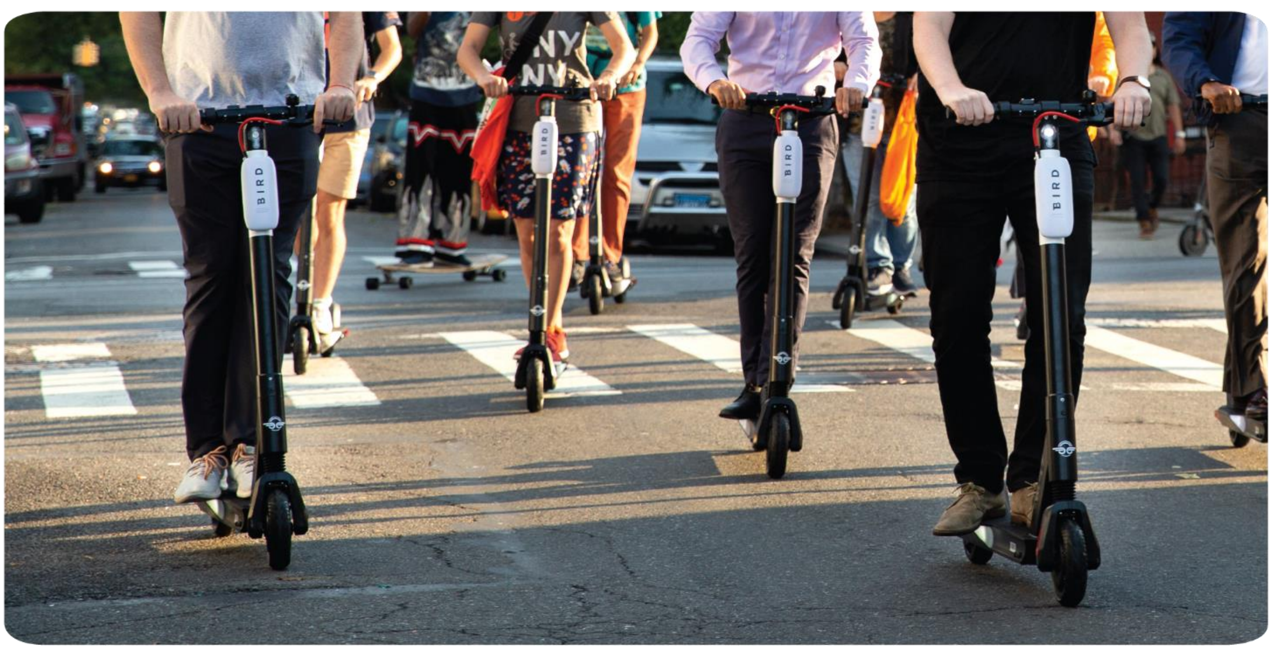
E-SCOOTER SCENARIOS

Evaluating the Potential Mobility Benefits of Shared Dockless Scooters in Chicago

BY C. SCOTT SMITH AND JOSEPH P. SCHWIETERMAN | DECEMBER 12, 2018



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Executive Summary

This study examines the potential for public e-scooter sharing systems to fill mobility needs within and between Chicago neighborhoods. It explores how availability of this micro-mode of transportation could influence travel time, cost, and the convenience of trips relative to other active and shared-use modes including walking, bicycling, bikeshare, and public transit.

To draw conclusions, it uses the Chaddick Institute's multimodal travel model to evaluate approximately 30,000 randomly selected hypothetical trips between locations on the North, South, and West sides of the city. Different assumptions about the quantity and distribution of shared dockless e-scooters are considered to assess the sensitivity of the results. The analysis shows that:

- **On trips between 0.5 and 2 miles, e-scooters would be a particularly strong alternative to private automobiles.** In parking-constrained environments, the introduction of e-scooters could increase the number of trips in which non-auto options are competitive with driving from 47% to 75%. The cost of using an e-scooter, inclusive of tax, would likely be around $1.10 per trip plus $1.33 per mile, making them cost-effective on short-distance trips. By filling a gap in mobility, e-scooters have the potential to increase the number of car-free households in Chicago.

- **Due to their higher relative cost on trips over three miles, e-scooters would likely not result in significant diversion from public transit on longer-distance trips**, particularly services operating to and from jobs in the transit-rich Loop business district. Often, the use of scooters on these longer journeys would likely be short connections to nearby transit stops.

- **The benefits of e-scooters can differ widely between geographic areas that are only a few blocks apart** due to the differential access of these areas to transit lines and bus routes.

- **E-scooters would make about 16% more jobs reachable within 30 minutes compared to the number of employment opportunities currently accessible by public transit and walking alone.** The gains tend to be markedly different across the North, South, and West study areas.

By fostering insights into how e-scooters could influence travel time, cost, and convenience, these results can help set the stage for an informed discussion on the many tradeoffs associated with this micro-mode of transportation.

Introduction

The character of urban transportation in the United States has dramatically changed in recent years, due in part to the growing interest in active transportation and the explosive growth and continuous iteration of shared-use modes of travel, including bikesharing, carsharing, ridesourcing, and, more recently, electric (e-) scooter-sharing. E-scooters and other novel forms of micro-mobility have already added to the growing menu of travel options available in cities by offering riders opportunities to experience urban environments in an unconventional way.

This report examines the degree to which e-scooter rentals could fill mobility needs by accommodating trips of various distances and modes within and between Chicago neighborhoods. The study explores how the availability of this shared mode of travel could affect the travel time, reliability, and convenience of trips relative to other active and shared-use modes including walking, bicycling, bikesharing, and public transit. The study does not attempt to summarize the "pros" and "cons" of e-scooter rental; rather, it focuses exclusively on the scooters' implications on mobility.

Although there has been considerable discussion about how to regulate e-scooters, dockless bicycles, and the sharing economy more generally, relatively little has been done to better understand multifold interactions between transportation modes and how specific networked trip configurations can influence travel times and accessibility. This lack of fine-scale analysis is due to the complexity of modeling multimodal travel, which must take into consideration such factors as the variability in public transit schedules, configurations of street networks, and the characteristics of shared-use vehicles with discrete check-out (e.g., dockless e-scooters and bikes) and check-in (e.g., docked bikeshare) locations.

E-scooter systems differ from bikeshare systems in several key ways. E-scooters are smaller and typically not as fast as bicycles, especially lightweight touring bikes. However, because e-scooters have a smaller footprint compared to bicycles, they can be made available in more places, and therefore are less geographically constrained. Furthermore, unlike many cities' docked bikeshare systems, e-scooters are free-standing and do not need to be returned to a designated station.

At the time of this writing, the City of Chicago has not permitted widespread use of e-scooter rental systems within its boundaries. As a result, it was not possible to examine actual e-scooter trips to inform the analysis. Therefore, for this study, we delineated three case studies: one each on the north, west, and south sides of the city. This allowed the study team to assess how scooters perform in different contexts, such as areas with differing levels of transit services (both buses and trains) and concentrations of Divvy bike rental stations. At the time of this writing, Divvy—Chicago's docked public bicycle sharing system—has approximately 580 stations and 7,000 bicycles distributed throughout the city.

In this paper, we include a cost analysis of trips made via e-scooter share – drawing from common assumptions about travel time based on USDOT data – to make general conclusions about the monetary benefits of the time savings to travelers who gain access to e-scooters. This is typically measured by valuing travel time as a proportion of the traveler's wage rate.

Methodology

When made available to the public, e-scooter systems share many characteristics with dockless bikeshare systems. The similarities range from stated missions, the technology and business models used, pricing, and sources of funding. Both systems typically rely on smartphone apps where riders can locate and unlock vehicles; both have a fixed cost to initiate a ride with additional expenses charged based on trip duration. Each emphasizes health and the environment, including reduced vehicle emissions, as key socio-ecological benefits. Further, like dockless bikeshare systems, e-scooter rental companies often geofence their systems to targeted areas of the city in order to better manage the fleet, optimize maintenance, and ensure adequate supply.

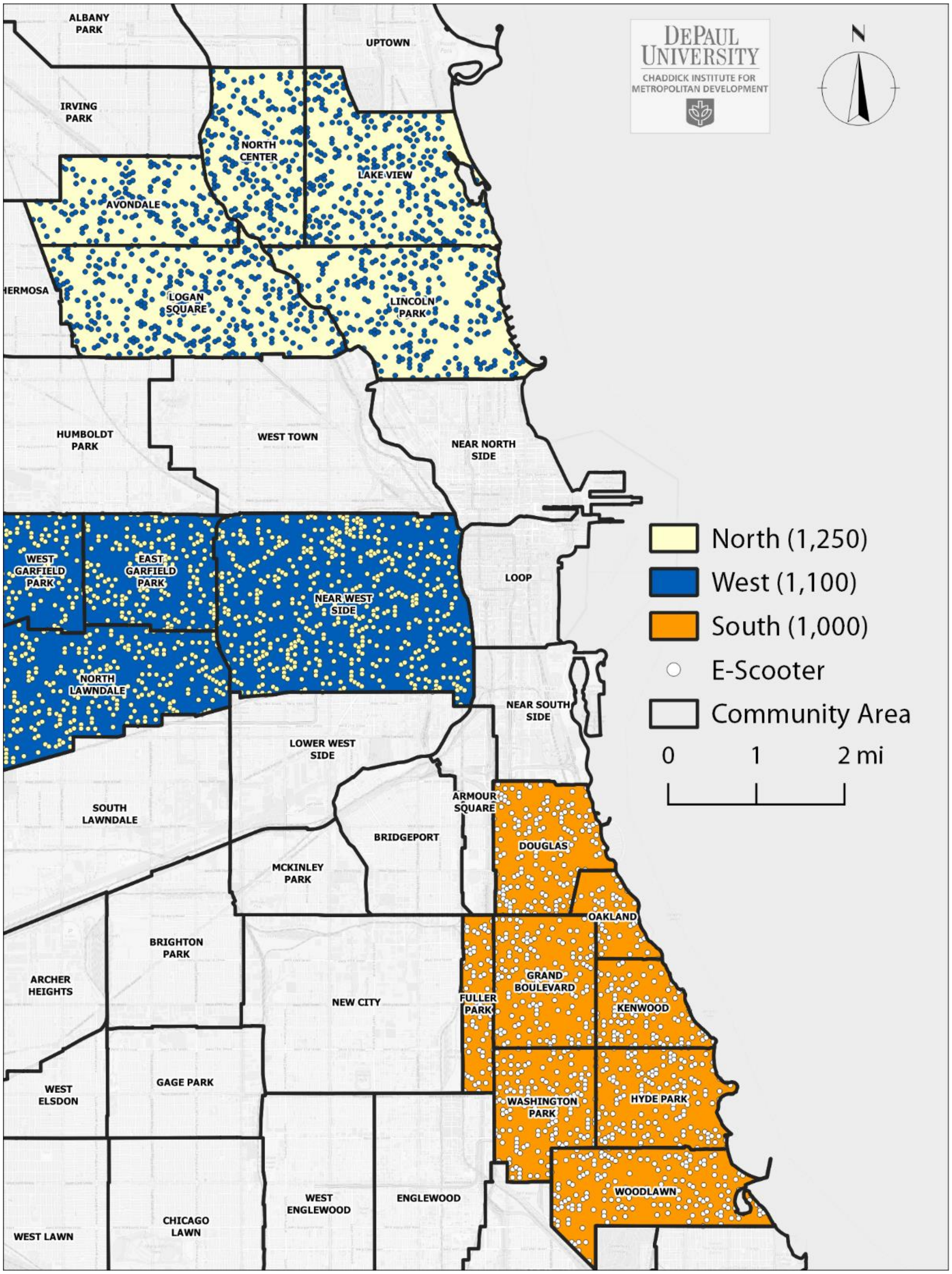
To manage some of these complexities, this study carries out a series of inter-related, multimodal network analyses. Each analysis explores a unique aspect of travel, with the combined goal of understanding how e-scooter sharing may potentially fit into the City of Chicago's rapidly evolving transportation system.

First, a multimodal network model representing Chicago's current transportation system was developed to estimate the accessibility potential of locations throughout the city, paying special attention to multimodal synergies and performance gaps among existing travel modes. To account for geographic variations in modal performance, we calculated three categories of accessibility for 7,682 trip origin locations spaced at ¼ mile intervals throughout the city based on a regular, hexagonal grid (Appendix A). The categories of transportation evaluated as part of this citywide accessibility analysis include active modes (i.e., walking, bicycling, and Divvy bicycle rental) and public transit (i.e., bus and rail transportation) as well as private automobile. Accessibility for multimodal trips such as *walking + public transit* and *walking + public transit + Divvy bicycle rental* were also estimated given both the interdependence (i.e., public transit and Divvy trips tend to begin and end with a walking trip) and complementary nature (i.e., Divvy trips can serve as first- and last-mile transit connections) of these modes. Results of this citywide accessibility analysis are reported in Appendix B.

Building on the citywide analysis, we delineated three case studies on the north, west, and south sides of the city (Figure 1). The **North study area** is comprised of Avondale, Logan Square, Lakeview, Lincoln Park, and North Center, while the **South study area** is comprised of Douglas, Fuller Park, Grand Boulevard, Kenwood, Hyde Park, Oakland, Woodlawn, and Washington Park. The **West study area** is comprised of the East Garfield Park, Near West Side, North Lawndale, and West Garfield Park community areas. These areas, while rather arbitrarily defined, were used to model how a series of hypothetical e-scooter rental implementations would likely influence overall trip travel times in communities with disparate levels of public transit and bikeshare service. Refer to Appendix C for maps of the geographic distributions of e-scooters for all case study areas by scenario.

A third network-based analysis explores the potential time savings and gains in employment accessibility when making commute trips to the Loop from each of the three study areas using some combination of walking, public transit and/or e-scooter rental. Like the above analyses, the accessibility model for this analysis makes use of detailed public transit schedules and route information to arrive at a more nuanced multimodal model that accounts for temporal variants in public transit networks.

FIGURE 1. Case Study Areas with Distribution of E-Scooters in Moderate Density (S2) Scenario



This map shows the random assignment of scooters under S2 (middle) scenario in the three case study areas. See the appendix for maps of the distribution of scooters the S1 and S3 scenarios.

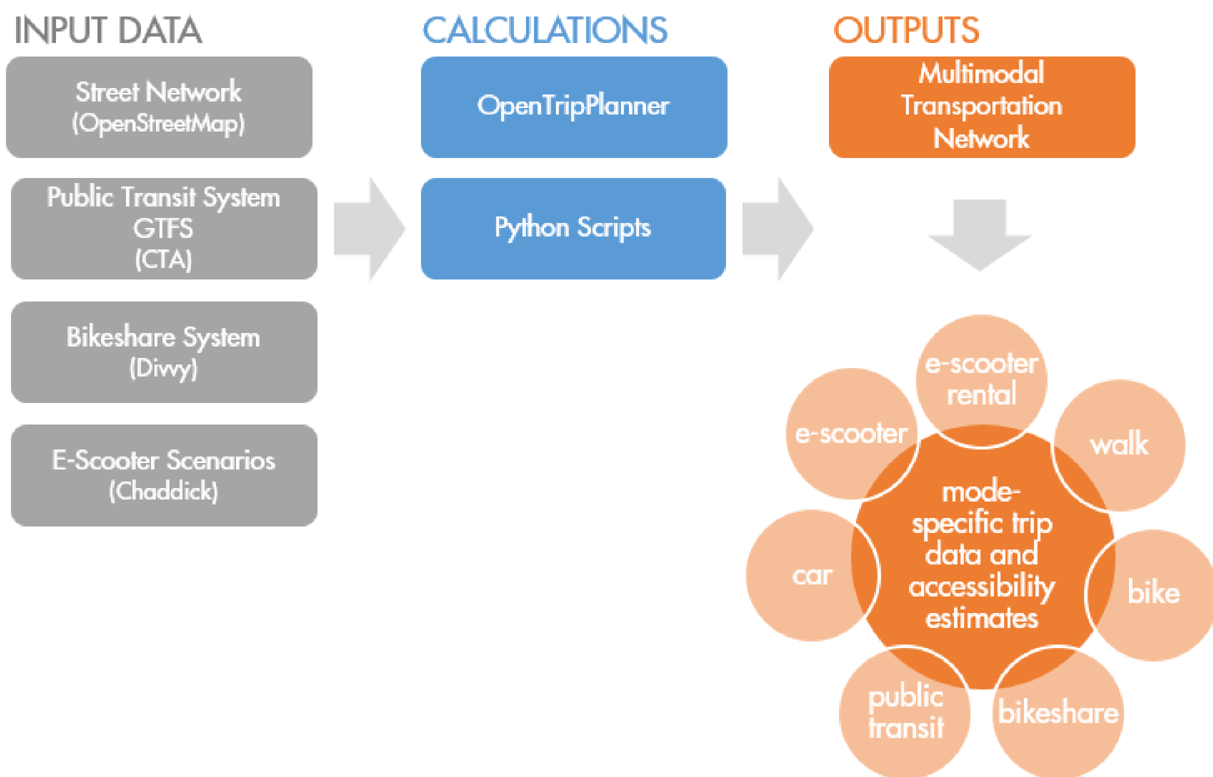
To improve model accuracy, we draw from related studies to make assumptions about how each transportation mode would function with respect to velocity, waiting times, and utilization of certain pathways. For example, we assume that car trips are constrained to posted speed limits and other directional requirements. Public transit trips are sensitive to scheduled pickup and drop-off times. Walking trips are limited to either neighborhood streets or streets with sidewalks. Bicycle rental trips are constrained to the distribution of bike-share stations. Both bicycle and e-scooter trips are limited to arterial roads and neighborhood streets, and banned from limited access highways. Table 1 summarizes the key characteristics of each mode and their respective network constraints.

TABLE 1. Model Parameters by Travel Mode

Transportation Mode	Average Speed	(Network/Model) Configurations
Private car	Posted speed limit	Banned from discouraged pathways
Walking	3.1mph	Banned from discouraged pathways
Private bike	11mph	Banned from discouraged pathways
Walking+bike rental (Divvy)	9.6mph + walk time	Banned from discouraged pathways 60s bike rental pickup penalty Geographically constrained stations Max walking distance = 0.5 mile
Private e-scooter	7.5mph	Banned from discouraged pathways
Scooter rental	7.5mph + walk time	Banned from discouraged pathways 60s e-scooter rental pickup penalty Geographically constrained locations Max walking distance = 0.5 mile
Walking+transit	Multimodal	Scheduled routes, wait times
Walking+transit+bike rental	Multimodal	Same as above
Walking+transit+e-scooter rental	Multimodal	Same as above

To operationalize the conceptual transportation model described above, we relied on a collection of open source data and tools. The base street network—including speed limits and pathway categories—was made available via OpenStreetMap, as was the points of interest dataset that was used to represent destinations in the accessibility model ("OpenStreetMap", 2018). Longitudinal Employer-Household Dynamics (LEHD) and Origin-Destination Employment Statistics (LODES) data made available via the US Census Bureau were used to represent the number and geographic locations of job opportunities in the employment accessibility model (US Census Bureau, 2018). Public transit data including scheduled travel times, routes, bus stops, and rail stations were drawn from the Chicago Transit Authority's (CTA) latest general transit feed or GTFS data (CTA, 2018). Bikeshare stations for the city's Divvy system were downloaded from the company's website (Divvy Bikes, 2018). Once the data were processed and organized, a series of Python scripts were developed to automate the calculation of trip travel times and accessibility (by trip origin), making use of mode-specific batch trip calculation algorithms available in OpenTripPlanner, an open source application. A simplified representation of the analytical framework is shown in Figure 2. Also, refer to Appendix D for a graphical *trip planner-style* display of modeled routes connecting a sample origin and destination in south Chicago with travel times by transportation mode.

FIGURE 2. Analytical Framework of DePaul Multimodal Modal



For each case study area, we estimated travel times for trips originating from 100 sample origins to 100 sample destinations. This yielded approximately 10,000 trips per study area for each of the six transportation modes evaluated. We also considered three scenarios, each with a different density of e-scooters, ranging from a relatively low number per study area (500-625 e-scooters in the S1 scenario) to higher numbers in the S2 and S3 scenarios (1,000 – 1,250 and 2000 – 2,500 e-scooters, respectively). Basic area, employment, and accessibility characteristics of the study areas, and the quantity of scooters distributed within them, are shown in Table 2 below.

TABLE 2. Case Study Area Characteristics

Study Area	Square Miles	Workers	Jobs	Average Neighborhood Accessibility *(walk+transit)*	Total Divvy Stations (per square mile)	E-scooter Scenario Distributions (S1; S2; S3)
North	13.9	171,859	98,255	509	106 (7.6)	625;1250;2500
West	12.1	54,606	136,312	535	63 (5.2)	550;1100;2200
South	11.0	50,265	36,108	436	53 (4.8)	500;1000;2000

After evaluating the output from the different models, it was determined that there were comparatively small time differences between the three e-scooter scenarios (S1, S2 and S3) in relation to the other variables considered. As a result, the analyses below focus entirely on the S2 (moderate density) scenario with only occasional references to the results of the other two scenarios. Further, although data was collected for private bicycle travel, this mode was not considered in depth in the present study, but will be the focus of future analysis.

Summary Travel Time Statistics

Simple summary statistics from the sample of 29,332 routes appear in Table 3. They show that, on average, private car (with no considerations made regarding parking or variations in traffic congestion) and private bicycle travel were the fastest modes. Adding e-scooters as a transportation option appears to provide a clear niche between bicycling, walking, and transit, suggesting that there may be some savings in travel time by combining modes on single one-way trips. E-scooters, when combined with transit, for example, tend to outperform trips that rely solely on e-scooters. When averaged across all distances and neighborhoods, the differences between the scooter options, Divvy, and transit are relatively small. As noted below, only when particular distances are considered do sharp disparities emerge.

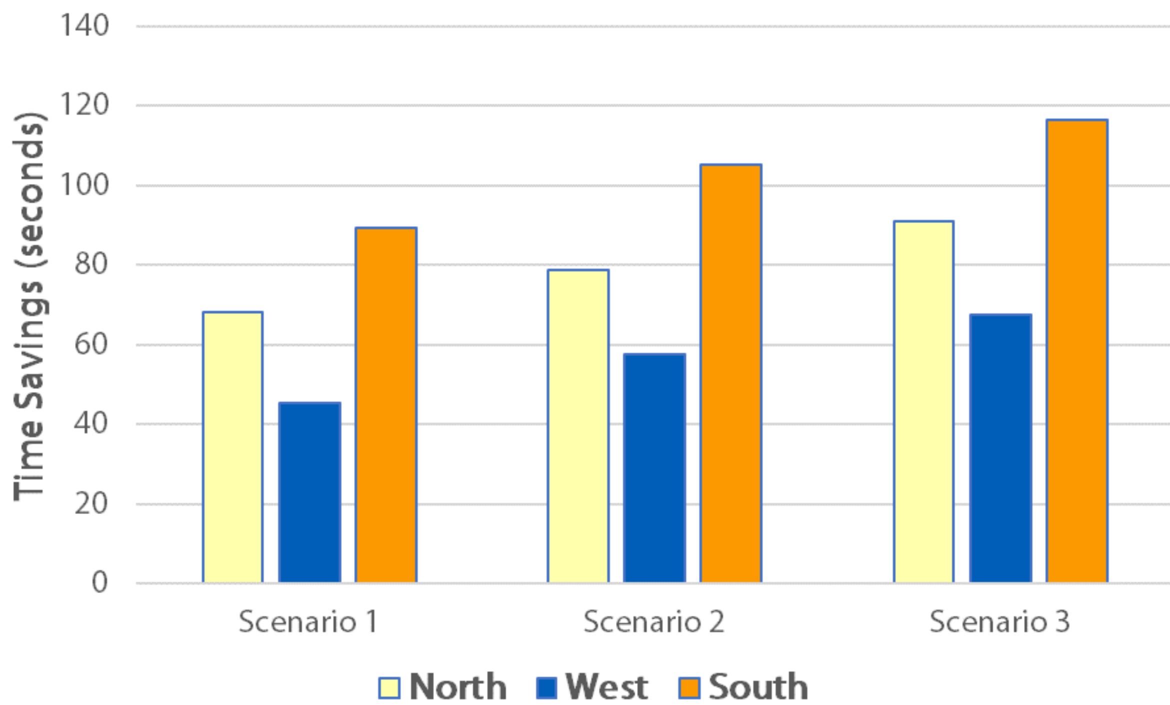
TABLE 3. Average Trip Travel Time Statistics (in minutes) by Transportation Mode and E-scooter Rental Scenario

Transportation Mode	Median	Mean	Std Dev
Private car	11.43	11.73	5.20
Private bicycle	13.83	14.67	7.32
Private e-scooter	19.95	21.16	10.67
E-scooter rental + transit (S3)	21.23	22.05	9.41
E-scooter rental + transit (S2)	21.55	22.38	9.45
E-scooter rental + transit (S1)	21.98	22.75	9.51
Divvy + walk + transit	22.83	23.22	8.63
E-scooter rental (S3)	22.95	24.14	10.69
E-scooter rental (S2)	23.40	24.61	10.75
E-scooter rental (S1)	23.97	25.21	10.83
Walk + transit	24.45	24.94	9.82
*Divvy bike rental**	26.02	26.41	9.11
Walking	47.18	50.02	25.39

This table shows the approximate order of average mode-specific trip speeds among all sampled trips within the case study areas (N=29,332), which range in distance from 0.14 miles to 7 miles. Note that travel time statistics for each multimodal option reflect the fastest available trip time among included modes. Traffic congestion was moderate on most routes when data were collected.

When trips are segmented geographically by case study area, a consistent pattern of time savings emerges across the three scenarios. For example, multimodal walking, public transit, and e-scooter rental trips yield an average time savings per trip from 40 seconds (in the West study area for e-scooter rental scenario 1) to nearly two minutes (in the South study area for the highest density scooter scenario 3) when compared to walking, public transit, and Divvy bicycle rental trips. As discussed in detail in the next section, the time-saving benefits vary sharply by the distanced traveled and other factors; because of this, these figures provide a simplified illustration of the impacts on travel time.

FIGURE 3. Average Time Savings per Trip by Case Study Area and E-Scooter Scenario (Walking + Transit + Divvy) vs. (Walking + Transit + E-Scooter Rental)



This figure shows the average change in travel time (in seconds) for trips with similar study area-specific origins and destinations after e-scooters are introduced. The values reflect the time savings achieved by subtracting the fastest combination involving walking, public transit, scooters, and Divvy bicycles from this same set of choices without e-scooter options. As noted throughout this report, scooters tend to save time on certain types of trips but not others, so these figures offer a simplified illustration of the time savings.

Major Findings

Seven findings from the multimodal model foster insights into the mobility implications from the introduction of e-scooters. Each of these findings is based primarily on the S2 (middle) scenario, in which 1,000 – 1,250 scooters were assumed to have been randomly distributed throughout each study area. Throughout this section, the term "e-scooter" is used to refer to shared electric dockless scooters.

Finding I. On short-distance trips, i.e., those between 0.5 – 2 miles, e-scooters would provide a new alternative to the private automobile, which is currently the dominant mode of travel in this mileage range. In parking-constrained environments within the North study area, for example, the introduction of e-scooters would increase the number of trips in which non-auto options are time-competitive with driving from 47% to 75%.

The origin-destination model was used to assess the degree to which e-scooters would provide an alternative to driving without significant increases in travel time. The amount of time spent driving, as previously noted, is based on driving conditions during the morning peak period, when traffic congestion was light to moderate on most routes.

The study team made two assumptions when evaluating whether travel times by non-automotive modes were competitive with driving in parking-constrained environments:

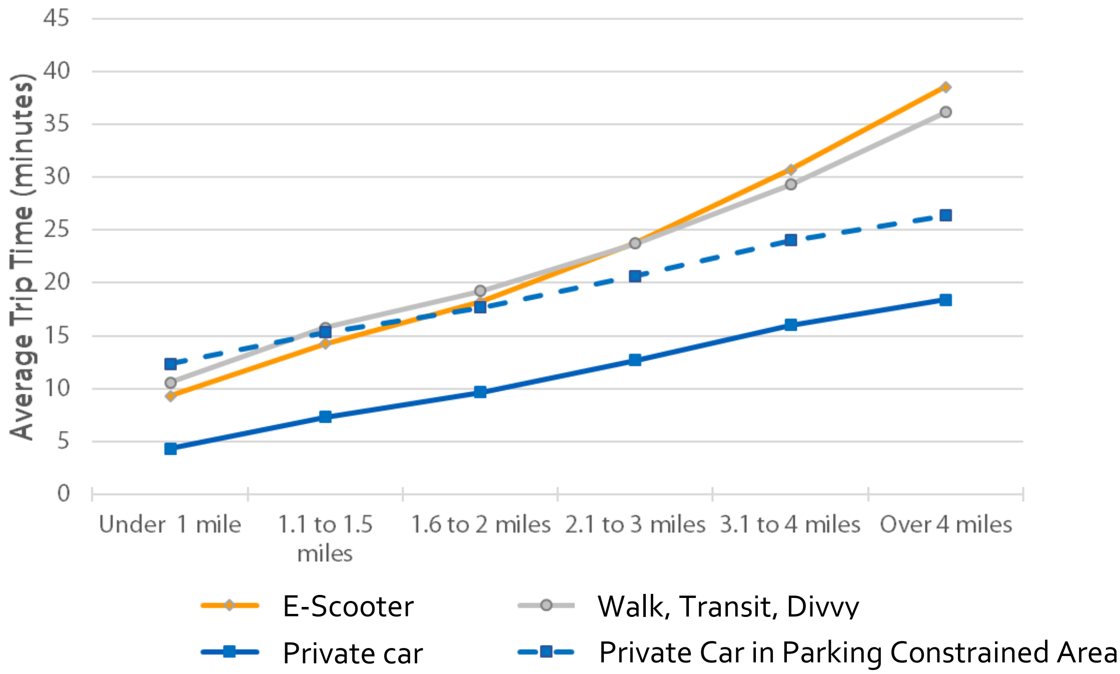
1) ***Due to greater trip predictability, travelers would consider a non-automotive option competitive if they would arrive no more than two minutes slower than the time required for driving and parking*.** This differential accounts for the fact that walking, bike, and e-scooter trips are more predictable, less subject to trip-by-trip variation than driving, and (in some instances) less stressful; and

2) ***Travelers would spend three minutes accessing a private vehicle and parking spot at the start and end of each trip***, for a total of *six minutes related to these tasks*. This includes time spent searching for parking, walking to and from the parking spot, accessing and egressing parking areas in a vehicle, and added travel time when parking spots are not located on the optimal travel path. This time allotment also includes time spent providing payment for parking and waiting for elevators in multi-deck lots.

Based on this definition, travelers would consider an e-scooter time-competitive if they would arrive within eight minutes of the shortest possible drive time before accounting for parking and the other factors mentioned above.

The advantage of e-scooter travel on short-distance trips compared to other modes is evident in the data shown in Figure 4. The average duration of the faster e-scooter option, whether or not the scooter is used in conjunction with transit, dips below all other options except private car travel (without allowances for parking or heavy congestion) at distances of less than two miles. The average duration is approximately equal to auto travel in parking-constrained environments at two miles, but well below it at the shortest distances. Although these aggregate futures do not capture the wide trip-by-trip variation we observed in the data, they illustrate why e-scooters perform best on short-hop trips.

FIGURE 4. Average Trip Time (minutes) by Transportation Mode and Trip Distance



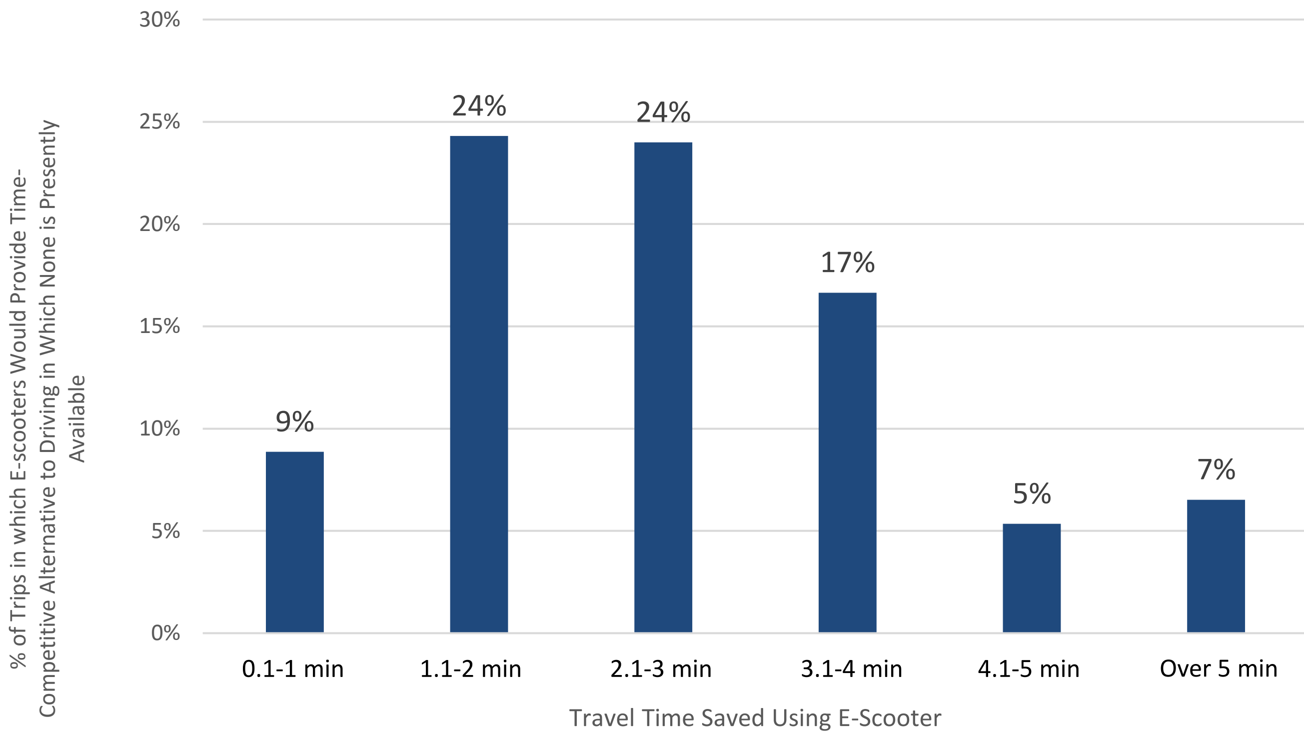
This figure shows the average time associated with different travel options, including those involving e-scooters for at least part of the trip (as denoted by the orange line). Congestion was only moderate when this data was collected. The data show that e-scooters perform best at distances < two miles and can be competitive with driving in parking constrained environments in this distance range. Many of the longer e-scooter trips included in these averages are those made in combination with public transit.

A review of the time savings on *individual trips* provides a more nuanced portrait of the potential time savings (Figure 3). In the North study area, the introduction of shared e-scooters would give travelers a time-competitive alternative to driving on 75% of routes in the 0.5 – 2 mile range, compared to 47% of routes at present. This represents a 60% increase in the share of routes in which time-competitive options to driving are available.

The benefits of shared e-scooters in this environment stem primarily from three factors:

1. Dockless e-scooters fill a void caused by the limited transit coverage available for intra-neighborhood trips. The radial nature of the city's transit system, and the lack of service on some arterial streets, limit the speed of transit on neighborhood trips. On many routes, the fastest transit option involves bus-to-bus connections, which can be time consuming. In the case study areas, consequently, the share of trips using transit in the 0.5 – 2 mile range is low.

FIGURE 5. Distribution of Time Savings for Short-Distance Trips in which E-Scooters Would Provide a Competitive Alternative to Driving Where None is Presently Available
(Trips in North study area between 0.5-2 miles)



Among short-distance routes in the North study area in which e-scooters would provide a time-competitive alternative to driving where none is presently available, this new option would provide more than two minutes of time savings on 61% of routes. This assumes there are parking constraints, and that the e-scooter user travels only at moderate speeds. Private bicycle, taxi, and rideshare services are excluded from consideration.

2. E-scooter systems tend to reduce the amount of time needed to access a vehicle. The potentially broad coverage of e-scooters means that travelers can often access a scooter more quickly than a docked Divvy bike or transit stop, a benefit that is particularly advantageous on short-distance trips. On longer trips, conversely, the higher assumed speed of bicycle and public transit travel offsets much of this advantage.

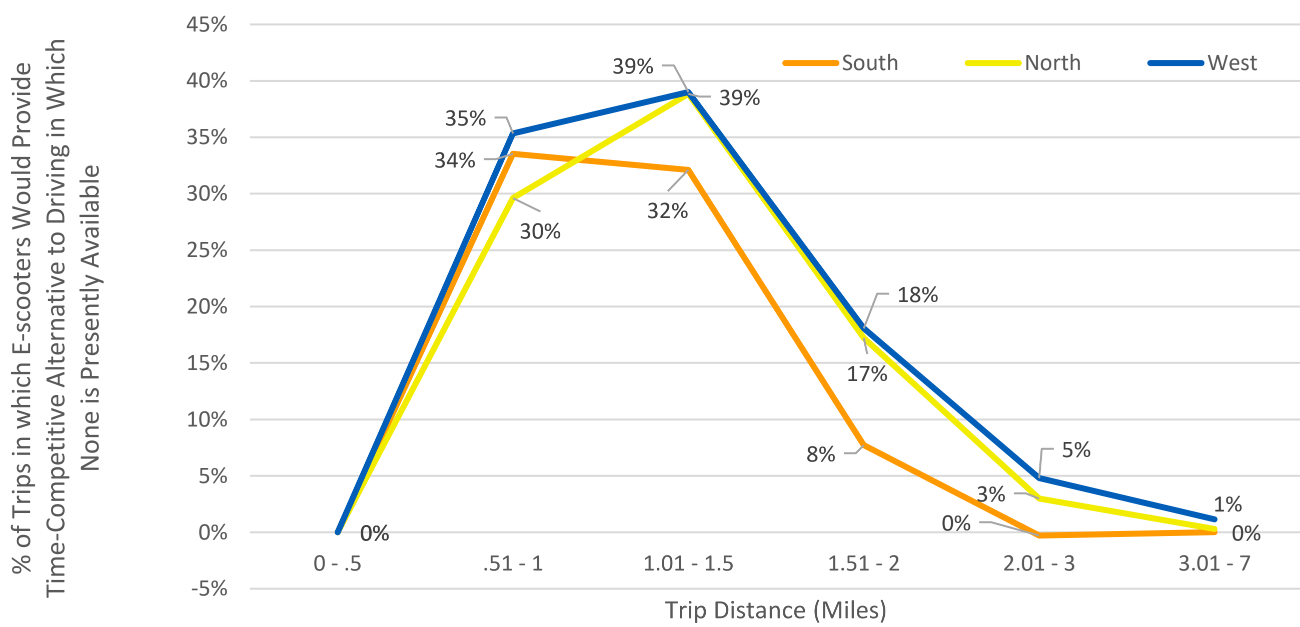
3. Unlike transit and Divvy, users of e-scooters do not face a "last mile" issue; instead, they can park their vehicle directly at their destination. Users of Divvy must walk to access a vehicle as well as walk to a final destination; e-scooter users need to walk only to *access* the vehicle.

However, on trips under a half mile, e-scooters would be less important for filling gaps in non-auto travel options. Walking is a time-competitive alternative to using e-scooters for all trips of such a short distance. While scooters still save a minute or two of travel time on roughly a quarter of these routes, few would consider their use cost-effective, for reasons explained below.

<u>Finding II</u>. On trips in the 0.5 – 2 mile range in the South and West study areas, e-scooters increase the number of trips that are competitive with driving in parking constrained environments by 55% and 66.8%, respectively. However, concerns over parking appear to be less acute in these areas, which may lessen the diversion from private automobiles.

Following the introduction of e-scooters in the South study area, the share of routes between 0.5 to 2 miles in which travelers have competitive alternatives to driving would grow from 41.0% to 63.7%, rendering 55.3% more trips time-competitive. In the West study area, the share of trips would grow from 44.6% to 74.4%, a margin of difference of 66.8%. This suggests that the benefits are similar across different contexts and neighborhoods. However, the time the typical motorist devotes to parking activities is likely less in these areas (the South and West sides) due to the lower population density, particularly in the areas farthest from downtown.

FIGURE 6. Share of Trips in which E-Scooters Would Provide a Time-Competitive Alternative to Driving in Which None is Presently Available by Case Study Area



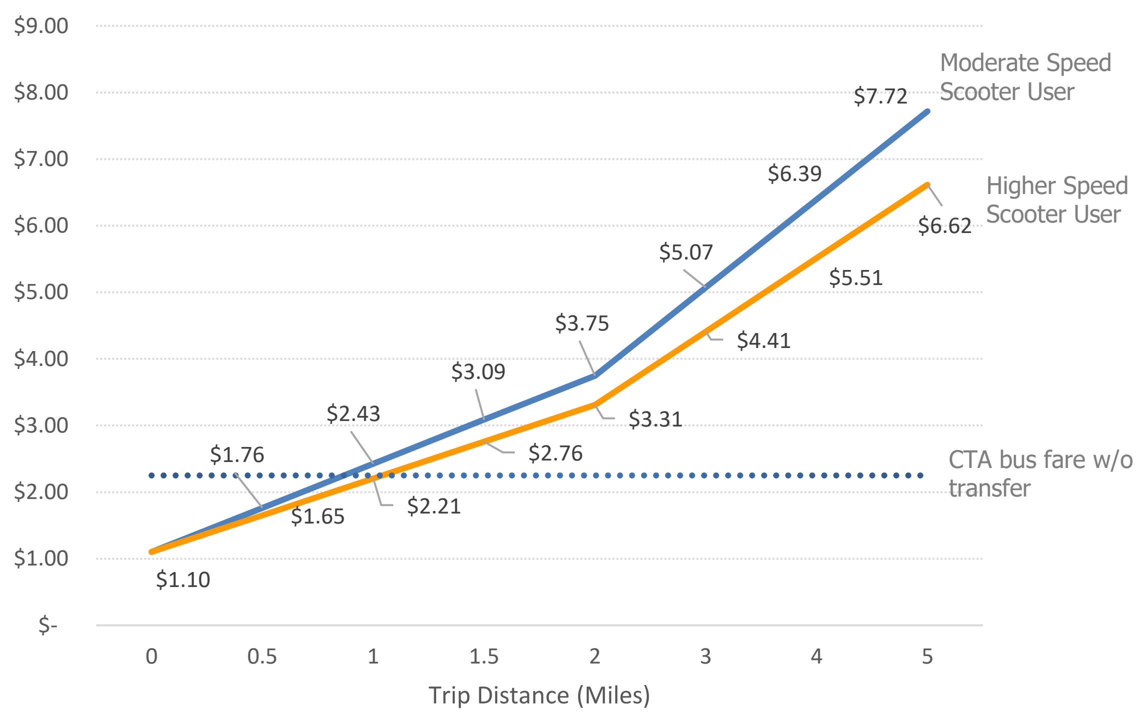
If e-scooters were introduced, between 30 and 39% of routes in the 0.5 to 2 mile range that currently lack a time-competitive alternative to driving would gain such an alternative (based on the S2 scenario). On longer routes, the share is lower primarily due to the attractiveness of Divvy and transit, which are assumed to allow for travel at higher speeds than e-scooters.

Finding III. The approximate amount users would spend per mile, inclusive of the 10.25% rental tax in the city, would likely be around $1.10 per trip plus $1.33 per mile. For urban drivers on short-distance trips, e-scooters would be a more cost-effective alternative to car ownership than ridesourcing or taxis. This creates the potential for increasing the number of car-free households.

The average cost of owning and driving a compact private automobile (including fixed costs such as insurance) is estimated by the American Automobile Association (AAA) to be $0.75 per mile in the United States for an owner who drives 10,000 miles per year. (This rate is higher than the $0.64 per mile for motorists who drive roughly 15,000 miles per year, which it regards as the national average; however, it is appropriate to use the higher $0.75 per mile rate for transportation analysis in Chicago, considering the tendency for city dwellers to drive less than suburban and rural residents.) Importantly, this $0.75 per mile rate assumes the user incurs no parking cost, and it does not take into account the "unproductive mileage" associated with automobile trips, such as accessing and egressing off-site parking areas and return trips after dropping off a passenger at their destination.

When parking, insurance premiums, unproductive mileage, and other costs of having a car in a congested environment are considered, the cost of owning and operating a private automobile in the case study areas easily exceeds $2 per mile for many motorists, even without factoring in costs a motorist may incur by parking at their place of employment.[i]

FIGURE 7. Expected Average Price of Using Shared E-Scooter, Inclusive of 10.25% City Tax



The cost of using an e-scooter for a 1.5 mile trip at moderate speed, inclusive of tax, would be around $3.09, or $2.06 per mile. For a three mile trip, it would be around $5.07 (around $1.69 per mile). Users who ride significantly faster, averaging 9 mph (above the 7.5 mph assumed in the analysis, perhaps due to the ability to use bike lanes on roads with few stoplights) would pay $2.76 ($1.84 per mile) on a 1.5 mile trip and $4.41 ($1.47 per mile) on a three mile trip.

As a result, these e-scooter costs are often similar to or below the $2 per mile average incurred by many car owners. As such, they suggest that scooters would fill a void in short-distance travel options. Our study of Lyft and Uber service noted that these ridesharing services cost much more over short distances, typically in the $4 - $9 per mile range; "ridesplitting" services such as UberPool and Lyft Line cost less, around $2 - $6 per mile. However, the value of the latter is limited on trips of less than two miles, where wait times and intermediate stops can result in slow average speeds. On longer trips, conversely, these ridesharing options provide a much better substitute for car ownership.

This analysis suggests that e-scooters, by offering time-competitive trips at rates per-mile-traveled at or below those of car ownership, could augment a car-free lifestyle that blends transit, carsharing, ridesharing, and Divvy. Conversely, if a resident already owns a car and avoids significant parking costs, e-scooters could still provide an added value of a more hassle-free manner of arriving at their destination.

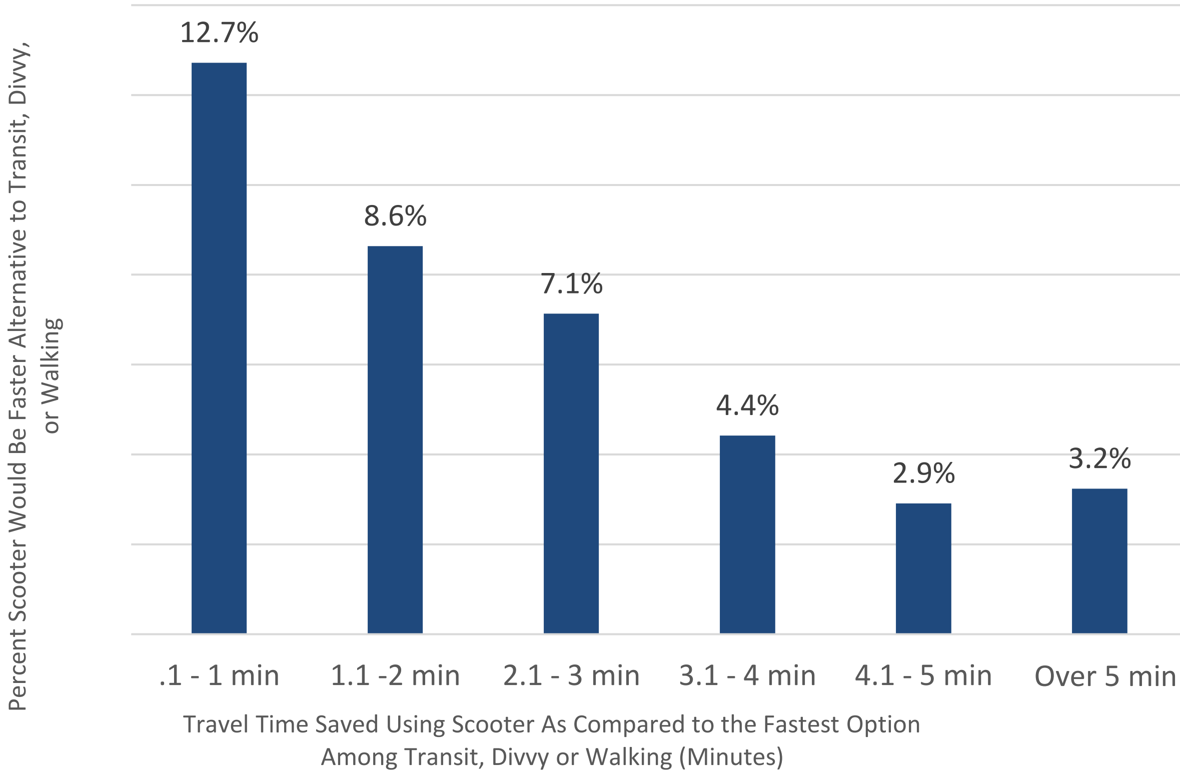
Finding IV. Due to their cost to consumers on longer trips, e-scooters would likely not result in significant diversion from transit on longer distance routes, particularly those serving Chicago's Loop and other core transit markets. On these longer routes, scooters would tend to serve as a first- or last-mile solution, often being used to reach transit stations.

For a moderate speed rider, the total cost for a three mile e-scooter trip, inclusive of tax, based on the assumptions made above, would be $5.07, while a four-mile trip would cost $6.39 (Figure 7). For a faster e-scooter rider, who achieves a 10 mph average speed, the costs would be $4.41 and $5.51, respectively. In either case, the costs are well above the full-fare Chicago Transit Authority (CTA) trips, which cost $2.25 - $2.75. CTA users with monthly passes or who are eligible for discounts pay less or nothing at all.

On these longer trips, Divvy tends to be far less expensive than using scooters as well. For those with a membership, the marginal cost of using a bike for less than a half-hour is nothing. If the $99 annual membership is amortized across 200 one-way trips yearly, the average cost is $0.50 per trip.

USDOT estimates indicate that the average transit user across the country is willing to pay approximately $1 more for each four minutes saved (USDOT, 2016).[ii] Analysis by Northwestern University researchers of the Chicago market yielded similar results (Frei, Hyland, & Mahmassani, 2017). Consequently, a three-mile e-scooter trip costing $5.07 would need to be 10 minutes faster than transit to be cost effective for the typical transit user. Similarly, a scooter trip of this length would need to save at least 20 minutes over Divvy to be cost effective.

FIGURE 8. Time Savings from Using E-Scooters vs. Using Public Transit, Divvy, or Walking on Trips More than Two Miles in North Study Area



Among trips between two and seven miles long in the North study area, only 7% of trips offer more than four minutes of times savings. This is partially the result of the comparative advantages of using Divvy. Few trips in this category save more than the minimum amount typically necessary to justify the added cost of using an e-scooter, suggesting transit diversion on longer journeys will be relatively small.

Based on analysis of the routes in the North study area, few long-distance scooter trips achieve this level of cost-effectiveness:

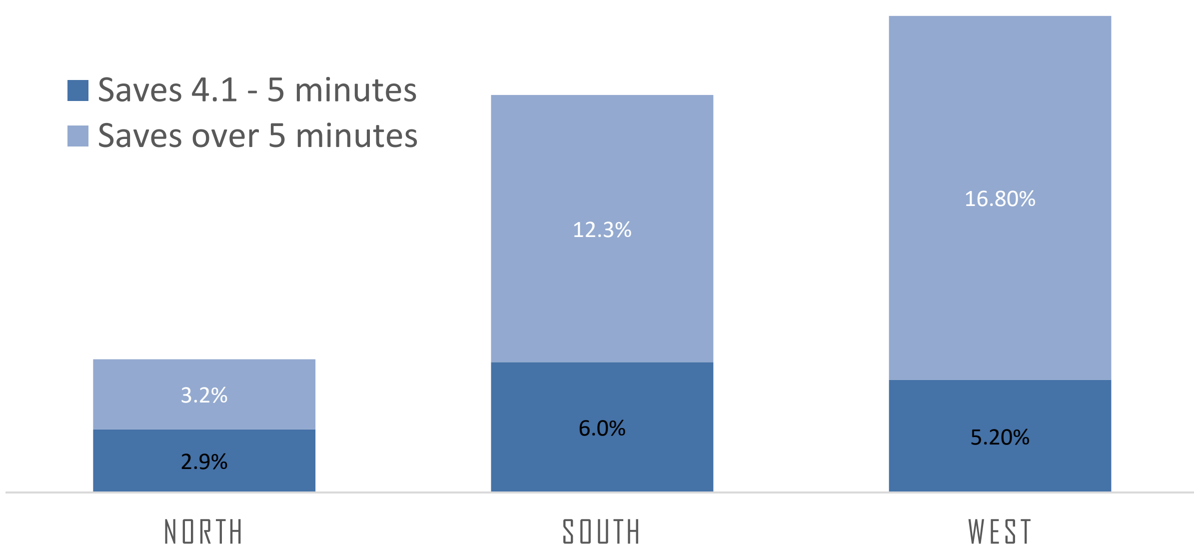
- Among trips evaluated that exceed three miles, in 80% of cases, travelers who use e-scooters for their entire journey (except for the distance they cover walking to the e-scooter) would save less than eight minutes of travel time compared to using transit.

- On no trips over three miles in which an e-scooter is used for the entire journey (except for the short distance covered walking to the e-scooter) would a traveler save more than 12 minutes compared to Divvy, which is generally both a cheaper and faster option for regular users. Similar results were observed in the South and West study areas.

This analysis suggests that, on longer trips, there would not be large scale diversion by regular commuters from transit to scooter-only trips. A more common change would be to use scooters to reach nearby transit stops, in some cases as a substitute for walking or feeder CTA bus service.

A similar pattern emerges when looking at trips over *two miles*. The tendency for e-scooters to save, at most, four or five minutes compared to existing options on trips over two miles is shown in Figure 8 (on previous page) and Figure 9 below. The share of trips in which e-scooters save over *five minu*tes is 16.8% in the West study area, compared to 12.3% in the South and just 3.2% in the North study areas. If a lower four-minute threshold is used, the shares rise to 22.0% in the West, 18.3% in the South, and 6.1% in the North.

FIGURE 9. Share of Trips Over Two Miles in Which E-Scooters Save at Least Four Minutes Relative to Transit and Divvy by Case Study Area

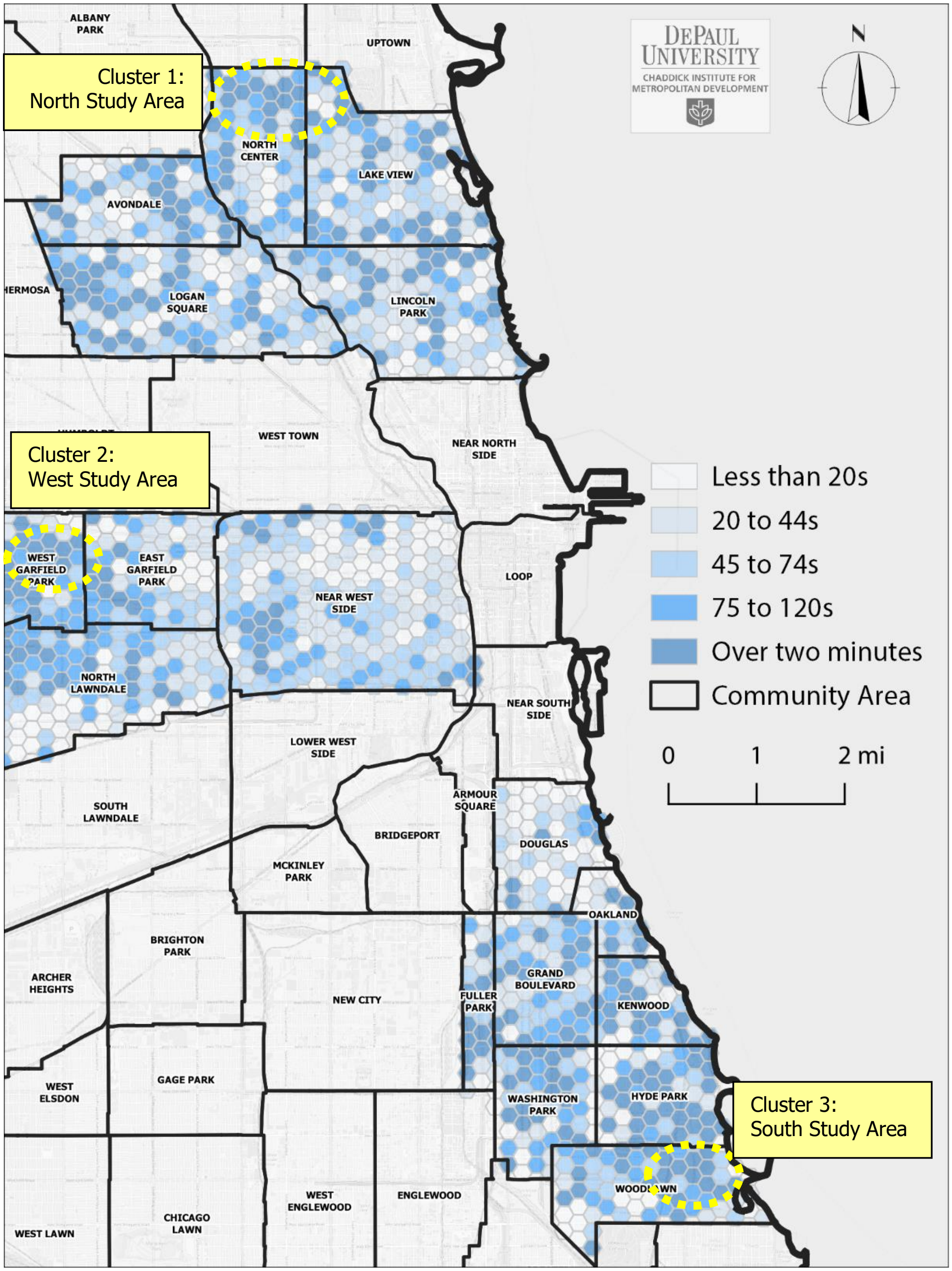


Due to the less extensive network of transit routes and Divvy stations in the South and West study areas, a greater share of e-scooter trips over two miles save over five minutes compared to these modes. E-scooters save at least five minutes 16.8% of the time in the West, compared to 12.3% in the South and just 3.2% in the North. On the preponderance of trips, however, the time savings is too low for most daily commuters to justify the expense.

Finding V. E-scooters fill gaps in the existing network of transportation options for trips to and from Chicago's Loop. The time-saving properties of e-scooters can differ widely between geographic areas that are only a few blocks apart.

To better understand how e-scooters could affect access to downtown, the study examined whether e-scooter rentals would reduce travel times for trips terminating in Chicago's Loop neighborhood. For this, we estimated a variety of mode-specific trips originating from each of the 1,240 origins within the North, West, and South study areas to 55 common destinations within Chicago's Loop neighborhood –

FIGURE 10. Average Time Savings for Trips Originating from Case Study Areas to Loop from the Introduction of E-scooters



This map shows the average time savings on randomly generated trips from geofenced areas to 55 Loop destinations. The darkest areas have the greatest savings, while the clusters are examples with large gains.

the city's predominant economic and cultural district. Figure 10 maps the average travel savings from each case study origin to the 55 modeled destinations within the Loop, where the darker colors represent greater time savings. Most of the time savings is achieved in areas located between rail or bus lines, where e-scooter rentals best connect riders to public transit stops.

The darkest shaded areas reflect areas in which average time savings to the Loop is more than two minutes, whereas the white areas reflect areas with savings less than 20 seconds. The map suggests there are distinct areas in which the gains are greatest. For example, in the North study area, the region surrounding Belle Plaine Street between Damen and Western (Cluster 1) would benefit significantly. In the South study area, the area around 60th Street east of Dorchester (Cluster 3) would also benefit, while in the West study area (Cluster 2), the region along Grand Avenue west of Pulaski could see improved mobility. Given the considerable traffic and congestion into and within the Loop, such time savings have the potential to shift trips from the private auto to public transit and other shared-use modes of transportation.

As is evident in Figure 10, there are many other examples. This mapping tool provides a systematic way to evaluate the benefits of e-scooters throughout various parts of the city.

Finding VI. E-scooters would increase access to about 16% more jobs within 30 minutes in the Loop business district compared to those accessible by public transit and walking. The gains were seen to be largest in the South study area, where the number grows by 37%.

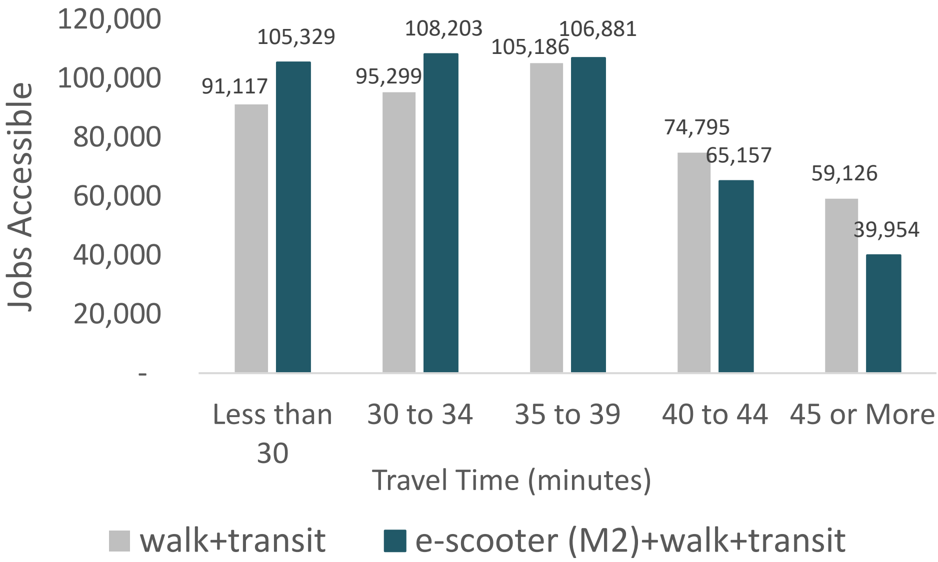
Shorter trips translate into greater employment accessibility. For example, the Loop community area hosts about 425,523 jobs within its borders according to the latest US Census Bureau LODES dataset (2018). Figure 11 shows jobs accessed within predefined time intervals, comparing e-scooter rental trips relative to public transit and walking alone.

This analysis draws upon the accessibility model described in Appendix B, which was also used to measure job access in the Chaddick Institute's 2017 report, *Dimensions of Divvy: Exploring the social, spatial and temporal performance of bikesharing in a period of growth and expansion.* Conventional measures of accessibility have focused primarily on opportunities achieved via the private motor vehicle, and have largely neglected alternative modes of transportation such as public transit and walking. However, this study made use of Chicago's detailed public transit schedule and route information to develop a more nuanced multimodal model of accessibility that accounts for temporal variants in topological public transit networks and periodicity in the patterns of transit accessibility.

Our analysis suggests that residents in the three case study areas could reach 42,742 more jobs (16% more) in 30 minutes and 106,412 more (11%) jobs than could be accessed via walking and/or using transit exclusively. These patterns are more pronounced at the case study level: for instance, when e-scooter rental is added as a transportation option from the South study area, over 37% more jobs are accessible within a 30-minute travel time compared to public transit alone.

FIGURE 11. Accessibility for Public Transit and E-scooter Rental Enhanced Trips by Travel Time Category to Jobs in Chicago's Loop Business District

a. Average Job Access



b. Results by Case Study Area

Results by Case Study Area *Trips by Travel Time Category and Case Study Area*	**Walk + Transit**		**E-Scooter Rental (S2) + Walk + Transit**		
	Percent of Trips	Jobs Accessible	Percent of Trips	Jobs Accessible	% Change in Jobs Accessible
North study area *(N=25,960)*					
Less than 30 minutes	8.4%	70,372	10.3%	84,801	21%
30 to 34 minutes	17.3%	113,204	20.1%	128,172	13%
35 to 39 minutes	24.3%	116,470	26.6%	116,266	0%
40 to 44 minutes	23.1%	75,071	22.1%	62,771	-16%
45 or more minutes	26.9%	50,407	20.9%	33,513	-34%
West study area *(N=22,165)*					
Less than 30 minutes	26.4%	159,232	28.7%	171,795	8%
30 to 34 minutes	17.1%	85,445	18.6%	90,455	6%
35 to 39 minutes	19.6%	86,211	20.5%	86,424	0%
40 to 44 minutes	16.5%	56,903	15.5%	50,739	-11%
45 or more minutes	20.3%	37,731	16.7%	26,110	-31%
South study area *(N=20,075)*					
Less than 30 minutes	12.3%	42,738	15.8%	58,488	37%
30 to 34 minutes	17.6%	83,026	20.8%	101,973	23%
35 to 39 minutes	22.6%	111,543	23.8%	117,332	5%
40 to 44 minutes	20.0%	94,194	18.3%	84,161	-11%
45 or more minutes	27.5%	94,022	21.3%	63,569	-32%

These figures show how e-scooters increase the number of Loop jobs that are accessible at various time intervals. Travel times shift to the shorter time ranges from the longer ranges. The shift is greatest in the North and South areas.

Conclusions

Mobility leaders have an expanding menu of options to address congestion, air pollution, and overall quality of life in their communities. Managing these options, however, is increasingly challenging due to the quickening pace of innovation, the scarcity of data, and pressures for implementation and analysis of how new transportation modes function within a multimodal network. This report developed tools to compare the performance of mobility options that are appearing in urban areas across the country, using Chicago and its neighborhoods as case studies.

The study team made attempts to account for the variety and diversity of Chicago's transportation system. Nevertheless, several simplifying assumptions were made to improve the applicability and interpretation of model results. Although the model explores the impacts of differing distributions of bicycle and e-scooter rentals, it does not account for a variety of factors that are known to affect demand, such as demographic factors, land use, and the quality of streets. Nor does it consider how performance changes under differing levels of traffic congestion.

The analysis presented here should *not* be read as a feasibility assessment of a proposed e-scooter implementation plan. A variety of urban planning challenges posed by e-scooters are already well known; for example, e-scooter systems rely on sidewalks and other public rights-of-way for scooter parking, and they may create safety challenges in dense environments. Furthermore, their prevalence would likely be complementary to transit in some situations and competitive in others, with certain transit routes (particularly bus lines oriented toward short-distance trips) being affected by diversion to scooter use. This study does not explore the likelihood or severity of such potential challenges; instead, the analysis was conducted only to assess the potential citywide mobility benefits of e-scooters if they were made available via an open public mobility system.

Several findings from the analysis stand out:

- **Attractive option for short trips**: Travelers making trips between a half mile and two miles would likely accrue the largest benefits from e-scooters. On these routes, e-scooters – filling a particularly large void resulting from the limitations of existing transportation options – could help foster more car-free living. E-scooter trips are generally faster than those on Divvy over this distance range, particularly at the low end of this range, due to the time required to walk to and from bikeshare stations, which can be located a considerable distance away. Ridehailing services, conversely, offer door-to-door service but are too costly for most urban travelers to use daily, having per-mile costs at least twice that of e-scooters.

- **Less important for the long haul**: Longer scooter trips, especially those over three miles, are generally too expensive to be workable for the typical urban travelers. The amount of time saved is generally insufficient to justify the additional amount paid compared to Divvy and transit. Although there would certainly be some exceptions, most travelers making trips of more than three miles would use scooters primarily to access bus and train stops.

- **First/last mile mobility**: A notable benefit of e-scooters is filling in the gaps in neighborhoods due to their differing juxtaposition to transit and bikeshare options. The potential time savings was found to vary significantly between places only a few blocks apart, largely based on proximity to transit stops and Divvy docks. E-scooters could help those living farther away from such stations access them more readily, thereby encouraging multimodal trips.

- **Improved job access**: E-scooters would enhance access to employment centers, particularly to jobs in Chicago's Loop business district. A higher share of jobs could be reached within 40 minutes, providing benefits even to those who use scooters only sporadically to deal with schedule issues.

By advancing understanding of the relationships between e-scooters and mobility, these results can help set the stage for an informed discussion on this emerging micro-mode of transportation.

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[i] An urban car owner who drives 4,000-10,000 miles per year, markedly less than the national average of 15,000, spends between $1.55 and $3.57 per mile, respectively, based on relatively conservative assumptions. This estimate is based on an American Automobile Association estimate of the fixed costs (insurance, depreciation, financing, registration, and taxes) for owning a Toyota Camry, with an upward adjustment on insurance (an additional $250/year to account for urban conditions, which brings the cost to $1,000 during the first year of ownership). This estimate also assumes that 15% of vehicle mileage is unproductive (e.g., return trips after dropping off passengers, altering routes to avoid congestion, and driving to find parking). It does not include costs from parking at locations away from the owner's place of residence, traffic tickets, and vehicle cleaning. It also uses AAA estimates that place variable costs at $0.1776 per mile (fuel, maintenance, tire wear), the estimate for a medium sedan.

[ii] For a discussion of the estimated value the typical transit user places on travel time using the USDOT estimates, see page 12 of our 2018 study, *Uber Economics: Evaluating the Monetary and Nonmonetary Tradeoffs of TNC and Transit Service in Chicago, Illinois*. The study uses a $14.95/hr. estimate on the average value of time savings, which equates to approximately one dollar per four minutes saved.

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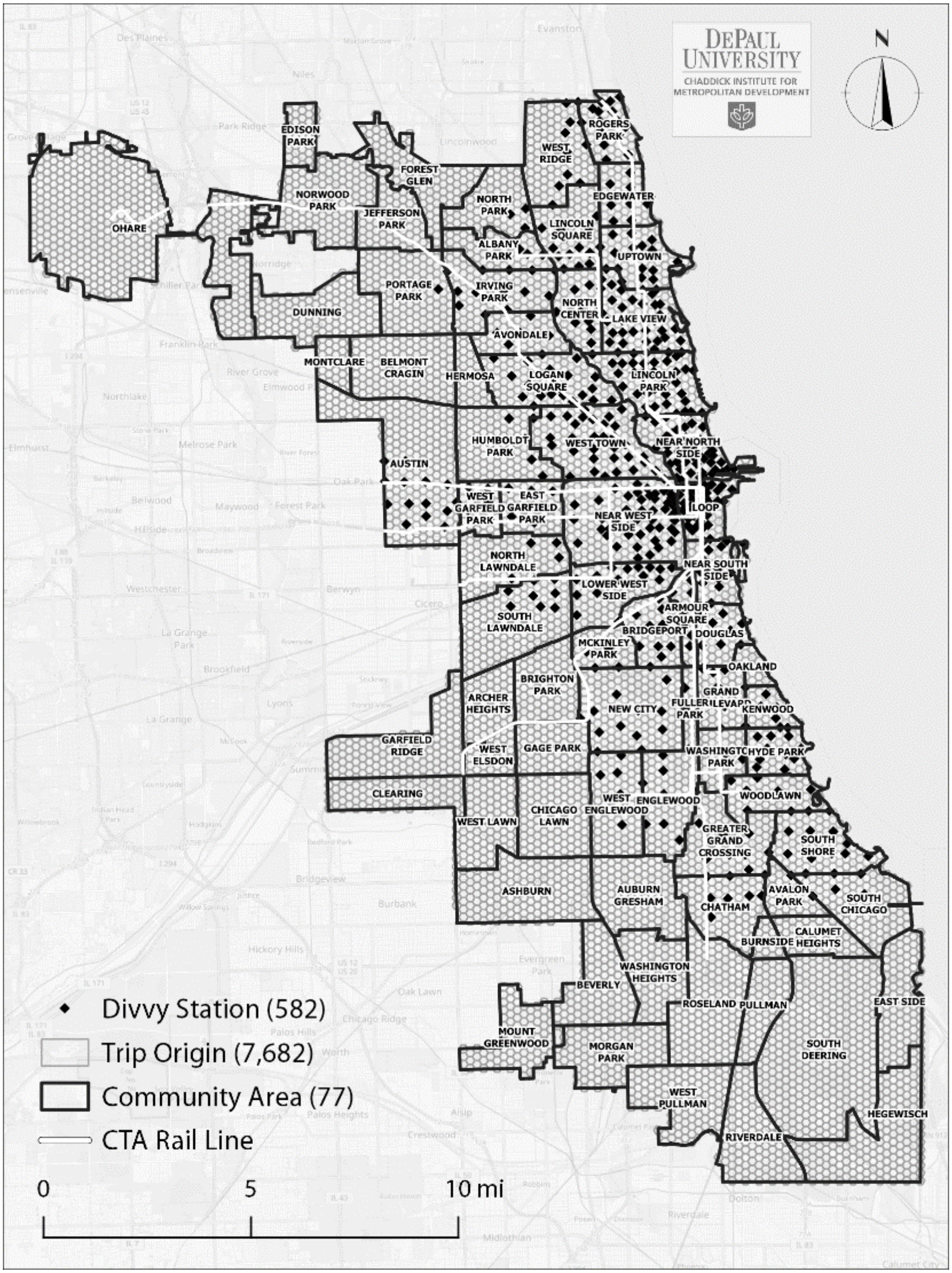
Appendices

Appendix A: Hexagonal Areas Used as Trip Origins



This map shows the hexagonal grid used to randomly select trip origins and destinations in the multimodal travel models. Chicago's community areas, CTA rail lines, and Divvy stations are also shown.

Appendix B: Citywide Multimodal Accessibility Model and Results

The authors developed a citywide transportation model of Chicago's existing modes in part to estimate the degree to which the Divvy bicycle rental program enhanced accessibility over public transit and walking alone. Toward this end, we developed three rather general indicators of physical or geographic accessibility, namely:

(1) ***neighborhood accessibility***, or the degree to which each origin location has access to other neighborhoods in the city;

(2) ***employment accessibility***, which measures the degree to which each origin location has access to jobs; and

(3) ***points of interest***, or POI accessibility access, which measures the degree to which each origin location has access to key landmarks such as public parks, schools.

To account for geographic variations in modal performance, we calculated the three categories of accessibility for 7,682 trip origin locations spaced at ¼ mile intervals across the city based on a regular, hexagonal grid. Trips were constrained to a maximum, 30-minute travel time threshold, which approximates an average city work commute.

Summary calculations for the three categories of accessibility are summarized in Table B.1 for trips made during a peak morning commute period, between 7am to 9am. The data, sorted by highest to lowest median accessibility for each index, suggests that private, single occupancy vehicles offer a superior level of access, exceeding private bicycles—the second highest performing mode—by three or more orders of magnitude. The table also suggests that adding Divvy bikeshare to the existing public transit network improved the potential for accessibility across the city.

TABLE B.1. Citywide Accessibility Statistics by Transportation Mode

		Min	Max	Median	Mean	std.dev
Neighborhood Accessibility	*Private car*	*1.0*	*4,182.0*	*1,909.5*	*1,886.0*	*843.4*
	Private bicycle	*1.0*	*977.5*	*647.0*	*606.5*	*213.7*
	Divvy + walk + transit	*1.0*	*1,069.4*	*384.6*	*369.6*	*194.4*
	Walk + transit	*1.0*	*523.0*	*89.0*	*138.8*	*103.7*
	Walking	*1.0*	*105.5*	*79.0*	*71.2*	*21.2*
POI Accessibility	*Private car*	*0*	*3,926.0*	*1,435.8*	*1,462.5*	*978.5*
	Private bicycle	*0*	*2,699.0*	*209.5*	*475.3*	*616.0*
	Divvy + walk + transit	*0*	*2,067.8*	*61.5*	*199.2*	*321.3*
	Walk + transit	*0*	*2,011.5*	*24.5*	*197.6*	*374.8*
	Walking	*0*	*1,049.0*	*15.5*	*57.7*	*114.1*
Job Accessibility	*Private car*	*0*	*944,971.0*	*418,817.3*	*382,472.5*	*234,812.1*
	Private bicycle	*0*	*811,012.5*	*43,051.0*	*107,738.0*	*168,006.8*
	Divvy + walk + transit	*0*	*720,829.0*	*14,315.8*	*45,699.0*	*92,989.8*
	Walk + transit	*0*	*692,318.9*	*6,514.3*	*45,012.3*	*111,936.8*
	Walking	*0*	*543,448.0*	*4,725.0*	*13,329.7*	*45,871.2*

Such gains are most pronounced at the neighborhood level. Figures B.1a-b thematically map employment accessibility by trip origin with high performing locations displayed in red and lower accessibility areas in dark blue. Figure B.1a represents job accessibility for public transit (both CTA bus and "L" rail) and walking trips during a two-hour peak AM period with a maximum total walking distance of a ½ mile and maximum travel time of 30 minutes whereas B.1b adds Divvy bikeshare. The bikeshare system, although geographically constrained, enables greater connections to public transit at the beginning and end of trips (first and last mile) and, sometimes, both. Adding Divvy bicycle rental through the distribution of over 580 stations and 6,000 bicycles across the city improved access to employment in many areas, with an estimated 17 percent of the city experiencing job accessibility gains of 25 percent or more (hexagons indicated with black outlines in Figure B.1b). Neighborhoods with Divvy bicycles located between CTA rail and bus lines—in transit gaps—show the greatest gains due to improved opportunities for making public transit connections, such as Bridgeport and Douglas—both of which have accessibility gains exceeding 40 percent according to our model (Table B.2). In these areas Divvy has the potential to dramatically extend the range of buses and trains, increasing the mobility of workers and access to the labor pool among employers, and perhaps even increasing transit ridership.

FIGURES B.1a-b. Increase in Average Public Transit Employment Accessibility by Adding Divvy Bike Rental

B1a. Walk + Public Transit *B1b. Walk + Public Transit + Divvy*

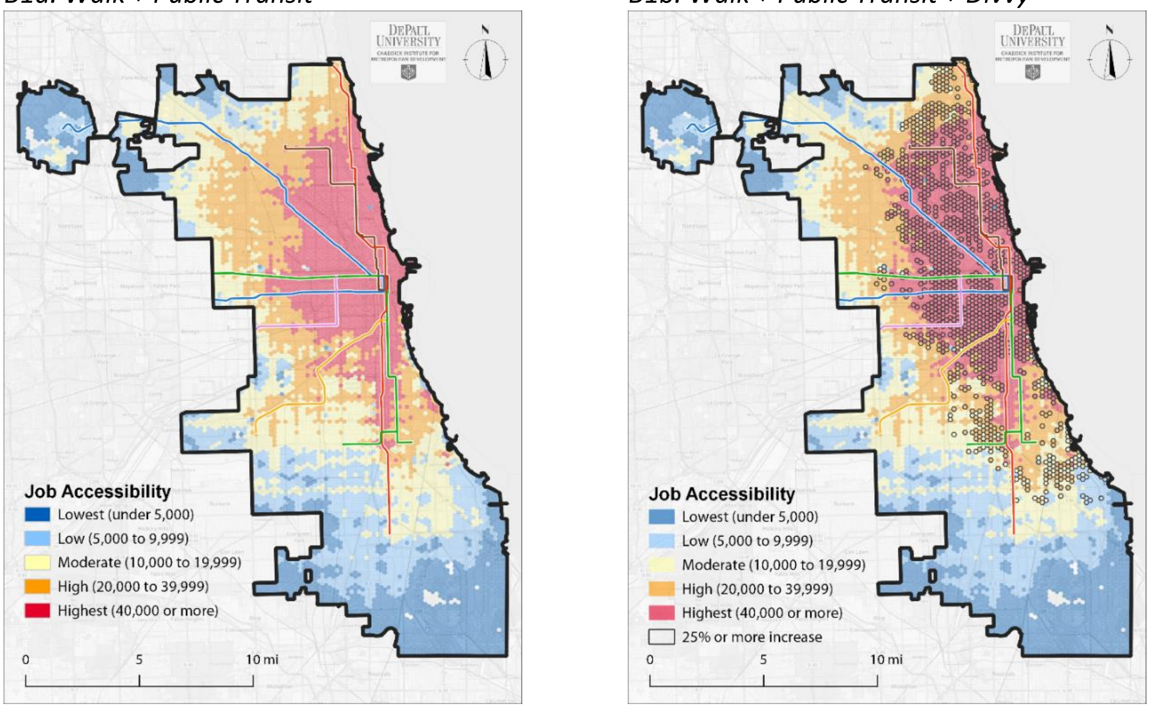
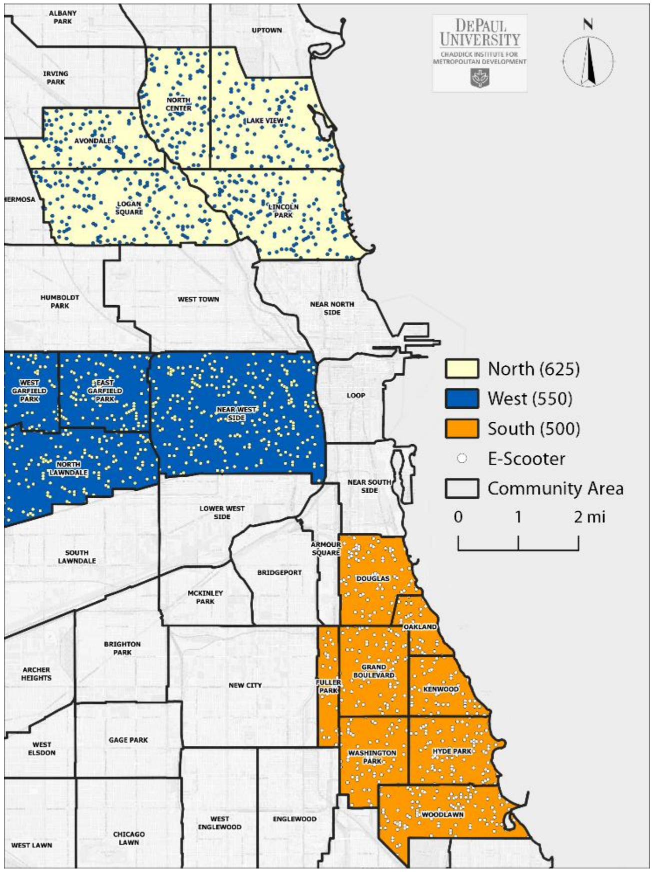


TABLE B.2. Divvy Bikeshare Accessibility Gains for Select Community Areas

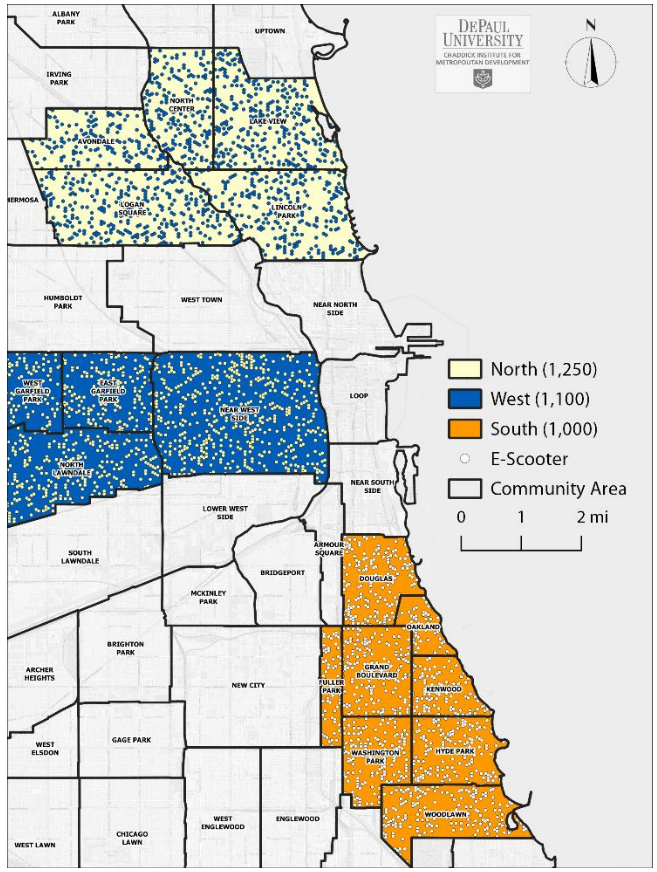
	Neighborhood Accessibility		POI Accessibility		Job Accessibility	
Community Area	Walk+Transit+ Divvy	% Increase	Walk+Transit+ Divvy	% Increase	Walk+Transit+ Divvy	% Increase
Bridgeport	640.6	45.1%	328.2	65.6%	118,861.1	72.7%
Lincoln Park	608.5	39.9%	1,443.0	34.8%	306,300.5	43.9%
Near South Side	463.0	39.6%	747.6	43.4%	298,217.0	40.0%
Douglas	492.4	38.9%	357.9	42.0%	124,568.6	43.8%
Uptown	458.7	37.5%	587.3	36.5%	65,521.4	27.8%
Armour Square	657.9	34.0%	623.9	46.1%	259,628.4	49.3%
Kenwood	402.9	33.2%	263.1	30.2%	47,483.2	30.4%
Near North Side	570.6	32.4%	1,618.2	23.2%	491,964.0	23.4%
Lincoln Square	557.8	31.4%	413.6	40.4%	45,082.0	35.7%
Oakland	363.2	30.7%	175.6	53.4%	28,377.5	25.6%

Appendix C: Geographic Distributions of E-Scooters by Case Study Area and Scenario

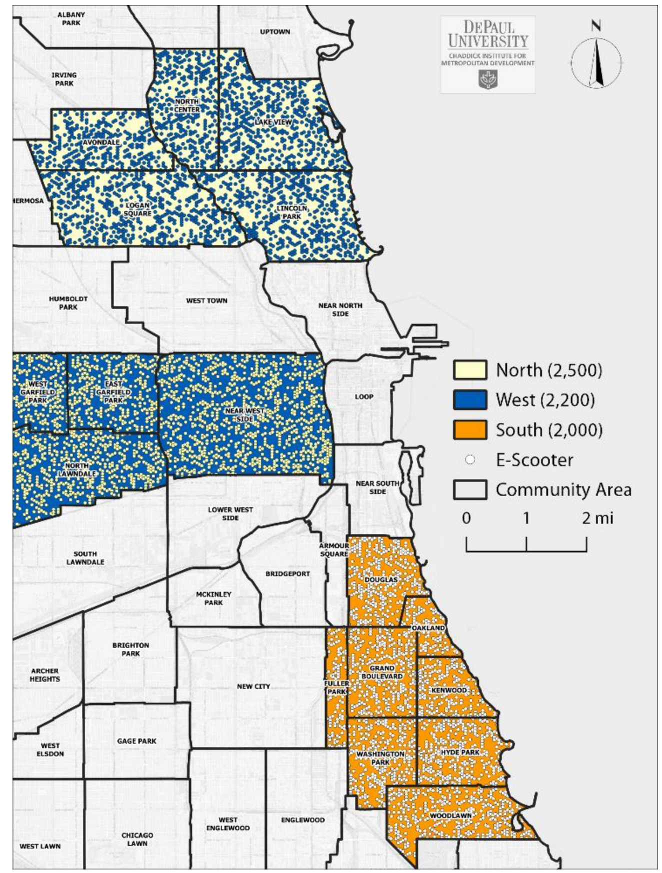
S1. Lower Density Scenario



S2. Moderate Density Scenario

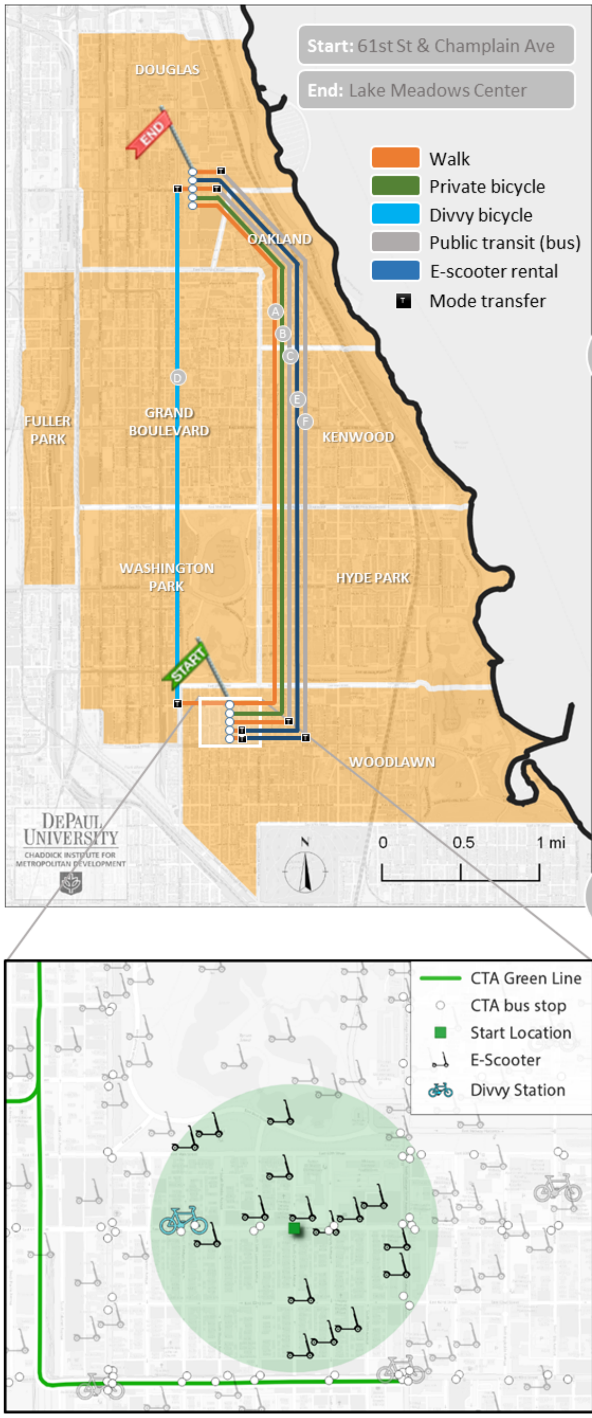


S3. Higher Density Scenario



Appendix D: Modeled Travel Summaries by Transportation Mode

The transportation model used in this study estimates travel times for different travel options. Displayed on the right are possible routes from a common origin (61st and Champlain) and destination (Lake Meadows Shopping Center) using different combinations of walking, bikeshare, e-scooter rental and public transit. Refer to the trip summaries (right) to compare respective travel times and walk distances.



A

Start: 10:18am 12/11/2018

Walk 3.68 miles to destination

End: 11:34am 12/11/2018

Trip Summary
Time 1hr, 16 minutes
Walk Distance 3.68 miles

B

Start: 10:18am 12/11/2018

Bicycle 3.68 miles to destination

End: 10:38am 12/11/2018

Trip Summary
Time 20 minutes
Walk Distance 0 miles

C

Start: 10:18am 12/11/2018

Walk 0.2 miles to Cottage Grove & 61st St

Board CTA #4 Bus Arrive at 35th St & Cottage Grove 10:46am

Walk 0.14 miles to destination

End: 10:49am 12/11/2018

Trip Summary
Time 31 minutes
Walk Distance 0.34 miles

D

Start: 10:18am 12/11/2018

Walk 0.21 miles to Eberhart & 61st St

Rent bicycle at Divvy station at 10:18am Ride 3.46 miles to Calumet Ave & 35th St

Walk 0.23 miles to destination

End: 10:52am 12/11/2018

Trip Summary
Time 34 minutes
Walk Distance 0.44 miles

E

Start: 10:18am 12/11/2018

Walk 92 feet to 61st & Langley Ave

Scooter 3.6 miles to destination

End: 10:47am 12/11/2018

Trip Summary
Time 29 minutes
Walk Distance 0.02 miles

F

Start: 10:18am 12/11/2018

Walk 92 feet to 61st & Langley Ave

Scooter 0.21 miles to Cottage Grove & 61st St

Board CTA #4 Bus Arrive at 35th St & Cottage Grove 10:46am

Walk 0.14 miles to destination

End: 10:49am 12/11/2018

Trip Summary
Time 31 minutes
Walk Distance 0.22 miles

References

Center for Neighborhood Technology (2016). Transit Deserts in Cook County. https://www.cnt.org/sites/default/files/publications/CNT_TransitDesertsCookCounty_0.pdf

C. Scott Smith (2017), *Dimensions of Divvy: Exploring the Social, Spatial and Temporal Performance of Bikesharing in a period of Growth and Expansion.* Chaddick Institute for Metropolitan Development, DePaul University.

Chicago Transit Authority (2017). Annual Ridership Report: Calendar Year 2017. https://www.transitchicago.com/assets/1/6/2017_CTA_Annual_Ridership_Report.pdf

Clewlow, R., Kulieke, S. (2017). *Disruptive Transportation: The Adoption, Utilization and Impacts of Ride-Hailing in the United States*. Institute of Transportation Studies, University of California, Davis.

Federal Transit Administration (2018). Shared Mobility Definitions, FTA. https://www.transit.dot.gov/regulations-and-guidance/shared-mobility-definitions. Accessed August 1, 2018.

Frei, C., Hyland, M., Mahmassani, H. S. (2017 March 1). Flexing Service Schedules: Assessing the Potential for Demand-Adaptive Transit via a Stated Preference Approach. Transportation Research, Part C (76). 71-89.

Metropolitan Area Planning Council (2018 February). Fare Choices: A Survey of Ride-Hailing Passengers in Metro Boston. https://www.mapc.org/farechoices/

Murphy, S.F. C. (2016). Transit Cooperative Research Program, Transportation Research Board, and National Academy of Sciences, Engineering and Medicine.

National Academies of Sciences (2018). Broadening Understanding of the Interplay Among Public Transit, Shared Mobility, and Personal Automobiles. http://www.trb.org/Publications/Blurbs/177112.aspx

Oei, S. Y., Ring, D. (2016). Can Sharing Be Taxed? Washington University Law Review, 93(4). 989-1069.

Schaller, B. (2017 December 21). Empty Seats, Full Streets: Fixing Manhattan's Traffic Problem. http://schallerconsult.com/rideservices/emptyseats.htm. Accessed Jul. 30, 2018.

Schwieterman, J. P. (2018). Sharing the Ride: A Paired-Trip Analysis of UberPool and Chicago Transit Authority Services in Chicago, IL. *Journal of the Transportation Research.*

Schwieterman, J.P., Pelon, M. (2017). *First Zipcar, Now Uber: Legal and Policy Issues Facing the Expanding "Shared Mobility" Sector in US Cities*. Publication ID 2978726. Social Science Research Network, Rochester, NY.

US Census Bureau (2016). American Community Survey Content Test: Journey to Work. https://www.census.gov/library/working-papers/2017/acs/2017_McKenzie_01.html. Accessed Aug. 1, 2018.

US Department of Transportation (2016 September 27). Memorandum: Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis.

Final Version: 12/12/18 10 a.m. CST