## Method to calculate the travel time and cost between census tracts on the driving network

**Step 1:** **Calculate link free flow travel time (FFTT):** For each link, we set the default free flow speed based on the link types specified in the OSM data (e.g., motorway, trunk, primary, residential, etc.), following the values provided in <https://osm2gmns.readthedocs.io/en/latest/quick-start.html>. Then we calculate FFTT through link length and speed. The FFTT on the connects are defined as 30 miles/hour.

**Step 2: Estimate fuel cost on each link:** If fuel efficiency is 25 miles per gallon and fuel price is 4 dollars per gallon, the travel cost for each link based on its link length can be calculated.

**Step 3: Find the shortest path between an OD pair (i.e., two centroids):** The generalized cost on each link are calculated using “FFTT + Fuel cost \* (60/25)” by adopting the mean VOT around 25 dollars/hour for local trips and business purposes provided by the US department of transportation ( <https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-valuation-travel-time-economic>). Then, we search the shortest path between centroids using the calculated generalized cost.

**Step 4: Calculate travel time and cost between OD pairs:** The travel time between the centroids are the summation of the FFTT along the path. The travel cost between the OD pair not only includes the summation of the fuel cost along the routes and add the average auto depreciation cost and insurance cost per trip.

1. Average vehicle price was about 20,700 dollars (used vehicle average transaction price, in U.S., 2019, <https://static.ed.edmunds-media.com/unversioned/img/industry-center/insights/2019-used-vehicle-report.pdf>)
2. Assume average length of car ownership was about 4 years since 64% of Americans have only owned their current cars for 5 years or less <https://www.thezebra.com/resources/driving/average-length-of-car-ownership/>
3. The average age of a purchased vehicle is assumed as 5 years. <https://www.powernationtv.com/post/used-car-higher-post-pandemic>
4. Depreciation cost percentage is set as 40% of the purchased price (for 4 years) with low future depreciation

<https://www.navyfederal.org/makingcents/tools/car-depreciation-calculator.html>

1. Average cost of car insurance is set as 2.7 dollars/day (= 80 dollars / 30 days )

<http://www.rmiia.org/auto/steering_through_your_auto_policy/Cost_of_Auto_Insurance.asp>

1. **The average trip number per day is 2.5 trips per day**

<https://aaafoundation.org/wp-content/uploads/2023/09/202309_2022-AAAFTS-American-Driving-Survey-Brief_v3.pdf>

## Method to determine the radius of the centroid connectors in the transit network

We use the percentage of the non-vehicle ownership households (NVP) to estimate the radius of centroid connectors. The radius is at least 500 meters in this case study and increases to 1500 meters as the NVP decreases. The FFTT on transit links are extracted from the service timetable of the buses. For simplicity, the FFTT on the connects are assumed as 5 miles/hour without differentiating the mode to access the transit stop (walking, kiss & ride, or park & ride). The formula to determine the radius of the centroid connectors in the transit network is shown as follows:

(100% - NVP) \* 1000 meters + 500 meters

## Method to calculate the travel time and cost between census tracts on the transit network

Step 1: Calculate link free flow travel time (FFTT) and travel cost

(see details in gtfs2gmns code)

* Transferring link threshold: 321.869 meters
* Ticket price: 1.5 dollar per ride
* Period 8:00 am – 10: am
* VDF\_fftt on boarding links: determined by service frequency
* VDF\_fftt on service links: determined by timetable
* VDF\_fftt on transferring links: straight-line distance over speed (1 kilometer/hour)
* Cost on boarding links is the ticket fare
* Cost on service links is zero
* Cost on transferring links is also zero
* Additional psychological penalty on transferring links: 15 minutes

**Step 2: Find the shortest path between an OD pair (i.e., two centroids):** The generalized cost on each link are calculated using “FFTT + cost \* (60/25) + Penalty” by adopting the mean VOT around 25 dollars/hour for local trips and business purposes provided by the US department of transportation

**Step 3: Calculate travel time and cost between OD pairs:** The travel time between the centroids are the summation of the FFTT along the path (without adding the psychological penalty). The travel cost between the OD pair is the summation of the cost along the route.

## Method to estimate OD trips using Gravity model:

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Generalized Cost = (60 / 25) \* (Auto travel cost + Transit travel cost) + Auto travel time + Transit travel time by adopting the mean VOT around 25 dollars/hour for local trips and business purposes provided by the US department of transportation. Trip ratio is assumed to be 1.25 trip / person. The population data adopted in the gravity model is collected from United States Census Bureau.