington D.C. Region

For the Washington D.C. Region, Metrobus and Metrorail are referenced by other transit agencies. Both are operated by WMATA.

Agency Name	Maryland Transit Administration
Fare URL	Multiple links, see below
Accessed in	1/28/21
Fare Media	CharmPass
Fare cost, transfers, and exceptions	
Fare URL's Local Bus/Light Rail fares: https://www.mta.maryland.gov/regular-fares Commuter Rail Fares: https://www.mta.maryland.gov/marc-fares Commuter bus fares: https://mta.commuterdirect.com/products/Commuter/onetime/ Fares: - local bus - flat: $1.90 one-way - light rail (tram) - flat: $1.90 one-way - subway - flat: $1.90 one-way - Commuter bus - zonal: 36 routes, added to exceptions. Many routes only cover 1 zone. For routes where multiple zones are covered, the average was taken and set as the route cost. Fares for each route can be found in separate PDF's. All links are the same except for the route#.pdf at the end of the link. Example link: https://s3.amazonaws.com/mta-website-staging/mta-website-staging/files/Routes+Schedules/315.pdf - Rail - zonal Transfer Rules: - Unlimited FREE transfers within 90 minutes on local MTA services (local bus, subway, tram).	

Agency Name	Arlington Transit (ART)
Fare URL	https://www.arlingtontransit.com/fares/
Accessed in	11/13/20
Fare Media	SmarTrip Card
Fare cost, transfers, and exceptions	

Fare cost is flat: $2.00 one-way Transfers (Only for SmartTrip Card) - 2-hour transfer time - ART to ART: Free - ART to/from Metrobus: Free - ART to/from Metrorail: $0.50 discount

Agency Name	Calvert County Public Transportation
Fare URL	http://www.co.cal.md.us/DocumentCenter/Home/View/669
Accessed in	11/13/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.50 one-way Exceptions - Shuttle Bus: $0.75	

Agency Name	Charles County VanGo
Fare URL	https://www.charlescountymd.gov/services/transportation/vango-public-transportation/vango-fares
Accessed in	11/13/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.00 one-way	

Agency Name	DASH Bus
Fare URL	https://www.dashbus.com/ride-dash/fares
Accessed in	11/13/20
Fare Media	Cash

Fare cost, transfers, and exceptions
Fare cost is flat: $2.00 one-way

Agency Name	DC Circulator
Fare URL	https://www.dccirculator.com/bus-basics/fares-payments-2019/
Accessed in	11/13/20
Fare Media	SmarTrip Card
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.00 one-way Transfers (Only for SmarTrip) - 2-hour transfer time - To Circulator: Free - From Metrobus: Free - From Metrorail: $0.50 - From Arlington Transit: Free - To Metrobus: $1.00 - To Metrobus Express: $3.25 - To Metrobus Airport shuttle:$6.50 - To Metrorail: $0.50 discount	

Agency Name	Washington Metropolitan Area Transit Authority (WMATA)
Fare URL	https://www.wmata.com/fares/index.cfm
Accessed in	11/17/20
Fare Media	SmarTrip
Fare cost, transfers, and exceptions	
Fare cost is zonal for Metrorail. - Metrorail fares vary by time of day and the distance between stations. - Peak fares occur weekdays from opening until 9:30 a.m. and from 3:00 and 7:00 p.m. Fare cost is flat for Metrobus: $2.00 one-way, but free bus-to-bus transfers enable round-trips within a 2-hour period. See bus-to-bus transfers below for more details.	

Exceptions
- Metrobus Express routes are $4.25 one-way
- Airport Express routes are $7.50 one-way

Transfers (from https://www.wmata.com/fares/bus.cfm)
- Metrobus to Metrobus: Bus-to-bus transfers with a SmarTrip® card are valid for free, unlimited Metrobus connections (including round trips) within a two-hour period. The two-hour transfer discount period begins when your trip starts on either bus or rail. Once the two hours expires you will incur the full fare on your next transaction and a new two-hour transfer period will begin.
- Metrobus to Metrorail: Metrobus riders who transfer to the Metrorail system will receive a discount of 50¢ if they use a SmarTrip® card. The two-hour transfer discount period begins when your trip starts on either bus or rail. Once the two hours expires you will incur the full fare on your next transaction and a new two-hour transfer period will begin.
- Metrorail to Metrobus: Metrorail riders who transfer to Metrobus will receive a discount of 50¢ if they use a SmarTrip® card. The two-hour transfer discount period begins when your trip starts on either bus or rail. Once the two hours expires you will incur the full fare on your next transaction and a new two-hour transfer period will begin.

Agency Name	DC Streetcar
Fare URL	https://dcstreetcar.com/
Accessed in	11/17/20
Fare Media	Free
Fare cost, transfers, and exceptions	
Fare cost is Free	

Agency Name	Fairfax Connector
Fare URL	https://www.fairfaxcounty.gov/connector/fares-and-policies
Accessed in	11/17/20
Fare Media	SmarTrip
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.00 one-way Exceptions	

- Routes 393, 394, 395, 396, 698, 699: $4.25 one-way
- Routes 422, 423, 424: $0.50 one-way
- Route 480: $2.50 one-way (fare is round trip, so it was halved for one-way)
- Route 599: $7.50 one-way

Transfers
- Fairfax Connector to Fairfax Connector (SmarTrip only):
    - 2-hours free transfers on regular routes.
    - To routes 422, 423, 424: 2-hours free transfers
    - To routes 393, 394, 395, 396, 698, 699: $2.25
    - To Routes 480 and 599: No transfer, full fare

To limit the number of transfer rules, only local to express that required an upcharge were considered.
- Metrorail to Fairfax Connector
    - $0.50 discount on all routes except route 599
- From Virginia Railway Express (VRE): 1 free transfer at VRE station (VRE ticket)

Agency Name	Fairfax CUE
Fare URL	https://www.fairfaxva.gov/government/public-works/transportation-division/cue-bus-system/cue-bus-rider-information
Accessed in	11/17/20
Fare Media	SmarTrip
Fare cost, transfers, and exceptions	

Fare cost is flat: $1.75 one-way

Transfers (SmarTrip only)
- CUE to CUE: 1 free within 2-hours
- CUE to Metrobus: 1 free within 2-hours
- Metrobus to CUE: 1 free within 2-hours
- To/from Metrorail: $0.50 discount

Agency Name	TransIT Services of Frederick County
Fare URL	https://www.frederickcountymd.gov/Faq.aspx?QID=606
Accessed in	11/17/20
Fare Media	Cash or Mobile Ticket
Fare cost, transfers, and exceptions	

Fare cost is flat: $1.50 Transfers - 1 transfer between TransIT buses is free within 60 minutes.

Agency Name	Prince George's County TheBus
Fare URL	https://www.princegeorgescountymd.gov/1121/Fares-Rules
Accessed in	11/17/20
Fare Media	SmarTrip
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.25 one-way Transfers - Bus-to-bus transfers are free only with SmarTrip. No other transfer rules defined. Assume unlimited transfers for 2-hours.	

Agency Name	OmniRide
Fare URL	http://omniride.com/service/fares/#fares-omnilink
Accessed in	11/17/20
Fare Media	SmarTrip
Fare cost, transfers, and exceptions	
Fare cost is flat: $1.55 one-way Exceptions - Metro Express fares: $3.45 SmarTrip ($4.25 cash) - Express fares: $6.90 SmarTrip ($9.20 cash) Transfers - OmniRide says there is a 3-hour transfer window only for SmarTrip, but says there are no FREE transfers without outlining any transfer discounts. Therefore, no transfer rules have been applied.	

Agency Name	Montgomery County MD Ride On
Fare URL	https://www.montgomerycountymd.gov/DOT-transit/fares/index.html
Accessed in	11/17/20
Fare Media	SmarTrip
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.00 Exceptions - Route 70 Express fare: $4.25 - Route 28: Free Transfer (SmarTrip only) - 2 hour - Between local bus routes: Free (unlimited within 2-hour time) - Local to express: $2.25 upgrade fare - From Metrorail to local: $0.50 discount - From Metrorail to express: $0.50 discount	

Agency Name	Regional Transportation Agency of Central Maryland
Fare URL	http://www.transitrta.com/tickets/
Accessed in	11/17/20
Fare Media	Cash
Fare cost, transfers, and exceptions	
Fare cost is flat: $2.00 one-way	

Agency Name	Virginia Rail Express (VRE)
Fare URL	https://www.vre.org/service/fares/
Accessed in	11/17/20

Fare Media	Ticket
Fare cost, transfers, and exceptions	
Fare cost is zonal: See the following for fare charts - https://www.vre.org/service/fares/fare-chart/ Transfers - 1 free transfer to Fairfax Connector (1-hour timeframe)	

4.0 Fare Testing and Validation

The fare database was generated primarily using real fares as described on each agency's website. National Transit Data (NTD) was used on occasions where accurate fare data could not be obtained from the agency. There is subsequently a high degree of accuracy in calculating static and zonal fares, including route exceptions with different fares. The complexity of the transfer rules for each region was the greatest source of error.

After fares were generated, a fare validation process was performed to determine the relative accuracy of the calculated fares for each region. The validation was performed by pulling a random subset of the trips generated. At least 50 trips were manually validated for each region. Additional trips were sometimes checked for uncommon rules unlikely to be randomly selected. The fare for each leg of a trip was verified, as well as the subsequent overall trip cost.

Target accuracy was to be greater than 80% by region and to ensure minimal impact on accessibility metrics. There were many reasons making 100% accuracy difficult and unlikely. These reasons include unavailable information, lack of fare data made available by an agency, poor data structuring in the GTFS feeds, inconsistent transfer structures within a region, and highly complex fare structuring and transfer rules between agencies, resulting in tens of thousands of transfers rules. The results for each region follow below.

1. **Chicago**: A total of 57 trips were validated for the Chicago region. All 57 trips were verified, resulting in 100% accuracy for the trips tested. There are few agencies in Chicago, resulting in simpler fare structures and transfer rules.
2. **Boston:** A total of 50 trips were validated for the Boston region. Forty-six of the 50 trips were verified correct, resulting in an accuracy of 92%.
3. **San Francisco**: A total of 54 trips were validated for the San Francisco/Bay Area region. Forty-five of the trips were verified correct, resulting in an accuracy of 83%.
4. **Los Angeles**: A total of 58 trips were validated for the LA region. Fifty-three of the trips were verified correct, resulting in an accuracy of 91%.
5. **Philadelphia**: A total of 54 trips were validated for the Philadelphia region. Forty-four of the trips were verified correct, resulting in an accuracy of 81%.
6. **Washington D.C**.: A total of 55 trips were validated for the Washington D.C. region. Forty-seven of the trips were verified correct, resulting in an accuracy of 85%.
7. **New York**: The region was validated during development, by using a test-driven development process.

References

[1] https://moovitapp.com/

[2] https://transit.land/

[3] https://transitfeeds.com/

[4] https://gtfs.org/

[5] https://developers.google.com/transit/gtfs

[6] https://www.sqlite.org/index.html

[7] https://www.google.com/maps

[8] https://www.transit.dot.gov/ntd/data-product/2018-metrics