Using New Urban Mobility Data in Accessibility Analysis

Executive Summary

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Title picture: *Cairo Bike* station in downtown Cairo, Egypt (11/08/22' TfC – Hazem Fahmy)

Highlights

- There is an observed modal shift towards individual modes of travel, like micromobility, triggered by the COVID-19 pandemic, and expected to continue in the post-pandemic era[1].
- Micromobility's value in accessibility to jobs has not been studied or compared to car-based mobility using realistic conditions like congestion and parking time.
- This report provides a largely open-source accessibility analysis framework with relevant mode combinations to investigate and quantify the potential of micromobility services for improving accessibility.
- The approach leverages realistic travel time estimates that account for congestion, a multimodal routing engine that accounts for safety considerations in non-motorized route choice, and a probabilistic approach to account for micromobility service availability.
- Four cities (Cairo, Mexico City, Minneapolis-Saint Paul, and the San Francisco Bay Area) are selected to showcase the workflow and understand the role of micromobility in different urban contexts.
- For short trips between 15 and 30 minutes, micromobility + public transit may provide accessibility comparable to travel by car, especially in congested CBDs, and in transit underserved outskirts. This is likely because congestion and parking is avoided.
- Micromobility, both docked and dockless, improves accessibility when coupled with Public Transport. It also distributes it more evenly, increasing the number of zones that fall within the 25th and 75th percentiles.
- Micromobility as a first and last mile solution is only as good as the public transport system it feeds into. Improving public transport services, like higher frequency, will better leverage micromobility's positive effect on accessibility.
- Due to vehicle supply constraints, most zones in San Francisco witness a reduction in potential accessibility gains of around 10% or less; the mean reduction was found to be 8.5%.
- The equity of the beneficiaries of micromobility services is calculated for race and income population groups in the US. A surprisingly equitable distribution is found among racial beneficiaries, but a more complex result is found for income groups. The main factor affecting equity is a group's proximity to the city center.

Background

New Urban Mobility (NUM) modes witnessed a boon in the last decade thanks to the advancement in smartphone technology, specifically a constant connection to the internet as well as accurate location data thanks to the Global Positioning System. There is an observed modal shift towards individual modes of travel, like micromobility, triggered by the COVID-19 pandemic, and expected to continue in the post-pandemic era. Micromobility is a subset of New Urban Mobility that encompasses shared small vehicles that can be hired for a single trip like bicycles, e-bikes, and scooters. These new modes have not been adequately studied for their effects on the accessibility of citizens to jobs and the equity of the distribution of that access. Moreover, micromobility's effects on accessibility to opportunities have not been studied

[1] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-future-of-micromobility-ridership-and-revenue-after-a-crisis

when it is used in tandem with other modes, like walking and public transit, or compared to other modes, like private bicycles or vehicles.

Due to the unique features of the shared micromobility system, analyzing its impact on accessibility should be tackled deliberately. Previously, most studies that compute accessibility by cars for comparison to other modes use theoretical speeds for cars which leads to a gross overestimation of car accessibility. Fortunately, some NUM providers like Uber and Mapbox have made data about driving speeds on roads publicly available. For the workflow we have developed to realistically measure and compare the effect of micromobility on accessibility, we have made use of this speed data with open-source routing software, along with parking and walking time, to compute much more realistic car accessibility for comparison with other modes.

About this Report

With growing micromobility services around the globe becoming a part of the daily commutes and transportation patterns of cities, a better understanding of the effect of micromobility on accessibility is needed to inform policies and initiatives that define it. This report provides a methodological workflow to evaluate and understand the role of micromobility services on trips of varying duration. Processes were developed to realistically compute accessibility by counting the jobs reachable from every zone in the study area at varying time thresholds and by varying modes for comparison. In addition to quantifying the gains in accessibility due to micromobility, we account for constraints in the supply of available micromobility vehicles on the potential for accessibility gain by citizens. Finally, for US cities where data on race and household income could easily be acquired, a method for quantifying the equity of the distribution of accessibility gains is developed. The workflow is applied to cities of distinct economic and social fabric to explore the role of micromobility in varying contexts. The chosen cities are Cairo (Egypt), Mexico City (Mexico), Minneapolis-St Paul and San Francisco Bay Area (USA). For the sake of brevity, results from San Francisco only are shown in this executive report.

The study aims to fill these gaps in our understanding of micromobility by answering the following questions:

1. How can accessibility be captured in a realistic way for each mode?
2. How can the decision to use micromobility be replicated intuitively?
3. How can micromobility vehicle supply constraints be reflected in accessibility?
4. How can equity in the distribution of benefits from micromobility be measured?

The major contributions of this study are its use of open-source data and software to create an analysis framework that (a) captures realistic accessibility by cars in congested road networks, and (b) measures and compares the accessibility due to micromobility with public transit to other modes realistically. To capture this realism, we developed processes to determine when micromobility is the best option (either on its own or as part of an intermodal trip) given the real speeds of every mode involved.

Accessibility Gains by Micromobility: Approach and Insights

Accessibility by private cars is the easiest to compute and the most recognizable as a reference for most commuters. We compare accessibility by cars to three mode combinations, as shown in Figure 1; Public Transport, Private Bicycle, and Shared Micromobility. As our accessibility measure, we chose to use a simple Cumulative Opportunities Measure (COM) which counts the number of points, jobs in our case, reachable from an origin point within a defined time threshold. To understand the impact of micromobility on accessibility at different trip lengths, we use 60-, 45-, 30-, and 15-minute thresholds. It is important to note that our accessibility metric measures potential accessibility which is a theoretical concept that only expresses the effect of transportation given the supply of jobs and does not take into account the traveler or their demand for travel.

To compute the accessibility from the origin of each zone in the city, we use the open-source routing engine r5 which works with the OpenStreetMap (OSM) network. By default, r5 uses the free flow speed of each road, assigned according to the type of road, to route cars which results in overestimated accessibility scores for car-based mobility. Therefore, to model realistic car travel times, we edited the OSM road network by replacing generic free flow speeds with the real speeds observed from Uber Movement and Mapbox[2]. Figure 2 shows the significance of congestion on accessibility by cars in San Francisco. Another element of a realistic car-based trip is the time it takes to find parking cruise time and time get to and from the final destination, called access and egress times. Access, egress, and parking cruise time components are also accounted for in this accessibility analysis framework using values from the literature.

For public transport, General Transit Feed Specification (GTFS) data, which includes bus schedules that take into account congestion, are consumed by the routing engine.

To account for user preferences toward choosing user-friendly routes for micromobility and bicycle modes, Level of Traffic Stress (LTS) is used to limit routing to OSM segments to those with a low stress score. LTS ranks all road segments based on the perceived discomfort of riding a bicycle close to traffic and is dependent on the level of vehicular traffic as well as the cycling infrastructure on the road. We chose to route cyclists and micromobility riders only on roads with low LTS scores (1 and 2) to represent the majority of potential cyclists and not just the most confident.

Micromobility vehicle availability at all origins and destinations is crucial for a traveler to realize the benefits of micromobility. Since not all users will find a vehicle at the dock or in the service area where they start or end their trips, it is important to account for this supply constraint in the accessibility gains attributed to micromobility. We compute the probability of finding a vehicle by using Mobility Data Specification (MDS) data from the micromobility service providers and define it as the portion of the study period (2 hours in the morning peak) where there is greater than 2 available bikes. This probability of finding a micromobility vehicle at the origin and destination is used to reduce the potential accessibility gain due to micromobility.

[2] We made the code to edit OSM files to change the maxspeed tag available to all on Github:

The final objective of the project is to analyse whether the distribution of the benefits of accessibility gain due to micromobility is equitable. We calculate the changes in accessibility as experienced by the populations of the zones witnessing these changes. Since the zones' populations can be stratified into groups based on race[3] and household income, we calculate the changes in accessibility for each group. Due to the difficulty in obtaining reliable race and income data in the cities in our study outside of the US, we apply this equity computation only for San Francisco and Minneapolis-St Paul. There are 2 ways to quantify the distribution of accessibility. The first is the Gini Coefficient which measures how a resource is distributed among a population and how far the reality is from equal distribution. It was developed to quantify income inequality and is 0 for perfect equality and 1 for perfect inequality. The second method is a Weighted Average Accessibility, which measures the average accessibility of each population group (race or income). It is computed by dividing the sum-product of the accessibility of the zone and the population of the group residing in that zone by the total population of that group in the city.

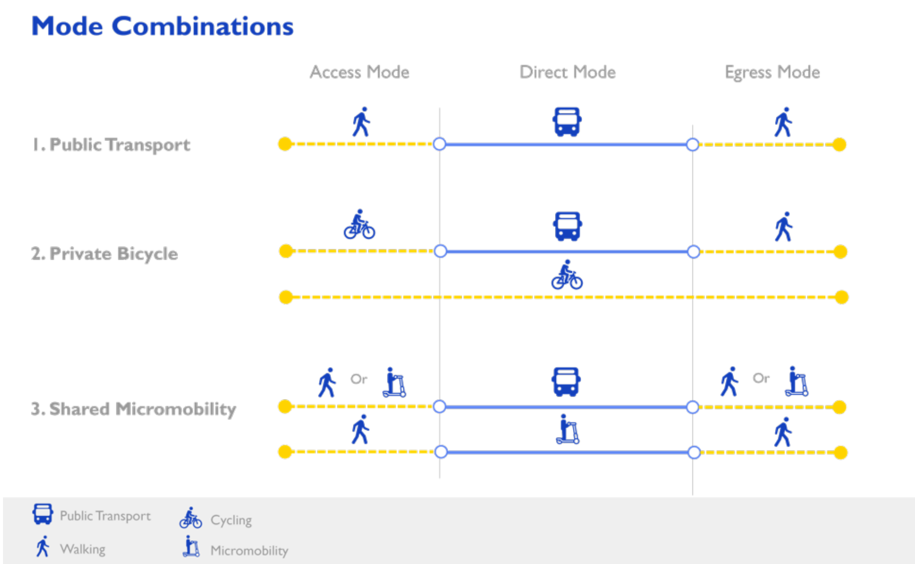

Figure 1: Mode combinations used in analysis

[3] This is applicable for US cities only. we use census data on racial composition and household income at the US census block level

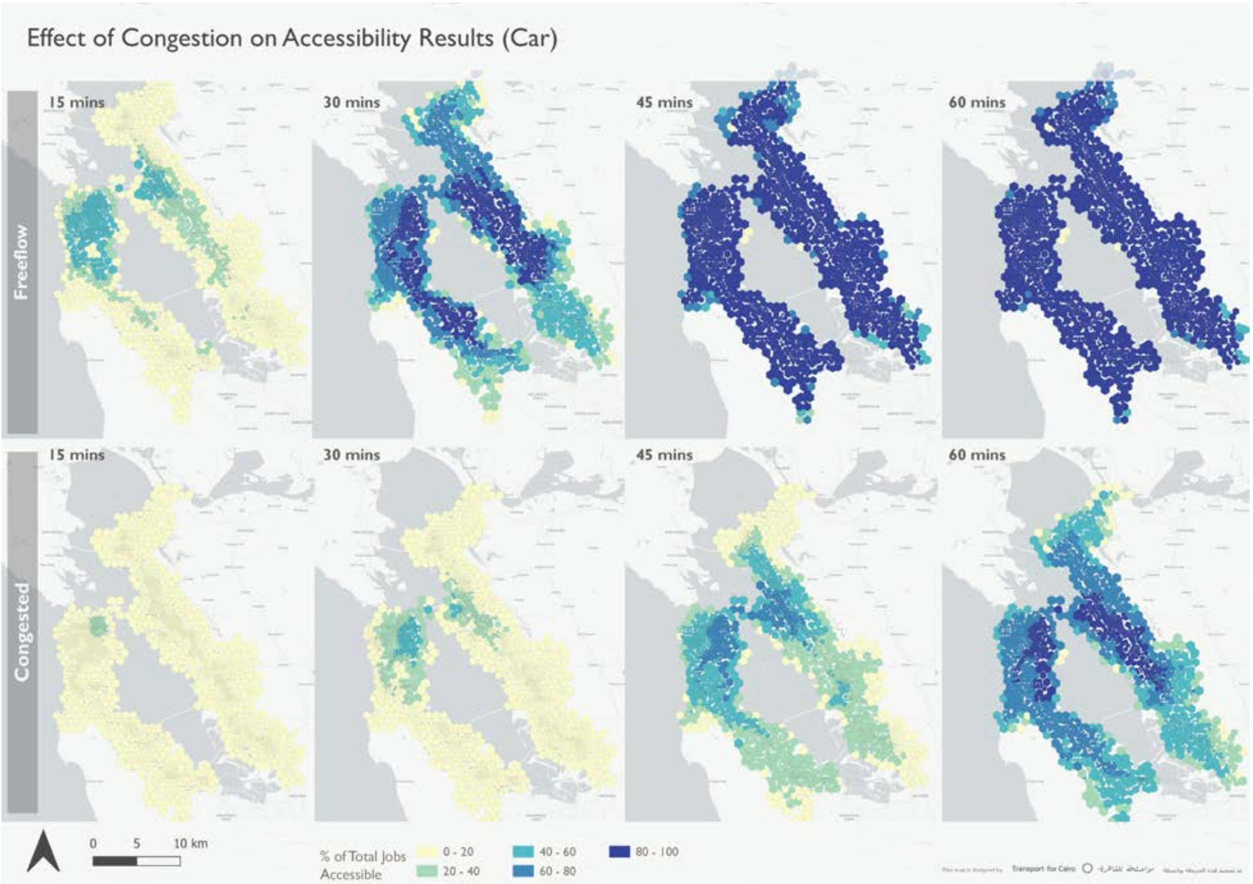

Figure 2: Effect of Congestion on Accessibility Results. (Top Row) Accessibility at Different Time Thresholds under Free Flow Conditions. (Bottom Row) Accessibility at Different Time Thresholds under Congested Conditions – San Francisco

Key Findings and Recommendations

Micromobility service, either docked or dockless, was found to enhance the accessibility of travelers to jobs either as a main mode or as a feeder to public transit. Dockless micromobility has a higher positive effect than its docked counterpart because it does not have the same spatial constraints, as shown in Figure 3. At the zone level, the highest mean improvement occurs at 30 minutes of travel time, or 45 minutes for docked micromobility in San Francisco, with larger maximum improvement but lower overall mean improvement as the time threshold increases. This improvement is most noticeable in areas with high public transit connectivity. For short trips of less than 30 minutes, micromobility is shown to be a competitive alternative to travel by car, likely because congestion and parking is avoided.

The boxplots in Figure 4 shows the trend that micromobility, both docked and dockless in San Francisco, improves accessibility when coupled with Public Transport. It also distributes it more evenly, increasing the number of zones that fall within the 25th and 75th percentiles. Micromobility as a first and last mile solution is only as good as the public transport system it feeds into. Improving public transport services, like higher frequency, will better leverage micromobility's positive effect on accessibility.

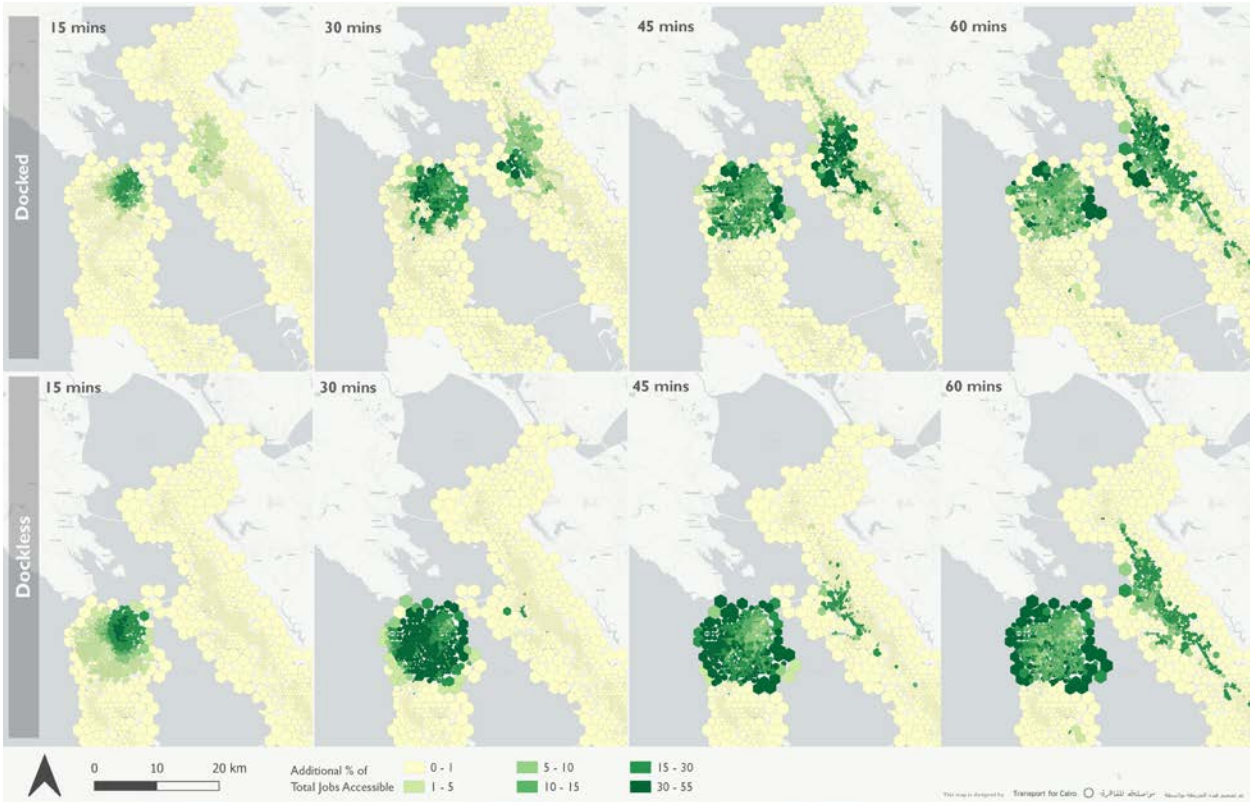

Figure 3: Accessibility gain due to micromobility (San Francisco)

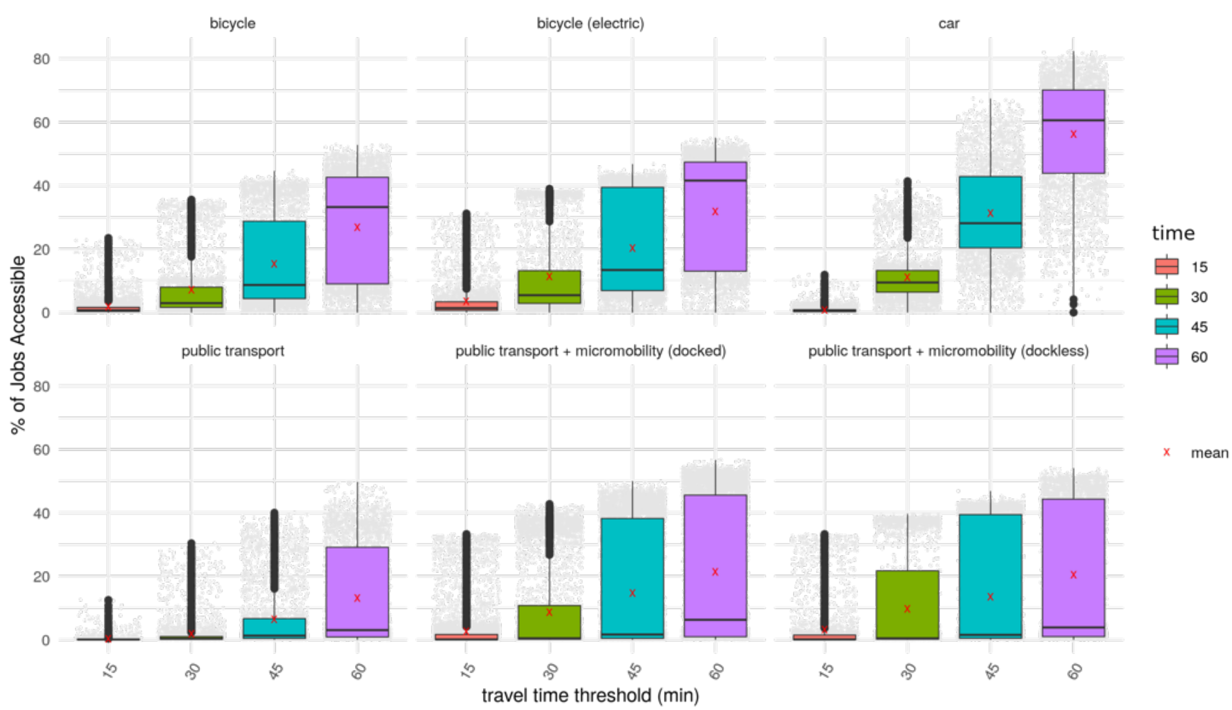

Figure 4: Distribution of accessibility for each mode – San Francisco. Bicycle (Top Left); Bicycle Electric (Top Middle); Car (Top Right); Public Transport (Bottom Left); Public Transport + Micromobility Docked (Bottom Middle); Public Transport + Micromobility dockless (Bottom Right)

Due to vehicle supply constraints, most zones in San Francisco witness a reduction in potential accessibility gains of around 10% or less; the mean reduction from users not likely to find a micromobility vehicle was found to be 8.5%. This reduction is realistic and consistent with the demand profile in the area. The spatial distribution of supply constraints and their effects can be seen in Figure 5.

One important observation on micromobility vehicle supply is its relative scarcity in the outskirts of San Francisco which reduces the potential accessibility gains achievable by residents of those areas. Therefore, the key recommendation that can be drawn from this analysis is to drive policymaking efforts to increase micromobility services in underserved areas since this relatively small investment in micromobility infrastructure can leverage the already existing public transport network to spread accessibility more evenly. This can be achieved via infrastructure as well as operational improvements.

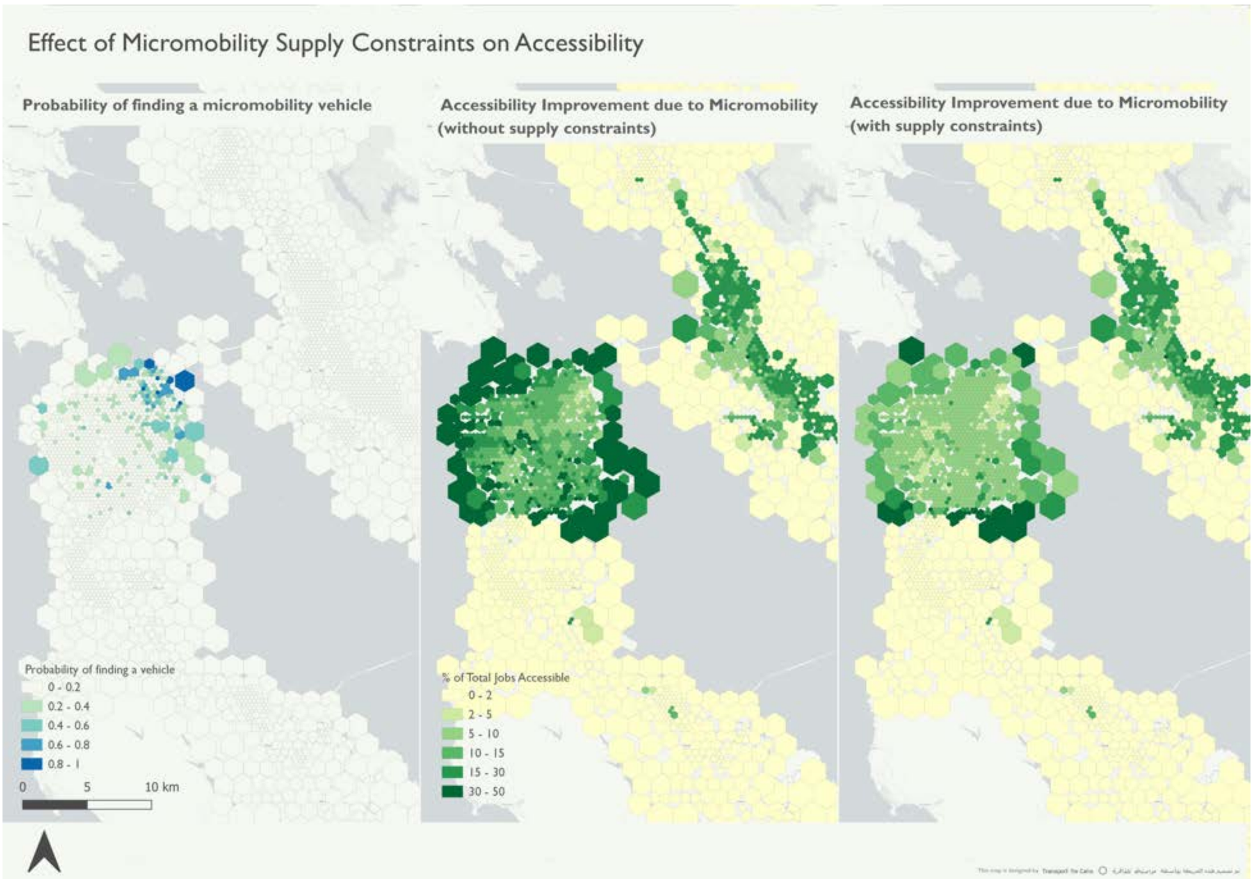

Figure 5. Effect of micromobility supply constraints on accessibility.

Micromobility was found to improve the equitable distribution of accessibility among the zones in San Francisco from 3 to 6% on the Gini Coefficient, depending on the docking style of the vehicles. White, Black, and American Indian residents of the Bay Area have Weighted Average Accessibility (WAA) scores higher than the that of the total population while Asian residents are at the average and Hawaiian, Other Race and Other Two Races are below the average. For most minority race groups except Asian and Hawaiian, improvement in WAA due to micromobility is higher than that of the total population. When the population is stratified into income groups, we found that most middle-income families have WAA scores lower than the average. This makes sense given San Francisco Bay Area's spatial distribution of income groups where the city proper has extreme wealth and poverty and middle-income families are in the suburbs, farther from transit. The main factor affecting equity is a group's proximity to the city center where most jobs opportunities can be found. Micromobility pushes the needle in the right direction, giving more low-income groups better access to jobs in the city.

Equitable access to micromobility services is key to its successful integration within regional multimodal transportation networks. Improvement due to micromobility varied across the different contexts studied in this report. Since it is a feeder to public transport and uses roadways, it depends heavily on both public transit connectivity and roadway LTS levels. Future work should further explore these dimensions. For example, the workflow developed in this study can be used to prioritize micromobility expansion to zones that would benefit the most from better access to the public transport network. Although the dimension of fares and affordability was not addresses in this study, an argument can be made for subsidizing micromobility in low-income zones that would benefit from it.