TRANSPORTATION NETWORK COMPANY (TNC) RIDEHAILING TRAVEL PATTERNS IN CHICAGO'S ECONOMICALLY DISCONNECTED AREAS

by

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ABSTRACT

TRANSPORTATION NETWORK COMPANY (TNC) RIDEHAILING TRAVEL PATTERNS IN CHICAGO'S ECONOMICALLY DISCONNECTED AREAS

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Transportation network companies (TNCs) like Uber and Lyft position themselves as a complement—rather than a detriment—to existing public transportation. Since the launch of TNCs, however, public transit ridership in major cities has steadily declined. This severely impacts economically disconnected residents, who often do not own automobiles and therefore rely on public transportation. The decline of public transit, coupled with the growth of TNCs, thus begs the question: *Do TNC services complement or substitute public transportation in serving economically disconnected urban residents?* Using data from the American Community Survey and new TNC data from the City of Chicago, this paper maps the destinations of rides originating on Chicago's Far South Side to analyze travel patterns of low-income individuals. The paper concludes that TNCs are a first mile/last mile solution for the economically disconnected and asks policymakers to improve high-quality transit service and consider public-private partnerships in transit-poor areas.

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LIST OF ABBREVIATIONS

ACS	American Community Survey
CMAP	Chicago Metropolitan Agency for Planning
EDA	Economically Disconnected Area
FMLM	First Mile/Last Mile
TNC	Transportation Network Company (also referred to as Transportation Network Provider)
TNP	Transportation Network Provider (also referred to as Transportation Network Company)
VMT	Vehicle Miles Traveled

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I. Introduction

When first launched in the early 2010s, transportation network companies (TNCs) like Uber and Lyft pitched themselves to city officials as a complement—rather than a detriment—to existing public and private modes of transportation. Ostensibly, these applications served to keep drunk drivers off the road (Uber Blog 2014; Brazil and Kirk 2016; Young and Farber 2019) and to close the gap in areas where public transit wasn't efficient (Uber 2020b; Shaheen and Chan 2016). Further, these services have long been provided at a relatively low cost compared to traditional taxis, thanks to large infusions of venture capital and reliance on contract labor.[1] These low costs, coupled with the flexibility of an app-based service, have led to the explosion of ridehailing's[2] popularity worldwide. As of April 2019, Uber and Lyft boasted 91 million and 18.6 million global users respectively (O'Donnell 2019).

At the same time, public transit ridership in major cities has been on a long and steady decline (Graehler, Mucci, and Erhardt 2019; CTA 2017; CTA 2019). This is particularly bad news for low-income urbanites, many of whom live in economically disconnected areas, or areas that "have higher than regional average concentrations of low-income households and minority...populations" (CMAP 2018a, 1). These individuals often do not own personal vehicles and rely on public transportation to commute to work and other activities (Glaeser, Kahn, and Rappaport 2008; Greenfield 2016; CMAP 2018b). Further, they are more likely to live in transit deserts than their higher-income counterparts, areas with "greater demand for mass public transportation than availability" which portend "an imbalance of transportation options within

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[1] This may change in the near future, now that both Uber and Lyft have gone public and California has passed legislation that mandates treating gig workers like employees (Conger and Scheiber 2019).

[2] There is no consensus in the literature as to which term to use: ridesharing, ridehailing, and ridesourcing are all used interchangeably. Throughout this paper, I refer to the activities of TNCs like Uber and Lyft as "ridehailing," and pooled services like Via, UberPool and Lyft Line as "ridesharing."

the same metropolis" (Allen 2018, 2). These areas lack access to high-quality transit—heavy rail or bus rapid transit—which forces those transit-dependent individuals to rely on infrequent or patchy bus service (CNT 2014, 1). The decline of public transit and the geographic imbalance of service, coupled with the continued growth of TNCs, thus begs the question: *Do TNC ridehailing services complement or substitute public transportation in serving economically disconnected urban residents?*

Because TNCs are still relatively new (both Lyft[3] and Uber[4] emerged in the early 2010s), literature on ridehailing only dates back a few years. Early TNC adopters were generally young urban professionals (see Rayle et al. 2016, among others) but, as this study demonstrates, TNC riders are economically diversifying as the augmentation of service coverage and popularity continues. Ridehailing writ large not only siphons users away from taxis, but can also replace other modes of transit, including public transit and driving a personal vehicle (Rayle et al. 2016; Clewlow and Mishra 2017; Graehler, Mucci, and Erhardt 2019; Jin et al. 2018). This replacement leads to declining public transit ridership (CTA 2019; Graehler, Mucci, and Erhardt 2019) and may portend a public transit "death spiral," where declining ridership prompts service cuts, which in turn drives down ridership further, and so on. Given the documented reliance of low-income individuals on public transportation (e.g. Glaeser, Kahn, and Rappaport 2008; Minocha et al. 2008; CMAP 2018b), we can predict that, if these trends continue, the economically disconnected will be disproportionately affected.

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[3] In 2012, the carsharing application Zimride expanded operations to a new ridesharing arm called Lyft, which provided shorter length trips in the city of San Francisco. Just over a year later, Zimride co-founders Logan Green and John Zimmer sold Zimride to car rental company Enterprise in order to focus solely on Lyft (Greiner et al. 2019).

[4] Uber was originally known as UberCab, a service that connected commercially licensed livery drivers with riders San Francisco. The company shortened its name to Uber in 2010, after the California Public Utilities Commission and the City of San Francisco both issued cease-and-desist orders to UberCab, citing the company's similarities with a traditional taxi service. Uber then launched its UberX service to compete with Lyft in 2012 (Flores and Rayle 2016, 3759).

New data can help us estimate the actual effects of TNCs. Though early studies on ridehailing relied on methods like intercept surveys rather than hard data from TNCs themselves, more stringent regulation in cities like Chicago have required the collection and public dissemination of TNC travel data. This in turn allows researchers to conduct more accurate analyses of TNC travel patterns. In April 2019, the City of Chicago publicly released anonymized data on individual trips taken through use of ridehailing apps Uber, Lyft and Via[5]. The data is updated quarterly. (See Appendix A for information on how rider data is collected and anonymized.) Analyzing the volume of rides over time, TNC users' trip origins and destinations, how long it takes them to arrive, and the cost of rides can reveal how TNCs are actually used today—and how TNC services complement or substitute public transit services. Not only is this study one of the first to use this new TNC data, it also closes an important gap by focusing on TNC users who have thus far been omitted from the literature: low-income individuals and people of color.

In this exploratory study, I analyze the destinations of TNC rides that originate on the Far South Side of Chicago, an economically disconnected area and a site of several transit deserts, in order to determine riders' current travel patterns and address the research question. The paper proceeds as follows. I begin with a literature review, focusing on the limited existing literature on TNCs, the effects of TNCs on public transportation ridership, and the reliance of the urban poor on public transportation across the United States. I then segue into sections on data and methodology, reviewing the datasets and GIS methods used to conduct a geospatial analysis of TNC travel patterns on the Far South Side of Chicago. I hypothesize that low-income riders use

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[5] While Uber and Lyft are more "traditional" TNCs, Via is a shared service that offers transportation from predetermined points: "corner-to-corner, not door-to-door" (Via 2020). It functions, essentially, like an on-demand bus.

TNCs as a first mile/last mile (FMLM) solution, particularly in areas that are transit poor. I determine the validity of my hypothesis in the Results section and discuss my additional findings: riders on the Far South Side are not traveling far via TNC and are ridesharing at a much higher rate than the citywide average. I conclude with an exploration of policy implications engendered by my analysis, particularly the case for improving high-quality transit in economically disconnected areas and the possibility of a public-private partnership to facilitate FMLM connections.

II. Literature Review

Early TNC adopters skewed younger, richer and better-educated than the population at large. Researchers have found that ridehailers are generally Millennial-aged (Rayle et al. 2016; Young and Farber 2019; Alemi et al. 2018), well-educated (Rayle et al. 2016; Clewlow and Mishra 2017; Grahn et al. 2019), and well-off (Amirkiaee and Evangelopoulos 2018; Alemi et al. 2018; Young and Farber 2019; Grahn et al. 2019). Further, individuals who have a higher willingness to pay—and the technology and disposable income to do so—use ridehailing more often (Alemi et al. 2018; Grahn et al. 2019). These findings are consistent with the origin stories of both Uber and Lyft, smartphone applications created by white male technology entrepreneurs for their "friends" (Inc 2012). However, Hughes and MacKenzie (2016) determine that access to TNCs is dependent far more on urban density than on service in areas that are considered "white and wealthy" (36). Yet riders who do not fit the typical profile—white, well-educated, well-off—potentially face discrimination when using the technology. For example, Ge, et al. (2016) find that riders with African American-sounding names are twice as likely to be cancelled on than riders with white-sounding names. Overall, this literature indicates that, while these applications were not made with low-income individuals or people of color in mind, these services *are* operated across a diverse array of neighborhoods.

Crucially, TNCs reduce transit ridership. Rayle, et al. (2016) find that TNCs not only siphon users away from taxis but also replace other modes of transit—including public transit and driving a personal vehicle—approximately 50% of the time. Clewlow and Mishra (2017) calculate that 49-61% of users surveyed made trips via TNCs that either could have been made on foot, by bike, or by public transit, or "would not have been made at all" (2017, 2).[6] In their longitudinal study, Graehler, Mucci, and Erhardt (2019) find that TNCs drive down public transit ridership approximately 1.3-1.7% per year, depending on the transit mode. This effect, they say, is "substantial—after 8 years this would be associated with a 12.7% decrease in bus ridership" (2018, 15). Given that early TNC adopters are generally well-educated and well-off, the subsequent loss of their public transit patronage hits municipal systems particularly hard. When economically advantaged members of a public transportation system stop patronizing that system, it shifts the onus of patronization disproportionately onto low-income users, many of whom rely on subsidized public transportation as the only affordable way to get around (Glaeser, Kahn, and Rappaport 2008). The problem with this, of course, is the potential for a public transportation "death spiral": declining ridership leads to service cuts, which in turn leads to declining ridership, and so on into obsolescence.

TNCs reduce transit ridership in part because TNCs are faster than public transportation, particularly buses. Barnes (2005) notes in her study of Gary, Indiana that errands that require the use of public transportation could "consume an entire day" (2005, 165), preempting the use of

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[6] Clewlow and Mishra (2017) further state that 91% of users surveyed have not made any changes to their level of automobile ownership after beginning to rideshare, undermining the notion that ridesharing could reduce personal vehicle ownership.

that time for other, more lucrative pursuits. Schwieterman (2019) compares TNC ridehailing, ridesharing and public transportation in a microeconomic analysis of amount spent per unit of time saved, and determines that passengers in locations poorly served by transit "will likely find TNCs cost-effective" due to the amount of time saved in proportion to the cost of the service (295). In a comparative study of ridehailing travel times versus transit travel times, Young, Allen, and Farber (2020) find that 31% of TNC trips have transit alternatives of similar duration, but most of these TNC trips take place in high density areas during peak travel hours. By contrast, 27% of *all* TNC trips surveyed are at least 30 minutes shorter than their transit alternatives, largely due to transfers and lengthy walks to and from transit connections. This is consistent with Schwieterman and Smith's 2018 findings in a paired-trip analysis of UberPool and Chicago Transit Authority services, wherein they determined that TNC travel *between neighborhoods* reduced trip times 67.6% as compared to public transportation. Overall, TNC travel times are similar to transit trips that do not require transfers or long walks. TNCs can therefore serve as an efficient substitute to public transportation in areas where transit infrastructure is not robust.

TNCs can serve as a solution for the perennial "first mile/last mile" (FMLM) problem facing urban planners. FMLM refers to the gap between "a traveler's origin/destination and a transit station/stop," which is ideally traversed in a short walk (APTA 2020). In cases where the distance is too far or the terrain is unsafe, planners are faced with a problem—one that TNCs may be able to solve. Using the 2017 National Household Travel Survey, Grahn, et al. (2019) find that TNC usage is highest metropolitan statistical areas with high population density (greater than 10,000 people per square mile) and access to a heavy rail transit system. Hall, Palsson, and Price (2018) offer a sound rationale for why this is the case: "rail riders typically have higher incomes, while high-income bus riders might be willing to pay for a pricier Uber ride," driving down bus ridership while acting as a complement to heavy rail (2018, 46). Indeed, Babar and Burtch (forthcoming) articulate a "heterogenous effect" of TNCs: "on average, ride-hailing services have led to significant reductions in the utilization of city bus services, while increasing utilization of commuter rail services" (1). Thus, ridehailing can ostensibly solve the FMLM problem by connecting to high-quality transit like heavy rail, provided that the TNC user can afford the cost of the service.

TNCs could complement transit services in a formalized way. In response to the tension between TNCs and public transit, Stiglic, et al. (2018), Li, Hua, and Huang (2018), and Yan, Levine, and Zhao (2018) have all proposed models of an integrated multimodal system that combines ridehailing and public transportation to reduce overall Vehicle Miles Travelled (VMT). However, each study concludes that such an integrated system is markedly complex and difficult to prove both sustainable and profitable. When implementing a beta version of this type of system called MTransit around the University of Michigan Ann Arbor campus, Yan, Levine and Zhao (2018) found that "replacing low-ridership bus lines with ridesourcing services [i.e. as an FMLM solution] could slightly increase transit ridership while reducing operations costs" (683). The success of this, of course, depends on the size of the populace and geographic area the ridehailing service is serving. In a 2018 policy report, Schwieterman, Livingston, and Van Der Slot find evidence of thirty public-private partnerships between TNCs and municipal governments across North America, at least eight of which have already sunset. These partnerships take a variety of forms, from free rides to local rail stations (Dayton, OH; Centennial, CO), to vouchers in exchange for late-night service cuts (Detroit, MI), to subsidized fares citywide (Monrovia, CA; Innisfil, ON). This report demonstrates that municipal transit authorities are considering TNC subsidization as a stopgap or permanent solution to the twin problems of reduced ridership and service cuts—but given the proportion of partnerships that have already sunset, they are experiencing mixed results.[7]

It is important to consider the mobility of low-income urban residents across the United States. The poor have long experienced low access to automobiles due the significant financial burden of ownership (Blumenberg and Pierce 2012) and maintenance (Barnes 2005). In addition, poor individuals are less likely to hold drivers' licenses, thanks to this reduced access to automobiles as well as high rates of license suspensions caused by minor offenses and nonpayment of civil fines (Pawasarat and Stetzer 1998). Consequently, the urban poor have concentrated in central U.S. cities, where high population density supports public transportation options (Glaeser, Kahn, and Rappaport 2008). Yet in recent decades, many of these individuals have been pushed out of high-quality transit areas by rampant gentrification and redevelopment, forced to move to the suburbs or areas of the central city with poor transit service (Kneebone and Garr 2010; Allen 2018).

Thus, the urban poor have mobility needs that cannot always be met by public transit. These individuals are now opting to use TNCs, even though they face barriers like high cost, access to technology, or potential discrimination. Areas populated by transit-reliant individuals who have poor access to public transportation due to the United States' long history of spatial segregation, suburbanization, and dependence on the automobile are referred to as "transit deserts" (Allen 2018). Transit deserts are notoriously hard to define spatially using strict rules (Jiao and Dillivan 2013), but "ever present once one attempts to move around in them" (Allen

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[7] Consider the case of Innisfil, Ontario. In 2017, town government in Innisfil decided to subsidize Uber rides for residents, so that residents would pay a flat fare of $3-5 CAD. When the service took off, the town was forced to raise fares, and received blowback from residents who exclaimed, "Uber was supposed to be our bus" (Bliss 2019).

2018, 12).[8] Not only are transit deserts home to many low-income individuals, they can also be the sites of employment centers. As numerous studies have shown (e.g. Pawasarat and Stetzer 1998; Glaeser, Kahn, and Rappaport 2008; CMAP 2018b), employment in urban areas is largely decentralized due to low rent for more space thanks to low density. Many employment centers fall outside of a 3-mile radius of a city's central business district and often take significantly longer to reach by public transportation, if they can be reached by public transit at all (Hu and Schneider 2017). This may mean that, for some low-income individuals, the introduction of TNCs provides reliable access to transportation via automobile—and thereby access to employment—for the first time. Given the emergence of low-income TNC users, the relationship between TNCs and public transportation, and the poor's historic reliance on public transit for employment and other opportunities, I am hypothesizing that low-income riders use TNCs as a FMLM solution to connect to heavy rail, particularly in areas that are transit poor.

III. Area of Study and Data Used

This study focuses on Chicago's Far South Side, the southernmost area within the Chicago city limits. For the purposes of this study, I've defined the Far South Side as community areas 44-55 and 70-75, with boundaries as roughly the following: Lake Michigan to the east, South Cicero Ave (IL-50) to the west, 71st Street to the north, and 138th Street (the southern city limits) to the south. The Far South Side encompasses several of Chicago's historic neighborhoods, including Auburn Gresham, Beverly, Chatham, Pullman, and Roseland. See Figure 1 for a map of Chicago's community areas, showing the study area in the spatial context of the rest of the city. The two specific sites of study, which I term the high- and low-quality

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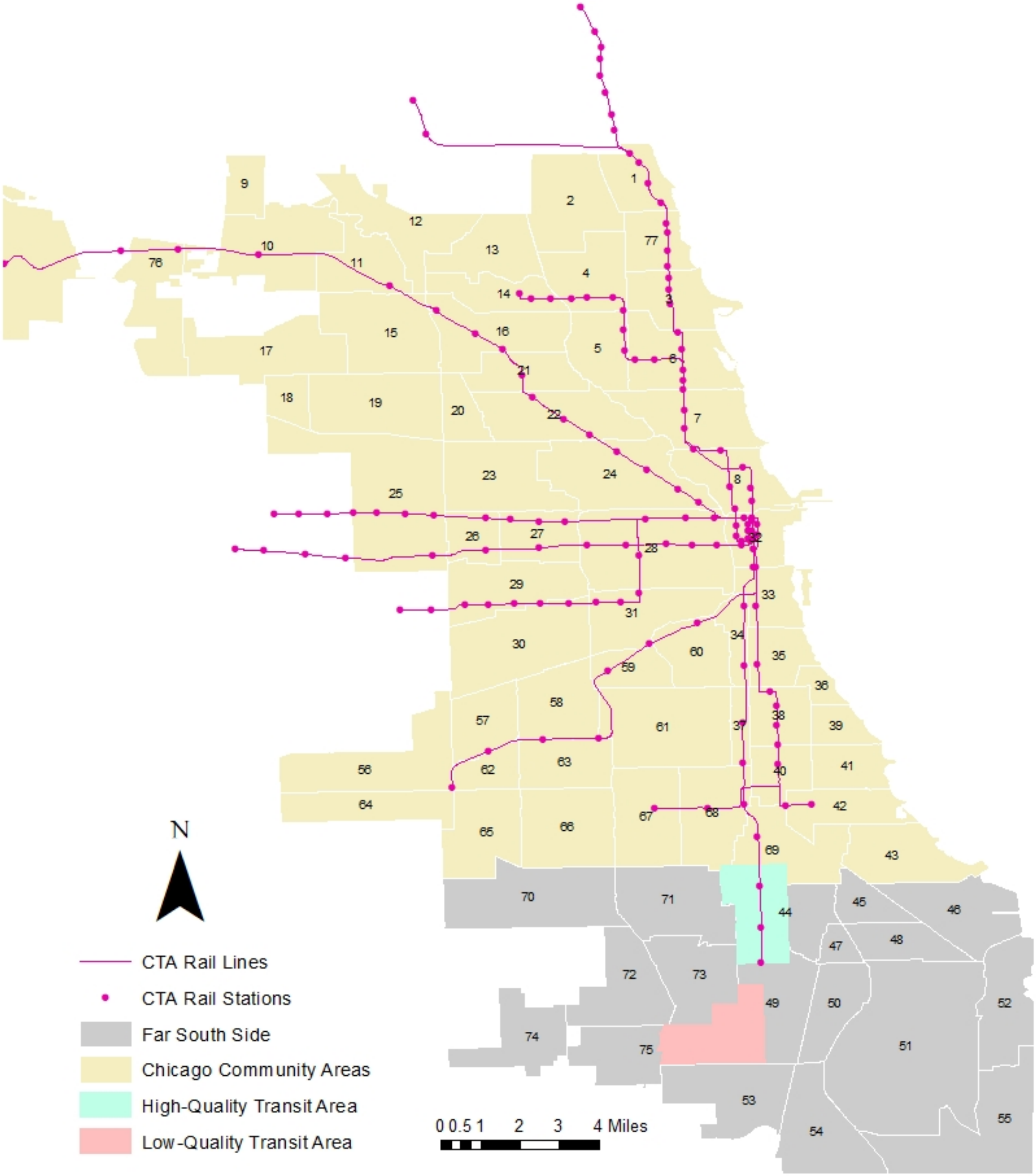
[8] Reliance on public transportation is key in defining a transit desert; suburban areas with high levels of personal car ownership are not necessarily transit deserts.

Figure 1. Map of the Study Area in Context



transit areas and discuss in greater detail in the next section, fall in the contiguous Chatham and Roseland neighborhoods along and directly south of the Red Line.

I chose the Far South Side as the study area for three reasons. First and foremost, residents of the Far South Side are historically dependent on public transportation, despite the fact that much of the area has been deemed a transit desert (CNT 2014). Figure 2 depicts a map of public transportation options on the Far South Side. Though the city boundary extends to 138th Street, the southernmost terminus of the Chicago Transit Authority (CTA) Red Line is at 95th Street, a station which saw an average of 12,000 people per day in 2017 (Hertz 2017). Many Red Line riders reach this station by bus, the predominant form of transit for residents of Chicago's Far South Side "in absence of other options" (Greenfield 2016; see also Addie 2013, 202). Further, the Far South Side is the site of a potential expansion of the Red Line from 95th to 130th Street, but the expansion has been discussed for over half a century without being funded (Sudo 2018).[9] According to the CTA website, the project is projected to require $2.3 billion in capital costs alone (CTA 2020b).

Second, while most of Chicago's historically disinvested South Side has relatively high access to transit through numerous bus routes and access to the Green, Red, and Orange train lines, residents have a low access to *employment* via transit, particularly those job centers that exist outside of the reach of the CTA (Minocha et al. 2008). Studies by organizations like the Chicago Metropolitan Agency for Planning (CMAP) demonstrate that the commute to work takes more time for South Side residents than it does for residents in other areas of the city due to the spatial segregation of the South Side and employment centers (CMAP 2018b). Therefore,

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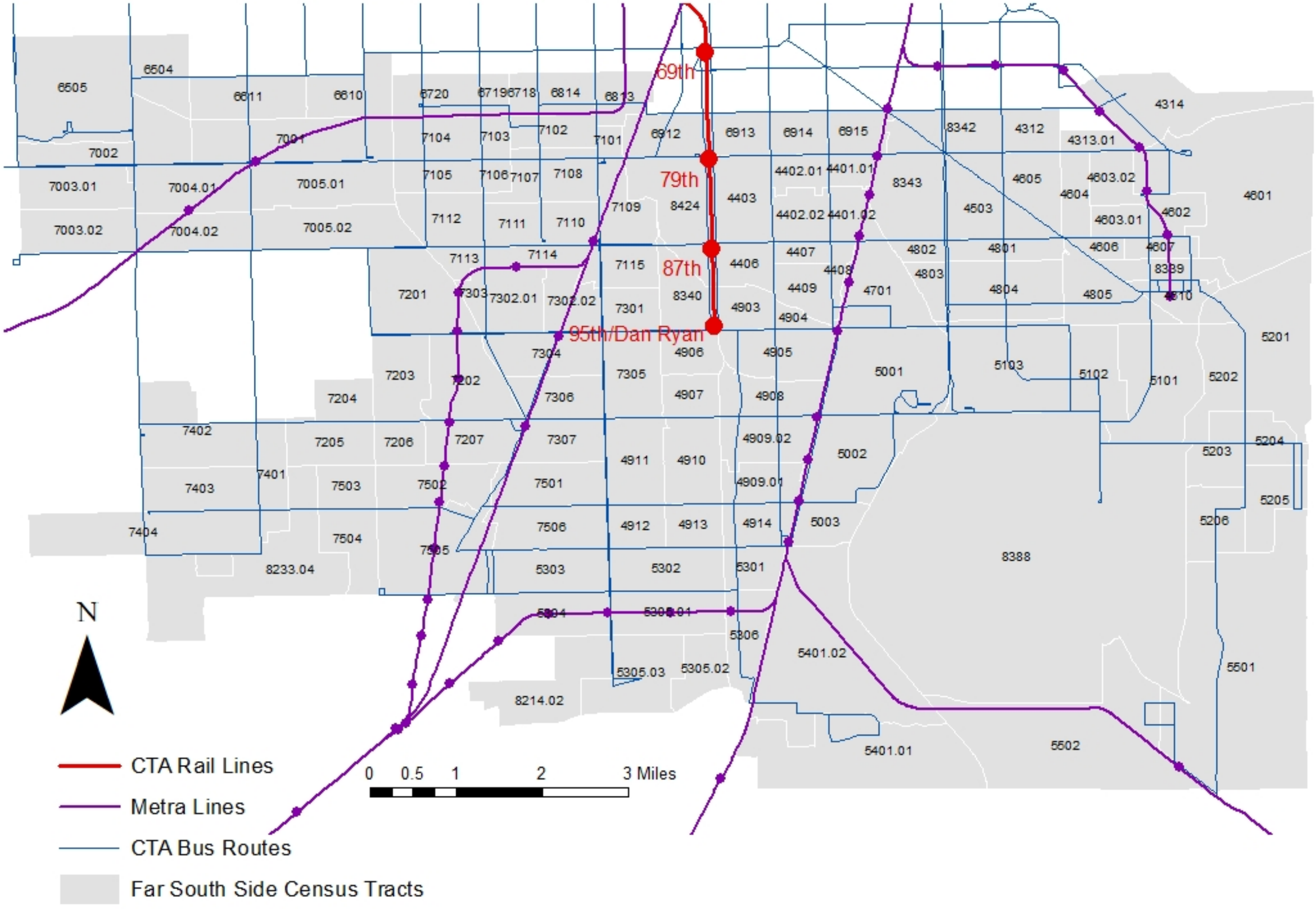
[9] As Farmer (2011) notes, this plan to extend the Red Line to the city limits first came about in the 1950s, when the Far South Side was predominantly white. By the time the City announced that it had run out of funding to complete the project, however, the neighborhood was mostly populated by black residents.

Figure 2. Map of Public Transportation Options on the Far South Side



TNCs can serve a vital purpose for workers living on the Far South Side and commuting elsewhere, either as an FMLM solution or as the sole means of transportation.

Third and final, Chicago's current mayor, Lori Lightfoot, has announced a plan to invest $750 million in Chicago's South and West Sides, $500 million of which is specifically earmarked for transportation improvements (Quig 2019). At the same time, Lightfoot has also refused to increase service or decrease fares for the regional South Side Metra train service (Greenfield 2019), which covers a greater area of the Far South Side than the CTA rail system (again, see Figure 2). This means that, for many Far South Siders, the bus is either the only option or the first step of many to reach the rest of the city. As I discuss later in more detail, inadequate coverage, lack of connections to high-quality transit, and limited hours of service reduce the reliability of these buses and can necessitate the use of other forms of transit.

The CTA has witnessed a continuous system-wide ridership decline since a peak in 2015, four years after Uber launched and two years after the entrance of Lyft. According to the CTA's Annual Ridership Report for 2012, ridership for the entire transit system (buses and trains) increased year-over-year from 1997. In 2016, however, the CTA reported a 3.8% decrease from the prior year, which the agency attributed in part to "competition from rideshare companies like Uber and Lyft" (CTA 2017, iv). Uber and Lyft are cited as cause for decline each year thereafter. For 2018—as of this writing, the most recent annual report available—the City reported that the approximately 106 million TNC trips taken across the city during the calendar year was "equivalent to 44% of CTA bus ridership (242.2m) and 48% of CTA rail ridership (225.9m) and it is more than Metra and Pace combined" (CTA 2019, iv). Metra has similarly experienced declining ridership each year since 2014, which annual ridership reports attribute to low gas prices, fluctuating employment levels, and severe weather, rather than TNC activity (Metra 2020, Metra 2019, Metra 2018, Metra 2017, Metra 2016). Regardless, between November 1, 2018 and October 31, 2019 (the parameters of this study), Chicagoans made over 110 million trips via TNC, according to the Chicago Data Portal. Particularly now that even lower cost options like UberPool, Lyft Line and Via are available, residents of varied economic backgrounds are able to avoid the quirks and challenges of the public system—including long wait times, inconvenient transfers, and safety concerns—by taking TNCs. Yet the fact remains that a decline in public bus and rail ridership across the city of Chicago may endanger the continuity of service, particularly in economically disconnected areas like the Far South Side.

Much like the rest of the city, the Far South Side is experiencing declining public transit ridership since the introduction of TNCs. Figure 3 demonstrates the number of boardings at each of the three Red Line stations that fall within the study area. These boardings are aggregated annually over a ten-year period, 2010 through 2019, from publicly available monthly data and demonstrate a clear downward trend. It should be noted that this graph depicts boardings (i.e. transit card swipes) at each of the three L stations only; because riders do not have to swipe their transit cards to disembark at their destination, evaluation of point-to-point transit is impossible. In addition, the southern portion of the Red Line from Cermak-Chinatown to 95th Street was shut down entirely from May 19 through October 19, 2013 as part of the Red South Reconstruction Project (CTA 2020a). Overall boardings at each of these three stations have continued to decline since Uber's launch in 2011, even after these improvements were made to update train station facilities and reduce travel time on the Red Line.

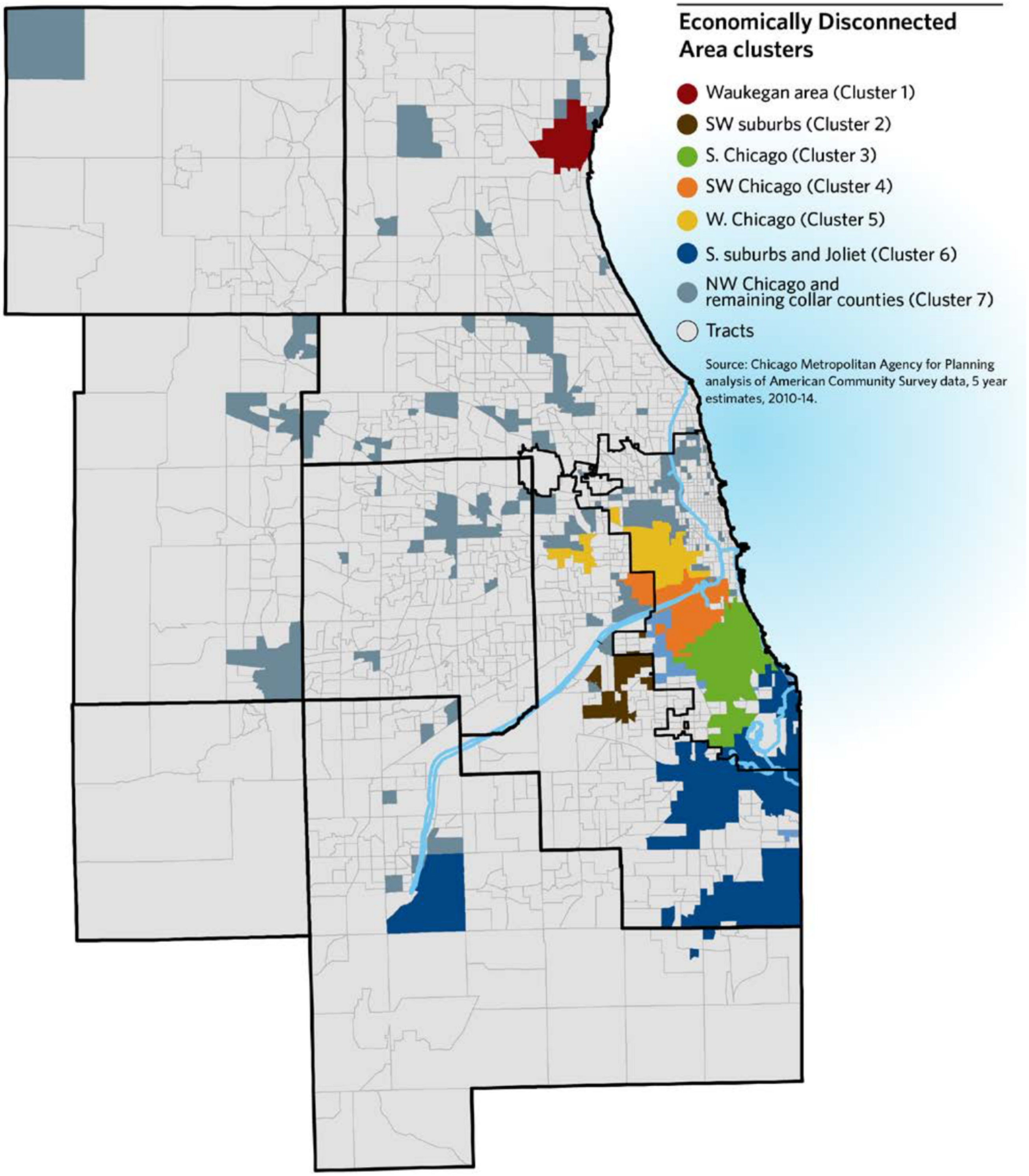
Travel time in economically disconnected areas of Chicago, particularly the Far South Side, is longer than more affluent sections of the city because of the reliance on slower modes of transportation, i.e. the bus. In her discussion of the transportation challenges facing the Far

Figure 3. CTA Rail Boardings on the Far South Side, 2010-2019

South Side, Farmer (2011) says, “In the area immediately south of the current Red Line terminus, 95% of residents are Black and one out of every five households, or 22%, do not have a vehicle available for personal use” based on 2000 Census data (1166). Because of these challenges, “it takes South Side residents 20% longer [in time] on average to get to work than it does for commuters traveling from other parts of the city” (Farmer 2011, 1166). Similarly, a report released by CMAP in January 2018 states that workers in economically disconnected areas within the City of Chicago face statistically longer commutes by time than that of the Chicago region as a whole. (See Figure 4 for a map of Chicago’s economically disconnected areas, courtesy of CMAP.) EDA Cluster #3, the area that encompasses much of Chicago’s South Side, has the longest average commute at 39 minutes, longer than any other EDA and 7.3 minutes longer than the regional average (CMAP 2018b, 5). The report speculates that the lengthier commute can likely be attributed to higher levels of public transit—“particularly bus transit”—ridership, rather than personal vehicle usage (CMAP 2018b, 12).

TNCs may be able to address the problem of long travel time. Though Schwieterman’s aforementioned 2019 study largely focuses on travel patterns across the North and Northwest sides of Chicago, in the small sample he studies on the Southwest Side, he finds that the average TNC trip was “26.3% less time-consuming than transit,” due in part to the high proportion of trips beginning on the Southwest Side that required transfers: 73%, as compared to 56% on the North and Northwest Sides (2019, 302). Further, TNCs can address FMLM considerations that are particularly salient on the South Side, including incidents of violent crime and dangerous pedestrian environmental conditions. If it’s not safe to walk a mile to the train, residents will avoid doing so as much as possible (Tilahun et al. 2016; Allen 2018).

Figure 4. Map of Chicago's Economically Disconnected Areas



Source: Chicago Metropolitan Agency for Planning

But, mobility options via TNCs are still limited due to high costs. Another report by CMAP, released in May 2019 after the City of Chicago's TNC data dump, notes that TNC "rides to and from EDAs are longer and more frequently shared by multiple riders [e.g. UberPool, Lyft Line] than trips outside of EDAs," ostensibly to keep fares low (CMAP 2019, 1). Though Schwieterman (2019) finds that the cost per hour saved is significant for both Lyft Line and UberPool for riders on the Southwest Side of Chicago, as compared to their North and Northwestern counterparts, this is more due to inefficiencies in the CTA system (low coverage and limited schedules necessitate transfers and/or long walks to one's destination) than to efficiency on the part of TNCs. The proportion of rideshares versus private ridehails for the entire city of Chicago is approximately 16.8%.[10] As I will discuss in the Results section, the proportion of shared rides picking up on the Far South Side is much higher, a mode choice that is less reflective of personal preference and more of geographic and economic need.

Overall, riders in economically disconnected areas like the Far South Side are more susceptible to travel mode choice constraints due to limited income, low population density, and other barriers to access (the necessity of a smartphone and a credit card to use a TNC, for example). As mentioned in the introduction, studying the TNC travel patterns of low-income residents and people of color closes a gap in the literature on TNCs by drawing attention to a userbase that has thus far received little emphasis in earlier studies, due to the relatively small numbers of initial TNC adopters in these two overlapping groups. I am therefore focusing on travel patterns on the Far South Side to answer my research question: *Do TNC ridehailing*

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[10] This statistic was calculated directly in the Chicago Data Portal due to the extraordinarily large size of the dataset. Observations that did not fulfill the following conditions were dropped: trip start time begins after midnight on November 1, 2018 and before midnight on November 1, 2019, and both pickup and drop-off census tract are provided. (As the metadata notes, rides that take place outside of Chicago city limits often do not include this location information.) These filter conditions yielded 79,208,159 total rides, 13,337,752 (or approximately 16.8%) of which were shared.

services complement or substitute public transportation in serving economically disconnected urban residents?

Three data sources are used in this study: The Transportation Network Providers[11] – Trips dataset (hereafter referred to as "TNP Trips") published on the Chicago Data Portal; the American Community Survey 2014-2018 five-year average; and Chicago Transit Authority ridership data, also published on the Chicago Data Portal. To avoid seasonal skew, I am limiting my use of TNP Trips to rides taken between November 1, 2018 and October 31, 2019: twelve total months of data. TNP Trips includes the following variables, among others: pickup and drop-off times, length of trip (in seconds), trip distance (in miles), and census tract of pickup and drop-off. Because these data includes the census tract of pickup and drop-off locations, I am able to connect the location information with the 2014-2018 American Community Survey (ACS) five-year averages to illustrate the demographic characteristics of residents living in these census tracts, including total population, race, per capita income, and percent living in poverty. I also use CTA ridership data over a ten-year horizon and the CTA's Annual Ridership Reports to evaluate transportation options and ridership trends on the Far South Side. Working with the aforementioned CMAP policy reports, TNP Trips, ACS, and CTA data cumulatively allows me to frame the current state of urban transportation in Far South Side Chicago, to analyze travel patterns among TNC riders, and to answer my research question.

Before delving into methodology, it is prudent to articulate the limitations imposed on this study by existing gaps in the data. The Chicago TNC data ("TNP Trips") presents several challenges to interpretation. First, in an effort to preserve riders' anonymity, pickups and drop-offs are specified only at the census tract and community area levels; point-to-point transit

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[11] Transportation Network Provider (TNP) and Transportation Network Company (TNC) are interchangeable.

information is not provided (again, see Appendix A for more information how the data was anonymized). Second, trip fares are rounded to the nearest $2.50, which reduces the efficacy of analyzing trip pricing, since most trips fall in the range of $5-20 and the rounding scheme does not allow for granular analysis. Third, trips are not categorized by type (i.e. commute to work or travel for pleasure) so any comparison to commuter data is imperfect at best, and largely meaningless in census tracts where workers' commutes take place on nights and weekends, outside of rush hour and/or the operational hours of public transportation. Fourth, the trip start and end times contain both date and time information in a single cell, rendering it difficult to easily analyze travel patterns by time of day or weekday versus weekend.[12] Finally, as mentioned the data is completely anonymized and does not give the researcher an understanding of *who* is taking the TNC, contrary to the thrust of the current literature surrounding TNCs. It should also be explicitly noted that I will be comparing 2018-2019 TNP Trips data to the most recent Census data available, the 2014-2018 ACS five-year average. I am therefore framing this study as an exploratory one, one that strives to make meaningful sense of Chicago's public transportation system alongside the TNP Trips data, while taking into account the data's limitations.

IV. Methods

In this study, I analyze two areas in the Far South Side that have similar socioeconomic characteristics but different levels of transit service, which I term the high- and low-quality transit areas. I then map the most frequent destinations of TNC rides originating from these respective areas, evaluating the proximity of riders' destinations to the pickup study area as well as the proportion of rideshares versus ridehails for each destination tract. I then compare these

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[12] CMAP has done an excellent job of breaking down these data (see CMAP 2019), which requires use of RSocrata and is beyond the technical capabilities of this researcher given the time constraints.

travel patterns that emerge with existing public transit options in the area (buses, heavy rail, and regional commuter rail). In doing so, I examine whether TNCs are transporting riders to destinations that could have been reached via public transportation or if public transportation connections *are* the destination. Using this analysis, I then evaluate my hypothesis that low-income TNC users are bypassing the bus and using TNCs as an FMLM solution.

See Figure 5 for a map of the high-quality transit and low-quality transit study areas, including their respective proximity to public transportation. Both areas fall within the boundaries of the South Side EDA as determined by CMAP, meaning that they “have higher than regional average concentrations of low-income households and minority or limited English proficiency (LEP) populations” (CMAP 2018a, 1). Further, the low-quality transit area falls within a transit desert according to a 2014 report by the Center for Neighborhood Technology.

The demographics of both the high- and low-quality transit areas are outlined in Tables 1 and 2. For both tables, the percentage of black residents was determined by dividing the number of ACS respondents who identify as black (not as mixed or other race[s]) by the population total for each tract. The percentage of residents living in poverty was determined by dividing the total number of respondents for whom the income-to-poverty ratio was less than one by the total number of respondents for whom poverty status can be determined (residents living in institutional homes or who are in the military, for example, cannot be included in this total). As evidenced by these tables, these two areas are nearly entirely black and have similar per capita incomes. Both areas also have poverty rates higher than the citywide average of 19.5% (United States Census Bureau 2020); nearly one in three residents in the low-quality transit area is living in poverty.

Figure 5. Map of High- and Low-Quality Transit Study Areas

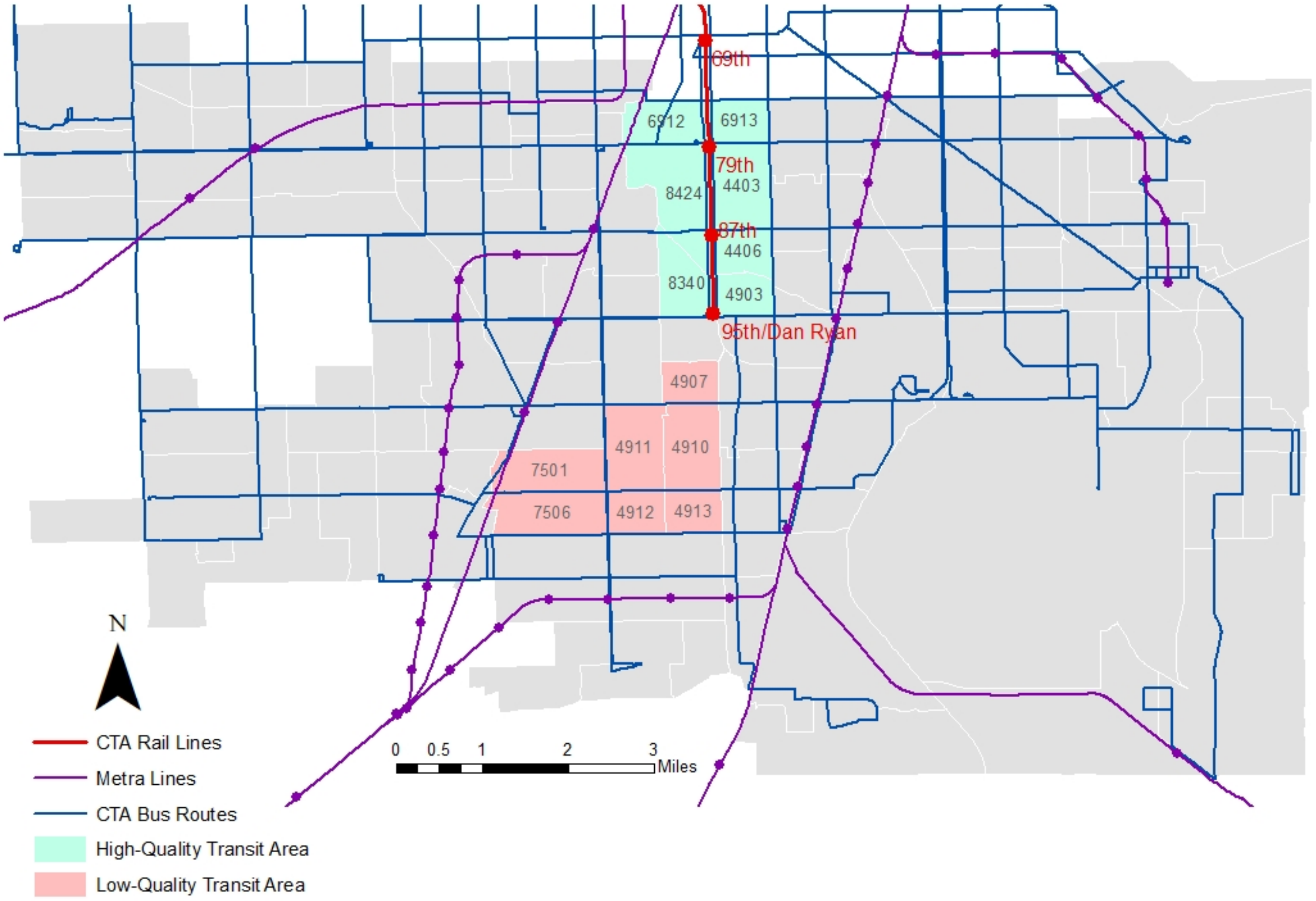


Table 1. Demographics of High-Quality Transit Area on Chicago's Far South Side

Tract Number	Total Population	% Black Residents	Income Per Capita	% In Poverty
4403	4,577	97.4%	$24,973	16.3%
4406	1,807	100.0%	$33,629	9.7%
4903	2,340	94.9%	$25,846	18.9%
6912	2,969	93.7%	$15,717	37.3%
6913	2,707	91.5%	$23,630	24.2%
8340	2,926	97.6%	$18,972	29.3%
8424	3,115	96.7%	$20,044	27.4%
High Quality Transit Mean	**2,920**	**96.0%**	**$23,259**	**23.3%**

Source: American Community Survey 2014-2018 5-year Average

Table 2. Demographics of Low-Quality Transit Area on Chicago's Far South Side

Tract Number	Total Population	% Black Residents	Income Per Capita	% In Poverty
4907	2,720	100.0%	$20,828	22.3%
4910	4,239	96.4%	$10,058	48.6%
4911	4,160	95.4%	$30,404	18.2%
4912	2,110	87.6%	$21,891	26.8%
4913	2,605	97.0%	$13,481	48.8%
7501	3,814	94.0%	$23,390	19.4%
7506	3,663	91.0%	$19,979	36.9%
Low Quality Transit Mean	**3,330**	**94.5%**	**$20,004**	**31.6%**

Source: American Community Survey 2014-2018 5-year Average

These tract groups were thus chosen for their relatively similar demographics and vastly different array of transportation options. (Again, see Figure 5.) The high-quality area consists of the seven census tracts that surround the three southernmost stations on the Red Line: 79th, 87th, and 95th/Dan Ryan. These stations are the only CTA rail stations that reach the Far South Side. In addition to proximity to heavy rail, this area also contains stops for three bus routes: #29 (State), which runs from the 95th Street Red Line to Navy Pier via downtown (The Loop); as well as #79 and #87, two routes that run east-west along 79th and 87th Street, respectively. The latter two buses connect much of the Far South Side to the Red Line train as well as to the Metra commuter rail lines. Thus, residents living in these seven tracts that make up the high-quality transit area not only have easy access to downtown via the Red Line and #29 bus but can venture east and west across the Far South Side on the #79 and #87 buses as well.

By contrast, the seven tracts that make up the low-quality transit area lie south of the Red Line terminus, contain no train lines or stations, and contain stops for just four bus lines: #108 (Halsted/95th), #111 (111th/King Drive), #115 (Pullman/115th), and #8A (South Halsted). The routes for buses #108, #111, and #115 cover a small geographic area: each bus route terminates northbound at the 95th Street Red Line station. Meanwhile, #8A terminates northbound at the 79th Street Station. This means that, for any resident living these tracts, access to the city north of 79th Street requires at least one transfer. Further, none of the four buses run later than 10:30 pm, and the #108 bus only runs during weekday rush hour. Overall, the mobility of residents living in this area via public transit outside of peak hours is severely limited, and nonexistent overnight. As the literature suggests, this combination of factors likely significantly increases commute time to work for anyone living in this area who works outside of the Far South Side and does not commute by automobile. Neither the high- nor the low-quality transit areas contain stops for either of the regional commuter rail Metra lines that run through the Far South Side: the Metra Electric line or the Rock Island line.

Figures 6 and 7 visualize the frequency of drop-offs for TNC rides picking up in the high-quality transit area and low-quality transit area, respectively. These maps were created using two subsets of the TNP Trips data that were filtered using the following conditions: the pickup census tract must fall within either the high- or low-quality transit area, respectively; the drop-off census tract must be provided (i.e. it cannot be blank); and the trip pickup time must fall between midnight on November 1, 2018 and midnight on November 1, 2019. This yields a total dataset of

Figure 6. TNC Trips Originating in High-Quality Transit Area

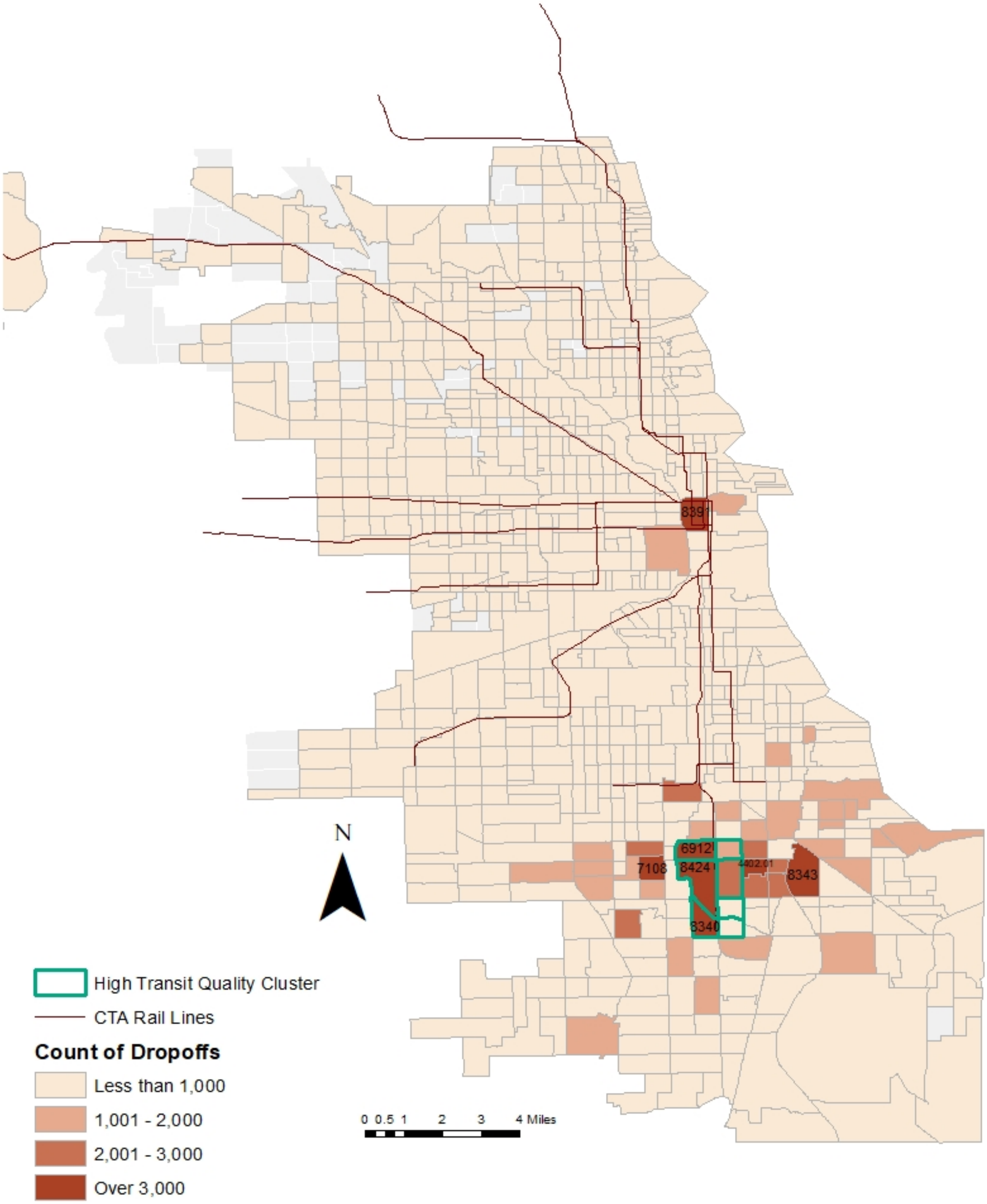
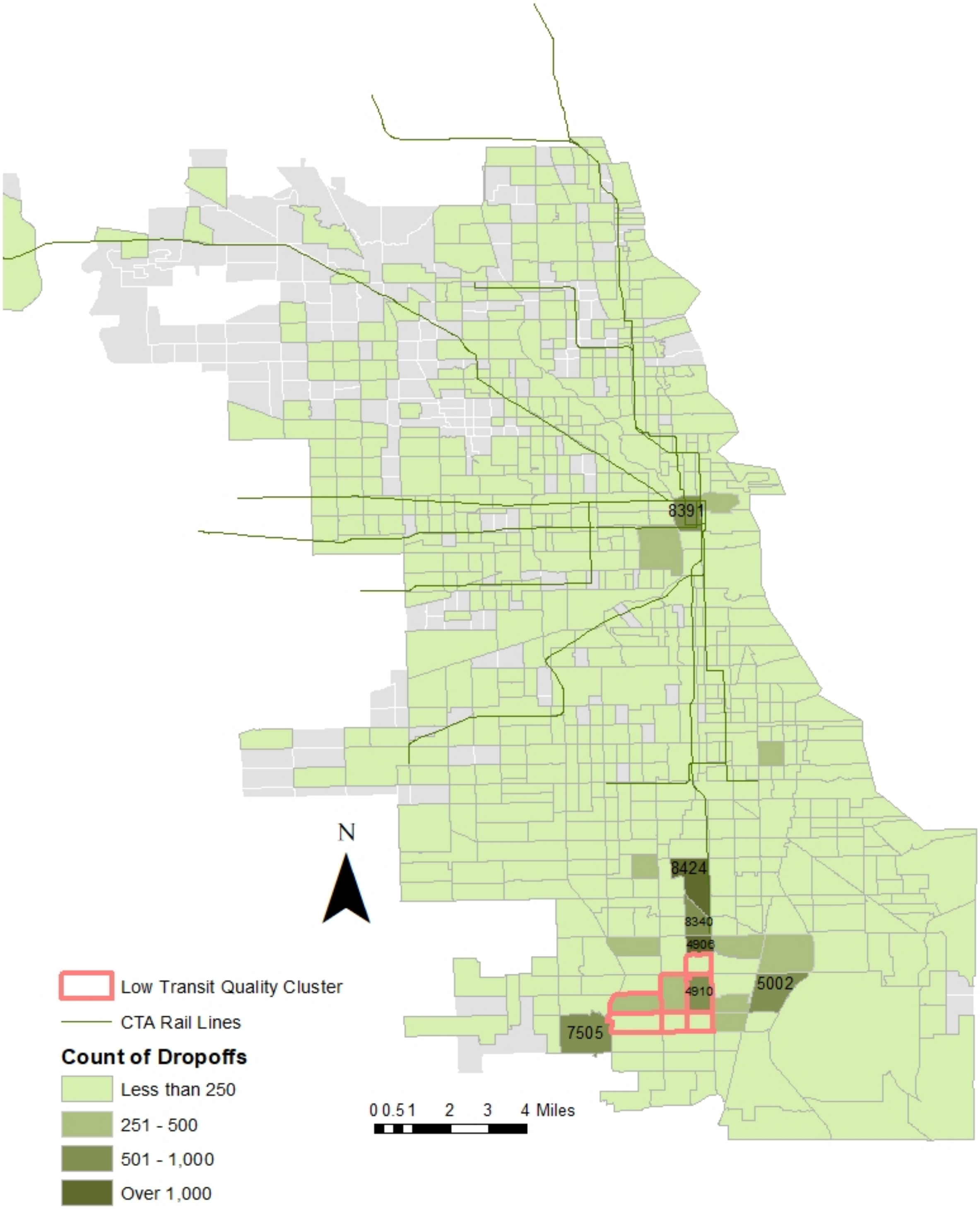


Figure 7. TNC Trips Originating in Low-Quality Transit Area



177,131 TNC trips picking up in the high-quality transit area and 26,298 trips picking up in the low-quality transit area. Once I produced these two sets, I joined the data in ArcMap to a layer containing all Chicago census tracts and used the summarize function to generate a count for the total number of drop-offs per census tract. I then visualized the frequency of drop-offs across the city through the choropleth maps shown in Figures 6 and 7. In addition, Tables 3 and 4 detail the following information: total ride count for each of the most frequent destination tracts, the proximity of those destinations to the respective study area, the availability of high-quality transit in each destination tract (i.e. CTA heavy rail or Metra commuter rail), and the proportion of rideshares (i.e. UberPool, Lyft Line, Via) to private ridehails (i.e. UberX, UberXL, UberSelect, Lyft, Lyft XL, Lyft Lux).

V. Results

Figures 6 and 7 support my hypothesis: riders are using TNCs as an FMLM solution. Nearly all of the most frequent destination tracts for rides picking up in the both the high- and low-quality transit areas connect to CTA or Metra rail. Interestingly, the most frequent destination for both study areas was Tract 8424. I identify two reasons for this. First, Tract 8424 contains two Red Line stations, 79th and 87th, meaning that TNC riders are likely transferring from TNC to heavy rail as they head further north in the city. Tract 8424 also contains a high level of commercial activity, including grocery stores like Jewel-Osco and ALDI and big box retailers like Lowe's Home Improvement and a Walmart Supercenter. These types of businesses do not proliferate across the South Side, and likely require shoppers to transport their purchases (i.e. groceries, construction materials, other large items) by car, including TNC cars, as they may be too cumbersome to take on public transportation. Despite being *contained* in the high-quality

Table 3. Most Frequent Destinations for Riders Picking Up in High-Quality Transit Area

Tract of Drop-off	Number of Drop-offs *(n = 177,131)*	Proximity to Study Area	Transit Availability	Percent of Rides Shared
8424	14,710	Within	Contains CTA rail	38.2%
4402.01	4,109	Adjacent		35.8%
8340	3,935	Within	Contains CTA rail	35.1%
6912	3,412	Within	Contains CTA rail	33.1%
7108	3,318	Nearby		39.3%
8343	3,256	Nearby	Contains Metra rail	44.3%
8391	3,147	Downtown Chicago	Contains CTA rail	43.2%

Source: TNP Trips in the Chicago Data Portal[13]

Table 4. Most Frequent Destinations for Riders Picking Up in Low-Quality Transit Area

Tract of Drop-off	Number of Drop-offs *(n = 26,298)*	Proximity to Study Area	Transit Availability	Percent of Rides Shared
8424	1,346	Nearby	Contains CTA rail	51.2%
4906	1,116	Nearby	Adjacent to CTA rail	29.3%
7505	916	Adjacent	Contains Metra rail	43.1%
5002	835	Nearby	Contains Metra rail	42.0%
8340	690	Nearby	Contains CTA rail	42.6%
4910	687	Within		31.6%
8391	535	Downtown Chicago	Contains CTA rail	46.0%

Source: TNP Trips in the Chicago Data Portal[14]

transit area, Tract 8424 attracted far more TNC trips for residents in the high-quality transit area than any other destination: 14,710 rides end in Tract 8424, as compared to 4,109 rides ending in the next most frequent destination, Tract 4402.01. This means that many riders in the high-quality transit area are venturing at most three miles to reach their TNC destination, underscoring the significance of TNCs as an FMLM solution.

For trips picking up in the low-quality transit area, the two most popular destinations were the census tracts containing or adjacent to the three closest CTA rail stations, Tracts 8424

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[13] Number of drop-offs calculated directly in ArcMap using the summarize function. Percent of rides shared calculated in R; see Appendix B for the full R script.

[14] Number of drop-offs calculated directly in ArcMap using the summarize function. Percent of rides shared calculated in R; see Appendix B for the full R script.

and 4906. Though the 95th Street Red Line station technically falls in Tract 8340, it is located at the boundary of Tract 4906 and 8340. This means that TNC riders are likely traveling to the train station and disembarking on the south side of 95th Street, in Tract 4906. Beyond these CTA connections, it's probable that riders are taking TNCs to Metra stations in Tracts 7505 and 5002, either the Rock Island or Metra Electric lines, respectively. None of the four buses that run through the low-quality transit area connect to the Rock Island line, and only the #115 (Pullman/115th) connects to the Metra Electric line. All of the most frequent destinations in the low-quality transit area, save Tract 4910 which is within the area of study, contain CTA or Metra stations.

By and large, Far South Side residents do not travel far via TNC, with the exception of traveling downtown to The Loop. As Tables 3 and 4 demonstrate, the only frequent destination for TNC riders in either study area that falls outside of the Far South Side neighborhood is Tract 8391 in The Loop.[15] The existence of these trips is evidence that disadvantaged groups like the low-income residents of the South Side still need automobile-mobility (i.e. TNCs) to job and activity centers (i.e. The Loop) even if public transit is available. Transit service can be limited outside of peak hours, trains during peak hours might be overly crowded, and unexpected circumstances like transit malfunctions and delays are not uncommon on the CTA system. Taken together, this means that Far South Side residents may need TNCs to reach their downtown destinations. It's also important to consider the transit options available in The Loop. Given that the Red Line is the only accessible train Far South Siders have access to—and limited access at that—riders may be using TNCs to connect to any of the train lines that connect in Tract 8391.

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[15] Curiously, for neither study area did the Chicago airports (O'Hare or Midway) show up among the most frequent destinations, despite neither airport being easily accessible by public transit from the Far South Side. This is likely correlated with the socioeconomic status of the residents.

The Pink, Brown, Purple, Green, Blue, and Orange lines all have stops within the boundaries of the tract. Whether TNC users are traveling downtown for work, pleasure, or transit connections, it is evident that TNCs serve a vital purpose for riders going to all parts of the city.

Many TNC riders on the Far South Side are using ride*share*, rather than ride*hail*. Ridesharing bears a lower, shared fare that is economically comparable to taking transit. Approximately 41% of all rides picking up in the high-quality transit area are rideshares, and 42% of rides picking up in the low-quality transit area are shared.[16] This percentage is significantly higher than the aforementioned citywide proportion of rideshares in all TNC trips of 16.8%. Rides to The Loop, the furthest and therefore most costly trip for a TNC user to take, are shared 43.2% and 46% of the time for rides picking up in the high- and low-quality transit areas, respectively. The economic benefits of sharing the ride are sizeable. Ride fares[17] from the high-quality transit area to Tract 8391 average $15.35, which drops to $7.89 when filtering for shared rides only. Similarly, fares from the low-quality transit area to Tract 8391 average $19.75, or $10.36 when filtering for shared, meaning that sharing the ride saves the average Far South Side TNC user nearly 50% of the fare.[18] While these sums are still substantially more expensive than the current CTA fare ($2.50 for rail, $2.25 for bus, and $0.25 to transfer), they are markedly less expensive than a private ride in a traditional taxi—and certainly far cheaper than owning and maintaining a personal vehicle.

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[16] 73,063 of the 177,131 rides from the high-quality transit area selected a pooled option, regardless of whether or not they were paired with another rider. 11,009 of the 26,298 rides from the low-quality transit area were similarly "shared trip authorized."

[17] Before additional fees and tip are added.

[18] See Appendix B for the R script detailing these calculations.

VI. Discussion and Recommendations

By engaging with real user data, this study has accomplished what prior studies have largely been unable to do: examine the actual travel behaviors and patterns of the TNC user population, rather than self-reported trends. Through this analysis, I've determined that my hypothesis about TNCs as an FMLM solution is valid. TNC services are currently being used primarily as a complement to existing heavy rail services and can substitute the bus for low-income riders. Crucially, TNCs can close the mobility gap for users in transit poor areas, for whom the bus may be infrequent, indirect, or otherwise uncomfortable.

Though my findings are supported by the current literature (see Schwieterman 2019; Graehler, Mucci and Erhardt 2019; Young, Allen, and Farber 2020), there remain limitations in the available data. Again, evaluation of point-to-point transit is impossible given the contours of the current TNC dataset. In addition, the measures to anonymize the data, while ethically sound, preempt a microanalysis of who TNC users are, if they are choosing to use TNCs for business or for pleasure, and why they choose TNCs over other forms of transit. The sheer volume of available data on TNC usage—the TNP Trips dataset contains information on over 129 million rides so far—renders it difficult to conduct population-level analyses (this researcher experienced several malfunctions when attempting to illustrate citywide trends). Thus, while the study conducted here speaks volumes about the activity of low-income TNC users and particularly those on Chicago's Far South Side, there is much more left to be said about the changing nature of urban transit.

I posit several suggestions for future research. First, replicating this methodology for other EDAs would strengthen the validity of my findings, and replicating these methods for census tracts across the City of Chicago would allow researchers to compare travel trends in

EDAs with those in more connected and affluent neighborhoods. This would facilitate a nuanced evaluation of the augmented inequality in urban transit due to the introduction of TNCs. Second, it is my hope that future studies will be able to articulate the complementary or substitutive effects of TNCs in urban areas beyond Chicago, to reach more causative conclusions. This would require a coordinated effort on the part of city legislatures to mandate reporting by TNCs as well as open access to this data. Third, a more granular analysis of travel patterns based on time of day and weekday/weekend trends could illuminate changing patterns in the commute to work and make the case for expanding service hours of existing public transportation. Further, including TNC ridehailing or ridesharing as modal options for ACS questionnaires on journey to work would inform transportation research on the pervasiveness of TNC usage nationwide. Fourth and final, this data offers the opportunity for natural experiments. Were the TNC dataset to reveal which company fulfilled each ride, for example, researchers would be able to analyze the effects of competitive pricing or expanded service area on user behavior.

The policy implications of this research are wide-ranging. Through this study, it is evident that the new tiered ridehailing tax structure in Chicago, which replaces a flat fee of 72 cents per ride, will likely not adversely affect users in transit poor areas like the Far South Side, despite claims in the media to the contrary. Most users are taking TNCs locally (within their broader neighborhood) or to make transit connections; they will therefore not be subject to the hefty $3.00 surcharge that the City has imposed on solo rides going to and from The Loop, which is currently the highest ridehail tax in the nation. For TNC riders who rideshare instead of ridehail, the total cost of fares may even minutely fall as the fee for shared rides has decreased to 65 cents (Freund 2020). The economic benefits of this tax structure for the City are notable; revenue is projected to be up to $40 million annually. In addition, this structure disincentivizes users to take TNCs to The Loop in an effort to reduce traffic congestion, which could reduce travel times for commuters throughout the city.

The case for subsidizing TNC usage as a viable (free or low-cost) FMLM option is obvious. At the current price point, sustained use of TNCs is not a viable permanent solution for low-income riders in transit poor areas. Further, as other scholars have noted, the long-term economic viability of TNCs is still unknown (i.e. Young, Allen, and Farber 2020, 9). Both Uber and Lyft are still propped up by venture capital and have performed poorly in the publicly traded market. These firms will thus have to increase their profit margins to appease shareholders, meaning that TNC fares are likely to rise in the future. While this may not affect TNC usage by more affluent riders, the cost could become prohibitive for regular use by low-income riders. Public subsidization could thus maintain the feasibility of this service while providing a badly needed source of steady revenue for TNCs as they attempt to transition from being venture capital-funded startups to public companies.

As of this writing in 2020, the current options for ridesharing in Chicago include UberPool, Lyft Line, or more recently, Via. Like other rideshares, the Via application essentially functions as a platform for an on-demand bus. For the first few years after the application's launch in Chicago in November 2015 (the same day, in fact, that Uber launched the UberPool service), Via only served the highly mobile, affluent areas of the city: largely downtown and the North Side (Graham 2015). In August 2019, however, midway through the sample of TNC rides, Via expanded service to the entire city and offered "first-and-last-mile connection[s] [sic] for riders to-and-from all CTA and Metra stations in the expansion zone for a flat $2.50 rate" (Via 2019). Though it's too early to tell, it's quite possible that these flat-rate rides to transit connections will spur use of both the Via application and use of heavy rail transit overall.

Brokering a partnership with a TNC like Via could ensure the fiscal solvency of the company despite its prominent competitors while simultaneously closing the transit gap for residents of the Far South Side and other economically disconnected areas.

Using a shared service like Via (or UberPool or Lyft Line) to connect to high-quality transit could be a cost-effective, albeit complicated, solution for both the City and riders. Connecting from TNCs to public transit does not permit riders to utilize an ultra-low-cost transfer option—at least, not yet. One possible way to create a public-private transit system would be to introduce a new TNC tier to the CTA fare system, which currently charges $2.50 per rail ride, $2.25 per bus ride, and $0.25 per transfer. A higher tier could include a moderately priced flat-fare TNC option—say, $2.50-$5.00, depending on the distance or the supply of drivers, with the standard transfer fee of $0.25 applying to a transfer between TNC and rail, for instance. Both Uber and Lyft currently use a technique called geofencing to moderate the availability of their services; this is why drivers cannot, for example, pull up directly to Arrivals at O'Hare Airport to wait for a fare. Geofencing could make this tiered subsidy accessible only available in economically disconnected areas or in transit deserts within the city of Chicago, regardless of the rider's individual identity. Alternatively, TNC users who already qualify for a CTA reduced fare program (students, seniors, people with disabilities) could also qualify for this flat-fare TNC subsidy, though this approach may not have the comprehensive effects desired in solving FMLM issues for the urban poor. In addition, participation in a public-private program such as this would likely require users to have access to a smartphone or necessitate another technological workaround. And of course, any kind of hybridized system would potentially be very difficult to sell to constituents who would not benefit from subsidies.

Thus, improving existing public transit infrastructure to better serve Chicago's economically disconnected areas could preclude the need for more expensive and congestive private transportation. The expansion of the Red Line from 95th to 130th Street, long discussed, is paramount to improving mobility for economically disconnected residents of the Far South Side. Expanding the Red Line's service area would also reduce pressure from constituents on Mayor Lightfoot to lower Metra fares or increase frequency of service for the commuter rail Metra trains, a system that has long been plagued by poor management and financial insecurity. The problem with this, however, is political: investment in transit infrastructure modernization is rarely implemented to support the actual travel behavior of poor individuals. Rather, these types of projects prioritize mobility for segments of the population that are already highly mobile (Ahmed, Lu, and Ye 2008). It is therefore unlikely that the City will scrape together the $2.3 billion in capital costs needed to break ground on this project, particularly as it moves ahead with Phase One of the Red and Purple Modernization, "the largest capital improvement project in CTA history" which will rebuild and add capacity to the Purple Line and northern portion of the Red Line, both of which run through the most affluent areas of Chicago and neighboring suburb of Evanston (CTA 2020c). In lieu of expanding heavy rail, then, the next best option to improve the mobility of low-income urban residents would be to facilitate TNC-to-transit connections in transit poor areas.

VII. Conclusion

Using newly available data on transportation network company trips in the City of Chicago, this study has demonstrated that TNCs, and particularly rideshares, serve as first mile/last mile solutions for riders in economically disconnected areas. Given the overall decline in public transit ridership across the city (a phenomenon that cities face nationwide), ridehailing and ridesharing will likely continue to be a popular option for urbanites of all economic backgrounds. As of this writing, the COVID-19 public health crisis is still unfolding. This crisis is devastating many aspects of the national and global economies, including and especially ridehailing and public transportation. While it's too soon to tell what sort of lasting effects the coronavirus will have on urban transportation, studies like this one, that emphasize the behaviors and needs of low-income individuals and people of color, remain of paramount importance.

It is therefore vital for urban governments to consider the salience of TNCs when planning for the future of urban transportation. Subsidizing TNC services could boost patronization of high-quality transit and reduce the need for bus lines or scheduled service with low ridership without requiring additional capital investment. From a sustainability perspective, a TNC-to-transit service might also facilitate a reduction in private vehicle ownership across the city, which could further reduce congestion and overall VMT. Overall, if the City of Chicago wishes to improve the lives and opportunities for all of its residents, municipal authorities need to consider using TNCs to address FMLM issues. Providing public subsidization of TNC services will keep costs feasible and close the mobility gap for residents who face substantial travel mode choice constraints by living in economically disconnected and transit poor areas.

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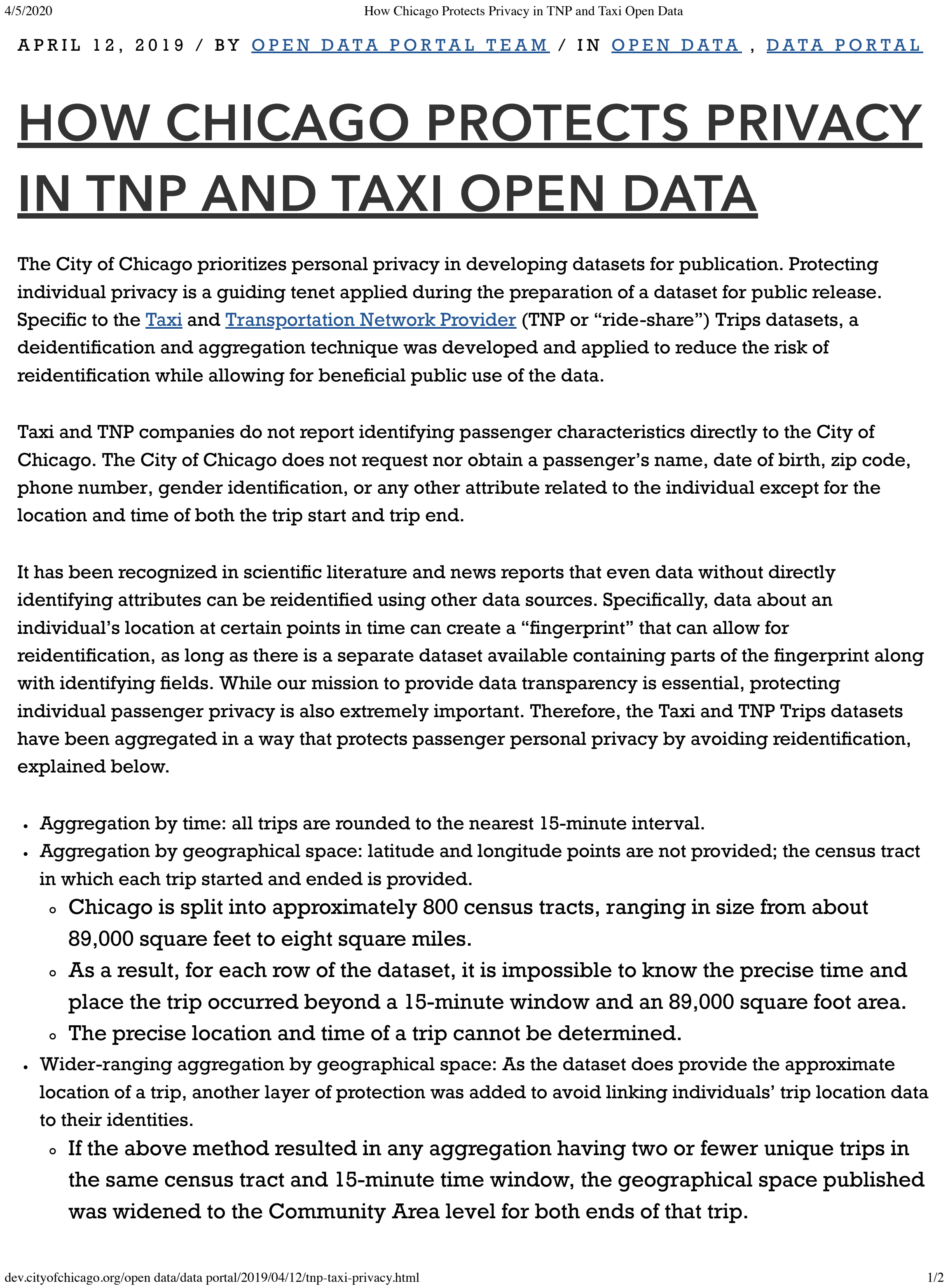
Appendix A: How Chicago Protects Privacy in TNP and Taxi Open Data



APRIL 12, 2019 / BY OPEN DATA PORTAL TEAM / IN OPEN DATA , DATA PORTAL

HOW CHICAGO PROTECTS PRIVACY IN TNP AND TAXI OPEN DATA

The City of Chicago prioritizes personal privacy in developing datasets for publication. Protecting individual privacy is a guiding tenet applied during the preparation of a dataset for public release. Specific to the Taxi and Transportation Network Provider (TNP or "ride-share") Trips datasets, a deidentification and aggregation technique was developed and applied to reduce the risk of reidentification while allowing for beneficial public use of the data.

Taxi and TNP companies do not report identifying passenger characteristics directly to the City of Chicago. The City of Chicago does not request nor obtain a passenger's name, date of birth, zip code, phone number, gender identification, or any other attribute related to the individual except for the location and time of both the trip start and trip end.

It has been recognized in scientific literature and news reports that even data without directly identifying attributes can be reidentified using other data sources. Specifically, data about an individual's location at certain points in time can create a "fingerprint" that can allow for reidentification, as long as there is a separate dataset available containing parts of the fingerprint along with identifying fields. While our mission to provide data transparency is essential, protecting individual passenger privacy is also extremely important. Therefore, the Taxi and TNP Trips datasets have been aggregated in a way that protects passenger personal privacy by avoiding reidentification, explained below.

- Aggregation by time: all trips are rounded to the nearest 15-minute interval.
- Aggregation by geographical space: latitude and longitude points are not provided; the census tract in which each trip started and ended is provided.
  - Chicago is split into approximately 800 census tracts, ranging in size from about 89,000 square feet to eight square miles.
  - As a result, for each row of the dataset, it is impossible to know the precise time and place the trip occurred beyond a 15-minute window and an 89,000 square foot area.
  - The precise location and time of a trip cannot be determined.
- Wider-ranging aggregation by geographical space: As the dataset does provide the approximate location of a trip, another layer of protection was added to avoid linking individuals' trip location data to their identities.
  - If the above method resulted in any aggregation having two or fewer unique trips in the same census tract and 15-minute time window, the geographical space published was widened to the Community Area level for both ends of that trip.

- Even if one acquires separate data about a trip location and trip time along with identifying information about a passenger/rider, the presence of at least three matching trips would inhibit isolating a specific trip's census tracts in this dataset.
- As a result of this protection, approximately a third of census tracts that would otherwise be shown in the initial dataset are blank. (Others are blank because of missing data or falling outside Chicago.) By removing the census tract from these particular records, we limit the location information that could be reidentified by providing only the Community Area in which the trip started and ended. On average, a Community Area covers 3 square miles of the City.

The above time and location aggregation methodology has been used by the City of Chicago since 2016, the year the Taxi Trips dataset was created and published.

Appendix B: R Script for Ridership Graphs and TNP Trips Data Analysis

```
# Load packages and ridership data  ####
## [nb. tidyverse contains dplyr]

install.packages("tidyverse")
library(tidyverse)

## Set working directory

setwd("/Users/kellyobrien/OneDrive - UWM/THESIS")

## Load data for ridership graphs

FSSLMonthlyBoardings <-
read.csv("FSSLMonthlyBoardings_2010_2019.csv")
FSSBusMonthlyRidership <-
read.csv("FSSBusMonthlyRidership_2010_2019.csv")

# Graph L boarding ridership trends ####

## Subset by station

LBoardings <- read.csv("FSSLMonthlyBoardings_2010_2019.csv")
S79 <- subset(LBoardings, stationame=="79th")
S87 <- subset(LBoardings, stationame=="87th")
S95 <- subset(LBoardings, stationame=="95th/Dan Ryan")

## Separate by year [nb. I originally viewed each year to check
that the data was correct, but eliminated these lines to make
running all commands easier.]

S79_2010 <- S79[1:12,]
S79_2011 <- S79[13:24,]
S79_2012 <- S79[25:36,]
S79_2013 <- S79[37:48,]
S79_2014 <- S79[49:60,]
S79_2015 <- S79[61:72,]
S79_2016 <- S79[73:84,]
S79_2017 <- S79[85:96,]
S79_2018 <- S79[97:108,]
S79_2019 <- S79[109:120,]
View(S79_2019)

S87_2010 <- S87[1:12,]
S87_2011 <- S87[13:24,]
S87_2012 <- S87[25:36,]
S87_2013 <- S87[37:48,]
```

```
S87_2014 <- S87[49:60,]
S87_2015 <- S87[61:72,]
S87_2016 <- S87[73:84,]
S87_2017 <- S87[85:96,]
S87_2018 <- S87[97:108,]
S87_2019 <- S87[109:120,]
View(S87_2019)

S95_2010 <- S95[1:12,]
S95_2011 <- S95[13:24,]
S95_2012 <- S95[25:36,]
S95_2013 <- S95[37:48,]
S95_2014 <- S95[49:60,]
S95_2015 <- S95[61:72,]
S95_2016 <- S95[73:84,]
S95_2017 <- S95[85:96,]
S95_2018 <- S95[97:108,]
S95_2019 <- S95[109:120,]
View(S95_2019)

## Sum to annual totals and combine into single column per
station

S79_2010$monthtotal <- as.numeric(S79_2010$monthtotal)
sum(S79_2010$monthtotal)
sum_S79_2010 <- sum(as.numeric(S79_2010$monthtotal))
View(sum_S79_2010)

sum_S79_2011 <- sum(as.numeric(S79_2011$monthtotal))
sum_S79_2012 <- sum(as.numeric(S79_2012$monthtotal))
sum_S79_2013 <- sum(as.numeric(S79_2013$monthtotal))
sum_S79_2014 <- sum(as.numeric(S79_2014$monthtotal))
sum_S79_2015 <- sum(as.numeric(S79_2015$monthtotal))
sum_S79_2016 <- sum(as.numeric(S79_2016$monthtotal))
sum_S79_2017 <- sum(as.numeric(S79_2017$monthtotal))
sum_S79_2018 <- sum(as.numeric(S79_2018$monthtotal))
sum_S79_2019 <- sum(as.numeric(S79_2019$monthtotal))

S79_Annual <- c(sum_S79_2010, sum_S79_2011, sum_S79_2012,
sum_S79_2013, sum_S79_2014, sum_S79_2015, sum_S79_2016,
sum_S79_2017, sum_S79_2018, sum_S79_2019)
View(S79_Annual)

## Repeat for 87th Street Station

S87_2010$monthtotal <- as.numeric(S87_2010$monthtotal)
sum(S87_2010$monthtotal)
sum_S87_2010 <- sum(as.numeric(S87_2010$monthtotal))
```

```
View(sum_S87_2010)

sum_S87_2011 <- sum(as.numeric(S87_2011$monthtotal))
sum_S87_2012 <- sum(as.numeric(S87_2012$monthtotal))
sum_S87_2013 <- sum(as.numeric(S87_2013$monthtotal))
sum_S87_2014 <- sum(as.numeric(S87_2014$monthtotal))
sum_S87_2015 <- sum(as.numeric(S87_2015$monthtotal))
sum_S87_2016 <- sum(as.numeric(S87_2016$monthtotal))
sum_S87_2017 <- sum(as.numeric(S87_2017$monthtotal))
sum_S87_2018 <- sum(as.numeric(S87_2018$monthtotal))
sum_S87_2019 <- sum(as.numeric(S87_2019$monthtotal))

S87_Annual <- c(sum_S87_2010, sum_S87_2011, sum_S87_2012,
sum_S87_2013, sum_S87_2014, sum_S87_2015, sum_S87_2016,
sum_S87_2017, sum_S87_2018, sum_S87_2019)
View(S87_Annual)

## Repeat for 95th Street Station

S95_2010$monthtotal <- as.numeric(S95_2010$monthtotal)
sum(S95_2010$monthtotal)
sum_S95_2010 <- sum(as.numeric(S95_2010$monthtotal))
View(sum_S95_2010)

sum_S95_2011 <- sum(as.numeric(S95_2011$monthtotal))
sum_S95_2012 <- sum(as.numeric(S95_2012$monthtotal))
sum_S95_2013 <- sum(as.numeric(S95_2013$monthtotal))
sum_S95_2014 <- sum(as.numeric(S95_2014$monthtotal))
sum_S95_2015 <- sum(as.numeric(S95_2015$monthtotal))
sum_S95_2016 <- sum(as.numeric(S95_2016$monthtotal))
sum_S95_2017 <- sum(as.numeric(S95_2017$monthtotal))
sum_S95_2018 <- sum(as.numeric(S95_2018$monthtotal))
sum_S95_2019 <- sum(as.numeric(S95_2019$monthtotal))

S95_Annual <- c(sum_S95_2010, sum_S95_2011, sum_S95_2012,
sum_S95_2013, sum_S95_2014, sum_S95_2015, sum_S95_2016,
sum_S95_2017, sum_S95_2018, sum_S95_2019)
View(S95_Annual)

## Plot annual ridership

ylab <- c(0:5)
plot(S79_Annual, type="b", xlab = "Year", ylab = "Annual Total
Riders", xaxt = "n", ylim = c(0,5000000), main = "CTA Annual
Boardings on Far South Side")
axis(1,at =
1:10,label=c(2010,2011,2012,2013,2014,2015,2016,2017,2018,2019))
axis(2,at = 1:6,labels = ylab)
```

```r
abline(v=2, lty=3)
abline(v=4, lty=3)
text(1.4,4700000, "Uber launches")
text(3.45,4700000, "Lyft launches")
text(3.1,4500000, "Red Line closed Summer ")
text(3.1,4350000, "2013 for improvements")
lines(S79_Annual, type = "b", col = "black")
lines(S87_Annual, type = "b", col = "blue")
lines(S95_Annual, type = "b", col = "red")
legend("topright", legend=c("79th", "87th", "95th/Dan Ryan"),
col=c("black", "blue", "red"), lty=1, bg="white", cex = 0.5)
text(1.1,3900000, "4,023,880", cex = 0.75, col = "red")
text(10,2700000, "2,818,826", cex = 0.75, col = "red")
text(1.1,2450000, "2,565,421", cex = 0.75, col = "black")
text(10,1850000, "1,975,866", cex = 0.75, col = "black")
text(1.1,1530000, "1,653,651", cex = 0.75, col = "blue")
text(10,1050000, "1,186,724", cex = 0.75, col = "blue")

# Load and clean data for TNC rides ####

PickupsfromHigh <- read.csv("PickupsfromHigh.csv")
PickupsfromLow <- read.csv ("PickupsfromLow.csv")

## Eliminate extraneous columns by first viewing column names

colnames(PickupsfromHigh)
colnames(PickupsfromLow)

## Making vector of column names

PFH <- cbind(colnames(PickupsfromHigh))

## Keeping columns 1-2, 4-10, and 14-15

PFH12 <- PickupsfromHigh[,1:2]
PFH410 <- PickupsfromHigh[,4:10]
PFH1415 <- PickupsfromHigh[,14:15]

## Making vector of new column names

PFH_ed <- cbind(PFH12, PFH410, PFH1415)

## Use colnames to check

colnames(PFH_ed)

## Repeat for low-quality transit
```

```
PFL <- cbind(colnames(PickupsfromLow))

PFL12 <- PickupsfromLow[,1:2]
PFL410 <- PickupsfromLow[,4:10]
PFL1415 <- PickupsfromLow[,14:15]

PFL_ed <- cbind(PFL12, PFL410, PFL1415)

colnames(PFL_ed)

## Write to CSV for use in GIS

write.csv(PFH_ed, "/Users/kellyobrien/OneDrive -
UWM/THESIS/PFH_ed.csv")

write.csv(PFL_ed, "/Users/kellyobrien/OneDrive -
UWM/THESIS/PFL_ed.csv")

# Find total number of rides shared for high and low study areas
####

table(PFH_ed$Shared.Trip.Authorized)
table(PFL_ed$Shared.Trip.Authorized)

## Calculate proportion of shared rides for each of the most
frequent destinations in high quality

STA8424_hi <- subset(PFH_ed, Dropoff.Census.Tract ==
"17031842400")
colnames(STA8424_hi)
view(STA8424_hi)
table(STA8424_hi$Shared.Trip.Authorized)

STA440201 <- subset(PFH_ed, Dropoff.Census.Tract ==
"17031440201")
table(STA440201$Shared.Trip.Authorized)

STA8340_hi <- subset(PFH_ed, Dropoff.Census.Tract ==
"17031834000")
table(STA8340_hi$Shared.Trip.Authorized)

STA6912 <- subset(PFH_ed, Dropoff.Census.Tract == "17031691200")
table(STA6912$Shared.Trip.Authorized)

STA7108 <- subset(PFH_ed, Dropoff.Census.Tract == "17031710800")
table(STA7108$Shared.Trip.Authorized)

STA8343 <- subset(PFH_ed, Dropoff.Census.Tract == "17031834300")
```

```
table(STA8343$Shared.Trip.Authorized)

STA8391_hi <- subset(PFH_ed, Dropoff.Census.Tract ==
"17031839100")
table(STA8391_hi$Shared.Trip.Authorized)

## Repeat for low quality

STA8424_lo <- subset(PFL_ed, Dropoff.Census.Tract ==
"17031842400")
table(STA8424_lo$Shared.Trip.Authorized)

STA4906 <- subset(PFL_ed, Dropoff.Census.Tract == "17031490600")
table(STA4906$Shared.Trip.Authorized)

STA7505 <- subset(PFL_ed, Dropoff.Census.Tract == "17031750500")
table(STA7505$Shared.Trip.Authorized)

STA5002 <- subset(PFL_ed, Dropoff.Census.Tract == "17031500200")
table(STA5002$Shared.Trip.Authorized)

STA8340_lo <- subset(PFL_ed, Dropoff.Census.Tract ==
"17031834000")
table(STA8340_lo$Shared.Trip.Authorized)

STA4910 <- subset(PFL_ed, Dropoff.Census.Tract == "17031491000")
table(STA4910$Shared.Trip.Authorized)

STA8391_lo <- subset(PFL_ed, Dropoff.Census.Tract ==
"17031839100")
table(STA8391_lo$Shared.Trip.Authorized)

## Trip statistics for rides to The Loop

mean(STA8391_hi$Trip.Miles)
mean(STA8391_hi$Fare)
STA8391_hi2 <- subset(PFH_ed, Dropoff.Census.Tract ==
"17031839100" | Shared.Trip.Authorized == "true")
view(STA8391_hi2)
mean(STA8391_hi2$Fare)

mean(STA8391_lo$Trip.Miles)
mean(STA8391_lo$Fare)
STA8391_lo2 <- subset(PFL_ed, Dropoff.Census.Tract ==
"17031839100" | Shared.Trip.Authorized == "true")
view(STA8391_lo2)
mean(STA8391_lo2$Fare)
```