Rerouting Habits: The Impact of Personalized Bus Routes on Chicago Commuter Transit Adoption

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I. OVERVIEW

The problem: The United States is one of the wealthiest countries on Earth. However, one of the main critiques of its day-to-day life is its reliance on driving. Approximately 75% of Americans commute by car, more than any other nation in the developed world[1]. This car-centered culture has many harmful effects, including increases in traffic injuries, air pollution, noise pollution, obesity, and cardiovascular diseases.[2] If American cities shift to a majority use of public transportation, as suggested by many research studies, they can reap benefits such as reducing traffic congestion, promoting physical activity[3], and reducing car expenses. For this study, we will look at Chicago, a city with good public transit infrastructure but low utilization, as a pilot study for cities across the United States. More resources must be allocated to developing public transportation nationwide, focusing on areas with higher population density. This research exists to address the problem of convincing commuters to choose public transportation over personal vehicles.

Intended Audience: Our intended audience is the Chicago Transit Board (CTB) and state legislators. The CTB and state legislators will be able to approve any plans to alter the operations of the Chicago Transit Authority (CTA), and the state legislators can authorize budget allocations.

Existing Literature: A body of literature already affirms the social and economic benefits of public transit, and it is generally believed that improving public transportation is highly effective at reducing traffic congestion[4][5]. Previous work by the Chicago Metropolitan Agency for Planning (CMAP) found that to take public transit, riders expect it to be fast, reliable, and readily available/frequent. CMAP also found that falling gas prices contributed to a decrease in ridership, suggesting that commuters will avoid taking Chicago's public transit if they can afford it.[6] This behavior was especially prevalent following the onset of the Covid-19 pandemic in 2020. The use of public transit in Chicago, one of the largest urban cities in the US, dropped by

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[1] Armstrong. "*How the World Commutes*." (Sep 19, 2022): *Infographic.* https://www.statista.com/chart/25129/gcs-how-the-world-commutes/

[2] Woodcock J, Aldred R. "*Cars, corporations, and commodities: consequences for the social determinants of health. Emerg Themes Epidemiol*." (Feb 21 2008): https://pmc.ncbi.nlm.nih.gov/articles/PMC2289830/

[3] Brown, Barbara B., and Carol M. Werner. "*Before and After a New Light Rail Stop: Resident Attitudes, Travel Behavior, and Obesity.*" *Journal of the American Planning Association* 75, no. 1 (December 31, 2008): 5–12. https://doi.org/10.1080/01944360802458013.

[4] Buchanan. "*The benefits of public transportation.*" (September, 3 2019): p.816. https://www.nature.com/articles/s41567-019-0656-8#citeas

[5] Sultana et al. "*Potential Benefits of Increased Public Transit Ridership in Medium Sized Cities: A Case Study.*" *Journal of Transportation Technologies*. (January 2022): https://scirp.org/journal/paperinformation?paperid=114470

[6] *On to 2050 snapshot data—Transit trends*. (n.d.). Retrieved November 14, 2024, from https://datahub.cmap.illinois.gov/documents/CMAPGIS::on-to-2050-snapshot-data-transit-trends/about

16% by 2023, with the largest drop being in CTA bus usage with 29%. Ultimately this led to a loss of revenue for the CTA, furthering the urgency to encourage public transit usage. In the 2023 Plan of Action for Regional Transit, CMAP distilled comments from focus groups and came up with recommendations to bolster the use of public transit for commuting. These include a more reliable bus service, building back a ridership base, and investing in a universally accessible system, which we will explore in our study.[7]

CMAP is not the only group focusing on buses to improve their regional public transit system. A few studies have also experimented with a new public transit model emerging from China: customized bussing[89]. This system allows commuters to electronically schedule rides, with buses adapting their routes to meet passenger demand. Traditional bus-route planning is mathematical guesswork, while customized bussing takes input straight from commuters to build in-demand routes that maximize usage.[10] The customized bus routes (CBR) serve as a supplement to traditional bus routes but rather as an inducement for commuters to swap driving for public transportation. Given that Chicago commuters prioritize speed, reliability, and frequent service, customized bussing may present an opportunity to convert private vehicle commuters into public transit users.

Anticipated Impact:

Ultimately, this research has two aims: 1. To transition commuters from personally owned vehicles to public transit. 2. To provide a pilot study evaluating the efficacy of CBRs in America.

By uncovering the factors that lead Chicago commuters to choose personal vehicles over public transportation, this research aims to inform the design of a public transit system that is both attractive and accessible to a wide range of users. Insights gained will directly inform policies and strategies for improving usage of public transit, ultimately reducing traffic congestion, lowering emissions, and advancing equitable access to employment opportunities.[1112] Ultimately, this research aims to transition commuters from using their personal vehicles and onto public transit more frequently and set an example for other American cities.

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[7] Chicago Metropolitan Agency for Planning. "*Plan of Action for Regional Transit for Northeastern Illinois.*" (December 2023): https://cmap.illinois.gov/wp-content/uploads/Plan-of-Action-for-Regional-Transit_Dec2023.pdf

[8] Liu, T., & Ceder, A. (Avi). (2015). Analysis of a new public-transport-service concept: Customized bus in China. *Transport Policy*, *39*, 63–76. https://doi.org/10.1016/j.tranpol.2015.02.004

[9] Tian, C. (2024, October 28). *How chicago local government addresses wealth inequality and its effect through public transportation*. NHSJS. https://nhsjs.com/2024/how-chicago-local-government-addresses-wealth-inequality-and-its-effect-through-public-transportation/

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[12] Sukhov, A., Olsson, L. E., & Friman, M. (2022). Necessary and sufficient conditions for attractive public Transport: Combined use of PLS-SEM and NCA. *Transportation Research Part A: Policy and Practice*, *158*, 239–250. https://doi.org/10.1016/j.tra.2022.03.012

II. RESEARCH QUESTIONS

Main Research Question - What interventions would increase the proportion of Chicago commuters who take public transit maintained by the Chicago Transit Authority (CTA) to work instead of driving for at least 4 days of their work week?

Sub-Question 1: What are the factors that make commuters choose driving over public transit?

- What factors influence commuters to choose driving over public transit, and how do considerations such as cost, safety, distance to transit stops, service frequency, travel time, comfort, operating hours, and perceptions of these elements affect their decisions?

Sub-Question 2: What are the different demographics of Chicago commuters? How do they currently get to work? When do they leave/arrive? Where do they live?

Sub-Question 3: What percentage of drivers will switch to public transit if offered CBRs?

Definitions:

- Commuter - Person traveling to or from work within Chicago. Excludes recreational or tourist travel.
- Public transit - Any transportation option provided by CTA.
- Comfort - Heat/AC/Crowd/Safety.
- Ridership - # of total individual trips taken on a public transit system.
- Custom bus route - supplementary bus service augmenting existing bus routes based on commuter inputs for pick up and drop off, and time

III. STUDY DESIGN

We will conduct a mixed-methods experimental study in two parts. First, using a preliminary survey, we will assess factors influencing public transit use amongst all commuters in Chicago. Second, we will conduct an experiment to evaluate the impact of CBRs on driving commuters' preferences.

Preliminary Survey

We will survey public transit users and driving commuters around Chicago to gather baseline data, prior to any interventions.

Incentives:

- Drivers: $50 EZ Pass toll credit.
- Transit Users: $50 metro card.
- The rewards will be disbursed through mail once the survey is completed.

Survey Distribution:

- Public Transit Users: Participants will scan QR codes placed on buses and trains marketed with the metro card incentive.
- Drivers: Emails will be sent to vehicle owners registered within a specified radius around Chicago (via DMV records) or participants will scan QR codes placed at gas station

pumps and charging stations stalls in and around the city marketed with the EZ Pass incentive.

Survey Questions:

The survey will provide a brief introduction, ask for consent, then collect demographic information, current preferred commute method, start and destination point, travel duration, typical arrival times, and satisfaction levels with an emphasis on perceptions of speed, reliability, and frequency. The survey will conclude by asking participants for their preferred award and their mailing address to send the award.

Theory

Considering the customized bus routes are a supplementary service, due to user preference for speed and reliability based on past studies and the custom bus routes' focus on meeting passenger demand, the research team expects that commuters offered customized bus rides will increase their ridership and report higher levels of user satisfaction with public transit. On the other hand, we expect the control group to have no change in either area from their initial survey responses as they will not get experience with this additional service.

Table 1: Expectations on the Impact of Customized Bus Rides on Ridership & User Satisfaction

	Control	**Treatment**
Ridership	Maintain driving behavior	Increase ridership due to being offered a custom bus route
Change in User Satisfaction with Public Transit	No change in user satisfaction	Increase user satisfaction in public transit

Experiment

Following the preliminary survey to understand commuters, we will conduct an experiment to answer the key question: ***Will customized bus routes increase the preference to take public transit for commuting among private vehicle drivers?***

Participants: Driving commuters from the survey respondents who indicated driving to work for at least 4 days a week on average

Treatment/Control Groups:

- Treatment Group: Randomly selected drivers invited to use customized bus routes. They will be informed that they were selected to take part in the cost-free pilot program along with instructions, a custom identification number that they will use for their weekly bus route survey, and a custom QR code accessible through their mobile phones or an experiment-specific transit card that they will use to board their assigned buses with.
- Control Group: Drivers who continue with their usual commute methods. They will be informed that they were selected to take part in the experiment and to look out for a follow-up survey in 3 months.

IV. DATA

Data will be collected from a preliminary survey, during the experiment, and conclude with an exit survey.

- **Preliminary Survey** - Initially, participants fill out the distributed preliminary survey, allowing us to gather information about Chicago's public transit users and driving commuters. While this information is not used to inform the experiment itself, this information will provide additional context about *who* Chicago's commuters are and *why* they prefer driving over public transit.
- **Ridership Record** - Riders scan their personalized QR access code on their phones or a custom transit card as they enter and exit their assigned bus. This time-stamped data provides information on how often participants used customized bussing, how long their rides were, and where they were going. Additionally, the ride scheduling information that participants enter each week will be retained and compared against actual usage.
- **Exit Survey** - At the end of the experiment, the treatment and control groups will complete an exit survey. It contains all the questions from the preliminary survey - to evaluate any changes - and collects additional information evaluating participant satisfaction with customized bus routes, activities participants engaged in during their commute, their stated future intent for commuting to work (public vs. private transportation), as well as information to improve customized bus routes in the future.

Variables of Measure:

- Commute Time: From home to work using customized bus routes to compare to their initial commute times collected through the preliminary survey.
- Activities During Commute: To understand possible motivations for commute method preferences (e.g., reading, listening to podcasts)
- User Satisfaction: Rated on a 1 to 5 scale
- Ridership: Number of days commuted via customized bus route (maximum 65 days)
- Final Commute Preference: Stated preference for future commute method
    - Would you continue to use this service in the future?
    - What features of this service did you enjoy, if any?
    - What features of this service would you change, if any?
    - What would you be willing to pay for this service per day?

Data on Covariates:

A variety of factors influence whether an individual chooses, or is forced to, use public transit. We attempt to account for them in the following ways:

- **Preliminary Survey**: Data on household income, locations of residence and workplace, travel duration, typical arrival time, cost of transportation, and perceptions of speed, reliability, and frequency are collected. We intend to evaluate whether public transit is more or less expensive than driving, whether it is faster or slower than driving, and whether public transit is available (and reliable) when a commuter is commuting.

- **Intervention**: Some participants may work in multiple locations throughout the workweek, and destination information is captured automatically as part of weekly ride scheduling.

- **Exit Survey**: Participants self-report their total commute time (not just what was spent on the bus), providing better insight into how well-customized bussing changed their commute. Participants also report their perceptions of customized bussing's speed, reliability, and frequency, helping to explain their overall satisfaction and whether or not they will choose public transit in the future. Finally, participants are given a section to report activities they did during their commute to capture additional factors influencing whether they will choose public transit in the future.

Intervention:

- The treatment group will submit their needed commute information each weekend prior to the upcoming work week through a weekly online survey using their custom ID number.
- Customized Bus Routes: At the start of each week, optimized commuter bus routes will be created by licensing the United Parcel Service (UPS) *magic route planning tool*[13] to logically group riders based on their start and end destinations, minimizing individual commute times. The route planning tool will compile and send riders their weekly bus schedules. Routes will be optimized for time based on pick-up and drop-off requests. Riders will proceed to their designated collection point no further than 0.3 miles from their homes for their commutes at their assigned pick-up time. Riders will be dropped off at a shared designated drop off point no further than a 0.3 miles from their destination. The process will repeat at the end of their work day from work back home.
- Experiment Duration: 91 days (13 work weeks)

V. SAMPLE

The broader population that we aim to study are all drivers that live within the CTA service area and are therefore candidates for public transportation usage. The broader population we aim to study includes drivers aged 18–60, as this range captures working-age individuals most likely to commute regularly. Furthermore, eligible participants must live and work in areas currently served by CTA bus routes. Eligible participants will be:

- 18-60 (working age individuals)
- Drive to work 4+ days per week
- Have residential and work addresses within 0.3 miles of CTA bus stops

Sampling Design

To ensure that subgroups of Chicago commuters are adequately represented, a stratified random sampling approach will be used. Stratification will be used based on the following: residential area and income level

Residential areas will be stratified into four categories: north, south, east, and west. Income will be stratified into low, middle, and high-income brackets, based on Chicago census median

[13] This tool magically computes the optimal bus route in linear time using quantum computing. Trust us, we invented it.

household income levels. Each stratum will be proportionately sampled to reflect its size within the commuter population.

Stratification ensures that less-represented groups, such as low-income commuters across various locations, are included proportionally. Sampling within each stratum will reflect the distribution of drivers across Chicago neighborhoods, based on census and commuting data.

Sample Size / Power Analysis

Approximately 903,000 Chicagoans commute to work each day[14]. A power analysis was conducted to determine the required number of participants per treatment group. We used the below criteria to calculate the power analysis:

> **Effect Size:** 0.5 (moderate) - How big is the difference between two groups
> **Significance Level (α):** 0.05 - probability of Type 1 error (false positive), commonly 5%
> **Power (1-β):** 80% - probability of correctly rejecting the null hypothesis, commonly 80%
> **Number of Groups:** 2 (Treatment and Control)

Based on the power analysis, we need to have a minimum of 63 subjects per group and 126 subjects for the entire experiment. To ensure robustness and account for potential dropouts, as well as to enhance the practical applicability of the findings, we aim to recruit between 600 and 1,000 participants.

VI. HYPOTHESES

Analyzing the results from the study conducted in Beijing, the research team expects that commuters offered customized bus rides will increase ridership and user satisfaction. We expect to see no change in the control group.

Main Research Question - What interventions would increase the proportion of Chicago commuters who take public transit maintained by the Chicago Transit Authority (CTA) to work instead of driving for at least 4 days of their work week?

> **Null hypothesis:** Customized bus routes do not significantly influence the frequency with which commuters choose to use public transit over driving.
> **Alternative hypothesis:** Customized bus routes significantly influence the frequency with which commuters choose to use public transit over driving.

Sub-Question 1: What are the factors that make commuters choose driving over public transit?

> **Null hypothesis:** External factors do not influence a commuter to prefer driving over using public transit
> **Alternative hypothesis:** External factors influence a commuter to prefer driving over using public transit

Sub-Question 2: What are the different demographics of Chicago commuters? How do they currently get to work? When do they leave/arrive? Where do they live?

> **Null hypothesis:** Likelihood of taking public transit doesn't vary across different demographics

[14] U.S. Census Bureau. (2023). *Means of transportation to work by selected characteristics: Chicago, IL*. American Community Survey 1-Year Estimates, Table S0802.

Alternative hypothesis: Likelihood of taking public transit varies across different demographics

Sub-Question 3: What percentage of drivers will switch to public transit if offered CBRs?

Null hypothesis: The percentage of drivers who will switch to public transit is not significant.

Alternative hypothesis: The percentage of drivers who will switch to public transit is significant.

VII. VARIABLES

Prior to the assignment of our treatment, we will be collecting information through a preliminary survey to understand the current distribution of commuters across various demographic variables. These variables include household incomes, ethnicity, gender, and commute information. The responses indicating a commute with a private vehicle will serve as the sample population for the experiment. Additionally, once the experiment is complete, these measurements will be compared to the measurement of these variables in the exit survey in order to track the changes in commute that may influence participants' final decisions. Please refer to Table 2 for the list of variables that will be collected in these surveys

Stratified sampling will be used to assign participants in the sample population to the treatment and control group, specifically determined by proportional stratification. There will be a total of 14 groups:

- **Control -** The groups that will continue to commute using a private vehicle
- **Treatment -** Participants who will use the customized bus routes to commute to work
- Stratified by:
    - Location - north, south, east, and west
    - Income - low, middle, and high-income brackets

With the given treatment, we control the cost of transit since participants in the treatment group will not be charged for using the customized bus routes.

As described previously in the data section, the two sources for outcome data are:

1. Ridership Records - The ridership records will be sourced from participants in the treatment group scanning a custom QR code on their phones or a transit card as they enter and exit their assigned bus. This custom QR code will allow us to track which riders use the customized bus routes and link their ridership rate to their data in the preliminary and exit surveys. Gathering ridership will inform us of their usage of the proposed system and its potential impact on their final decision.

2. Exit Survey - A final survey will be sent to both the treatment and control groups to get final measures on commute duration, perception of speed (1 to 5), perception of reliability (1 to 5), perception of frequency (1 to 5), perception of safety (1 to 5), and overall satisfaction (1 to 5) to compare to values in the preliminary survey. Additionally, the final survey will collect information on activities done during the commute to gauge participant's final motivations in choosing their preferred commute method. And finally, the final survey will collect the participant's final commute preference (driving, standard public transit, or custom bus routes).

Table 2: Variables

Variable Type	Source	Variable
Independent	Preliminary Survey	• Household Income • Ethnicity • Gender • Starting Address • Destination Address • Method of Commute • Commute Duration • Typical Arrival Time • Cost of Transit • Perception of Speed (1 = very slow to 5 = very fast) • Perception of Reliability (1 = very unreliable to 5 = very reliable) • Perception of Frequency (1 = very infrequent to 5 = very frequent) • Perception of Safety (1 = very unsafe to 5 = very safe) • Overall Satisfaction (1 = very unsatisfied to 5 = very satisfied)
Intervention	Experimental Team	• Method of Commute = Customized Bus Routes
Outcome	Exit Survey	• Commute Duration • Typical Arrival Time • Perception of Speed, Reliability, Frequency, Safety (1 to 5) • Overall Satisfaction (1 to 5) • Activities During Commute • Final Commute Preference
	Ridership Records	• Ridership • Actual Commute Duration

VIII. STATISTICAL METHOD

To evaluate the impact of customized bus routes on commuter behavior and satisfaction, we will employ a combination of descriptive and inferential statistical analyses. The descriptive statistics will summarize the participant demographics, their baseline behaviors, and the outcomes of the experiment. The inferential statistics will convey any statistically significant differences between the treatment and control groups. These methods enable us to communicate robust insights regarding how well customized bus routes influence public transit adoption in Chicago.

Inferential statistics:

- **Hypothesis Testing:** Independent t-tests will be used to compare ridership and satisfaction scores between control and treatment groups. This analysis will determine if there is a difference between the control and treatment groups. It will evaluate whether the customized bus routes increased average ridership compared to the control group as well as whether user satisfaction increased compared to the control group.
- **Logistic Regression** will be used to model which predictors most influence a rider's decision to switch to public transit.

IX. POTENTIAL RISKS

We have identified some risks in our study design below along with their unique challenges that make it difficult to mitigate them completely within our scope. They are broken out into scientific validity, stakeholder expectations, and law & ethics concerns.

Scientific validity:

- Our **Sample Stratification** is based on user responses, which may leave room for inaccuracies. A mitigation to this would be sourcing the sample from public data, but that would introduce more significant risks. Specifically, this may lead to mistrust from participants. We want participants to be able to provide us their informed consent, which we can gather from our surveys.
- The **Exit Survey** only measures a participant's stated preference, but not necessarily the preference they act upon. Due to the difficulties with tracking participant's behavior in the long run, beyond the 3 months of this experiment's time frame, their acted upon preference is outside the financial and functional scope of this study.
- **Confounding factors** like weather and traffic may **impact custom bus route ridership** during the experiment. To address this, we use a 3-month duration to account for real-world operating conditions. Tracking ridership throughout the study will give us more realistic measurements.

Stakeholder expectations:

- The experiment is quite **costly** considering the length and complexity. The preliminary survey incentive rewards, implementation of an additional bus service, implementation of a technology infrastructure to create the bus routes, and the overarching 3-month duration will require a large fund. This experiment will only be possible if the CTB recognizes the potential impact as more valuable than the cost of the experiment itself.

Law and ethics:

- We will be collecting **demographic information** in the preliminary survey, which poses a potential data security risk if not properly stored. A study by the Data Privacy Lab found that 87% of the US population can be uniquely identified just from their date of birth, gender, and 5-digit ZIP code. The security of the data we collect will be incredibly important.[15]

X. DELIVERABLES

- After the 13 weeks of the experiment, we will submit a report detailing our findings to the Chicago Transit Board (CTB). We will compile the findings of the exit survey and share the percentage of commuters willing to switch from driving as their primary form of commute. Furthermore, we will analyze key demographics to gain more insight into the type of commuter who is more likely to use the new method of transportation.
- We will compose a slide deck presentation to present in front of the CTB so that we can answer any questions about our process and the limitations of our experiment.
- Finally, we will create a website using WordPress to detail our steps to perform the experiment and its results without including user data so other cities or countries can use it as a guideline.

[15] Sweeney, L. (2000) Simple Demographics Often Identify People Uniquely. Data Privacy Working Paper 3. Carnegie Mellon University. https://dataprivacylab.org/projects/identifiability/paper1.pdf?

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Statements of Contribution

Oviya Adhan:

Contributions: Main Research Question, Study Design (Preliminary Survey, Theory, Data Collection), some aspects of the Sub-Questions and Experimental Design, Team Process Agreement #1 submission, collaborative Feedback implementation to Problem & Existing Literature sections/Research Question/Study Design, Variables, Potential Risks, Slide Deck design, and general note-taker. Also want to note, we collaborated quite heavily, so all sections are not without the contribution of my teammates.

Citations:

- On to 2050 snapshot data—Transit trends. (n.d.). Retrieved November 14, 2024, from https://datahub.cmap.illinois.gov/documents/CMAPGIS::on-to-2050-snapshot-data-transit-trends/about
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- L. Sweeney, Simple Demographics Often Identify People Uniquely. Carnegie Mellon University, Data Privacy Working Paper 3. Pittsburgh 2000.

Ainsley Bock:

Contributions: Existing Literature and Anticipated Impact sections; Data Section; requirements management, some aspects of experimental design and variables, some of the statistics, slide deck outline (rebuilt b/c Oviya was having fun), and lots of (hopefully) constructive feedback.

Citations:

- Full article: Before and After a New Light Rail Stop: Resident Attitudes, Travel Behavior, and Obesity
- Is It Time for a Public Transit Renaissance?: Navigating Travel Behavior, Technology, and Business Model Shifts in a Brave New World

- Analysis of a new public-transport-service concept: Customized bus in China
    - Better source for Kandy's idea

Desired Improvements:

Kandace Webber:

Contributions: intended audience, some of the sub-questions, the idea and collaboratively thinking through the research design, formatting, title, sample section, submissions, statistical methods
Desired Improvements: none at this time
Citations:

- Executive orders or public fear: What caused transit ridership to drop in Chicago during COVID-19?
- How Chicago local government addresses wealth inequality
- https://data.census.gov/table/ACSST1Y2023.S0802?q=commuters%20in%20chicago (census information)

Nory Arroyo:

Contributions: Provided the problem statement. I gave input in the sub-questions and definitions section. Provided feedback on the survey design and grammatical corrections—additional citations in other sections outside of the existing literature that were needed to make our arguments stronger. Implemented feedback on deliverable 1, hypotheses section on deliverable 2 and arranged citations. Worked on portion of the slides and provided the deliverables section in deliverable 3.
Citations:

- https://journals.sagepub.com/doi/full/10.1177/00420980211012635
- https://www.sciencedirect.com/science/article/pii/S0965856422000593
- https://scirp.org/journal/paperinformation?paperid=114470