Gendered Dynamic Choice Profiles: Costs of Transportation in Chicago for Women and Men

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Abstract:

The aim of this study is to study gendered urban mobility through the framework of dynamic mode choice profiles. Women have historically faced differentiated conditions and expectations in the labor market, while conducting the majority of household labor. As a result, women face different costs of transportation for a number of reasons: their unpaid labor has traditionally been unaccounted for in the opportunity cost of time, they go to different destinations than men, have a lower on average income, and face a higher threat of public harassment and assault. This paper dives into transportation data modelling to empirically demonstrate how labor market factors and other gendered determinants lead to gendered differentiation in costs incurred across two modes of transportation: public transportation and rideshare. This paper calculates dynamic modal cost-distance trade-offs for specific times, routes, and geographic areas of interest in the Chicago region in order to estimate the transportation costs incurred by women and men by Chicago census tract. It finds that on average, women incur more costs for multiple modes of transportation than men. This paper draws upon literature discussing social exclusion and unpaid labor across genders and indices of opportunity cost. It models transportation cost outcomes while taking these indices into account; these indices have not been merged with cost outcomes in previous transportation literature. It finds that in general, public transportation is more costly for women than for men in Chicago.

Introduction:

The modern transportation landscape in Chicago is a rapidly changing and historically rich object, beginning from the inception of lost railroads to the Chicago Transit Authority's multimodal map spanning the entire metropolitan area with buses and subways. In today's Chicago metropolitan landscape, external modes of transportation such as rideshare services and Divvy bikes have proliferated, leaving a variety of consumer options on the table for Chicago residents. However, consumer choices are never randomized, but rather a response to a set of price options and opportunities to access different modes, which have historically been unequal for marginalized communities and for women across Chicago. The focus of this paper is to investigate the impact of gender on consumer choices for transportation. I am interested in the following questions: How accessible are different options of transportation for women and men across Chicago? How do labor market indicators, factors of gender, and pricing across modes affect the cost incurred to consumers on multiple modes of transportation in Chicago? This topic is essential in order to understand the relationship between all these emerging modes of transportation and whether they are able to be deployed equitably for the Chicago population.

The aim of this study is to study gendered urban mobility through the framework of dynamic mode choice profiles as established by Credit et. al (2021) in order to answer the above questions. Gendered urban mobility is the study of how gender shapes people's ability to move around an urban environment, and how this in turn produces gendered outcomes in transportation use (Urban Design Lab, 2021). As women in Chicago are subject to different patterns of labor force participation (many women still perform domestic unpaid work at a higher proportion than men) (Bianchi et. al 2012) and thus traverse the urban landscape to access a different set of social amenities than men, the choices to opt in to one mode of transportation over another (or use a

combination of modes) might consequently look different by gender. This study hopes to explore that question by modelling the costs associated with each possible mode of transportation for both men and women by utilizing both market and non market costs. While commuters who are paid wages (and who take different modes of transportation to work) spend time and money commuting, those who also perform domestic unpaid labor spend additional time and money that has been unaccounted for in transportation literature. This time that they spend on transportation takes additional time away from performing necessary domestic labor. As women's presence in the labor market has increased in the last half century, many women in households who perform domestic unpaid labor also perform wage labor (Fry et. al 2023). This means that the time spent in transit is valued even higher by the working woman, who is often taking time away from household, caretaking, and wage labor tasks. The phenomenon of being strapped for time given other more pressing obligations has been termed termed time poverty, and leads to patterns of social exclusion for those who do not have the time to leave the house, or time to spend on, say, public transportation instead of taking a car in an area where the reach of public transportation might be sparse (Aitken et. al 2024). This study aims to take this phenomenon and model the monetary costs associated with time poverty. Since unpaid labor is monetarily unaccounted for, this study monetizes this social cost and estimates the value of time spent in transit for those who perform unpaid labor, comparing it to the costs incurred for those who do not perform as much unpaid labor in the household (historically, these have been men's labor expectations). Although gender is a fluid framework and an ever changing social designation, because of historically significant gendered labor roles, gender is a framework by which these unaccounted costs can be accounted for. By estimating the costs incurred in transit as a result of unaccounted labor, this

study aims to look at two modes of transportation in Chicago in terms of unaccounted accessibility disparities.

Transportation accessibility literature is only recently opening up to exploring modal mismatch, or the significant difference in the accessibility of transportation based on the mode used (Credit et. al 2021, Lee et. al 2019, Zheng et. al 2023). While there is literature around spatially mismatched jobs and housing, the question of differentiated paid and unpaid labor and its effect on modal mismatch in Chicago has yet to be explored in the literature. Gender is not a biological determinant of differentiated labor patterns, but rather a social construction that has ended up defining labor differences. Vastly different labor expectations between half of the population have led to differences in the makeup of the labor market, the household labor force, and even in transportation outcomes. Transportation planning has also been a gendered labor sector, which has led to planning outcomes that empower the nuclear family with traditional gender roles, like suburbs, roads, and commuting design to name a few examples (Khalid et. al, 2022). The correlation between gender and differentiated labor patterns informs this study in order to investigate not the cause of this disparity but rather the material effect on the costs accrued by different genders in the urban mobility scheme of Chicago.

This study involves the monetization of a cost that is not monetized or quantified in the labor market; Unpaid labor is not monetarily accounted for in labor market figures, so undertaking cost modelling requires assumptions and estimations in order to yield a quantified value. Calculating and assigning a monetary cost to different modes of transportation based on a variety of patterns of behavior (both in and out of the labor market and in perceptions of modes of transportation) appears like an abstract exercise, but costs are vital in the calculation of optimal price and quality setting for a commodity. Models of marginal cost determine the supply

of a commodity while the demand often follows an inverse relationship, allowing for the intersection to be an optimal point for price setting. When costs of transportation are quantified, strategies can then be set to shift the quality and price of transportation in order to make it a viable option for a community it is currently too costly for. Costs are used in policy making to set prices and estimate how consumer behavior will change as a result, so it is important to consider all the costs that factor into transportation decisions made by women. Because women's costs across modes of transportation might not be adequately accounted for, there is a likelihood of inefficient policy responses as a result. For example, the efficiency of trains on a public transportation system (wait times, arrivals at different times of the day, pricing, etc.) might not be meeting women's needs because their needs have not been accounted for. In looking at the costs associated with different modes of transportation, this study will point to trade-offs in decision making, and point us in the direction of understanding how to shift preferences towards one mode of transportation to another, for instance, from taking a personal vehicle to using public transportation, and most importantly, how to make this equitable and accessible for both men and women.

This research is not only vital to painting a more robust picture of transportation consumer choice, but also to how our interactions with the urban environment in Chicago might be different as a result of gender. Gender is related to transportation access and use, and this has a direct impact on the environment. The choice to opt in to one mode of transportation over another, though it might be an economic question, ultimately leads to an environmental impact of differing sizes. If customers are increasingly opting into rideshare services, this bolsters emergent platform economies and invigorates greenhouse gas (GHG) intensive car infrastructure and industries (through demand for rideshare and auto services). If customers increasingly opt

into public transportation in Chicago, this would fulfill the need for customers on the CTA and reduce the carbon footprint for the average Chicagoan.

Literature review:

Chicago's urban transportation picture has a history thick with a systematic denial of access. Transportation access in today's economy, however, is vital towards the success and connectedness of different communities in Chicago, as well as the success of the CTA with its recently tapering ridership numbers. I discuss transportation access and its connection to the labor market and spatial differences in the urban workforce, to identify gendered labor differences that are unaccounted for in relevant transportation literature. Then I discuss how women have historically played a part in the urban workforce and the labor market, argue that transportation access is a gendered problem, and how gendered mobility research has largely neglected empirical methods of measuring gendered disparities in transportation in Chicago. Finally, I discuss the empirical methods involved in cost modelling and how they can be used to paint a picture of gendered access disparities in the urban environment of Chicago. I argue that dynamic mode choice profiles are an effective way to empirically map the many gendered costs associated with transportation, and are an effective way to bridge the gap between three disparate areas of transportation research.

Accessibility of Transportation

Transportation is a technological vehicle of urban development. A transit network's start and end nodes carry with them the politics of space as they carry goods, materials, and labor towards their developmental destination. In Chicago, public transportation is the great urban

connector of a demographically and economically segregated space. Segregation was central to the development and economic planning of the city, relegating black Americans to the south and west sides of Chicago especially following the wave of the Great Migration. This legacy was continued and enforced by violent practices like red lining and measures of racialized "risk" in bank lending for mortgages. Chicago's racially segregated urban development was and is doubly enforced by the lack of public transportation access. As the CTA destroyed L infrastructure and built an above ground subway system in the loop (following the Columbian Exposition), the south and west sides were systematically denied access to modes of smooth public transportation, an act that operated on outright neglect rather than forcible exclusion (Swyngedouw, 2013). Yet, the operation of infrastructural neglect is one that enacts a kind of slow violence——systematic denial of access to a technological resource that was inextricably tied to Chicago's urban development meant that excluded populations could not reap the social benefits of the CTA, and the economic development they benefited from followed local neighborhood patterns as opposed to interconnected lines of development in the loop, where people with transportation access could more easily find jobs and engage in global options for commerce. Chicago neighborhoods that were historically not invested in lack walkability, bikeability, and other modes of sustainable and accessible transportation (Segregation by Design, 2022).

There is an abundance of research surrounding accessibility of transportation in Chicago. Using a framework of access that aggregates the cartesian distance of transportation stops to different social amenities like parks and schools as well as jobs, Tilahun et. al (2020) outline, using the American Community Survey (ACS) and Chicago Transit data, the number of jobs and public infrastructure access points within a time range of a public transit stop in Chicago. They

find that the south and west sides (and notably Black and Latino neighborhoods) still have the greatest lack of access to these resources across the city. Another recent study that maps modal preference in Chicago (Credit et al., 2022) folds in recent options for transportation in Chicago (rideshare) in its study of access. It finds and models how rideshare users are paying a significant premium for the various advantages that rideshare affords, and that across different modes of transportation, black and hispanic people in Chicago face slower speeds and less mobility than other communities even with rideshare services. The historical exclusion of minorities from transportation has had cascading effects on their access to mobility today, even with new emerging transportation modes. Both public transportation and rideshare are significantly used modes of transportation in today's Chicago, and access to both of these modes will be the focus in this study due to the availability of data and a body of literature that already attempts to map access for these modes.

Jobs, commerce, and the relegation of different demographics to certain labor markets are deterministic factors driving transportation development and continued transportation ridership. If systematic neglect of certain communities meant that they could not be connected to the center of international global commerce (the finance and corporate sectors of Chicago have long been concentrated in the loop, which is largely far and more inaccessible to the south and west sides of the city), then local economies emerged, allowing for distinct neighborhood character and economies to emerge (Swyngedouw, 2013). Access to transportation has long been thought of as a problem of spatial proximity and income, but there is evidence in contemporary transportation research to suggest that the labor market and jobs that transportation connects people to are more important in the assessment of accessibility.

El-Geneidy et. al (2015), Foth et. al (2013), Grengs (2010), and Grengs (2015) studied urban development and the relationship between income, transportation, and urban development to find that in many large metropolitan cities, lower income neighborhoods do have transportation access to employment and other opportunities, bolstering the argument that lower income families move to inner city neighborhoods in the pursuit of easier access to transportation. However, authors of a study (Legrain et al., 2016) find that even if transportation is available, low income workers still might not be able to access the jobs that they have, and so the problem of access as it relates to transportation is not necessarily lack of access to transportation itself but the fact that destinations may not be connected to transit stops. The issue of accessibility then is twofold—the people and their destinations are just as important as is their connectedness to transit stops. One study found that transportation access had very little impact on the search for employment for welfare recipients (Sanchez et al., 2004), providing evidence that people choose or find their jobs first, and then worry about finding ways to commute afterwards. Jobs and labor market participation appear to be the first decision people make about their position in the urban environment of Chicago, and then their spatial connection comes as an afterthought to this decision. There is a clear gap in this research that aims to model the relationship between jobs and transportation access—women interact differently with the labor market, and unpaid domestic labor (and the locations that unpaid laborers use transportation to access) is unaccounted for in this research.

How people get access to different labor markets and work in different industrial sectors in Chicago is a complex social and economic question that is beyond the scope of this research, but it is certain that people's labor market outcomes in Chicago greatly affect their accessibility to transportation and the costs that they may incur trying to get from their place of residence to

their place of work. Gender is a distinction that affects labor market participation and has been largely unaccounted for in labor-focused transportation research. My research aims to undertake this gap and account for unpaid labor, which is largely undertaken by women in Chicago. Later on in my discussion of gendered urban mobility I will discuss how this might actually become a self perpetuating cycle for women who lack secure wage labor employment.

Gendered Inequalities in Labor and Transportation

There are a variety of demographic and economic indicators determining the labor that different communities engage in in Chicago, which in turn affect their transportation access. One of these economic indicators is gender, because gender is correlated with different types of labor. An often overlooked sector of the labor force is one somewhat unaccounted for in the specifics of their work: domestic unpaid laborers. I use the terms “domestic unpaid labor” or “domestic labor” to describe labor that involves taking care of dependents, cooking, cleaning, and other forms of caregiving which are not paid activities but are socially necessary. While domestic labor is not necessarily a gendered labor possibility, historically, women have been relegated to domestic labor and have been excluded from different sectors of the American workforce, although that continues to change. 65% of women in Chicago participate in the labor force, which is above the national trend but still lagging behind men in Chicago, of whom 71% participate in the labor force (City of Chicago, 2022). Even if the labor force participation gap continues to close, there is still an average income disparity for women compared to men in the labor force. Markedly, women who are in the labor force are still likely to do a higher proportion of domestic labor, all of which is unpaid labor (Hsu, 2023).

Gender is a socially constructed phenomenon assigned by the typological hegemony of the US medical system and enacted in performance by the surrounding community and infrastructure (Butler, 1990). My study recognizes that gender is not a biological determinant of differentiated labor patterns, but rather a process of production of labor differentiation in the economic order of the US. Gender not only empirically is correlated with the proportion of time spent working in the household but also in perceptions of safety and wait time in transit (Fan et. al 2016, Lubitow et. al 2017), meaning that women are likely to experience harassment in different transportation modes.

Because gender is correlated with different labor outcomes and perceptions of safety as a result of harassment, women have a different relationship to transportation access than men. Transport Related Social Exclusion (TRSE) is a phenomenon that has been observed for a variety of populations in Chicago across the body of transportation access literature (Lucas, 2019). Another dimension affecting access to transportation is time poverty, or situations in which household and work commitments decrease people's available time for necessary activities. Time poverty directly affects transport poverty, which is the inability to afford or access transportation. A study by Aitken et. al (2024) integrates both concepts to understand transportation's contribution to time poverty. The study finds that the issue of people spending an excessive amount of time traveling, leading to time poverty, can be exacerbated for women, immigrants, and non-white residents. (Lucas, 2012) outlines a transport-related social exclusion framework, which describes how people will experience transport disadvantage if they face a high cost to be mobile, and might face transport poverty if they are low income, have inadequate housing, or other social disadvantages. Aitken et. al (2024) develops a model using the TRSE framework for free time that departs from the conventional labor economics distinction of labor

and leisure. It calculates free time as the number of hours per week minus necessary time, committed household time, and contracted time. In the study's panel data analysis, gender was a high indicator of time poverty, as was income and race. Because women to this day are overwhelmingly performing domestic labor, while their labor market participation continues to increase, the value of free time for women is increasingly valuable and thus more costly if it is spent in transit rather than at work or at home (or other locations where they perform domestic labor, such as grocery stores and schools).

Uteng (2021) reviews literature on patterns of women's use of transportation, which tries to map the transportation habits of women who don't participate in the labor force, raise dependents, perform more household labor than men, and those who do participate in the labor market. Scheiner and Holz-Rau (2017) demonstrate that even if license holding and access to cars has increased for women over time, there is still a preference for public transportation and walking among women. Paleti et. al (2011) and Scheiner and Holz-Rau (2017) find that women's trips are more spatially complex and involve chaining multiple nodes of travel. This points to why there might be a preference for public transportation amongst women over men–if there are spatially complex nodes women go to that require multiple legs of travel, public transportation is a cost effective option to get to all of them with one or a few fixed costs. To complicate this story, Ceccato and Loukaitou-Sideris (2020) find that the fear of sexual harassment and concerns over personal safety are still significant factors driving women's mobility choices. A higher share of women are either unemployed, work part time, or work close to home to balance household responsibilities. Many trips that women take on modes of transportation are done in difficult to schedule slots of time that usually require the coordination of work schedules and sometimes school schedules (for women with children) and of the availability of transportation within the

urban system (Madariaga, 2013). With public transportation comes the heightened risk of harassment and the complex coordination of schedules to optimize travel, yet it has enough benefits that women are still opting into the mode. Because this picture is so complex, folding in some of these factors in estimating costs might give a clearer picture of women's issues and needs when it comes to transportation access.

Transportation accessibility, outlined as a problem of bringing people to the sites of their employment or unpaid labor, is a much more complex issue for women and those who do a higher share of housework, or raise dependents. My study takes these characteristics of women's labor market outcomes and the time they spend on average doing housework to assess gendered urban mobility in Chicago.

The aforementioned literature that studies women's relationship to labor and transportation identifies that women face higher costs and utilities to transportation than men do. However, there is a lack of research attempting to explicitly quantify these distinctions in costs between genders in Chicago. While the gendered distinctions are important to qualitatively identify to understand the story of gendered access, quantifying these distinctions would give a clear indication of how transportation is not equitable between the genders, and what can be done to bridge the gap. This literature provides a roadmap for variables and gendered distinctions that can be used to quantifiably demonstrate the different costs that women face in transit than men.

Cost Estimation for Gendered Mobility

Gauvin et. al (2020) conducted a study in Santiago, Mexico using mobile phone data to assess patterns of gendered mobility. The study found that access to transportation reduced mobility (the ability to be mobile and utilize transit) differences across socio-economic segments

for men but significantly less for women. This provides evidence for the idea that when women are connected to transportation, having a low income is a factor constraining women's mobility in the urban environment. Income and labor market outcomes are a driving factor in keeping women in a socially exclusionary paradigm of mobility. Because so many women perform domestic labor and face expectations to continue doing so, they end up using transportation for domestic labor uses, even if they gain access to more reliable public transportation that could connect them to urban centers (areas where wage laborers are employed). The value of household labor might account for this difference. Women and families might value household labor highly, and this is unaccounted for in the valuation of transportation. Because of this, the trade off for mobility may not be equivalent to the social trade off of wage employment over household labor. By including and monetizing the value of household labor, we might be able to value and analyze patterns in mobility with culturally informed calculations of the cost trade offs of transportation.

I use the framework of costs here because costs can tell us about why consumers make the choices that they do; consumers might opt into one type of transportation over another because the latter is too costly in ways that are more than just monetary (for example, women might choose one mode of transportation because they will save more time that would be spent doing household labor). Because women make chains of complex decisions when they decide to opt into transit for a variety of labor and income related reasons, modelling the costs associated with transportation for women in Chicago—using the gender distinction of income disparity—can give us a deeper and wider picture of gender inequities in mobility across Chicago. It can also give us an indication of why some modes might be more preferred than others among different genders in different regions across Chicago.

Calculating and assigning a monetary cost for different modes of transportation is vital in the calculation of optimal price and quality setting for transportation. Models of marginal cost determine the supply of a commodity while the demand often follows an inverse relationship, allowing for the intersection to be an optimal point for price setting. As an example of the effects of gendered cost calculation in practice, the City of Buenos Aires is collaborating on the the Global New Mobility Coalition's Urban Mobility Scorecard initiative (UMSi), as it has been working on a Gender and Mobility plan to plan, manage, and design transportation with a gender perspective. This program aims to assess the needs, patterns, and costs associated with public transportation in order to make the public infrastructure more accessible to women. In looking at the costs associated with different modes of transportation, this study will point to trade-offs in decision making, and point us in the direction of understanding how to shift preferences towards one mode of transportation to another, for instance, from taking a personal vehicle to using public transportation, and most importantly, how to make this equitable and accessible for both men and women.

Credit et. al (2021) established a method to explore neighborhood-level inequity in Chicago using dynamic transportation mode choice profile. The study used statistics of fixed costs associated with all modes of transportation as well as average income data to estimate the costs incurred on all possible modes of transportation in Chicago, and how the cost has a relationship to the distance of the trip. In this study, heterogeneity of the findings was organized by race, ethnicity, and the form of the built environment. Modal mismatch, or the idea that different transportation modes differ in cost across different regions, has not been extensively explored in transportation literature, but is important to understand why the transportation landscape might be changing as more modes (like rideshare) come into the picture, and why

some communities might opt to use one mode over another. The estimation of dynamic transportation mode choice profiles has not been explored through the lens of gender disparity, which is the gap that my framing of transportation as a gendered labor problem addresses.

Methods to integrate gendered costs to evaluate Chicago Transit

There are several parameters around gender that I use to estimate costs associated with transit for men and women. One such parameter is perceived wait time. Although time spent waiting for transportation might be significantly more costly for some demographics over others, the perceived time spent waiting for transportation might also differ across modes and for different demographics, which will inadvertently affect the cost of each mode of transportation, even if that perceived time spent is not being realized. (Fan et. al 2016) demonstrates in a study that the perceived wait time at public transportation stops exceeds the actual waiting time, and this is delineated between demographics including race and gender. Notably, the study found that women perceive wait times to be 1.5 times the actual time of the wait (before they board a train or bus), and this number was statistically significant in the analysis. The study provides a number of explanations for this, the foremost one being the higher incidence and probability of harassment at transit stops for women and the perception of being in an unsafe place. Women or people who fear for their safety at transit stops might perceive the time to be a lot longer out of worry or anticipation of violence. The perception of a lack of safety and the lengthening in the perception of time is part of the cost incurred by women—if they worry they will have to wait longer than they actually will, then this might affect women's decisions to wait until their bus or train comes to the stop. The number that the study found, 1.5, is later used as a "wait time premium" in my calculation of costs for women on transit modes.

An inflated wait time perception may also have an effect on the "last mile problem," which affects most customers of public transportation. The last mile problem is the fact that even though public transportation might be able to take a person from one place to another by covering most of the distance, the first and last miles (or even more) of the journey that may not be covered end up presenting a significant barrier to the traveler, and might be the reason they either opt out of using public transit (and use rideshare today) or facing the consequences of a long commute time (Lee et al., 2022). The last mile problem might be amplified for women, who actually take more chained trips and might be more inclined to take transit despite the long start and end legs, but might opt out because the perception of a longer wait time, which could amplify unsafe feelings or perceived exposure to the threat of sexual violence. If one perceives the "last mile" of their journey to be longer than they anticipated due to threats to their safety, then they might be even less likely to opt into that transportation journey. The last mile problem is currently being addressed by the addition of transit nodes across Chicago's map, or the inclusion of micro mobility (for example, bike sharing) at transit stops to allow for quick transit for the "last mile." Micro mobility solutions might orient towards equitable transportation experiences between genders, but as the problem still exists, the last mile problem further exacerbates gender disparities in transportation, because the "last mile" could prolong exposure to unsafe environments for women.

Lee et al., 2022's research utilized cost models to see the trade off point between modes. The study identified the determinants of consumer's choices in using rideshare in San Francisco and why they opted for one mode over the other, and how this was related to each location's spatial urban structure. While this study employed a cost function for each mode of transit and modeled consumer choice on multidimensional axes, the unique landscape of Chicago has yet to

be investigated in this granularity of modal preference with respect to access to different urban amenities, specifically using gender as a distinguishing parameter of access. This question is especially pertinent when we investigate consumer choice for women and gender minorities, who value time much higher on average than men.

While my research does not attempt to extensively explain the potential causes and consequences of time poverty, I aim to draw from multiple methodologies attempting to model the costs of transportation for different people across Chicago using the cost modelling frameworks described by (Credit et. al 2022), adapted by the social costs and value of time in the TRSE framework, and scaling costs using perceived waiting times as described by Fan et. al (2016). Modelling the costs accrued per mode of transit by gender across neighborhoods of Chicago, my research will fill a gap in questions of quantified gendered urban mobility, transportation cost estimation, and in the effects of labor and income on transportation access.

Research from the Civic Federation posited that the CTA's productivity——or the labor cost per actual unlinked passenger trip and operating expense per passenger mile–had increased between 2014 and 2018, due to a decrease in ridership and competition from alternative transit options like rideshare. The economic costs of a variety of transportation options, as economic theory purports, is a driver behind the demand for each modal choice (Credit et. al, 2022). If one option is less costly than another, consumers are more likely to adopt that mode of transportation. When assessing the accessibility of transportation as a commodity and in order to predict or describe the demand patterns that act as market signals, the assessment of costs is vital in the assessment of demand across different demographics. While the CTA has conducted surveys finding that women perceive a greater threat to their safety on the public transportation system,

there is no existing literature attempting to model the costs associated with different modes of transportation for women and gender minorities.

To summarize the literature around this topic, my study aims to bridge the gaps between three disparate areas in transportation research. Firstly, transportation accessibility research in Chicago provides frameworks and findings that identify certain spatial districts of Chicago to have less access to certain modes of transportation (rideshare and public transportation), and they look at labor and employment as parameters and explanations of the lack of access to transportation. However, this literature does not take into account that women, who perform domestic unpaid labor, utilize transportation for the ends of their labor differently. There is a body of research that shows how women use transportation differently and are more likely to face transportation poverty than men, but this research does not quantify how women face different costs to transportation than men. Methodological research that aims to look at costs across different modal options also does not account for gendered differences in costs. To bridge these gaps, my research looks at gendered determinants of transportation poverty (unpaid labor, wage disparities, perceptions of safety) to quantify the gendered costs of transportation across two modes. This will give a picture of access that has been unaccounted for in Chicago transportation research.

In order to bridge the gaps in this literature as it relates to Chicago, it is necessary to employ a rigorous estimation of cost modelling in order to make sense of consumer behavior in recent years. By using the American Community Survey (ACS) and the OpenTripPlanner routing resource as outlined by previous literature, this study composites large datasets in order to estimate costs for each mode of transit by gender and by census tract. For the sake of granularity and because of the relevance of the modes in recent years (one growing in prevalence and one's

ridership numbers decreasing), I am focusing on rideshare and public transportation (CTA) modes for this analysis. My research will further our understanding of accessibility across all the modes available in Chicago, and how they affect the demand and consequently the urban dynamics of the metropolitan area.

Data and Methods:

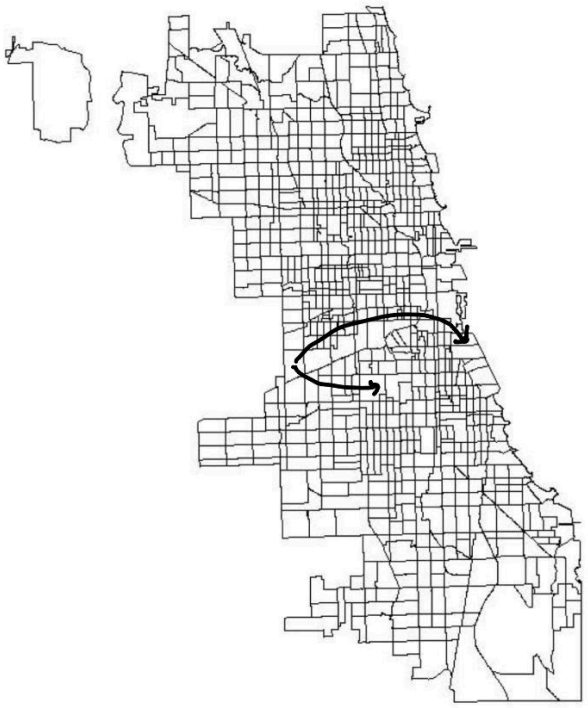
In order to estimate the costs incurred on two modes of transportation (rideshare and public transportation), I utilize several data sources and combine them to make statistically significant inferences about the gender disparity in transportation mobility across Chicago census tracts.

Data Sources

The primary data that will be used in this study are travel times, travel distances, wait times, and travel tracts by mode to and from 2023 Census tract centroids in Chicago. I used a similar process to that outlined by Credit et. al (2021). These centroids are obtained from OpenStreetMap (OSM), which gives information about street, bicycle, pedestrian, and transit networks. Using a census application programming interface (API) key, I queried OSM data to find all the coordinates of the bus and train stops in the city of Chicago. Based on computational constraints, I sampled one centroid from each census tract out of Chicago's 866 for both bus and train modes. Next, I created a graph object (a spatial file) using OSM data and General Transit Feed Specification (GTFS) data, which provides routing, headway, and arrival information about the CTA system. I created this graph using OpenTripPlanner (OTP), an open-source Java-based routing service. By creating this spatial data file that has information about all stops and routes in the city of Chicago, I built an "OTP instance," or a connection to the OTP server given the location and routes of interest.

Next, for each transit mode (bus and train), I used a loop using the R package "otpr" to execute the "get time" command and query travel times, which gives us the total travel time from distance i to j, including time spent walking, waiting, and on transit, and the total number of

transfers the traveller had to make. This loop takes the sample of centroids that I inputted and makes simulated possible routes to get from every combination of one centroid to another (866x866 combinations total). It routes from each centroid to every other centroid by finding the quickest routes by CTA by both the bus or subway (not a combination of the modes). The centroid origins are also the centroid destinations computed in the loop. It finds wait times and travel times of these routes given the CTA schedule on 12/15/2023 at 8 am. I picked this time because it is the time of the largest density of rides, although if I were to choose a different hour the wait and travel times between centroids would be longer, given that morning hours have the highest density of trips on the CTA. The date was arbitrarily chosen with the assumption that differences in costs incurred for women versus men would not be drastically altered by seasons, although that would be a separate hypothesis to test outside of the scope of this research. Riders across Chicago are likely to chain rides across different public transportation modes (subway and bus in combination), but for the sake of computational constraints, the trips I extracted were either solely by bus or subway. Utilizing the census API key I obtained, I matched each origin and destination coordinate for each trip to a census tract so that I could do further analysis on tract wide gender disparities. I cleaned the resulting dataset and stored it in a csv file, which was used to plot travel time cost curves by gender. The resulting csv file had 363,577 hypothetical trips routed from one census tract to another.



The loop calculates the quickest path from one centroid from one census tract to another. It executes this process from each census tract shown to every other census tract.

The most computationally intensive part of the data collection process was the execution of the for loop to create the csv file with the parameters of interest. For each centroid, the loop linked the centroid origin (866 origin centroids) to each of the other 866 centroids as their destination. For each of these trips, OTP was utilized to extract the latitude and longitude point of every origin and destination, and then route the quickest path using public transportation (bus and subway modes) using the OTP instance. Then, the haversine function is used to calculate and store the distance between the two coordinates as a variable. Next, the transit duration, walk duration, waiting duration, and number of transfers are extracted and stored as variables. Lastly, the census tract origin and destination are stored as variables, and then the loop goes on to link the next pair of centroids until the process is complete. I ran two separate loops for bus and subway centroids for computational ease.

OTP is able to compute travel times for auto, walking, and bicycling modes, but does not take into account traffic congestion. Just as the study by Credit et. al (2021) deals with this

discrepancy, I use the Transportation Network Providers (TNP) dataset that contains all individual rideshare trips from Uber, Lyft, and Via which gives the actual distance and travel time per trip, as well as the paid fare for each trip. To use the same time parameters as the query made through OTP, I extracted the TNP dataset for 12/15/2023 from 8 am to 1 pm. In order to model Cost as a function of Distance, I used the Haversine distance between tract centroids when comparing the modes from OTP data while I used the actual precise distance from the TNP dataset. I had two parallel working datasets for the cost calculation analysis: travel times, wait times, and distances obtained from OTP for trips via public transportation, and travel times, distances, and fare obtained from the TNP dataset for trips via rideshare.

Finally, I utilized census bureau data using a census API key for the American Community Survey (ACS) in order to find the median yearly income for men and women across all Chicago census tracts. In my calculation of costs, I use these tract-level disparities in order to calculate the costs incurred on trips from each Chicago tract for women and men. In addition, I utilize the Organization for Economic Cooperation and Development's estimate of the time spent each day doing unpaid labor for men and women in order to calculate the total accounted-for income in opportunity cost, as will be shown in the subsequent cost models. The reported value is 4 hours on average per day for women, and 2.5 hours on average per day for men (Donner, 2020).

Travel Costs

In order to calculate the empirical cost curves associated with each mode of transportation, I utilize the cost models established by Credit et. al (2021) and adjust the calculation of opportunity costs in order to accurately represent the value of time for each gender. I utilize trip-level data (each row of csv chicagocentroids2) in order to calculate the costs per trip, and add four columns to the csv: I calculate both the raw and relative costs of travel for women and men. The raw cost is the monetary cost incurred to each traveller given the parameters shown below, and the relative cost is the raw cost divided by the traveler's income by minute. The goal of using the relative cost is to demonstrate how costly a trip might be for a customer based on their income, since an expensive trip might incur even more expense for a person who earns less income. The subscript *share* in the following equations denotes the rideshare mode, and *trans* denotes the public transportation modes. The following are the equations used to model cost and below is a table describing each variable and how it is calculated:

Raw Cost Equations:

$$C^{\text{raw}}_{\text{share},ij} = \left(T_{\text{share},ij} \cdot N_{\text{vgt}} \cdot d^{-0.044}_{\text{share},ij}\right) + l_{ij} \quad (1)$$

$$C^{\text{raw}}_{\text{trans},ij} = \left(T_{\text{trans},ij} \cdot (W_{\text{trans},ij} \cdot \lambda) \cdot N_{\text{vgt}} \cdot d^{-0.044}_{\text{trans},ij} \cdot e^{-0.4}\right) + F + q_{ij} \quad (2)$$

Relative Cost Equations:

$$C^{\text{relative}}_{\text{share},ij} = \frac{C^{\text{raw}}_{\text{share},ij}}{\text{wage\_income\_per\_minute}} \quad (3)$$

$$C^{\text{relative}}_{\text{trans},ij} = \frac{C^{\text{raw}}_{\text{trans},ij}}{\text{wage\_income\_per\_minute}} \quad (4)$$

Variable	Description
$T_{\text{share},ij}$	Exact time spent travelling via rideshare from point i to point j.
$d_{\text{share},ij}$	Distance from point i to j. 0.044 is the base elasticity reported by auto users of increasing value of time with trip distance (Abrantes and Wardman, 2011).
l_{ij}	Trip cost total from the TNP dataset.
$T_{\text{trans},ij}$	Time spent on transit from point i to point j, with data on time spent at each stop and scaling by perceived wait times for men and women (Fan et al., 2016).
$W_{\text{trans},ij}$	Time spent waiting at a transit stop during the trip from point i to point j.
$d_{\text{trans},ij}$	Distance from point i to j.
F	Chicago Transit Authority (CTA) fare for a trip.
q_{ij}	Any additional cost associated with the transit for the trip, such as transfer fare.
λ	Wait time premium multiplier applied to $W_{\text{trans},ij}$: 1.5 for women and 1 for men (Fan et al., 2016).
N_{vgt}	Calculated as: $$N_{\text{vgt}} = \frac{\left(\frac{\text{yearly income}}{2080} \cdot (\text{household\_labor\_hours} \cdot 365) + \text{income}\right)}{525,600}$$ where income is the annual income, household_labor_hours represents the number of hours spent doing household work per day, 2080 is the number of hours spent working in a year (assuming full-time employment), and 525,600 is the number of minutes in a year.

$Nvgt$ is the average opportunity cost per minute of travel, or total yearly income divided by 525,600 minutes in a year. At a high level, opportunity cost is defined as the cost incurred opting to do one activity over another. Here, the opportunity cost is the cost incurred by opting to be on transit instead of work, whether that be your labor market work or your housework. By taking the household labor hours and multiplying that by the hourly income, I value household hours with the same income rate as paid work in order to make sure that household labor is being appropriately valued and accounted for in the opportunity cost. If a woman who spends a lot of hours doing housework is on transit, she is losing time that could be utilized for her household labor, and may incur further costs as a result. I employ the Organization for Economic Cooperation and Development's estimate of the time spent each day doing unpaid labor for men and women to calculate the total income (the total monetary value of both contracted and household labor) as the wage + (the wage * the number of hours spent working in the household).

The estimate used for the number of hours worked in the household per day for men and women is a national average, which may not give an accurate indication of the per neighborhood differences in the time women and men spend working in the household. There are several factors driving why in some households men and women perform different amounts of household and child care labor, including culturally constructed attitudes towards women's place in the labor market or in the household (Hsu, 2023). These differences are not available in tract wide data, which is why I opt to use a national average. Additionally, I scale the hours people spend doing household work by the average hourly wage of women and men in that census tract, which might not contain all the monetary value that household work contains, although there is no quantitative literature estimating the value of household work without using wage and GDP

estimates. Since this is the paradigm in most economics literature around the value of household labor or child care labor, I use this methodology to calculate the opportunity cost of time for men and women in each census tract.

All of these equations of cost can be used to plot cost-distance modal trade off curves, which will look different based on the value of $Nvgt$ and λ for men and women. Plugging each Cost calculation (by mode) into T in the following equation: $T_i m_i = \beta_i d + \varepsilon_i$, with m_i as the mode of transportation, I plot a regression between the cost and distance for each mode, for men and women respectively.

Hypothesis

In order to frame and test my hypothesis, which concerns the role of gender in affecting costs, I restructured my data (chicagocentroids2) to duplicate each trip (row) and include gender as a column, so that for each trip, the costs incurred to women and men would still be included but on different rows. This made it so that gender, a binary variable (a 1 for women and 0 for men) could be used in a regression specification and thus used for hypothesis testing. The following is the regression equation I used in order to set up my hypothesis test, as well as the parameters of interest:

$$\text{Cost} = \beta_0 + \beta_1 \cdot \text{Distance} + \beta_2 \cdot \text{Gender} + \beta_3 \cdot (\text{Distance} \times \text{Gender}) + \varepsilon$$

Coefficient	Interpretation
β_0	Baseline cost (intercept) for men when distance = 0
β_1	Effect of distance on cost for men
β_2	Baseline cost difference between women and men (intercept shift)
β_3	Additional effect of distance on cost for women compared to men

The primary hypothesis that I test is:

H1: Gender Hypothesis: Women will display significantly lower potential mobility by mode while men will display higher potential mobility by mode. In the above terms, H1 describes β_2 as positive and significant, which would indicate that the baseline cost is different between the genders (higher for women). H1 describes β_3 as positive and significant, which would indicate that women experience a higher marginal cost per unit of distance, meaning women incur a higher cost by increasing one unit of distance in their trip compared to men.

This hypothesis can be empirically tested by testing the signs and statistical significance of β_2 and β_3. The statistical significance will be determined by the p-value, specifically that it is less than 0.05. If the p value is <0.05, we can reject the null hypothesis. The null hypothesis is as follows: **H0**: there is no empirical difference in the costs associated with different modes of transportation between men and women. This hypothesis will be tested with each mode of transportation: rideshare and public transportation.

Additionally, I utilize ArcGIS Online to plot the disparity between the cost ratio for men and women by Chicago census tract, in order to give an indication of where there might be higher disparities in costs by gender across Chicago.

Results:

In mapping cost-distance trade offs, I observe and test differences in costs incurred on rideshare and public transportation between men and women. Beginning by establishing differing labor parameters for men and women, I differentiate between the opportunity cost and the expense of time spent in transit and time spent waiting at transit stops. After extracting trips taken via rideshare and by transit in the city of Chicago, I map both the raw and relative cost as a function of distance, differentiated for women and men, and create a line of best fit using a Least Squares Regression in order to find the trend that will empirically determine the average trend of costs incurred to both genders as the distance of travel increases. Using my regression equation I conduct my gender hypothesis test, and using the calculations in the gender cost disparity, I map disparities across the Chicago census tract to demonstrate heterogeneity amongst different communities. Lastly, I compare the relative costs incurred on public transportation and rideshare for women and men to assess whether there is a potential for a different "modal trade off" between the genders, meaning whether there is a difference in the optimal point at which men or women will choose one mode over another.

Rideshare

In observing the cost of rideshare by the duration of travel for all trips on 12/15/2023, below is the cost-distance tradeoff for men versus women. The following are figures and values computed based on the census tract origin of trips, in order to demonstrate the gendered costs incurred by leaving from the given census tracts. Compared to the transit mode, where wait times play a part in differentiating costs by putting a premium on the value of wait time, the main differentiating factor for the cost of rideshare is the opportunity cost of time, calculated by the

total yearly income of men and women and scaled by the number of labor hours spent in the household by both genders.

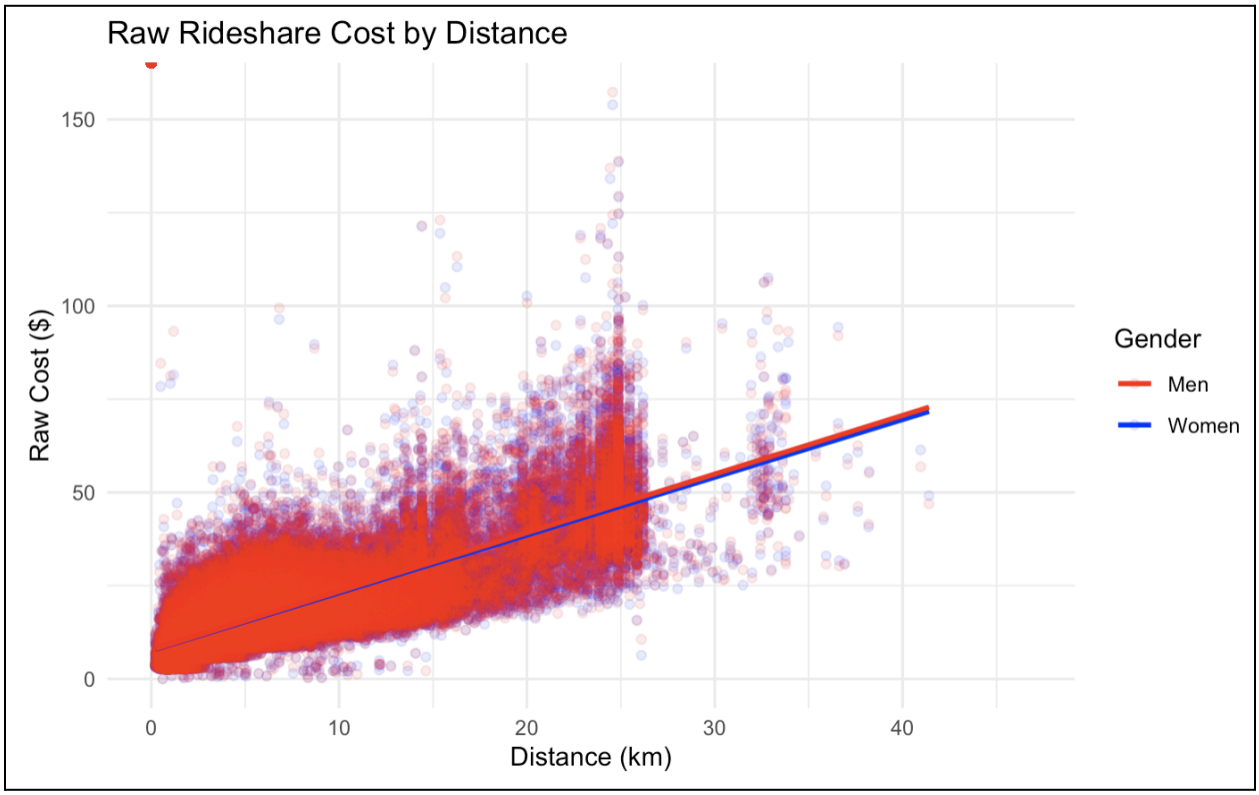


Figure 3: The Raw Costs of Rideshare by the distance traveled for Men and Women

The chart above shows the plotted raw costs for each rideshare trip, distinguishing between the costs for women and men. The lines shown are the lines of best fit using the Ordinary Least Squares (OLS) regression. Although the lines look almost overlapping, there is a distinction between the average raw costs for men versus women, which are shown in the regression coefficient results below:

Term	Estimate	p-value
β_0 (Intercept)	7.7270	< 0.001
β_1 (Distance)	1.5725	< 0.001
β_2 (Gender: Women)	-0.0981	0.043
β_3 (Distance $\times$ Gender)	-0.0250	< 0.001

Figure 4: Regression Coefficients of Raw Costs by Gender and Distance for Rideshare

The results for the raw costs of rideshare by gender fail to reject my null hypothesis for the mode. β_2 and β_3 are negative values, although they are close to zero, and they are statistically significant. The costs incurred by men exceed the costs incurred by women on average for rideshare modes. Even though the opportunity cost of travel that I used is scaled by the number of hours women spend working in the household, the fundamental differentiating factor here is that men on average still have a higher income, even if household labor is valued with wages. The average disparity in cost is still not very high, and the differentiating factor is the opportunity cost of time. With rideshare, most of the costs per trip are fixed by the rideshare service, fluctuating based on the demand for riders and the availability of riders. The opportunity cost of time only marginally shifts how much each trip costs, since the majority of the cost you are paying goes directly to the rideshare service provider.

Although the costs incurred for this mode are higher than other modes, they are short term, one time pay costs and not incremental costs that require other forms of long term commitment and car insurance—like owning a personal vehicle would entail. Riders do not have to spend a long time waiting for their rides and deal with the premium of wait time, which is differentiated across gender. Rideshare services provide isolation and insulation from the public

world, which might appeal to women who feel especially unsafe in public spaces. Yet, being in a vehicle alone with (largely male) drivers poses its own risk, as there have been a series of assault cases amongst drivers and their passengers (Sharp, 2025), although the power dynamic is warped by the dynamic of service provider and paying customer.

I fail to reject the null hypothesis for gender disparity and actually find the opposite of my hypothesis–that men incur more raw costs on rideshare than women. If I map the relative cost (the cost relative to income) however, I find the opposite—that because women on average have less money to spend, each rideshare trip is relatively more costly for women than for men. Below are the results of my regression analysis when observing the relative rideshare cost by distance, which is the raw cost divided by the income per minute.

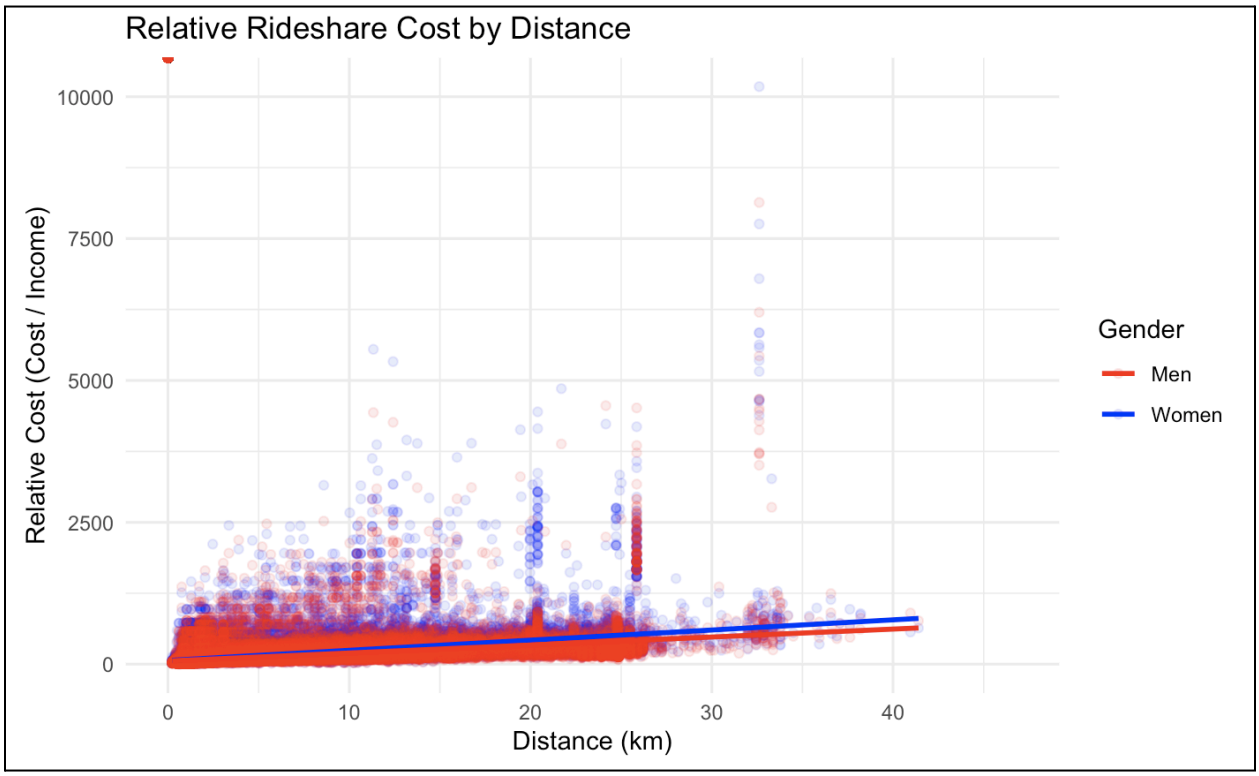


Figure 5: The Relative Costs of Rideshare by the distance traveled for Men and Women

The chart above shows the plotted relative costs for each rideshare trip, distinguishing between the costs for women and men. The lines shown are the lines of best fit using the Ordinary Least Squares (OLS) regression. Although the lines look almost overlapping, there is a distinction between the average relative costs for men versus women, which are shown in the regression coefficient results below:

Term	Estimate	p-value
β_0 (Intercept)	57.7217	< 0.001
β_1 (Distance)	14.0292	< 0.001
β_2 (Gender: Women)	7.8355	< 0.001
β_3 (Distance $\times$ Gender)	3.8738	< 0.001

Figure 6: Relative Costs by Gender and Distance for Rideshare

In this relative cost estimate, I find that β_2 and β_3 are both positive and statistically significant, which means we can reject the null hypothesis and conclude that women still experience lower potential mobility than men on rideshare modes. Rideshare services are relatively more costly for women because of the difference in income between women and men across Chicago census tracts. To demonstrate the disparity visually, below are the values for the disparity in raw and relative costs incurred for women and men on rideshare. This gives a sense of which census tracts experience the highest gender disparity in costs of rideshare. This disparity is calculated by the origin census tracts of the trips:

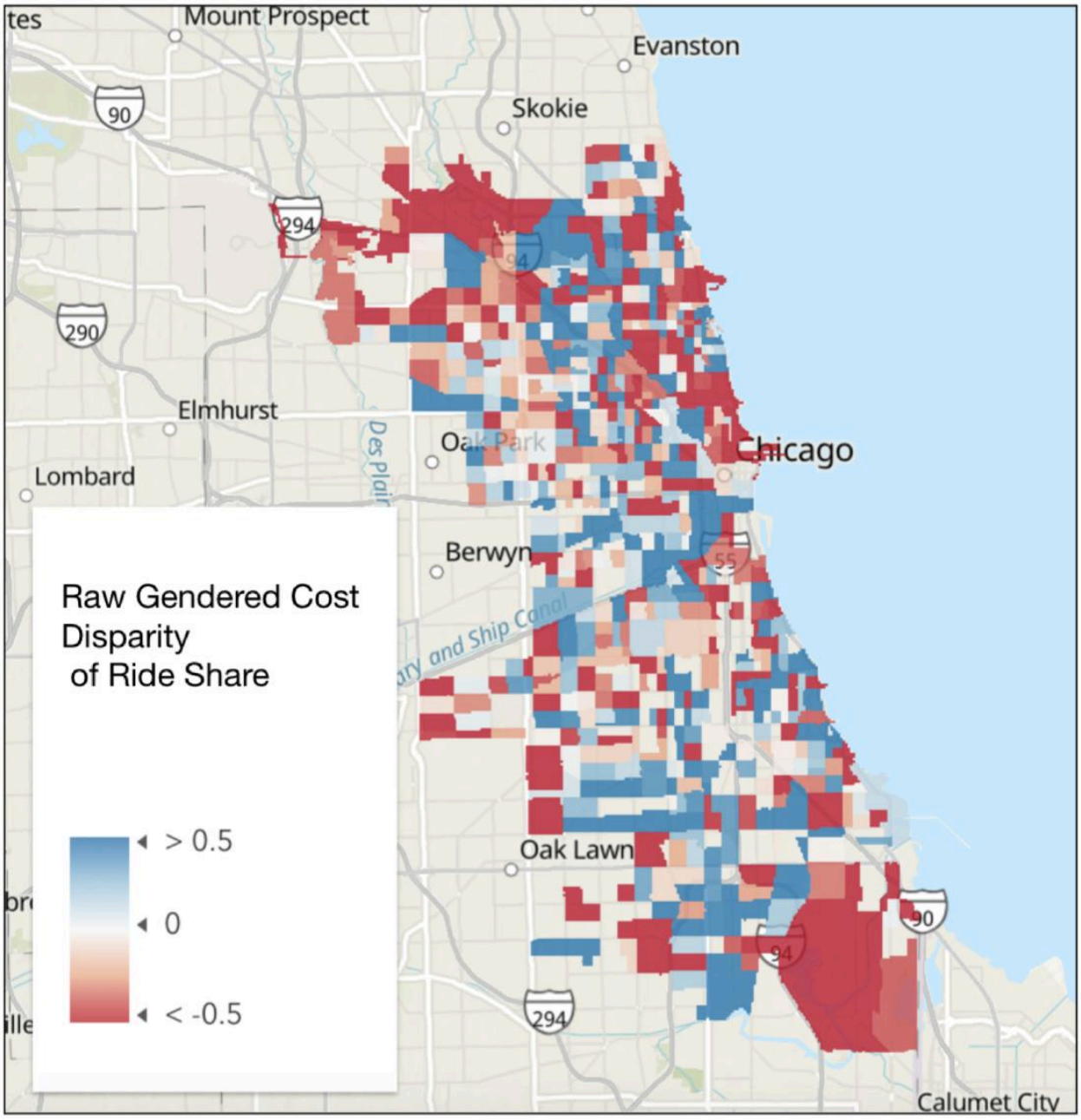


Figure 7: Gender Disparity in Raw Costs of Rideshare

In this chart, the blue tracts indicate where the raw costs of rideshare are more for women than men on average. The red tracts indicate where the raw costs of rideshare are more for men than women on average.

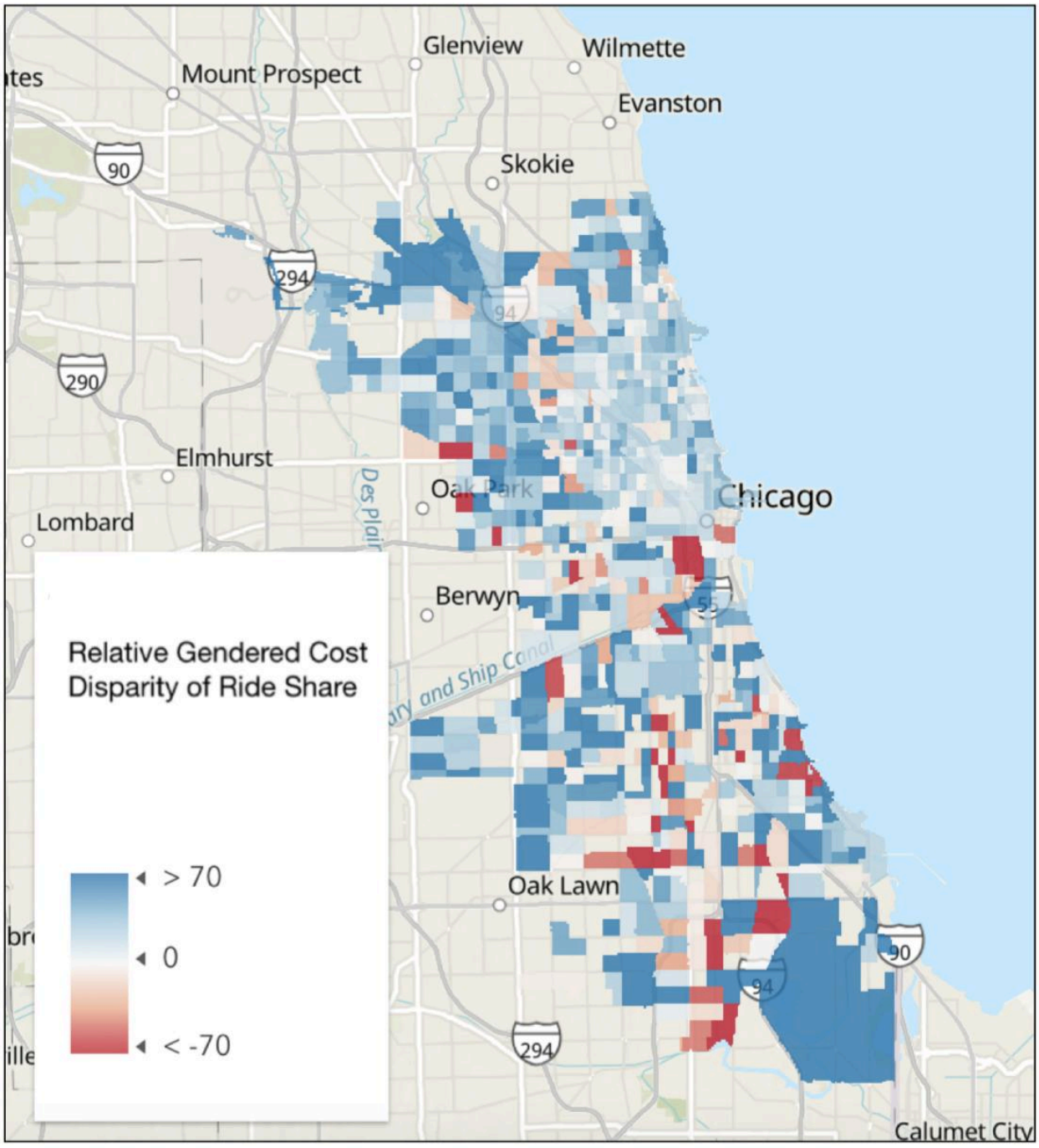


Figure 8: Gender Disparity in Relative Costs of Rideshare

In this chart, like the one above it, the blue tracts indicate where the relative costs of rideshare are more for women than men on average. The red tracts indicate where the relative costs of rideshare are more for men than women on average.

In the mapping of relative cost, we see that there are still census tracts across Chicago where the relative costs of rideshare are still higher for men than for women. This can be explained mathematically by the increased costs of trips originating from those census tracts, or by women having above average incomes compared to men in those tracts. Although on average, women incur more relative costs across the observed tracts, this spatial organization reveals that there are still some regions where the opposite is true.

Public Transportation Modes

For public transportation modes, the costs look slightly different, since another factor being applied is the wait time premium. The following table shows 363,577 potential trips taken on 12/15/2023 at 8 am, with their cost scaled by both the opportunity cost of time and the premium of wait time. Below are origin-based results, meaning the costs and disparities were calculated given the origin of each trip.

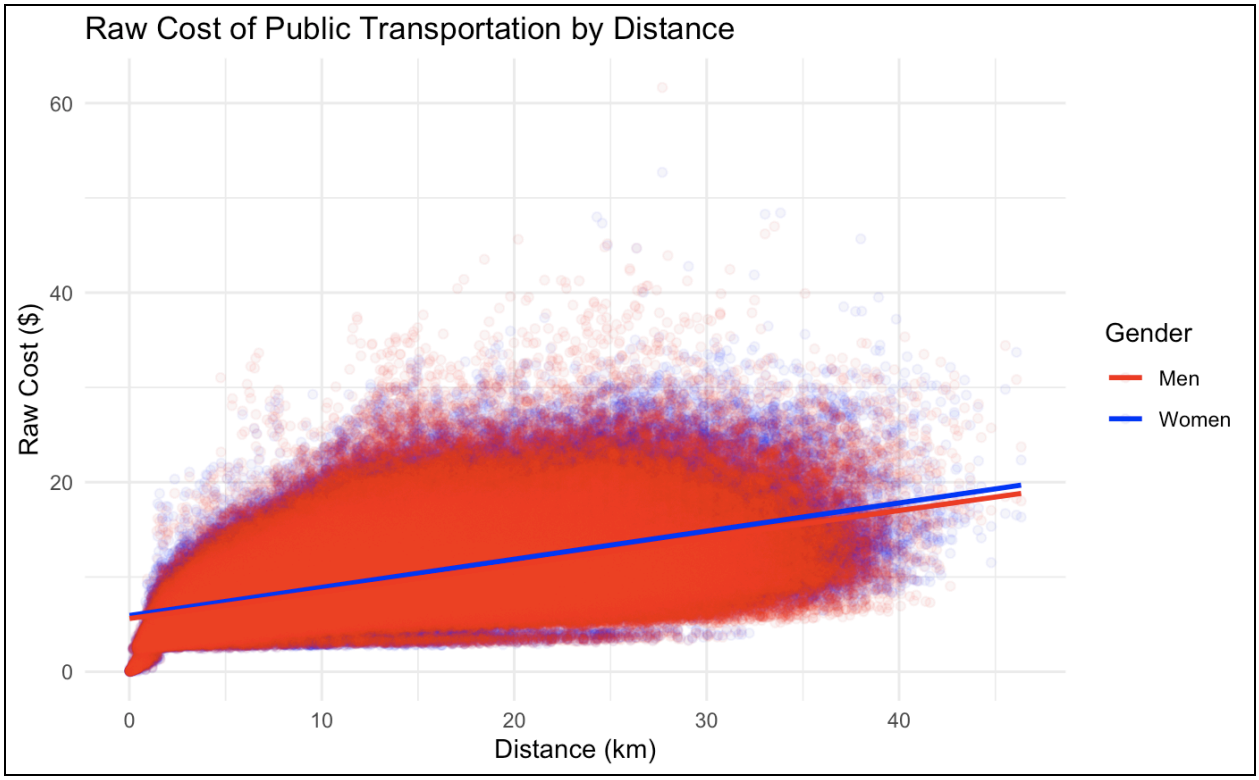


Figure 9: The Raw Costs of Public Transportation by the Distance Traveled for Men and Women

The chart above shows the plotted raw costs for each public transportation trip, distinguishing between the costs for women and men. The lines shown are the lines of best fit using the Ordinary Least Squares (OLS) regression. Although the lines look almost overlapping, there is a distinction between the average raw costs for men versus women, which are shown in the regression coefficient results below:

Term	**Estimate**	**p-value**
β_0 (Intercept)	5.6174	< 0.001
β_1 (Distance)	0.2849	< 0.001
β_2 (Gender: Women)	0.3197	< 0.001
β_3 (Distance $\times$ Gender)	0.0121	< 0.001

Figure 10: Regression Coefficients for Raw Cost by Gender and Distance for Public Transportation

Here the data is more granular than rideshare data with respect to the amount of time in each trip spent on transit, time spent walking, and time spent waiting at transit stops. With public transportation, I reject the null hypothesis and find that on average, the costs incurred by women on modes of public transportation are higher than for men. Although β_2 and β_3 are both positive and statistically significant, they are still close to zero when the regression is computed for the raw costs. The wait time premium (based on women's perceptions of safety) greatly influences this disparity.

β_3 is less than one, which tells us that although women on average incur more costs for each marginal increase in distance, the cost disparity does not increase much as the distance of travel increases. This might be explained by the opportunity cost of time far outweighing the wait time premium on long legs of journey. Since the fare is fixed (unlike rideshare), shorter rides are likely to be relatively more costly than longer ones. It is also likely that for the especially long distances traveled, wait times were not nearly as high as the amount of time spent on transportation.

Similar to rideshare, if I plot the relative cost incurred by women based on the income they make in total, we see a higher disparity. The following are results for the relative cost of public transportation:

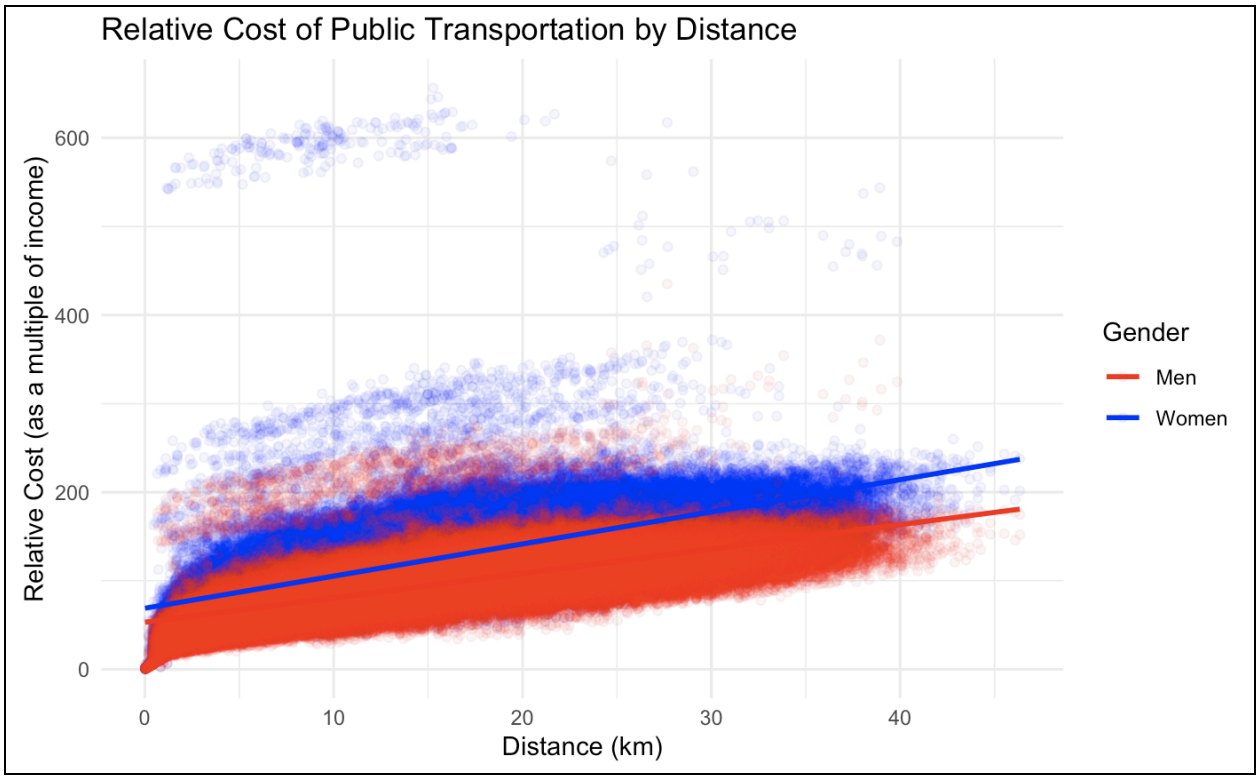


Figure 11: The Relative Costs of Public Transportation by the Distance Traveled for Men and Women

The chart above shows the plotted relative costs for each public transportation trip, distinguishing between the costs for women and men. The lines shown are the lines of best fit using the Ordinary Least Squares (OLS) regression. There is a significant distinction between the average relative costs for men versus women, which are shown in the regression coefficient results below:

Term	**Estimate**	**p-value**
β_0 (Intercept)	53.1479	< 0.001
β_1 (Distance)	2.7559	< 0.001
β_2 (Gender: Women)	15.8328	< 0.001
β_3 (Distance $\times$ Gender)	0.8720	< 0.001

Figure 12: Regression Coefficients for Relative Costs by Gender and Distance for Public Transportation

β_2, the fixed difference between the gendered costs, is significantly higher and is statistically significant. β_3 is positive but also small, for the same reasons why it was small when the raw costs were calculated. We can reject the null hypothesis and conclude that women have significantly less potential mobility using public transportation than men.

The CTA shares some of the same benefits as rideshare—the price you pay is not a long term repeated cost for owning a vehicle, but rather a series of short term costs that do not have the same volatility as rideshare modes. It has been empirically demonstrated that people who earn less income are more inclined to use public modes of transportation, and even though women incur more costs on transit than men, we know that women still opt to use public services.

As discussed earlier, women prefer public transportation modes over men, whether that be because of the relative lower cost of transit over vehicle ownership or the flexibility afforded by not having to keep track of one's vehicle at all times—also because of the one time fixed cost in fare means you can take chained trips for significantly less money than other modes. It is also possible that some women might feel less safe taking rideshare trips, sharing a car with an unknown driver. Women are more likely to take chained public transportation trips at non rush hour times. Since I sampled trips based on train and bus schedules at 8 am, the trips we are seeing might be more reflective of commuters, a higher proportion being men. Still, this estimation demonstrates that even at the time where there is the highest density of rides throughout the day, women still incur more costs than men by losing time on transit and incurring the costs of the lack of perceived safety at transit stops.

I was interested in mapping the tract by tract gender disparity in order to see if gender disparities for public transportation modes follow any clear geographic pattern. Below is a map of gender disparity on public transportation modes by Chicago tract, first by raw costs and then by relative costs:

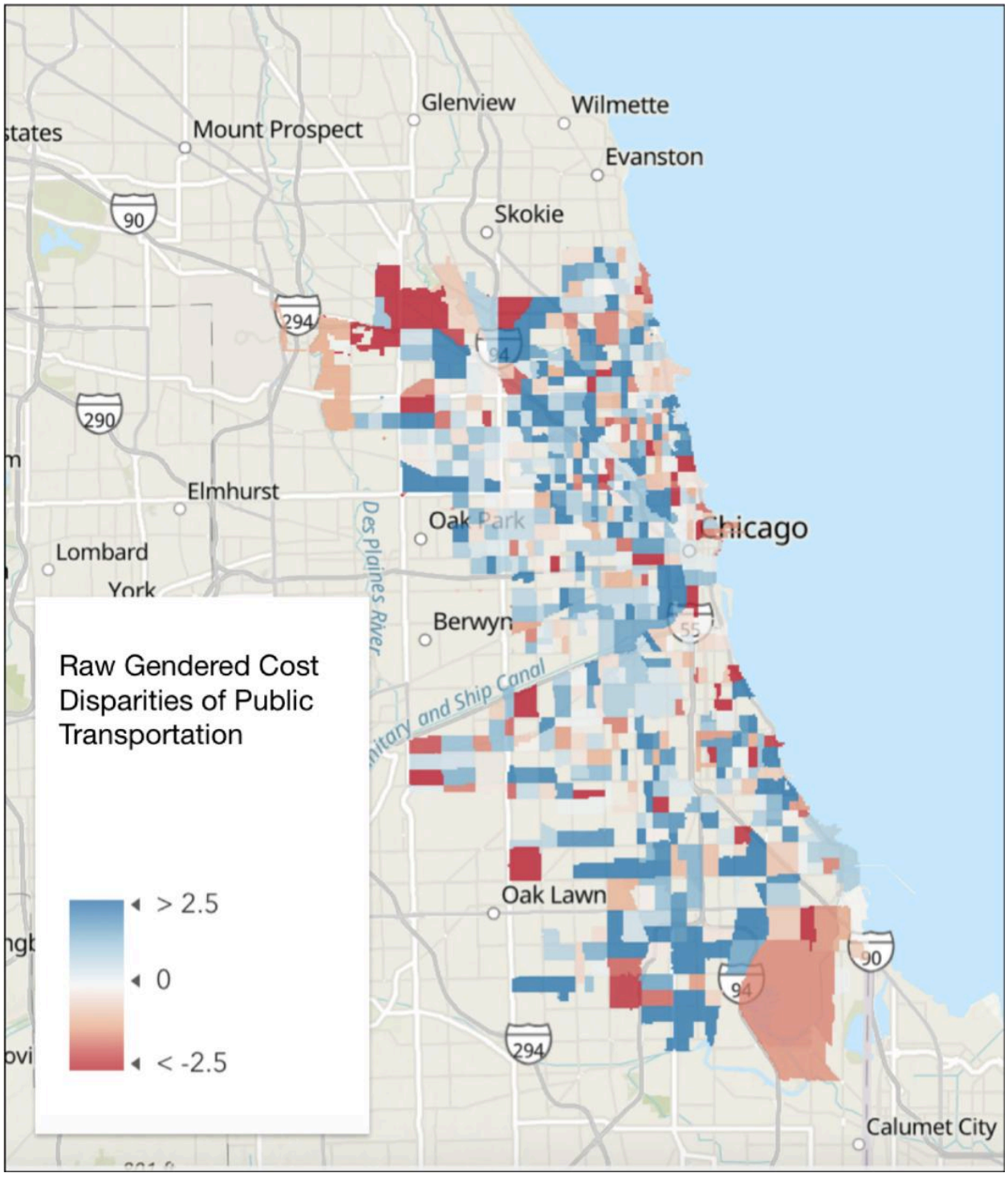


Figure 13: Gender Disparity in Raw Costs of Public Transportation

In this chart, the blue tracts indicate where the raw costs of public transportation are more for women than men on average. The red tracts indicate where the raw costs of public transportation are more for men than women on average.

The blue tracts indicate regions where the costs incurred on transportation for women are higher than for men, meaning that because of the wait times incurred on transit stops, the share of time spent by women working in the household, and the average income disparity between women and men, women have more to lose per minute as they spend time on public transportation. The red tracts show regions where the costs incurred on public transportation are higher for men than women. In these tracts, the income disparity between men and women is such that if men spend more time on transit, they have more to lose because their income in these tracts is much higher than women's. One explanation for this might be that in these tracts, there might be less working women bringing in wage labor to the household, and thus the time they spend on transit to do external home related tasks (ex. Grocery shopping, childcare) is less costly to them.

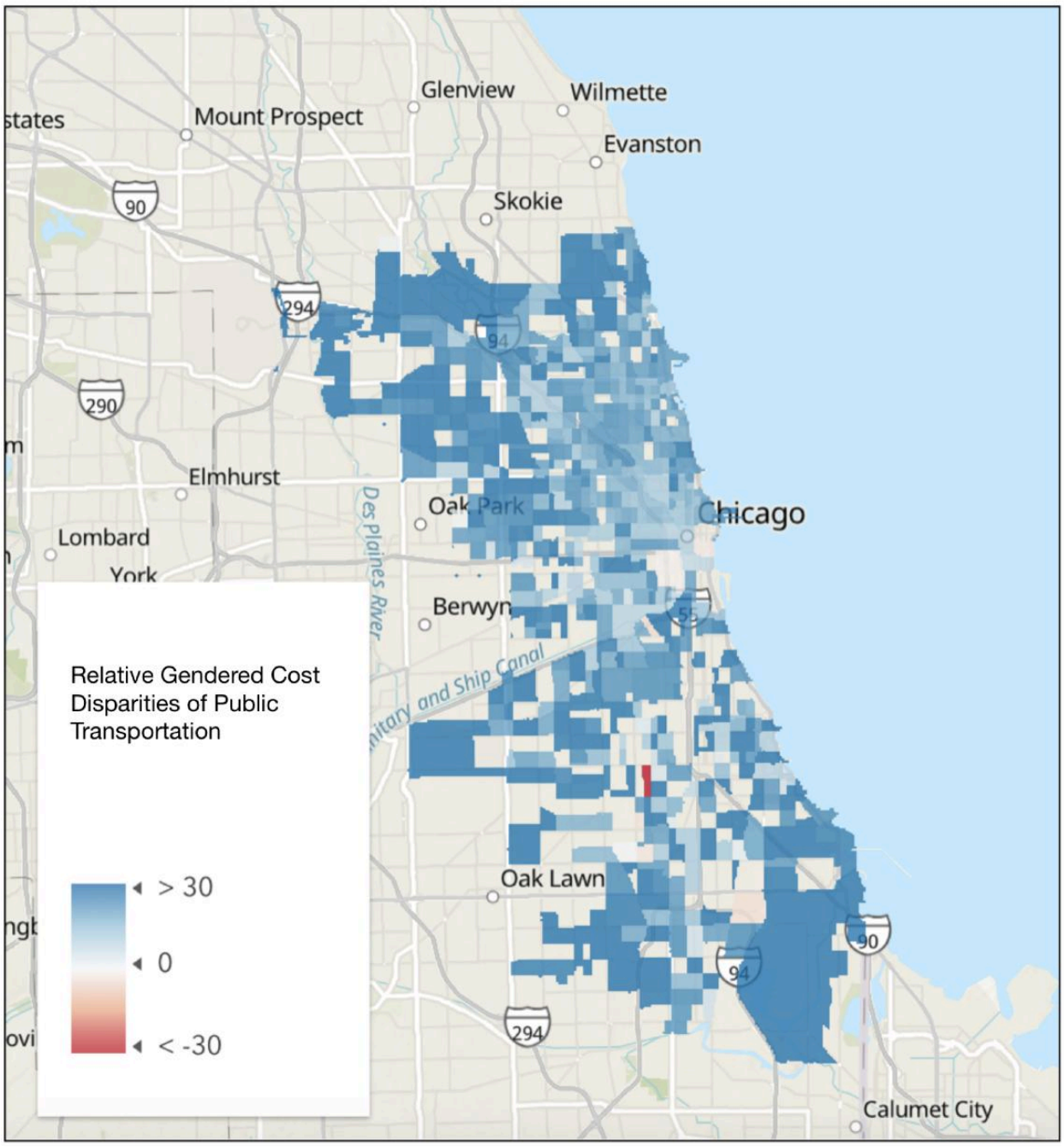


Figure 14: Gender Disparity in Relative Costs of Public Transportation

In this chart, the blue tracts indicate where the relative costs of public transportation are more for women than men on average. The red tracts indicate where the relative costs of public transportation are more for men than women on average.

The same story as before occurs when we look at the map of relative costs; you can see that across Chicago, there is lower potential mobility for women compared to men, except for one census tract. The tracts where it appears that men incur more costs than women in the raw cost map are scaled by the fact that women earn less and have less money to spend in general. Compared to the relative cost map for rideshare, you can see–spatially represented–that women incur more costs on public transportation across most of the census tracts. Additionally, due to the scaled representation you can see that the cost disparity is closer to zero as you approach the center of the city and generally increases at the city outskirts. While income inequality between genders might be differentiated across the city, the gender disparity is affected by the wait times incurred on transportation and the time spent in transit. Transportation access and wait times have historically been worse at the outskirts of the city, markedly the south and west sides (Freishtat, 2024), and it is clear that these factors also exacerbate the gender disparity in costs of public transportation in these areas as well.

Modal Trade Offs

Finally, to plot the costs incurred by mode of transportation on the same chart for the question of optimality, below is a graph of the relative cost distance trade offs for both transit and rideshare modes for women versus men:

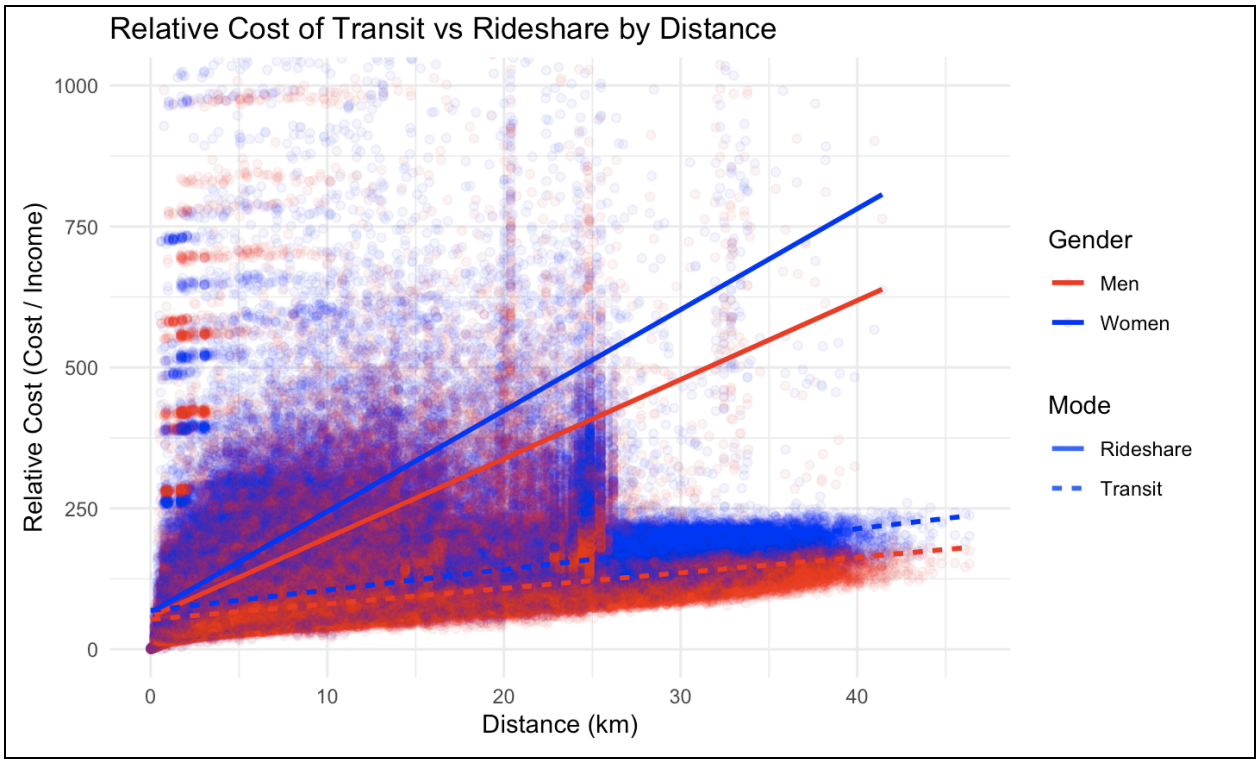


Figure 15: The Relative Costs of Public Transportation by the Distance Traveled for Men and Women

I plot the relative costs because they have the most clear and statistically significant gender disparity, and relative costs functionally give us a more accurate estimate of how costly each mode is to the consumer based on how much money they have to spend. Based on this chart we can immediately conclude that rideshare is more costly than public transportation for men and women. To investigate the point at which there might be a modal trade off (where the costs between modes are the same) for each gender, I conducted a regression to estimate the line of best fit and calculated the intersection point as follows:

Gender	Intersection Point (km)
Women	0.24
Men	-0.41

Figure 16: Regression Coefficients for the Relative Costs of Public Transportation by the Distance Traveled for Men and Women

This result tells us that if the distance is small enough, women might be more inclined than men to opt for rideshare over public transportation. However, since this intersection point (for women) is at 0.24 km, it is unlikely that a customer would even be making a decision between modes of transportation, since it might be quicker to walk that distance. Nevertheless, the difference in these intersection points tells us that if the cost decision is close enough, women might opt into rideshare because of the differences caused by the average value of time and the cost of wait times on transit.

Because men incur more opportunity cost on rideshare and generally face lower costs on public modes of transportation, they might be more likely to substitute rideshare with public transit at longer distances. Women might be inclined to do the exact opposite since the opportunity cost of time and wait times lead to more costs than men on public transportation, and the same wait time costs do not exist with rideshare. However, this may only be a viable substitute to the affluent Chicago woman who has a higher income to spend on rideshare. It is still empirically demonstrated in transportation literature that women prefer public modes of transportation over men, but this result might point to an elasticity in decision making; if women more readily have money to spend on rideshare, they might be more inclined to opt out of public transportation than men. The immediate further research I propose is to observe the empirical

transportation habits of men and women across Chicago census tracts to see if this substitution of modes plays out in the real world.

Conclusion

While my research frames the question of differentiated costs across mode as a gendered one, what I have posed is essentially a labor problem. If you are someone who earns less in the city of Chicago and does domestic unpaid labor, then transportation might be more costly for you in the identified areas across certain modes. The costs incurred on different modes of transportation are more than the up front costs, and can explain more why in this newly shifting transportation paradigm, more people are opting into rideshare services because it appears to be more equitable on this front. While my research is not establishing a causal relationship between gendered cost disparity and mode choice, it might be one, among many explanations for low ridership.

Since this model uses both economic indicators and transit service indicators to model cost, this framework can be used to further assess the equitability of transport when upgrades are made to the system, like the recently promised frequent lines, amidst a loose labor market. Increasing the frequency of public transportation services would not only reduce the pesky wait time but also expand equity and access to women and those who do not have as much time and money to spend in transit. If this model is expanded to include more labor parameters like the types of household or caretaking labor, then this framework can be used to assess accessibility of public transportation across Chicago for caretakers who require stroller and wheelchair access for their work.

Limitations to the analysis

Cost competitiveness is not the sole reason people opt into one mode of transportation over the other. While this paper attempts to endogenize some parts of the hidden and unmonetized social costs associated with different modes, this analysis does not account for the entire cost calculation the consumer may go through in the decision making process to opt into one mode of transportation over another, but does give a representation of how these costs might be affected by the socially constructed parameter of gender.

The functions utilize metrics from other studies for the elasticity of time and for labor time estimates, and these are heterogeneous across different populations, but the census data does not capture this heterogeneity. Future research might use estimates of tract by tract housework disparities to make more accurate estimates of the costs incurred by gender.

I have used Ordinary Least Squares Linear Regression to demonstrate the relationship between distance and cost for each mode of transportation, but this is not necessarily the best regression specification to plot a trend because even visually, you can see there is heteroskedasticity, or a variance that changes across the regressed data. Computationally, this work was expensive, utilizing energy and hours to simulate trips using the available massive datasets. It might be more convenient to use R5, another transportation software, for this type of research as opposed to OpenTripPlanner, which recent transportation accessibility literature has utilized.

Another unaccounted for piece in this research is the origins, destinations, and their proximity to different urban amenities, which are generally utilized by different genders. My estimations make the assumption that both men and women would try to go to the same destinations and make cost calculations based on that assumption, however, we know this not to

be the case in practice. While women use public transportation to commute, and the time they spend in transportation might be an opportunity cost, sometimes using transportation is part of the labor of care that women enact. For instance, part of a woman's caretaking labor might be accompanying dependents to school, parks, libraries, hospitals, doctors offices, or other locations. Further research might triangulate locations and their proximity to different public goods like parks in order to estimate the true costs (and benefits) of women and men utilizing transportation.

Different neighborhoods where the average income for women is lower are also characterized by a lack of accessibility to transportation generally, which means the trips are more costly and become even more expensive, while the relative disparity between costs incurred for women vs men increases. Although my methodology did not establish a causal relationship between urban transit accessibility and the cost disparity between genders, it demonstrates that there may be a positive feedback loop in gender labor disparity and the fragmentation of transportation access. Urban mobility may have a hand in creating gender disparity, creating a further fragmentation and divergence in the labor possibilities of people of different sexes.

Bibliography:

Affairs, B. C. for R., Peace and World. (n.d.). *Taking Pink Buses in Mexico City*. Retrieved March 14, 2025, from https://berkleycenter.georgetown.edu/posts/taking-pink-buses-in-mexico-city

Bianchi, S. M., Sayer, L. C., Milkie, M. A., & Robinson, J. P. (2012). Housework: Who Did, Does or Will Do It, and How Much Does It Matter? *Social Forces; a Scientific Medium of Social Study and Interpretation*, *91*(1), 55–63. https://doi.org/10.1093/sf/sos120

Chicago, IL Income By Gender—2024 Update | Neilsberg. (n.d.). Retrieved December 6, 2024, from https://www.neilsberg.com/insights/chicago-il-income-by-gender/

chm_admin. (2020, July 18). *A Brief History of Redlining*. Chicago History Museum. https://www.chicagohistory.org/redlining/

Comparison of CTA Productivity Measures and Fares | Civic Federation. (n.d.). Retrieved January 17, 2025, from https://www.civicfed.org/civic-federation/blog/comparison-cta-productivity-measures-and-fares

Credit, K., Dias, G., & Li, B. (2021). Exploring neighbourhood-level mobility inequity in Chicago using dynamic transportation mode choice profiles. *Transportation Research Interdisciplinary Perspectives*, *12*, 100489. https://doi.org/10.1016/j.trip.2021.100489

CTA bus service came back slowest in these neighborhoods. (n.d.). Retrieved April 11, 2025, from https://www.chicagotribune.com/2024/12/30/cta-bus-service-analysis/

de Madariaga, I. S. (2013). From Women in Transport to Gender in Transport: Challenging Conceptual Frameworks for Improved Policymaking. *Journal of International Affairs*, *67*(1), 43–65.

Donner, F. (n.d.). *The Household Work Men and Women Do, and Why—The New York Times*. Retrieved March 14, 2025, from https://www.nytimes.com/2020/02/12/us/the-household-work-men-and-women-do-and-why.html

El-Geneidy, A., Levinson, D., Diab, E., Boisjoly, G., Verbich, D., & Loong, C. (2016). The cost of equity: Assessing transit accessibility and social disparity using total travel cost. *Transportation Research Part A: Policy and Practice*, *91*, 302–316. https://doi.org/10.1016/j.tra.2016.07.003

Ermagun, A., & Tilahun, N. (2020a). Equity of transit accessibility across Chicago. *Transportation Research Part D: Transport and Environment*, *86*, 102461. https://doi.org/10.1016/j.trd.2020.102461

Ermagun, A., & Tilahun, N. (2020b). Equity of transit accessibility across Chicago. *Transportation Research Part D: Transport and Environment*, *86*, 102461. https://doi.org/10.1016/j.trd.2020.102461

Evidence of Racial Discrimination in the $1.4 Trillion Auto Loan Market—Federal Reserve Bank of Chicago. (n.d.). Retrieved January 17, 2025, from https://www.chicagofed.org/publications/profitwise-news-and-views/2023/discrimination-auto-loan-market

Fan, Y., Allen, R., & Sun, T. (2014). Spatial mismatch in Beijing, China: Implications of job accessibility for Chinese low-wage workers. *Habitat International*, *44*, 202–210. https://doi.org/10.1016/j.habitatint.2014.06.002

Fan, Y., Guthrie, A., & Levinson, D. (2016a). Waiting time perceptions at transit stops and stations: Effects of basic amenities, gender, and security. *Transportation Research Part A: Policy and Practice*, *88*, 251–264. https://doi.org/10.1016/j.tra.2016.04.012

Fan, Y., Guthrie, A., & Levinson, D. (2016b). Waiting time perceptions at transit stops and stations: Effects of basic amenities, gender, and security. *Transportation Research Part A: Policy and Practice*, *88*, 251–264. https://doi.org/10.1016/j.tra.2016.04.012

Female Labor Force Participation in the Post-Pandemic Era—Federal Reserve Bank of Chicago. (n.d.). Retrieved December 6, 2024, from https://www.chicagofed.org/publications/chicago-fed-insights/2024/female-labor-force-participation

Gauvin, L., Tizzoni, M., Piaggesi, S., Young, A., Adler, N., Verhulst, S., Ferres, L., & Cattuto, C. (2020). Gender gaps in urban mobility. *Humanities and Social Sciences Communications*, *7*(1), 1–13. https://doi.org/10.1057/s41599-020-0500-x

Hiller, V. (2014a). Gender Inequality, Endogenous Cultural Norms, and Economic Development. *The Scandinavian Journal of Economics*, *116*(2), 455–481.

Hiller, V. (2014b). Gender Inequality, Endogenous Cultural Norms, and Economic Development. *The Scandinavian Journal of Economics*, *116*(2), 455–481.

Hsu, A. (2023, April 13). Women are earning more money. But they're still picking up a heavier load at home. *NPR*. https://www.npr.org/2023/04/13/1168961388/pew-earnings-gender-wage-gap-housework-chores-child-care

Hyde, E., Greene, M. E., & Darmstadt, G. L. (n.d.). Time poverty: Obstacle to women's human rights, health and sustainable development. *Journal of Global Health*, *10*(2), 020313. https://doi.org/10.7189/jogh.10.020313

Lee, K., Jin, Q., Animesh, A., & Ramaprasad, J. (2019). *Impact of Ride-Hailing Services on Transportation Mode Choices: Evidence from Traffic and Transit Ridership* (SSRN Scholarly Paper No. 3244207). Social Science Research Network. https://doi.org/10.2139/ssrn.3244207

Legrain, A., Buliung, R., & El-Geneidy, A. M. (2016a). Travelling fair: Targeting equitable transit by understanding job location, sectorial concentration, and transit use among low-wage workers. *Journal of Transport Geography*, *53*, 1–11. https://doi.org/10.1016/j.jtrangeo.2016.04.001

Legrain, A., Buliung, R., & El-Geneidy, A. M. (2016b). Travelling fair: Targeting equitable transit by understanding job location, sectorial concentration, and transit use among low-wage workers. *Journal of Transport Geography*, *53*, 1–11. https://doi.org/10.1016/j.jtrangeo.2016.04.001

Lubitow, A., Carathers, J., Kelly, M., & Abelson, M. (2017). Transmobilities: Mobility, harassment, and violence experienced by transgender and gender nonconforming public transit riders in Portland, Oregon. *Gender, Place & Culture*, *24*(10), 1398–1418. https://doi.org/10.1080/0966369X.2017.1382451

Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy*, *20*, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013

McKane, R., & Hess, D. (2021). Ridesourcing and urban inequality in Chicago: Connecting mobility disparities to unequal development, gentrification, and displacement.

Environment and Planning A: Economy and Space, *54*, 0308518X2110478. https://doi.org/10.1177/0308518X211047872

Office, C. P. I. (2018, September 4). *Beginning of the end of Citizen Potawatomi displacement*. Potawatomi.Org. https://www.potawatomi.org/blog/2018/09/04/beginning-of-the-end-of-citizen-potawatomi-displacement/

Open Knowledge Repository. (n.d.-a). Retrieved January 29, 2025, from https://openknowledge.worldbank.org/entities/publication/b61813eb-9124-5f10-b722-9bfad188c8b4

Open Knowledge Repository. (n.d.-b). Retrieved January 29, 2025, from https://openknowledge.worldbank.org/entities/publication/3867d5d3-4f2c-5b2a-8d7a-9204fc9dcae6

Parker, R. F., Carolina Aragão, Kiley Hurst and Kim. (2023, April 13). In a Growing Share of U.S. Marriages, Husbands and Wives Earn About the Same. *Pew Research Center*. https://www.pewresearch.org/social-trends/2023/04/13/in-a-growing-share-of-u-s-marriages-husbands-and-wives-earn-about-the-same/

Priya Uteng, T. (2021). Chapter Two—Gender gaps in urban mobility and transport planning. In R. H. M. Pereira & G. Boisjoly (Eds.), *Advances in Transport Policy and Planning* (Vol. 8, pp. 33–69). Academic Press. https://doi.org/10.1016/bs.atpp.2021.07.004

Putting women at the heart of transportation strategy. (2023, February 8). World Economic Forum.

https://www.weforum.org/stories/2023/02/the-city-putting-women-at-the-heart-of-mobility/

Reed, C. R. (2015). The Early African American Settlement of Chicago, 1833-1870. *Journal of the Illinois State Historical Society (1998-)*, *108*(3–4), 211–265. https://doi.org/10.5406/jillistathistsoc.108.3-4.0211

Role Of Gender In Urban Mobility: Women Right's To The City. (2022, May 9). https://urbandesignlab.in/role-of-gender-in-urban-mobility/

Satter, B. (2009). Old Settlers, New Negroes, and the Birth of Modernity in Black Chicago. *American Quarterly*, *61*(2), 383–393.

Scheiner, J., & Holz-Rau, C. (2017). Women's complex daily lives: A gendered look at trip chaining and activity pattern entropy in Germany. *Transportation*, *44*(1), 117–138. https://doi.org/10.1007/s11116-015-9627-9

Swyngedouw, E. (2013). The Segregation of Social Interactions in the Red Line L-Train in Chicago. *Symbolic Interaction*, *36*(3), 293–313.

Tilahun, N., & Fan, Y. (2014). Transit and job accessibility: An empirical study of access to competitive clusters and regional growth strategies for enhancing transit accessibility. *Transport Policy*, *33*, 17–25. https://doi.org/10.1016/j.tranpol.2014.02.002

Tiznado Aitken, I., Palm, M., & Farber, S. (2024a). Exploring the interplay of transportation, time poverty, and activity participation. *Transportation Research Interdisciplinary Perspectives*, *26*, 101175. https://doi.org/10.1016/j.trip.2024.101175

Tiznado Aitken, I., Palm, M., & Farber, S. (2024b). Exploring the interplay of transportation, time poverty, and activity participation. *Transportation Research Interdisciplinary Perspectives*, *26*, 101175. https://doi.org/10.1016/j.trip.2024.101175

Transit. (n.d.). SEGREGATION BY DESIGN. Retrieved April 11, 2025, from https://www.segregationbydesign.com/chicago/transit

Transport has a gender bias problem. This is what needs to change. (2022, April 6). World Economic Forum. https://www.weforum.org/stories/2022/04/transport-women-gender-gap-world-bank/

Whitehead, K. (2021, June 17). New analysis highlights racial disparities in Chicago area transit access. *Active Transportation Alliance*. https://activetrans.org/blog/new-analysis-highlights-racial-disparities-in-chicago-area-transit-access

X, Instagram, Email, & Facebook. (2025, March 12). *More than 1,600 sexual assault cases against Uber merged in far-reaching court ruling*. Los Angeles Times. https://www.latimes.com/california/story/2025-03-12/9th-circuit-uber-sex-assault-lawsuits

Zheng, Y., Meredith-Karam, P., Stewart, A., Kong, H., & Zhao, J. (2023). Impacts of congestion pricing on ride-hailing ridership: Evidence from Chicago. *Transportation Research Part A: Policy and Practice*, *170*, 103639. https://doi.org/10.1016/j.tra.2023.103639