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Social Carpooling-Based Road Congestion Mitigation: A Three-Level Analysis

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16. Abstract

Different from Transportation Network Companies and shared-car providers, social carpooling is personalized incentives-based and smartphone-enabled peer-to-peer ridesharing. Social carpooling emerges as a community-based strategy to reduce car ownership and mitigate congestion. It facilitates the transition from solo driving to effective carpooling by matching individuals' travel demand in space and time. Personalized incentives, such as real-time information, travel feedback, and monetary incentives, are leveraged to spur the change. This project investigates the impact of social carpooling on users' travel behavior and the system's performance. The empirical data are supported by Metropia, which is a social carpooling platform enabling ride-match. Three research tasks are planned. First, at an individual level, we will identify what factors impact the travel mode change toward social carpooling. The findings will help explain how social carpooling varies by individuals' income, gender, race, and other sociodemographic characteristics. Meanwhile, we will explore the effectiveness of different personalized incentive schemes to use social carpooling. Second, at an area level, we will estimate how many social carpooling trips can be generated if such programs are fully deployed by the public. This step will generate social carpooling trip demands for all traffic analysis zones, which is the basis for the following trip distribution, mode split, and dynamic traffic assignment. Third, at the system level, we will answer how much road congestion can be mitigated with a large-scale social carpooling deployment. Statistical models, machine learning algorithms, and simulation methods, including panel data analysis, synthetic minority oversampling technique, and dynamic traffic assignment, will be applied.

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Executive Summary

The mission of the National Institute for Congestion Reduction (NICR) is to provide congestion reduction strategies that use scientific research on big data and cutting-edge travel options to maximize the effectiveness of the transportation system for all users, particularly those who are experiencing traffic jams on freeway corridors. NICR 3-4: A Three-Level Analysis for Social Carpooling-Based Road Congestion Mitigation is a joint research effort between the University of South Florida (USF) and Texas A&M University (TAMU).

The proposed research closely complements NICR's emphasis on enhancing the effectiveness of the road infrastructure (Topic 1) and giving people additional mobility options (Topic 3), which are directly related to NICR's goals. The project evaluated the success of social carpooling initiatives intended to reduce car ownership and mitigate traffic congestion (Pillar 2-3) and examined how incentives can encourage social carpooling (Pillar 3-2). Therefore, these project findings offer insights into congestion mitigation strategies that decision-makers should consider when creating future mobility solutions.

The research approach of the project consisted of a three-level analysis including the individual-level analysis, the area-level analysis, and the system-level analysis. Metropia data and the regional travel demand forecasting model in Austin, Texas, were used as the data source of the three-level analyses. Meanwhile, a qualitative study including two interviews with practitioners was conducted to complement the findings that cannot be identified by quantitative analysis.

An individual-level analysis was conducted to find what factors are significant predictors of individual preference for social carpooling. The binary choice between social carpooling and driving alone over time and the ratio of individual social carpooling usage were two dependent variables in this analysis. Individual factors and trip characteristics were the factors specified in the models. Individual factors included age, gender, and income. Trip characteristics, such as the time of day and the day of the week, were recorded with app usage. A panel binomial logit model was applied to analyze the individual factors and trip characteristics correlated with the binary choice between social carpooling and driving alone for each individual over time. A generalized linear model was implemented to analyze the individual factors associated with the ratio of social carpooling.

For policy implications, the simplest strategy is to raise awareness of the benefits of social carpooling. Individuals' propensity to carpool among coworkers may increase significantly if flexible work schedules become available. Companies can encourage carpooling among their staff by offering subsidies and other rewards, such as guaranteed or preferred parking at the workplace. Telecommuting and compressed work weeks are two additional employer-related transportation strategies that may aid in promoting social carpooling and increasing time flexibility. To create a more welcoming climate for social carpooling, local organizations can implement several policies or programs, such as differentiating toll rates for different times of the day and different days of the week, and promoting social carpooling and raising awareness about the benefits of social carpooling through public advertising.

An area-level analysis aimed to find how many social carpooling trips can be generated for each traffic analysis zone (TAZ) and which factors would be significant predictors of social carpooling trip counts. The data collected by the Metropia tool were aggregated to the number of carpooling trips made in 1,538 TAZs. The data include information on settlement type, the number of jobs in different industries, household size, and household car ownership. A generalized linear model was applied to examine the relationship between multiple variables and TAZ-level carpooling trip counts. The results offer insights into where and how carpooling promotion would be more cost-effective, such as area size, settlement types, income, employees in different industries, household car ownership, and household size. Future transportation planning initiatives in Austin and other cities with similar populations and localized mobility management policies can benefit from the conclusions of this analysis.

A system-level analysis in this project structured a system model to solve how much traffic can be mitigated by large-scale social carpooling if deployed at a large scale. Four-step modeling was applied to investigate the impact of the regional scale of social carpooling on traffic mitigation with the assistance of a dynamic trip assignment simulation tool. OpenStreetMap was used to prepare the network data, and origin and destination (OD) pairs at the TAZ zonal level were used to distribute zonal trip generation over the whole Capital Area Metropolitan Planning Organization (CAMPO) area. The assumption made in this study was that solo driving trips would be converted to social carpooling trips using the same mode, a passenger vehicle. Mode choice was not taken into consideration. The results show that as technology advances and the population changes, more solo driving trips will be converted to high-occupancy vehicle travels expectation, which will further reduce traffic in the CAMPO region. In conclusion, this study emphasizes the potential advantages of social carpooling in easing traffic and enhancing the effectiveness of the transportation system.

The qualitative analysis included two interviewees, a travel demand manager from Texas Department of Transportation (TxDOT) and a consultant from Movability. Their responses indicated there were some difficulties or limitations in collecting individuals' trip data. The interviewees noted that one challenge is getting users to log their trips to track metrics, and the State of Texas has only a small number of high-occupancy vehicle (HOV) lanes; however, the preferential usage of HOV lanes is a significant inducement for carpooling. Meanwhile, the discussion between the interviewer and interviewee focused on the topic of social carpooling and transportation issues in Austin. For example, as more people moved to Austin, car companies promoted private car ownership, which may discourage social carpooling. They also talked about the mobility patterns of different demographics, including low to moderate income families, downtown workers, service industry workers, and construction workers. The interviewee expressed concerns about traffic congestion and the difficulty of changing public policy around transportation in Austin. They also discussed the impact of sexual offenses and discrimination on social carpooling and suggested using technologies for safety. The interviewees emphasized the importance of community-driven approaches to social carpooling and promoting alternative modes of transportation.

Overall, social carpooling is an innovative method of transportation that has a lot to offer both people and the community at large. Social carpooling is projected to become an increasingly popular and practical mode of commuting in the future as technology-assisted mobility services expand. It is a developing trend in the transportation sector, offering a budget-friendly and environmentally beneficial substitute for conventional transportation modes. It is crucial for academics to comprehend when and why people select social carpooling, where carpooling trips are generated, and how to operate a social carpooling system that complies with their demands and preferences. This will help to promote social carpooling for large-scale deployment.

Chapter 1. Introduction

Social carpooling is personalized incentive-based, smartphone-enabled, peer-to-peer ridesharing, as opposed to taxicabs, Transportation Network Companies (e.g., Uber), rental cars, and shared-car providers (e.g., Zipcar). Social carpooling is an innovative method for reducing car ownership and road congestion. It enables the transition from solo driving to efficient carpooling by coordinating people's travel needs in terms of location and timing. To promote the change, personalized incentives are used, including real-time data, traveler feedback, and monetary rewards. This project investigates how social carpooling affects user travel habits and how well the system works in mitigating congestion. The Metropia social carpooling platform, which enables ride-matching, provides support for the empirical data. Individualized incentive-based initiatives aimed at streamlining social carpooling are anticipated to have greater positive effects on the economy, society, and the environment. By boosting vehicle occupancy rates, social carpooling has the potential to significantly reduce traffic. Through panel data modeling, simulation, and policy analysis, researchers offer a thorough evaluation of personalized incentive-based social carpooling to address congestion reduction. This project also identifies, at three different levels, the following explanations that are essential to social carpooling.

1. **Individual level**: Using data gathered by Metropia, this project studies the impact of individual factors and trip characteristics on mode choice and utilization of social (peer-to-peer, p2p) carpooling. Both a generalized linear model and a panel binomial logit model were computed. Results were obtained as (1) Older individuals and men are more likely to carpool; (2) Less carpooling is done by commuters and persons with higher education levels; (3) Carpooling is more likely to occur when individuals have flexible departure times; (4) Long journeys and peak hours are unlikely instances for carpooling; and (5) Weekends and evenings are the most preferred times for carpooling. Based on the above results, women, educated people, employers, and commuters should receive more attention in order to encourage peer-to-peer carpooling. There are many actions that may be taken, including increasing public awareness, building infrastructure for carpooling, rewarding employers for fostering conducive settings and policies, and supporting platforms for carpooling apps.

2. **Area level:** Utilizing data gathered by Metropia and the regional travel demand model, this project investigates how different zone characteristics are associated with the number of carpooling trips. Carpooling trips and different zone variables, such as zone type, job counts in different industries, household car ownership, and other socioeconomic factors, can have a substantial effect on travel behavior and the overall effectiveness of the transportation system in each area. Results were obtained as (1) The number of carpooling trips are lower in the larger traffic analysis zones (TAZs); (2) The number of carpooling trips is positively correlated with the density of settlements; (3) There would be more carpooling trips in zones with a higher concentration of employees in the basic, retail, service, or educational industries; and (4) The number of carpooling trips is positively correlated with the number of households with more than two cars. Vehicle ownership plays a key role in carpooling. Carpooling trips are more likely to happen in areas with a high concentration of residential and industrial land use.

3. **System level**: Given the assessments at the individual and area levels, it is critical to simulate how the traffic will behave when applied to a wider population. This chapter uses a dynamic trip assignment approach to model the effect of social carpooling on traffic. Using four-step modeling and a dynamic trip assignment simulation tool, this project looks at the effects of

social carpooling on traffic mitigation at the regional level. OpenStreetMap was first used to prepare the network data. The possible social carpooling trips were then distributed by origin and destination (OD) pairings at the zone level across the entire Austin Metro region.

The development of community-based social carpooling apps like Metropia, which match people's travel needs in terms of time and space, has recently benefited from advances in smartphone technology. These initiatives, which receive funding from regional organizations as well as venture capital and advertising fees from sponsors, offer tailored incentives to encourage travelers to switch to on-demand social carpooling to decrease peak-hour driving, emissions, and traffic congestion. A few examples of individualized incentives are traveling advice, traveler reviews, and financial incentives. Understanding how various personalized incentives influence changing travel modes at the individual level is essential for maintaining the success of these new travel options. Forecasting future travel demand at the area level requires a better grasp of how many social carpooling trips can be produced. Simulating how traffic would behave if social carpooling were made available to a larger population is crucial at the system level. For the Metropia deployment in Austin, Texas, this project has adequately investigated the effects of social carpooling at the individual, zonal, and system levels.

The following three chapters detail three pieces of quantitative analyses, namely individual-level, area-level, and system-level. The next chapter details keynotes and findings from the qualitative interviews with social carpooling practitioners. The last chapter contains a summary of the findings.

Chapter 2. Individual Level: Who Carpools and How Often Do People Carpool?

This chapter discusses who prefers social (peer-to-peer, p2p) carpooling and how frequently they take part. Social carpooling, also known as "slugging," "community rideshare," "casual carpooling," or "informal spontaneous carpooling," is a neighborhood-based tactic that utilizes smartphone apps to connect drivers and passengers for road trips (Burris et al., 2012; Julagasigorn et al., 2021; O'Brien and Dunning, 2014; Shaheen et al., 2016; Tahmasseby et al., 2016).

On-demand social carpooling is becoming more popular since it encourages people to share rides by matching travel demand in terms of location and timing and it lowers transportation expenses for both drivers and passengers (Tahmasseby et al., 2016). Drivers divide their car trips into segments and give rides to passengers who roughly have the same origin or destination. Social carpooling benefits two types of users: those who are motivated to carpool and those who are looking for a ride. Passengers can search for rides near them or from other users and either book them for free or at a reduced rate. Incentives are used to encourage peer-to-peer carpooling. A passenger rides with a driver who is not a professional driver and is merely searching for others to ride with, such as friends, family, and coworkers. In contrast to Uber and Lyft, p2p carpoolers receive significantly less money but do it at their convenience. The way people travel has been altered by such cutting-edge, cost-effective mobility services.

Social carpooling offers seven benefits. On a systemic level, social carpooling (1) reduces costs by lowering the cost of transportation for both drivers and riders, including the cost of fuel, maintenance, and vehicle depreciation; (2) promotes environmental friendliness by lowering traffic congestion and carbon emissions; and (3) enhances parking availability by lowering the number of vehicles on the road, which in turn lowers the demand for parking spaces, enhancing availability and convenience (Shaheen et al., 2016; Tafreshian et al., 2020). At the individual level, social carpooling (4) increases convenience and flexibility for individuals by letting them choose their travel partners, create their own timetables, and offer a more individualized, convenient, and adaptable travel experience; (5) enhances social connections by giving people the chance to meet new people and form new relationships, enhancing their social lives; (6) increases car utilization by reducing the need for additional car ownership and reducing the overall number of vehicles on the road; and (7) enhances transportation equity by giving people the chance to remove travel restrictions and address equity issues presented in vulnerable groups with access to affordable mobility services (Bulteau et al., 2019; Shaheen et al., 2016).

Who and why people favor and adopt social carpooling has rarely been studied. Metropia is a leading social carpooling practitioner in the United States. The following questions are investigated in this chapter using Metropia data to examine social carpooling: (1) What elements contribute to the difference in mode preference between solo driving and social carpooling? and (2) What characteristics of social carpooling can be used to differentiate between users who frequently carpool and those who do so occasionally?

Literature Review

Social carpooling becomes an effective approach to match drivers and passengers with comparable routes and time constraints thanks to smartphone-assisted technology. It enables visitors to split the cost of their anticipated journey, including tolls, parking, and gas, as well as occasionally additional incentives supported by regional governments. Social carpooling also has the potential to advance the public's access to secure, convenient, and economical mobility services (Shaheen et al., 2016). Despite this, social carpooling remains new in both the literature and the practice to date, and it is often confused with ride-hailing. Its practice remains at a small scale. Most studies are unable to study individual profiles and trip characteristics due to a lack of observational data. The history of carpooling in the United States, as well as variables that encourage and discourage it, are discussed in the section that follows.

Early Carpooling Practice and Experiments

Carpooling is not a brand-new concept. Due to worries about affordability, people frequently shared cars with family members, neighbors, acquaintances, and coworkers during World War II (Ferguson, 1997). After World War II, carpooling rapidly declined as oil production and oil extraction productivity rose, removing the affordability barrier (Ferguson, 1997). In the mid-1970s, carpooling was popular again due to the oil crisis (Ferguson, 1997), but such a phenomenon was only temporal. Later, concerns with air quality in the 1980s and 1990s were caused by suburbanization and automation. In the states with the highest population, projects to cut commute times were started to address environmental issues. To encourage carpooling among coworkers, various travel demand management systems have been created (Abrahamse and Keall, 2012; Canning et al., 2010; Chen and Yang, 2023; Giuliano et al., 1993). First observed as ride matches, carpooling methods later developed into a guaranteed transport home. This plan gives workers access to frequent carpools, vanpools, or other environmentally friendly transport options, as well as a free and dependable ride home in the event of an emergency (Chen and Yang, 2023; Giuliano et al., 1993). Despite initiatives to encourage coworkers to carpool, empirical data indicated that carpooling was more frequently used for leisure, then shopping, then for commuting and school excursions (Arbour-Nicitopoulos et al., 2012; Gheorghiu and Delhomme, 2018; Olsson et al., 2019). Social carpooling had a negligible impact on reducing congestion when it was incorporated into employer-based travel demand management schemes.

To encourage peer-to-peer carpooling, numerous studies have been conducted over the last 20 years. Colleges and institutions, for instance, looked into ways to encourage participation by offering staff and students discounts or more transportation options (Dobrosielski et al., 2007). Without using an internet-based platform, a sizable experiment was carried out throughout several states. Back in 2010, funded by the Federal Highway Administration (FHWA), an exploratory advanced research (EAR) program was implemented to study how community rideshare works in Washington D.C., San Francisco, CA, and Houston, TX (Burris et al., 2012). Some cities then implemented free community rideshare pilot programs to encourage social carpooling instead of driving alone, such as Austin, TX (Griffin et al., 2016). Overall, carpooling has not been a common practice, but it recently saw a revival against the backdrop of rising shared mobility and the pervasive use of smartphone apps.

Factors Encourage Carpooling

A prior study categorized factors enabling social carpooling practice, namely urban life, sociodemographic, and mobility patterns. These factors facilitate the institutionalization and configuration process of social carpooling practice (Mote and Whitestone, 2011). Another study organized factors encouraging social carpooling as situational factors, third-party interventions, sociodemographic, and psychological factors (Neoh et al., 2017). Social carpooling is likely to be successful in metropolitan areas with supportive incentives, and the high degree of efficiency is predicated on the desire for time and money savings shared by both riders and drivers (Amirkiaee and Evangelopoulos, 2018; Li et al., 2007; Shaheen et al., 2016).

The fundamental motivation for encouraging peer-to-peer carpooling on the part of the driver is the financial gain (Amirkiaee and Evangelopoulos, 2018; Hunecke et al., 2021), such as assured parking at worksites, free use of the high-occupancy vehicle (HOV) lane, and tolling exemption or discount (Canning et al., 2010; Li et al., 2007; Shaheen et al., 2016). Social carpooling is substantially encouraged by financial rewards and a high level of dispositional trust, as was found in immigrant towns where inhabitants had developed strong links to their respective ethnic groups (Blumenberg and Smart, 2013). Yet, although social carpooling offers less money than ride-hailing, it is more convenient for drivers. The passengers also receive benefits. Ridesharing applications such as Click-and-Ride on smartphones enable users to arrange rides at a lesser rate without owning a vehicle. Social carpooling helps riders cut down on pointless driving excursions.

Promoting peer-to-peer carpooling can be challenging in big cities because it may entice some bus passengers away from environmentally friendly options, and therefore indirectly reduce transit usage. However, in medium-sized and small cities, smaller vans can be utilized in place of bigger buses or trains, allowing for more flexible and efficient use of resources. These shared trips can be provided along busy commuter routes. In rural locations, where there is often no access to public transportation, community ridesharing can be very helpful for getting around without a car.

In terms of sociodemographics, carpoolers are more likely to be women, parents, low-income individuals, immigrants, and transit users (Blumenberg and Smart, 2013; Bulteau et al., 2019; Delhomme and Gheorghiu, 2016; McKenzie, 2015; Tahmasseby et al., 2016). A social network with many users can make carpooling much easier when people know each other (Blumenberg and Smart, 2013).

Factors Discourage Carpooling

Early studies also showed that there were still numerous obstacles to promoting social carpooling, particularly related to psychological difficulties. These included worries about comfort, safety, and dependability, including loss of autonomy, invasion of privacy, difficult social situations, and interpersonal mistrust (Amirkiaee and Evangelopoulos, 2018; Bachmann et al., 2018; Correia and Viegas, 2011; Hunecke et al., 2021; Nielsen et al., 2015).

Safety is one of the main issues. Many carpooling sites now demand background checks and personal information verification for both drivers and riders in order to reduce the danger (Perren and Kozinets, 2018). It is possible to establish institutionalized pickup carpool zones in a way that legitimizes the activity to increase the perceived and observed security of social carpooling (Buliung et al., 2010; Gandia et al., 2021).

Trust is a problem that both drivers and passengers must overcome for carpooling to be successful and enjoyable. The likelihood of peer-to-peer carpooling is adversely connected with autonomy loss and privacy violation (Hunecke et al., 2021). An empirical study suggested using carpooler clubs to boost trust and coordinate rides (Correia and Viegas, 2011). The use of online matching tools substantially speeds up the process, fosters more confidence between drivers and passengers, and makes carpooling more fun (Gheorghiu and Delhomme, 2018; Julagasigorn et al., 2021).

Overall, with smartphone-aided technologies, there is a trend that social carpooling is beginning to take off in many apartment communities, university campuses, and job centers. Prior studies have emphasized the significance of employing tailored incentives to actively engage potential poolers (Margolin et al., 1978), and the significance of having a thorough understanding of the unique profiles and trip features of social carpooling. The available research on carpoolers' preferred mode and frequency of use is insufficient. Therefore, this chapter investigates the factors that influence the mode selection of p2p carpoolers and seeks to uncover specific criteria and trip characteristics that are linked to higher social carpooling.

Research Design

Data

The data gathered by Metropia, a mobility management app that encourages peak avoidance and social carpooling, was used to address the research concerns outlined above. Metropia offers incentives to change travel plans and departure times, assists users in getting real-time traffic information, and facilitates the planning of travel. Researchers used Austin, Texas, for the empirical analysis, which spanned the period from 07/01/2016 to 12/31/2018, and involved 1,128 customers. Metropia has operated its services in Tucson, Arizona, El Paso, Houston, and Austin, Texas, as well as San Francisco, California. The trip level and individual level analytical units are appropriate for the two analyses. Table 1 provides a description of the chosen variables.

The Metropia users were split into four groups. A major portion of the users never used the app for carpooling but did for peak avoidance, which accounted for 60.02% (677). Among the carpoolers, one group of users were willing to carpool but had no successful record of carpooling, another group of users were characterized as mostly driving alone but occasionally carpooling, and the last group carpooled only (riders), accounting for 5.50% (62), 33.95% (383), and 0.53% (6), respectively. As the research objective was social carpooling, the analysis in this chapter included only 445 users, excluding individuals who drove alone only and carpooled only (riders).

Two categories of factors—individual factors and trip characteristics—were included in the conceptual models. Users provided personal information, including their age, gender, and income. The time of day and the day of the week were two trip characteristics that were automatically generated when an app was used and were connected to the trips' occurrence.

Table 1. Variable Description for Metropia Social Carpooling Data

Variable	Description
Social carpooling	If the user chooses social carpooling, 1; else, 0.
P2P carpool ratio	The ratio of carpooling trips among all trips advised by Metropia for one user.
Individual factors	
MetropiaID	The ID of a user.
Age	The age of a user. 7 levels: Under 18 years old, 1; 18-25 years old, 2; 26-34 years old, 3; 35-45 years old, 4; 46-55 years old, 5; 56-65 years old, 6; Over 65 years old, 7.
Gender	If a user is a female, 1; else, 0.
Educational attainment	Three levels: high school or lower, 1; college or university, 2; graduate, 3.
Telecommute	The number of days that a user works from home per week. Four levels: 0 days, 0; 1-2 days, 1; 3-5 days, 2; More than 5 days, 3.
Household income	Three levels: low (<53K), 1; medium (53–84K), 2; high (>84K), 3.
# of children	The number of children that a user has.
Driving experience	If a user obtained his/her driver's license over a year, 1; else, 0.
Commute	If a user commuted to workplace or school, 1; else, 0.
Departure time flexibility	If a user has some flexibility to change departure time, 1; else, 0.
App usage	The number of trips advised by Metropia. (1) low app usage (≤1080.09 trips); (2) median app usage (1080.09~4968.77 trips); (3) high app usage (>4968.77 trips). The thresholds are defined by the mean ± one standard deviation.
Trip characteristics	
Travel time	The travel time of each trip was recorded by the app, in mins.
Peak travel	If a user travels during peak hours (6:00–10:00 AM, 3:00–8:00 PM), 1; else, 0.
Temperature	The highest temperature during that day, in ◦C.
Time metric	The number days from 2016-07-01, in counts.
Weekday/Weekend	If the trip occurred on a weekday (Monday to Friday), 1; else, 0.
PM/AM	If the trip occurred during the PM period (12:00–23:59 PM), 1; else, 0

Methodology

Two statistical modeling analyses were performed to answer the two research issues in this work. Researchers first examined the binary decision between social carpooling and solo driving over time. To examine the varied effects of explanatory variables on travelers' mode of transportation, a panel binomial logit mixed model was used. Second, a cross-sectional analysis was conducted using a generalized linear model to examine the impact of other explanatory factors on the ratio of peer-to-peer carpooling trips.

Panel Binomial Logit Mixed Model

The panel binomial logit mixed model calculates the combined impact of individual profiles and trip parameters on the mode choice between social carpooling and solo driving, expressed by Equations (1) and (2). Some variables are time-varying, and interaction effects are specified to capture the changes over time.

$$P_{kt} \sim Binomial(p_{kt}) \tag{1}$$

$$log\left(\frac{P_{kt}}{1-P_{kt}}\right) = \alpha_0 + \sum_{i=1}^{I} \alpha_i X_{ik} + \sum_{j=1}^{J} \beta_j Y_{jkt} + \gamma_0 * T + \sum_{j=1}^{J} \gamma_j Y_{jkt} * T + \delta\xi_{kt} + \varepsilon_{kt} \tag{2}$$

where P_{kt} is the probability of the carpooling for the trip of individual k at time t; α_0 denotes the intercept; there are I cross-sectional variables, such as age and gender; and there are J time-varying variables, such as temperature; X_{ik} is the ith explanatory variable of kth individual, and the corresponding coefficient is α_i. Y_{jkt} represents the jth time-varying variable for individual k at time t; β_j is the coefficient of Y_{jkt}; T is the time metric, ranging from 1 to 914, representing the active days using Metropia, and its corresponding coefficient is γ_0; $Y_{jkt} * T$ denotes the jth interaction effect between the time metric and time-varying variables on the kth observation at time t, and γ_j is the corresponding coefficient; ξ_{kt} is the random effect (Metropia ID) on the kth observation at time t with the corresponding coefficient δ; ε_{kt} is the random error.

Generalized Linear Model

The combined impact of individual information and trip variables on the social carpooling ratio was investigated. The generalized linear model (GLM) was selected for analysis, as shown in Equation (3).

$$y_k = \alpha_0 + \sum_{i=1}^{I} \alpha_i X_{ik} + \delta_k \tag{3}$$

where y_k is the social carpooling ratio (the number of social carpooling trips divided by the total number of trips advised by Metropia) for individual k during 07/01/2016 to 12/31/2018; α_0 represents the intercept; there are I cross-sectional variables; X_{ik} is the ith explanatory variable of kth individual, and the corresponding coefficient is α_i. δ_k is the random error for the kth observation following a normal distribution.

Results

Descriptive Analysis

Researchers used trip-level and user-level analytics to examine data from the Metropia app in Austin, where 445 users completed 271,298 journeys between July 1, 2016, and December 31, 2018. Table 2 displays the data summary. Only 10.80% of the trips, as seen, involved peer-to-peer carpooling. There were supporters of peer-to-peer carpooling in the sample. Using Metropia, one user carpooled 95.8% of all trips. On average, 16.6% of their journeys were carpooling while using Metropia.

Most users were adults, according to the individual profiles. A total of 93.26% of users were between the ages of 26 and 65, and 41.12% of the carpoolers were female, which was more than predicted. Fascinatingly, 82.25% of users reported better incomes than the national average, and 93.71% had degrees equivalent to or higher than a college degree. According to all available data, Metropia customers were adults with high incomes and decent educations. According to trip characteristics, 80.84% of trips took place on weekdays, 56.68% of journeys took place in the evenings, and 78.08% of trips happened during peak hours (6:00–10:00 AM and 3:00–8:00 PM).

Table 2. Data Summary for Metropia Social Carpooling Data

Variables	Mean	St. D.	Min.	Max.	Percentage of "1"	N
Social carpooling			0	1	10.80%	29,300
Social carpooling ratio	0.166	0.214	0	0.958		455
Individual factors						
Under 18 years old			0	1	0.67%	3
18-25 years old			0	1	3.82%	17
26-34 years old			0	1	25.39%	116
35-45 years old			0	1	24.94%	113
46-55 years old			0	1	16.40%	75
56-65 years old			0	1	22.70%	103
Over 65 years old			0	1	6.07%	28
Female			0	1	41.12%	187
High school			0	1	6.29%	29
College			0	1	73.71%	335
Postgraduate			0	1	20.00%	91
0 days working from home			0	1	79.78%	363
1-2 days working from home			0	1	14.38%	65
3-5 days working from home			0	1	2.70%	12
More than 5 days working from home			0	1	3.15%	14
Low annual income (<53K)			0	1	8.09%	37
Medium annual income (53–84K)			0	1	9.66%	44
High annual income (>84K)			0	1	82.25%	374
# of children	0.48	0.99	0	4		455
Driving experience			0	1	98.88%	450
Commute			0	1	95.51%	435
Departure time flexibility			0	1	70.56%	321
Low app usage			0	1	61.07%	278
Medium app usage			0	1	34.90%	159
High app usage			0	1	4.03%	18
Trip characteristics						
Travel time	17.25	12.45	5.42	119.37		271,298
Peak travel			0	1	78.08%	211,830
Temperature	27.32	8.06	-1	42		271,298
Time metric	435.16	246.32	1	914		271,298
Weekday/Weekend			0	1	80.84%	219,317
PM/AM			0	1	56.68%	153,772

The sample represents adults with good education and high-income. Figures 1, 2, and 3 show comparisons between Metropia users and the American Community Survey. As shown in Figure 1, people aged from 26 to 65 are significantly overrepresented in the sample. Evidenced in Figures 2 and 3, Metropia users were more likely to be well educated and of high income. The bias was more represented in income.

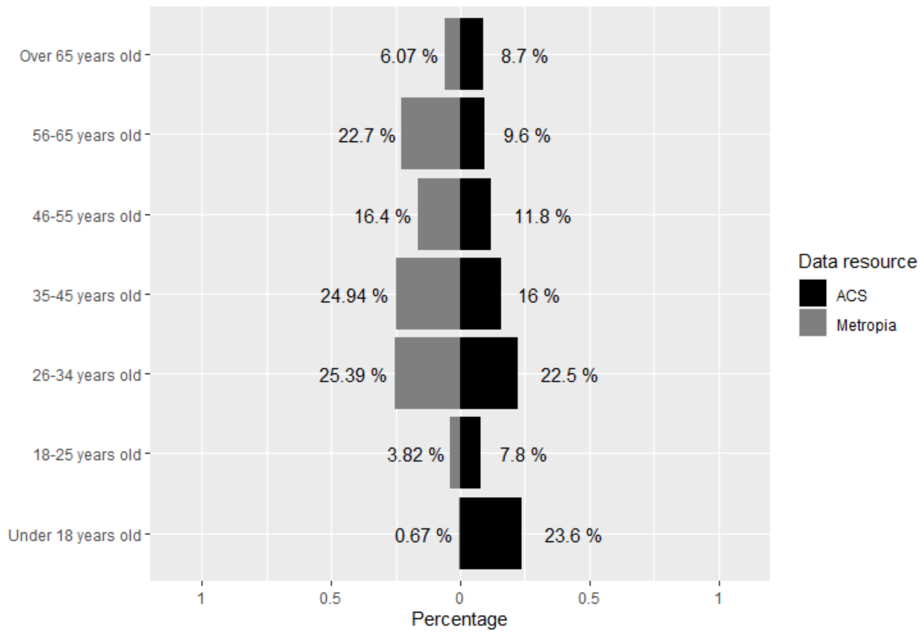


Figure 1. Age groups of Metropia users and 2018 5-year ACS estimates

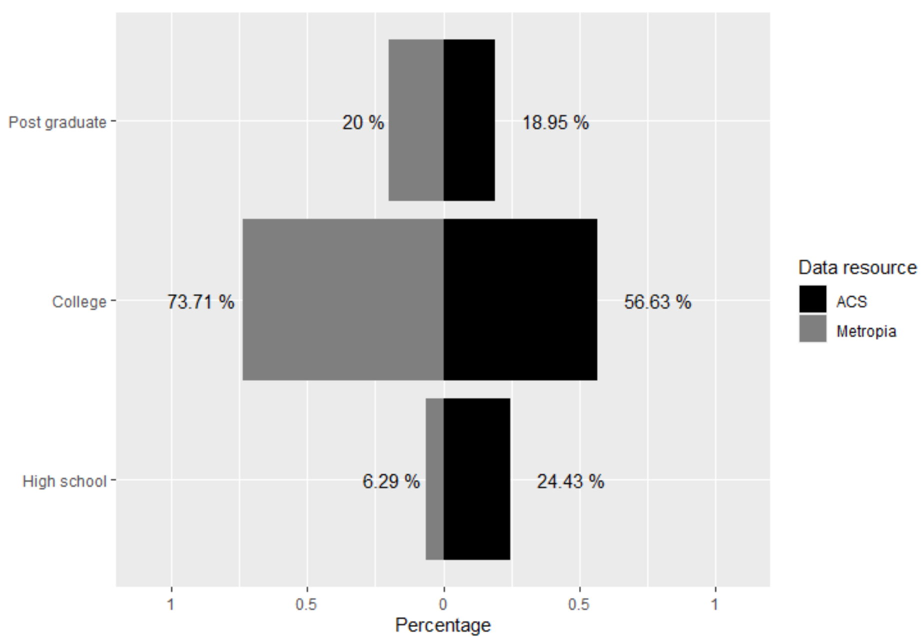


Figure 2. Educational attainment groups of Metropia users and 2018 5-year ACS estimates

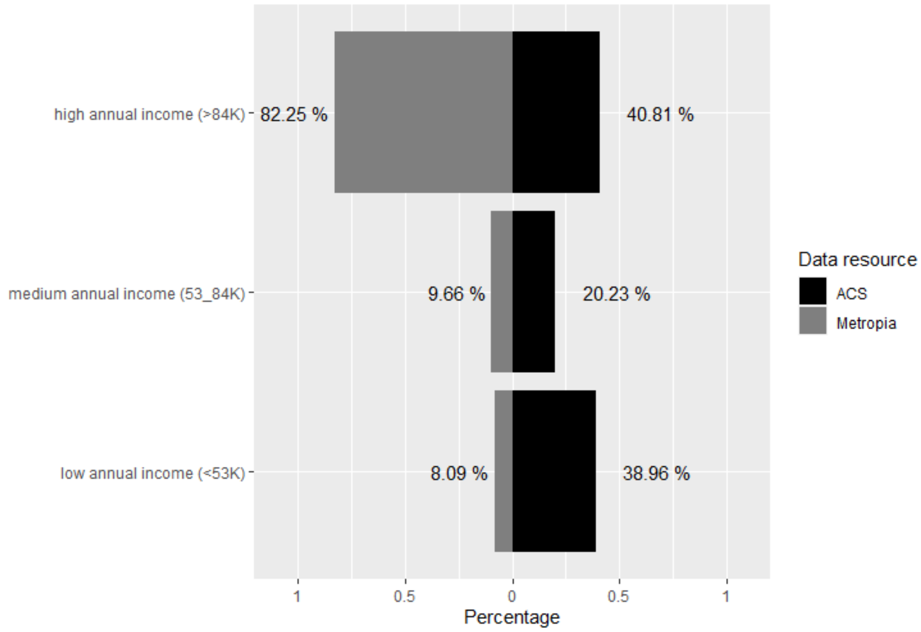


Figure 3. Income groups of Metropia users and 2018 5-year ACS estimates

Panel Binomial Logit Mixed Model Results

With a total of 271,298 trips, the first analysis was done at the trip level. The panel binomial logit mixed model was used to analyze how individual attributes and trip features affect the decision to opt for social carpooling or drive alone. Table 3 displays the results of the modeling. The model fits the data well, as shown by the McFadden R squared of 0.302. According to the Metropia ID's random impact, users' preferences for social carpooling differed substantially.

Among individual factors, males were more likely to carpool than females, and older persons were more likely to carpool overall with coefficient 0.273. Although the relevance was only small, those with higher levels of education were less likely to carpool (-0.417). People were less likely to carpool if they spent more days working from home (-0.404). It was marginally significant that drivers who had only been licensed for a short time were more likely to carpool (-1.742). Carpooling was less prevalent among commuters (-1.775). More people were likely to carpool if their departure timings were flexible (1.114).

Regarding trip characteristics, long trips made people less willing to carpool (-0.007), although this impact gradually faded. Carpooling was less prevalent during rush hour (-0.122). People were more likely to carpool on warmer days (0.004). Carpooling was more prevalent on weekends (-0.895) and in the evenings (0.263).

Table 3. Results of the Panel Binomial Logit Model (Metropia Social Carpooling Data)

Variables	Estimate	Std. Dev.	P-value	
Intercept	1.343	1.136	0.237	
Individual factors				
Age	0.273 **	0.087	0.002	
Gender	-0.887 ***	0.226	< 0.001	
Educational attainment	-0.417	0.223	0.062	
Days work from home	-0.404 *	0.170	0.018	
Household income	-0.162	0.205	0.429	
# of children	-0.095	0.151	0.530	
Driving experience	-1.742	0.907	0.055	
Commute	-1.775 ***	0.488	< 0.001	
Departure time flexibility	1.114 ***	0.269	< 0.001	
App usage	-0.182	0.192	0.344	
Trip characteristics				
Travel time	-0.007 ***	0.001	< 0.001	
Peak travel	-0.122 ***	0.017	< 0.001	
Temperature	0.004 ***	0.001	< 0.001	
Time metric	0.212 ***	0.046	< 0.001	
Weekday	-0.895 ***	0.016	< 0.001	
PM time	0.263 ***	0.016	< 0.001	
Interaction effects				
Time metric: Travel time	0.017 ***	0.002	< 0.001	
Level of Significance: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Random effects	Variance	Std. Dev.		
MetropianID	4.225	2.056		
Model accuracy	AIC	BIC	log-likelihood	McFadden R2
Panel model	129,596	129,796	-64,779	0.302(*d.f.* = 19)
ANOVA test	AIC	BIC	log-likelihood	P-value
Null model	185,697	185,707	-92,847	<.001 (*d.f* .= 18)
Fixed effects only	165,840	166,030	-82,902	<.001 (*d.f* .= 1)

Generalized Linear Model Results

The second analysis included 445 users at the individual level. This analysis was cross-sectional since it aggregated people's p2p usage over time. The social carpooling ratio, which represents the total number of carpooling trips divided by the total number of journeys, was examined using the generalized linear model (GLM). Table 4 displays the modeling outcomes.

The trip-level analysis and the outcomes substantially agree. A higher percentage of older persons carpooled with others (0.027). Males carpooled more than ladies (-0.062), as was expected. Less commuters were carpooling peer-to-peer (-0.170). People who could change their departure time were more likely to carpool (0.085).

Table 4. Results of the Generalized Linear Model (Metropia Social Carpooling Data)

Variables	Estimate	St. Dev.	P-value
Intercept	0.534 ***	0.126	< 0.001
Individual factors			
Age	0.027 ***	0.008	< 0.001
Gender	-0.062 **	0.020	0.002
Educational attainment	-0.032	0.020	0.112
Days work from home	-0.018	0.015	0.233
Household income	-0.022	0.018	0.216
# of children	-0.004	0.014	0.772
Driving experience	-0.148	0.096	0.126
Commute	-0.170 ***	0.048	< 0.001
Departure time flexibility	0.085 ***	0.023	< 0.001
App usage	-0.002	0.018	0.919
Model accuracy	AIC	BIC	Log-likelihood
	148.021	98.791	-86.011 (*d.f.=12*)

Summary of Findings

This chapter looked at the specific elements and trip characteristics that are connected to social carpooling. According to the results of the experiment, social carpooling was quite popular but also experienced numerous difficulties. Metropia seems to be an unreliable choice for carpoolers (riders), perhaps because it was operated on a limited scale; only 0.55% of users were strictly passengers. Fortunately, 33.95% of the users (vehicle owners) were able to carpool successfully using the app's ride match feature. The fact that so many people are eager to carpool if a trustworthy platform is made available is encouraging since it suggests the possibility of creating a successful social carpooling system on a broad scale in the future.

To investigate the impact of individual factors and trip characteristics on social carpooling at the trip-level and individual-level, researchers built a panel binomial logit model and a generalized linear model. The results reported in the two models are essentially consistent, despite the two models' significance levels differing. The panel model's findings, which offer further insights, are the subject of the discussion that follows.

Most findings are largely consistent with the prior research. Older people are more likely to carpool (Park et al., 2018). Males are more likely to carpool, but mostly as drivers (Park et al., 2018). Income suggested no statistical significance, while this result can be misleading because most Metropia users were richer than the average in the sample. This result needs to be further examined in future research. More educated people, who may have a higher income, showed a negative association with the likelihood of carpooling (Blumenberg and Smart, 2013; Bulteau et al., 2019). Commuters are unlikely to carpool given the limited time budget during peak hours (Olsson et al., 2019). In contrast, drivers with departure time flexibility are more likely to carpool (Mitropoulos et al., 2021; Tahmasseby et al., 2016). People who drive for long distances are unlikely to carpool (Monchambert, 2020; Tahmasseby et al., 2016). People are unlikely to carpool during peak hours unless HOV lane priority is provided or additional incentives are offered because people value time savings when roads are congested (Li et al., 2007).

Numerous discoveries have recently been added to the body of knowledge. First, carpooling is more prevalent among drivers with less experience. Inexperienced drivers may be anxious when behind the wheel; a companion can offer guidance and emotional support to ease their fears. Second, when it's hot outside, more individuals are inclined to carpool. There has to be more research done on this conclusion because the causes could be complex. Third, because people have more time flexibility in the afternoon and evening, as well as on weekends, carpooling appears to be more popular.

Key Takeaways

The examination of individual factors and trip characteristics suggests key takeaways by focusing on females, educated people, commuters, and employers. To encourage female participation in social carpooling, their concerns need to be addressed, such as safety, social awkwardness, and interpersonal distrust. Various measures can be taken. App platforms can validate user profiles, provide in-app emergency services, and offer real-time tracking to assure safety. Platforms for apps can design female-only carpooling solutions where both the drivers and the passengers are female. Similarly, app platforms can create carpooling networks where users can interact with other female drivers, exchange stories, and create a caring community. App platforms can use female carpoolers as a marketing tool by rewarding them with unique incentives.

Educated people are less likely to carpool. To incentivize their willingness, small monetary rewards may not work. Other strategies should be prioritized, such as promoting awareness about the benefits of carpooling and building clubs to expand their social networks. Some individuals are interested in partially releasing their driving duties, pairing colleagues or neighbors who live and work in approximating areas with similar schedules is attractive to them. Sharing rides to social events, weekend trips, or other leisure activities with friends or family is attractive to many solo individuals. App platforms should enable functions to pair long-term carpoolers and organize social events for carpoolers of different needs.

Employees may find it hard to carpool due to the limited time budget during peak hours. Saving travel time and adding time flexibility are important to social carpooling among employed individuals. Other travel demand management tools should be applied cautiously with social carpooling incentives. On the employer side, the easiest ways are promoting awareness about the benefit of carpooling and matching rides for employees. If flexible work schedules can be provided to individuals by their employers, they will remove the time constraint and may greatly improve the willingness of carpooling among employees. Employers may also offer subsidies and other incentives, such as guaranteed or prioritized parking at workplaces, to promote carpooling among employees. Other employer-related support may also help increase time flexibility and indirectly promote carpooling, such as telecommuting and compressed work weeks (Chen and Yang, 2023).

The creation of dedicated carpool lanes, which can be the most appealing incentive for carpoolers during peak hours, differentiating tolls for different times of the day and different days of the week, and raising awareness of the advantages of carpooling through public cameras are just a few of the strategies local agencies can implement to create a more welcoming environment for carpooling.

Chapter 3. Area Level: Where Social Carpooling Trips Frequently Happen?

From the individual-level analysis to the area-level analysis, the study broadens its scope to examine the collective impact of social carpooling on traffic congestion and transportation efficiency at a larger scale. While the individual analysis provided valuable insights into the factors influencing social carpooling behavior and suggested targeted strategies for promoting carpooling uptake among individuals, the area-level analysis takes a system-wide approach. This comprehensive investigation incorporates factors such as area size, settlement types, income, employees in different industries, household car ownership, and household size to assess the overall potential for carpooling promotion in different zones. By shifting focus from individual behavior to aggregated data across zones, the research aims to provide a more holistic understanding of how social carpooling can be effectively harnessed as a traffic mitigation tool, with the goal of enhancing mobility services and reducing traffic congestion in the Capital Area Metropolitan Planning Organization (CAMPO) region and beyond.

This chapter investigates the trip generation of social carpooling trips. Carpooling is the practice of sharing a ride with others who are traveling to the same destination, usually with the aim of reducing the number of cars on the road system and minimizing traffic congestion (Kelley, 2007), regardless of commuting, shopping, or schooling trip purposes. Carpooling saves individuals travel costs on both money and time (Teal, 1987), such as fuel, parking costs, and traffic delays, which can result in significant savings for both drivers and riders. Carpooling is an attractive option for individuals, especially those who are facing financial burdens and mobility constraints (Delhomme & Gheorghiu, 2016). Carpooling can be an effective strategy through advocating for environmental sustainability, reducing social costs paid by our civil society, addressing equity issues by providing mobility services, and promoting the social integrity of our communities.

To estimate carpooling trips, several factors must be taken into account, including: population density and employment density – the more people concentrated in a particular area, the more likely that carpooling will be attractive; the availability of public transportation – areas with good public transportation options may see lower rates of carpooling; parking facilities – if there are parking difficulties in a particular area, people are more likely to carpool to save money on gas and parking, and the frustration of finding a parking space; the availability of carpooling infrastructure – this includes designated carpool lanes, carpool parking spaces, and other facilities that make it easier for people to carpool; and the time of day – carpooling may be more popular when people have greater flexibility.

Historically, estimating the number of carpooling trips can be challenging. First, data on carpooling trips can be difficult to obtain, especially in areas where carpooling is not widely practiced or where there is no centralized tracking system for carpooling. Second, carpooling can be unpredictable as it depends on the willingness of individuals to share a ride, which can be influenced by various factors such as the weather, personal schedules, and the availability of parking and carpool lanes. Third, people lack awareness about the benefits of carpooling and the availability of carpooling options can discourage individuals from carpooling. Similarly, the absence of incentives such as reduced tolls or parking fees can also reduce the attractiveness of carpooling.

Metropia is a mobility management app that addresses the three abovementioned challenges by providing well-tracked real-world social carpooling data, and the benefit of social carpooling is well informed to the users. In this chapter, the number of carpooling trips in each traffic analysis zone (TAZ) is aggregated and selected as the dependent variable to examine the effects of various independent variables, such as settlement types, income, the number of employees from different industries, household car ownership (no car, one car, and more than two cars), and household size. The results serve to inform policies and programs that support peer-to-peer carpooling and promote social and environmental well-being.

Literature Review

Researchers explored the effect of various attributes that are associated with carpooling trip counts. As mentioned, empirical studies examining factors associated with carpooling trip counts are rare due to the lack of data. This section lists factors correlated with carpooling trip counts.

A few prior studies examined factors that are associated with carpooling trips. Some of the commonly studied factors include income, employment density, household size, access to public transportation, and the availability of alternative modes of transportation (Dewan & Ahmad, 2007; Donovan, 2010; Huan et al., 2022; Ma et al., 2018; Vanoutrive et al., 2012; Wang et al., 2018). Additionally, some studies found that the availability of carpooling programs, such as vanpooling and ride-sharing, is positively associated with the number of carpooling trips (Dueker et al., 1977; Kocur & Hendrickson, 1983). This indicates that certain promotion efforts help match rides and increase the willingness of carpooling among some individuals. Some prior studies have found that the presence of high-occupancy vehicle (HOV) lanes is positively associated with the number of carpooling trips (Daganzo & Cassidy, 2008; Dahlgren, 1998).

Density is a key measurement associated with carpooling. Denser urban areas, such as central business districts (CBDs), are more likely to be places that have frequent carpooling as there are more potential carpooling partners in closer proximity, making it easier for individuals to find and coordinate with others (Bulteau et al., 2021). Also associated with density, the availability of public transportation is positively associated with carpooling trips (Dewan & Ahmad, 2007). Transit is positively associated with density, and only dense environments can support the operation of a successful transit system. Carpooling can provide alternative travel options to regular bus riders (Blumenberg & Smart, 2014).

Prior studies suggested that the distribution of jobs within an area can significantly affect the likelihood of individuals engaging in carpooling trips (Benita, 2020; Hartgen & Bullard, 1993; Liu et al., 2021; Padhy et al., 2022; Padhy & Chou, 2021). If a zone has a high concentration of jobs, this may indicate more potential carpooling partners, as individuals may be traveling to and from similar destinations (Liu et al., 2019). This can increase the potential for carpooling and reduce the number of single-occupancy vehicles, which can reduce traffic congestion. In addition, the type of jobs in each area can also correlate with the number of carpooling trips (Wang, Wang, Ettema, et al., 2020). For example, if a zone has many jobs with flexible schedules, individuals may be more likely to adjust their travel times to facilitate carpooling. Understanding how these factors are related to carpooling provides insights into how mobility management strategies can be tailored to the specific needs and characteristics of each zone, in order to encourage carpooling practices and reduce traffic congestion and its negative impacts.

Data

Researchers explored the carpooling trip counts in Austin, with a focus on Williamson and Travis Counties. Metropia is a mobility management tool that is designed to encourage and facilitate peer-to-peer carpooling. The app provides users with ride-match, real-time traffic information, route and departure time recommendations, and other features to help them make informed decisions about their travel choices. By using data collected by the Metropia tool from 01/01/2016 to 12/31/2018, the researchers aimed to identify patterns in the number of carpooling trips made in each of the 1,538 TAZs. This information can then be used to inform future policy decisions and mobility management strategies for reducing traffic congestion and encouraging sustainable transportation options. The data contain information on settlement type, the number of jobs in different industries, household size, and household car ownership. These data enabled researchers to better understand the broader context of where and how many carpooling trips were taking place, detailed in Table 5.

Table 5. Variable Description for Traffic Analysis Zone (TAZ) Data

Variables	Description
Trips	Metropia carpooling trip counts in the TAZ, in counts.
Area size	Area size, in squire miles.
Settlement type (sorted by density)	Settlement types: 1: Rural; 2: Suburban Residential; 3: Urban Residential; 4: Urban Intense; 5: CBD
Medium income	Median income in the TAZ, in K$.
Basic	Number of employees in basic industries.
Retail	Number of employees in retails.
Service	Number of employees in service industries.
Education	Number of employees in education.
Auto 0	Number of households with no auto, in counts.
Auto 1	Number of households with 1 auto, in counts.
Auto 2	Number of households with 2+ autos, in counts.
Household size	Average household size in the TAZ, in counts.

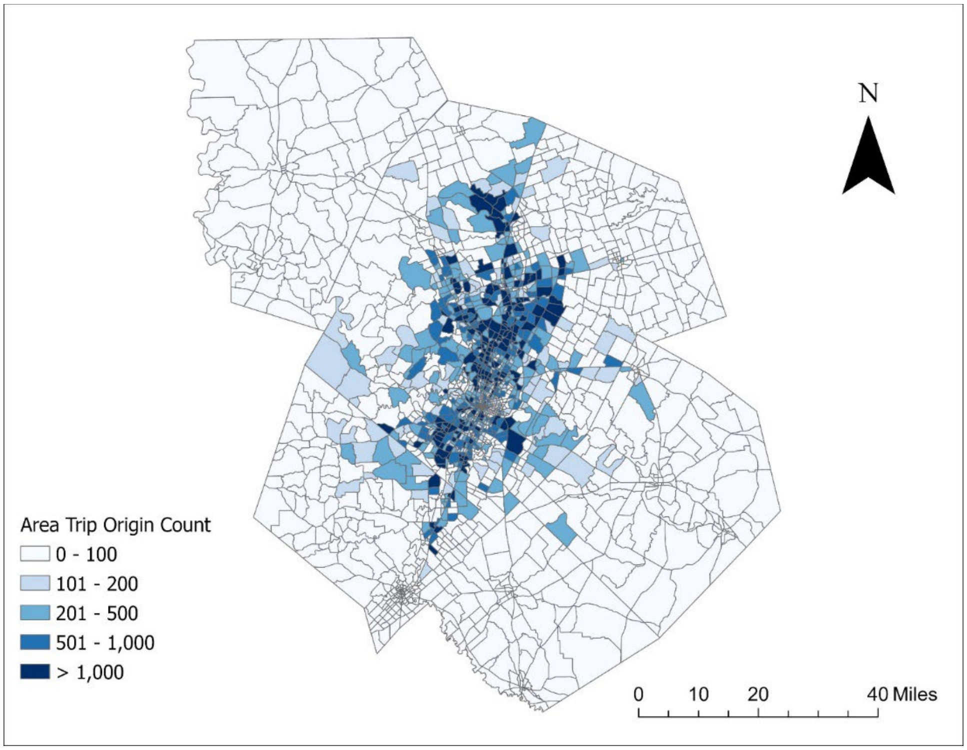


Figure 4. The TAZ-level carpooling trip counts for origins

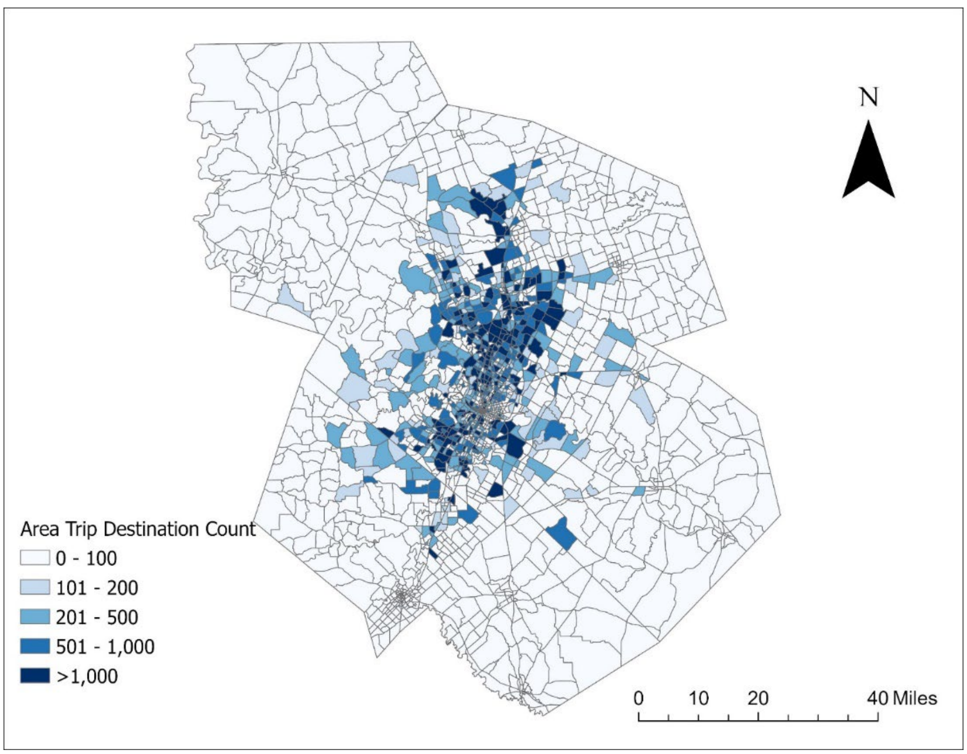


Figure 5. The TAZ-level carpooling trip counts for destinations

Methodology

The use of a generalized linear model (GLM) provided a statistical framework to examine the relationship between multiple variables and carpooling trip counts. The independent variables include settlement types (coded into an ordinal scale), income, number of employees in different industries, household car ownership, and household size. By assuming that the number of carpooling trips follows a negative binomial distribution, the model can account for the overdispersion that is often present in count data. The expression is simplified as Equation (4).

$$\log(Y) = \beta_0 + \sum_{i=1}^{N} \beta_i X_i + \varepsilon \qquad (4)$$

where Y is the dependent variable (the number of carpooling trips); β_0 is the intercept; X_i is the i^{th} independent variable from total N variables with the corresponding coefficient β_i; ε is the random error.

Results

Descriptive Analysis

The trip count of 1,538 TAZs was collected by the Metropia app in Williamson and Travis Counties from 01/01/2016 to 12/31/2018. The settlement type, jobs in different industries, household car ownership, and other socioeconomic factors were collected in 2015. Table 6 presents the data summary. As shown, there are TAZs with no carpooling trips. 5.98% of TAZs are located in the CBD and 11.25% are located in areas labeled 'urban intense.' There are also TAZs with no basic, retail, services, and educational industries, noticed as undeveloped areas.

Table 6. Data Summary for Traffic Analysis Zone (TAZ) Data

Variables	Mean	St. D.	Min.	Max.	Percentage of "1"
Carpooling trips	709.91	1,332.99	0	21,121	
Area	1.40	2.38	0.004	33.129	
CBD			0	1	5.98%
Urban intense			0	1	11.25%
Urban residential			0	1	30.04%
Suburban residential			0	1	30.04%
Rural			0	1	22.69%
Medium income	63.77	38.93	0	232.778	
Basic	111.75	519.94	0	14,370	
Retail	120.93	251.21	0	3,816	
Service	257.78	570.58	0	7,930	
Education	44.90	405.77	0	14,768	
Auto 0	3.81	8.04	0	93	
Auto 1	108.58	193.93	0	2,141	
Auto 2	273.61	376.68	0	2,684	
Household size	2.44	1.16	0	6	

Inferential Analysis

The use of a generalized linear model (GLM) allowed for an examination of the relationship between multiple variables and the carpooling trip counts in Austin. The r-square value of 0.24 indicates that the model is a good fit for the data. The model result is shown as Table 7. As shown, the larger area has a smaller number of carpooling trips (-0.192). The density of settlements shows a positive association with the number of carpooling trips (0.133). A TAZ, which has a higher number of employees in basic (0.025), retail (0.174), service (0.044), or education industry (0.021), would have more carpooling trips. The households owning two or more cars show a positive relationship with the number of carpooling trips (0.140).

Table 7. Model Summary for Traffic Analysis Zone (TAZ) Data

Variables	Estimate	P-value	Sig.
Intercept	5.258	< 0.001	***
Area	-0.192	< 0.001	***
Density	0.133	0.007	**
Medium income	0.001	0.322	
Basic	0.025	0.002	**
Retail	0.174	< 0.001	***
Service	0.044	0.000	***
Education	0.021	0.041	*
Auto 1	0.051	0.050	.
Auto 2	0.140	< 0.001	***
Household size	-0.048	0.250	
The level of significance: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'			
Model accuracy			
AIC	20,779.34		
BIC	20,843.40		
Log-likelihood	-10,377.67	(df=12)	
R-square	0.24		

Discussion

In this chapter, a GLM model was utilized to explore the relationship between various explanatory factors, such as settlement type, job counts in different industries, household car ownership, and other socioeconomic factors, and the number of carpooling trips, which can provide insights for transportation planning and policy making. From the descriptive analysis, it is important to note that certain types of industries, such as basic, retail, services, and educational industries, significantly correlate with the number of carpooling trips taken in each TAZ. TAZs without these types of industries may see lower levels of transportation activity, as there may be fewer opportunities for jobs or other activities in these areas.

This result suggests that larger areas have fewer carpooling trips compared to smaller areas. Larger TAZs are associated with a lower density of traffic per unit, where people may have more difficulties finding carpoolers. The positive association between settlement types (sorted by density) and carpooling trip counts indicates that denser areas have a greater availability of alternative modes of transportation (such as public transportation or bike-sharing), which makes it easier for people to travel without driving alone. Additionally, a higher density of settlements is associated with a higher demand for alternative modes of transportation. Carpooling is substitutional to alternative modes, but it can be considered a more on-demand mobility service to reduce car dependence and mitigate traffic congestion. Meanwhile, larger areas may also have more dispersed land use, scattered job centers, and longer commutes, making it difficult for people to match rides.

The model shows that TAZs with a higher number of employees in basic, retail, service, or education industries have more carpooling trips. This could be explained by these types of jobs often being located in denser regions, making it easier for people to travel without driving alone. Additionally, the positive relationship between households with two or more cars and carpooling trips suggests that access to personal vehicles may also play a role in the willingness to carpool.

Chapter 4. System Level: Dynamic Trip Assignment Simulating the Impact of Social Carpooling on Congestion Mitigation

From the individual-level and area-level analyses, the study extends its examination to encompass the broader transportation network and its impact on traffic congestion and mobility services. While the area-level analysis provided valuable insights into the potential effectiveness of carpooling promotion in specific zones and informed targeted strategies for traffic mitigation, the system-level analysis takes a more comprehensive view. By adopting a four-step modeling approach and dynamic trip assignment simulation, this analysis delves into the complex interplay of various transportation factors and explores how social carpooling can impact the entire CAMPO region's traffic flow. The study accounts for changing technology trends and population demographics, projecting the potential shift from solo driving trips to high-occupancy vehicle travel. Emphasizing the region-wide implications, this research seeks to reveal the broader benefits of social carpooling in reducing traffic congestion and enhancing overall transportation efficiency, providing crucial insights for sustainable transportation planning and decision-making at a system-wide level.

Given the individual and zonal level analyses, simulating how the traffic would perform when deployed to a larger population becomes crucial. The fourth task of this project was to simulate the impact of social carpooling on traffic with a dynamic trip assignment. With trip counts estimated from the previous tasks, along with trip distribution and mode split, this step simulated how a city- and region-level broader use of social carpooling could impact the traffic. A large-scale simulation model was developed by hypothetically substituting travelers using personal vehicles with social carpooling mode with an increasing penetration rate. Therefore, this task’s ultimate goal was to determine how much traffic can be mitigated by large-scale social carpooling.

The dynamic trip assignment simulation model was programmed in DTALite. This task followed the classical four-step modeling with specific considerations on time-dependent travel demand and the interrelated changes between social carpooling and solo driving. The abovementioned method forecasts the time-dependent demand for social carpooling trips. In addition to trip generation, a time-dependent OD matrix was estimated. Researchers assumed the substitution between the increment of social carpooling trips and the decrement of solo driving trips. Accounting for time-dependent demand, the last step was to simulate how much individual change from solo driving to social carpooling can impact traffic, where a conversion scenario would be assumed.

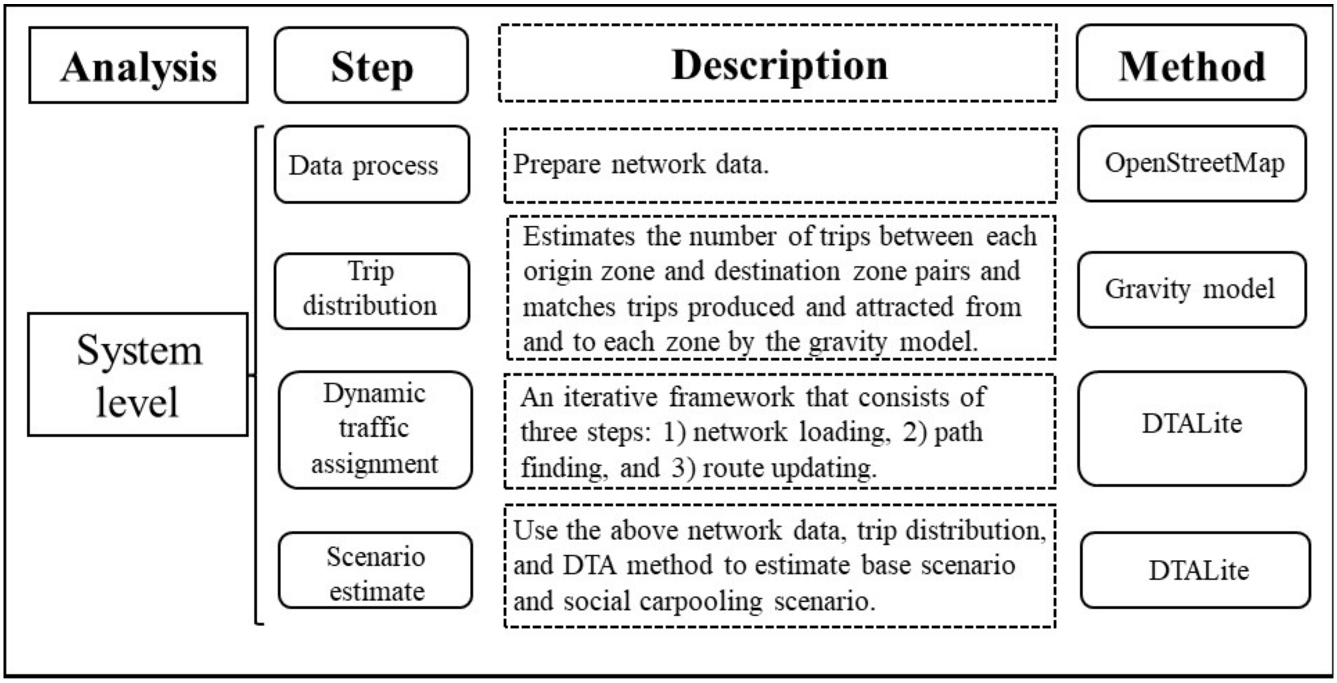


Figure 6. The flowchart of system-level analysis

Methodology

Trip Distribution

Trip distribution, the second step of the classical four-step traffic modeling, estimates the number of trips between each origin zone and destination zone pairs and matches trips produced and attracted from and to each zone by the gravity model (Klotz Associates, 2015). The gravity model considers two factors: (1) shorter travel time to the destination zone would induce more trips from the origin zone (indirect factor), and (2) more attractions in a destination zone would induce more trips from the origin zone (direct factor).

Researchers used a doubly constrained gravity model with two balancing factors, and the friction factor was assumed to be an inverse function of travel time. The mathematical description of the gravity model is as follows (Xie & Levinson, 2011):

$$T_{ij} = K_i K_j P_i A_j F_{ij}$$

where:

K_i = Balancing factor, total trips originating from zone i matches with trip production of zone i;
K_j = Balancing factor, total trips destined to zone j matches with trip attraction of zone j;
P_i = Trip production of zone i;
A_j = Trip attraction of zone j;
F_{ij} = Friction factor, a function of the travel impedance between zone i and zone j.

Dynamic Traffic Assignment (DTA)

DTA has been introduced to reflect real traffic flows to static traffic assignment. The principle of dynamic user equilibrium, which is the backbone of DTA, is that all routes used by travelers leaving the same origin at the same time for the same destination have equal and minimal travel time (Boyles et al., 2022). DTA is an iterative framework that consists of three steps: (1) network loading, (2) path finding, and (3) route updating. First, given each vehicle's path and departure times, travel times along all paths, edge by edge, for all possible departure times were identified using a traffic flow model. Then, the shortest paths were found for each OD pair at each departure time using a time-dependent shortest path algorithm. Vehicles could use the identified time-dependent shortest paths for all possible OD pairs and departure times to update their choices toward the most updated shortest paths (Boyles et al., 2022).

DTALite

DTALite, developed by Zhou & Taylor (2014), is an open-source simulator and a large-scale agent-based dynamic traffic assignment modeling tool with a visualization software called NeXTA. The software's four modeling components are (1) time-dependent shortest path calculation, (2) vehicle/agent attribute generation, (3) dynamic path assignment, and (4) queue-based traffic flow models (Zhou & Taylor, 2014). By utilizing relatively simple inputs, such as link capacity and free-flow speed, in the queue-based traffic simulation model, the authors expect that transportation planners could readily run DTA for large-scale network simulation. The DTALite utilizes a mesoscopic simulator considering vehicles individually but following macroscopic continuum fluid traffic flow, which balances macroscopic and microscopic models. The software mainly uses the point queue model for a simple queue model to track wave propagation. Limitations of the point queue model related to spatial storage capacity can be complemented by adopting the spatial queue model, which captures queue spillbacks (Zhou & Taylor, 2014). Then, Newell's simplified kinematic wave model is adopted as an advanced queue model to capture forward and backward wave propagation.

Analysis

Preprocessing

Network Data

Researchers designated the entire CAMPO area as the focus area, which includes Bastrop, Burnet, Caldwell, Hays, Travis, and Williamson Counties. The street network of the CAMPO area was prepared using the OSMnx python package (Boeing, 2017). The OSMnx package enables network modeling, analysis, and visualization of real street networks by downloading administrative boundary geometries, building footprints, and street networks from OpenStreetMap.[1] The geospatial data retrieved from the OpenStreetMap includes but is not limited to network characteristics, such as the number of lanes, length of segments, capacity, and speed, given different network types. The following network preparation process is primarily inspired by Yedavalli et al. (2021).

[1] https://www.openstreetmap.org/

First, researchers combined six counties and captured the boundary of the study area. The US County shapefile was retrieved from the US Bureau's MAF/TIGER geographic database (United States Bureau, 2021). The cartographic boundary map file used for this chapter is a scale of 1:500,000. The Federal Information Processing Standard (FIPS) codes for identifying six counties from the shapefile are 48021, 48053, 48055, 48209, 48453, and 48491, respectively. The convex hull boundary polygon of the study area is extracted with a buffer of 1 mile to capture the connectivity close to surrounding areas.

Then the roadway network and its components, such as nodes and edges, were identified. The initial network was created by filtering the network type only for the drivable public streets, excluding service roads. The initial number of nodes and edges for the network are 703,370 and 1,369,768, respectively. As the initial network components directly extracted from OpenStreetMap could have inconsistency issues (Boeing, 2017; Neis et al., 2011), correcting and simplifying network topology using OSMnx was necessary. Using the highway key values provided by the OpenStreetMap, the edge types for the analysis were limited as follows: motorway, motorway_link, trunk, trunk_link, primary, primary_link, secondary, secondary_link, tertiary, tertiary_link, unclassified, and road.[2] All other minor roads not classified as one of the types were excluded from the analysis. Also, isolated nodes with no incident edges (i.e., dead ends and self-loops) and weakly connected components were removed from the network. Hence, the network was further simplified and prepared for analysis with the final number of nodes and edges of 13,758 and 29,567, respectively. The simplified network is shown in Figure 7.

Data for nodes and edges were created in .csv files. The nodes file consists of the unique node ID, x- and y- coordinates, and geometry information. The edges file contains starting and ending node ID, directional information, highway classification, street name, length, capacity, number of lanes, and maximum speed.

Although the retrieved network data contains ample information for the analysis, there were still missing entries that needed to be deduced from the existing data. Therefore, the median value of the number of lanes for each highway type were assumed as defaults for the missing number of lanes. Referring to the free-flow speeds and capacities lookup tables (Capital Area Metropolitan Planning Organization, 2019b), researchers defined default values for missing entries in maximum speed and capacity based on the highway type and the number of lanes.

[2] https://wiki.openstreetmap.org/wiki/Key:highway

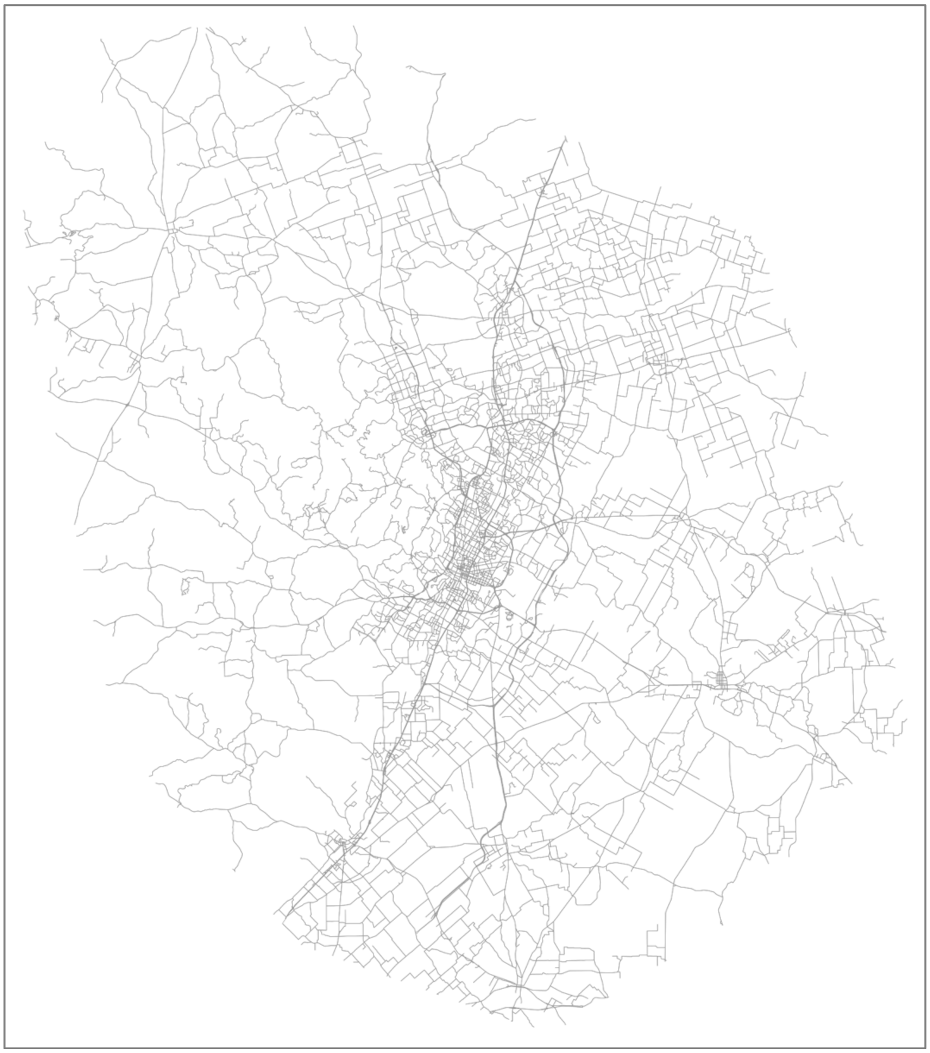


Figure 7. The simplified network of the CAMPO area

Traffic Analysis Zones

Traffic analysis zones (TAZs) are commonly used spatial units for travel demand modeling in the United States (Zhao et al., 2019). Since the trip generation data were aggregated to the TAZ level, researchers first needed to distribute the network components to the corresponding TAZs, which required joining nodes and zones from two different sources. The TAZ shapefile of the CAMPO area was retrieved by their 2040 travel demand model. The TAZ TransCAD layer file was transformed to a shapefile to be accessible via ArcGIS. Including Bastrop, Burnet, and Caldwell Counties, along with dummy and external TAZs that were not considered in the analysis, there are 2,391 TAZs in total in the CAMPO area. Only 2,258 TAZs were considered for the analysis to match the trip generation data. Using the geopandas (Jordahl et al., 2020) tool and python, researchers read the TAZ shapefile and extracted their polygon coordinates and polyline, then identified whether each node was within the polygons of each TAZ, given the x- and y- coordinates of nodes. With nodes from the simplified network, 404 TAZs were identified that did not contain any nodes in their polygon.

Trip Distribution

The trip generation from the CAMPO's TDM and the social carpooling data were aggregated in production and attraction for each TAZ, which did not contain the trip's origin or destination information. Also, to simulate AM peak trips with DTALite, the primary purpose of the AM and PM peak-hour social carpooling trips, trips between 6–10 AM and 3–7 PM, was assumed to be the same. Hence, the AM peak trips for social carpooling can be retrieved by dividing peak-hour social carpooling trip generation in half. As for the CAMPO's AM trip data, it was assumed that 25% of the trip in a day starts from 6 AM to 9:59 AM, given 2017 CAMPO's household travel survey (Singh et al., 2020), as shown in Figure 8.

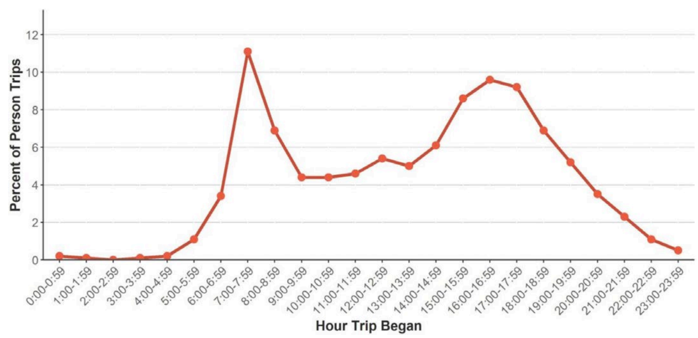


Figure 8. Distribution of trip start times in CAMPO (Source: Singh et al. 2020)

To distribute the trip data into origin and destination (OD) pairs, researchers created an OD cost matrix given travel distance for all the OD pairs at the TAZ level and disengaged the trip data using the gravity model. Figure 9 demonstrates a process of trip distribution with a sample dataset.

TAZ ID	Production	Attraction
1	273.824	240.109
2	87.7105	76.9583
3	629.096	598.183
4	0.701738	4.44029
5	135.805	146.258
6	31.3947	52.2098
7	1727.34	1742.5
8	11.8533	22.1125
9	5.18562	10.935
10	13.1232	20.9982

(a)

Index	1	2	3	4	5
1	0	0.109412	0.16856	0.0592621	0.100265
2	0.104424	0	0.0847719	0.0469136	0.0531415
3	0.170732	0.0849889	0	0.0447622	0.100113
4	0.0576808	0.047574	0.0453011	0	0.041254
5	0.100351	0.0541291	0.103776	0.0418635	0

(b)

O_TAZ	D_TAZ	Volume
1	118	167.931
1	121	2.22601
1	148	8.46068
1	174	2.03363
1	178	1.39178
1	184	6.0516
1	201	1.34274
1	216	1.00219
1	442	2.55767
1	462	3.41367

(c)

Figure 9. Screenshots of the sample trip data: (a) partial trip generation data aggregated by TAZ, (b) OD cost matrix, and (c) trip distribution data

We utilized ArcGIS Pro's Network Analyst extension (ArcGIS Pro, n.d.) to create the OD cost matrix. The Network Analyst tool utilizes Dijkstra's algorithm for finding the shortest paths. The OD Cost Matrix solver, one of the solvers that the tool provides, uses a multiple-origin, multiple-destination algorithm and provides actual network distance rather than a straight-line distance. Following the network distance approach, the travel time from point A to point B may not necessarily be identical to the travel time from point B to point A. Therefore, we calculated the OD cost matrix with a size of 2,258 by 2,258, assuming the demand generator of each TAZ as its zonal centroid.

Given the cost matrix, a doubly constrained model was performed using python. The doubly constrained algorithm iteratively distributes productions and attractions over rows and columns based on the willingness to travel (Xie & Levinson, 2011), identified by the friction factor. At this stage, we assumed the friction factor as the inverse of travel distance for trip distribution purposes. Different distribution functions, such as exponential, gamma, or lognormal, can be explored for future studies.

Therefore, a total of 4,896,927 OD pairs were identified for both the CAMPO trip demand and potential social carpooling trip demand for the morning peak hours, with approximately 4,742,713 trips and 120,805 trips, respectively. To measure the impact of potential social carpooling on roadway congestion, a base scenario was created that considers CAMPO's AM trip demand with 4.7 million trips and a comparison scenario with a decrement of 241,610 solo driving trips supposedly converted to the social carpooling trip and resulted in 4,621,908 in the study area for the same period.

Dynamic Traffic Assignment

Given OD trip demand for two scenarios, the research team performed a dynamic traffic assignment using DTALite. The software utilizes node, link, and demand files for input to load the network. Node file contains unique node ID, x- and y- coordinates, associated zone ID, and geometry information. The link file, equal to the edge file as produced in the network preparation step, contains a unique link ID, link name, origin node ID, destination node ID, link type, length, number of lanes, free-flow speed, link capacity, and geometry information. The demand file consists of origin and destination zone IDs and associated trip volume for each OD pair.

Researchers assumed the value of time of $17.4 per hour for the AM peak hour (Capital Area Metropolitan Planning Organization, 2019a). Therefore, for both scenarios, 13,758 nodes, 1,855 zones, 4,896,927 demand information records, and 29,567 links were loaded on the network, as shown in Figure 10.

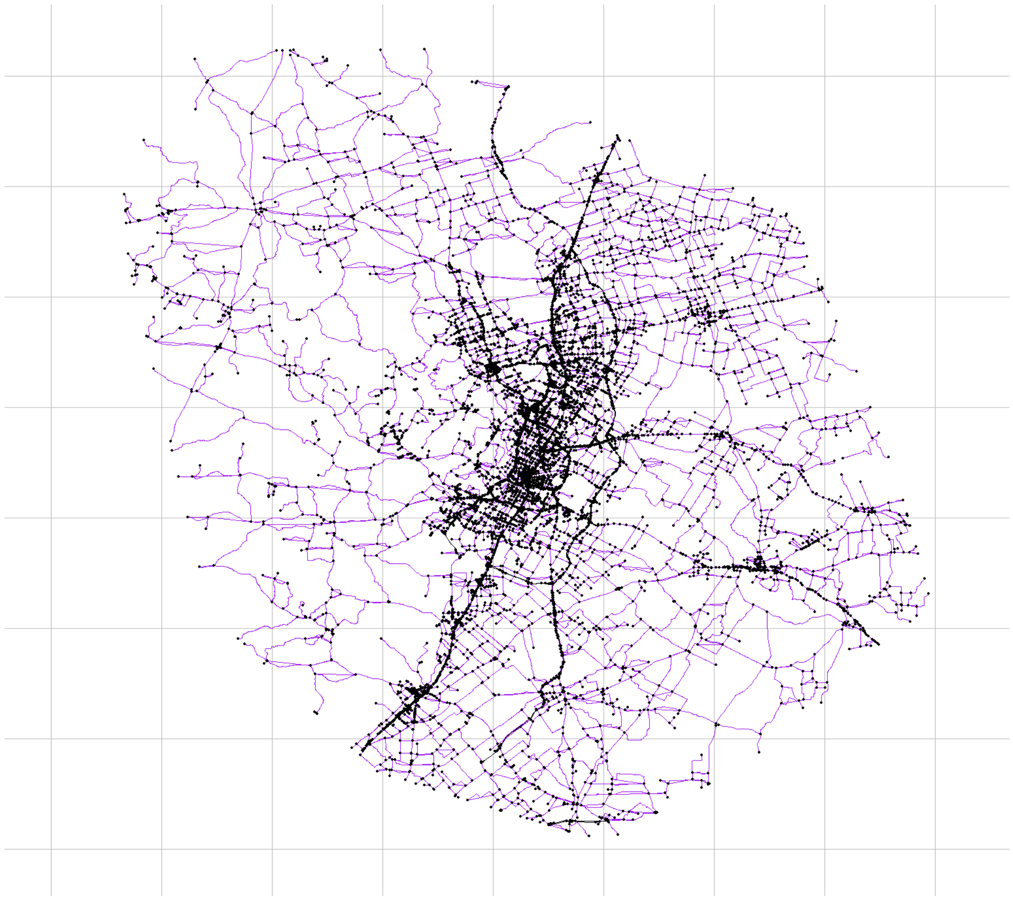


Figure 10. Screenshot of the traffic network components loaded to NeXTA

Base Scenario

In the base scenario, OD demand data was used for the entire CAMPO area in the morning peak period. Figure 11 depicts the density (vehicle per mile per lane) for every link in the study network. It shows high traffic, mainly along the Mopac expressway, I-35, and US-183 in the morning. In addition, the city of Austin and its downtown area show higher traffic density than surrounding areas, such as Bastrop, Burnet, and Caldwell Counties.

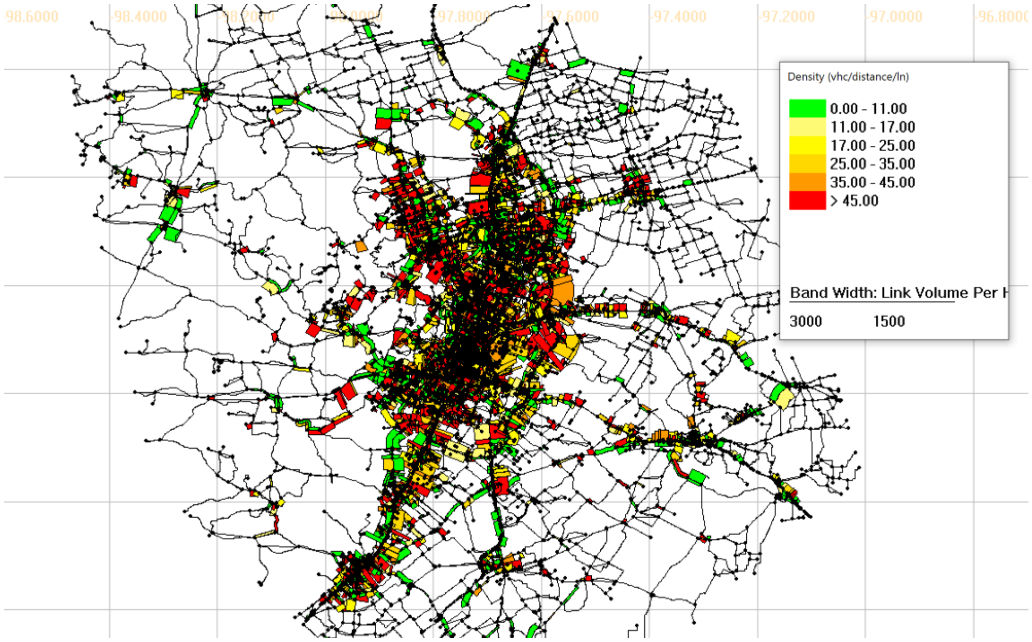


Figure 11. Visualization of traffic density for the study network in the base scenario

Social Carpooling Scenario

In this scenario, it was assumed that the potential social carpooling trips will substitute solo driving trips and further reduce the traffic demand during AM peak period. Figure 12 shows the density (vehicle per mile per lane) for every link in the study network. It shows high traffic, mainly along the Mopac expressway, I-35, and US-183 in the morning.

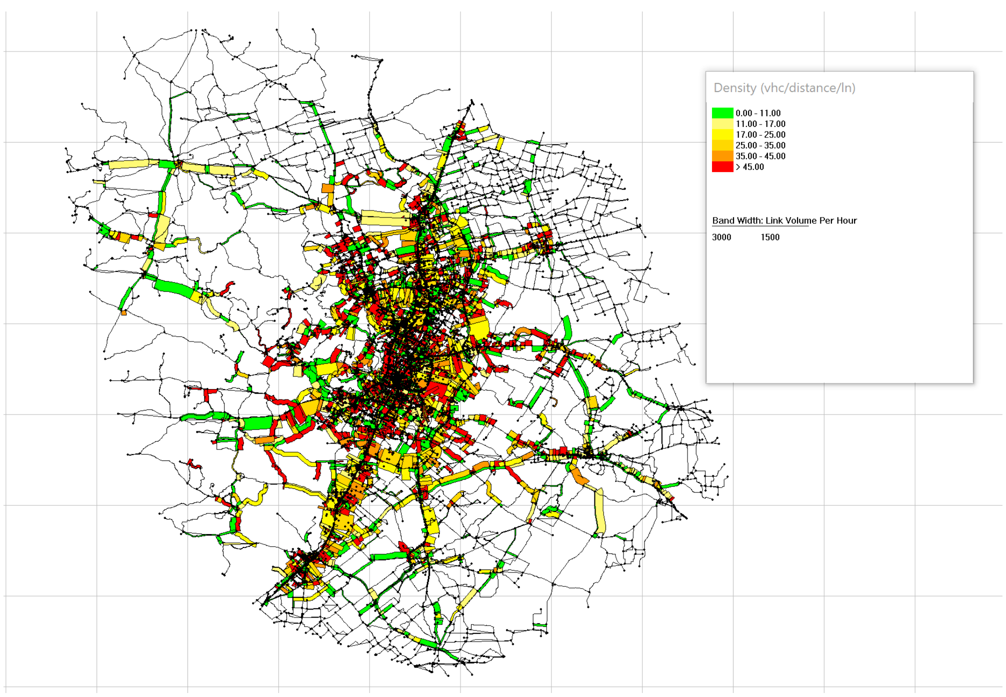


Figure 12. Visualization of traffic density for the study network under the social carpooling scenario

Scenario Comparison

As OD demand trips are distributed to nodes in each zone differently at every iteration during simulation, though the total number of trips in the social carpooling scenario is 120,805 trips less than the base scenario, each link's hourly lane volume may not be consistently less in the social carpooling scenario compared to the base scenario. Still, as the top ten Volume-to-Capacity ratio (V/C) links listed in Table 8, travel time and V/C reduced or remained at a similar level, and speed increased. Five links have V/C > 1, and three links close to one, which is expected to cause excessive delay. Compared to the base scenario, the number of links that have V/C > 1 is reduced by two, and hourly lane volumes are reduced on every link.

Table 8. Top 10 V/C Links from the Base Scenario

Link Name	Link Type	Base Scenario			Social Carpooling Scenario		
		Travel Time	Speed	V/C	Travel Time	Speed	V/C
Sycamore Creek Drive	Unclassified	6.31	19.89	1.4457	6.31	19.88	1.52
McAngus Road	Unclassified	10.57	13.45	1.2971	7.64	18.61	1.2657
South US Highway 281	Trunk	0.59	15.01	1.2765	0.6	14.68	1.2647
Taylor Lane	Unclassified	0.08	12.77	1.1257	0.08	13.22	0.9686
Taylor Lane	Unclassified	1.05	11.93	1.0914	0.86	14.58	0.9343
Tandem Boulevard	Unclassified	0.32	17.74	0.9943	0.31	18.54	0.7057
Farm to Market Road 110	Secondary	2.05	15.18	0.9138	1.71	18.18	0.705
Lockwood Road	Unclassified	11.34	12.36	0.9114	7.43	18.86	0.7543
Ranch Road 150 West	Unclassified	0.19	20.63	0.8314	0.19	20.56	0.9114
Mount Gainor Road	Tertiary	4.66	13.09	0.8214	4.65	13.13	0.8357

Let's assume a person travels from the Avery Ranch area, one of the residential areas in north Austin, to downtown Austin in the morning (see Figure 13). The path contains 111 links with a distance of 19.35 miles and a free-flow travel time of 33.68 minutes.

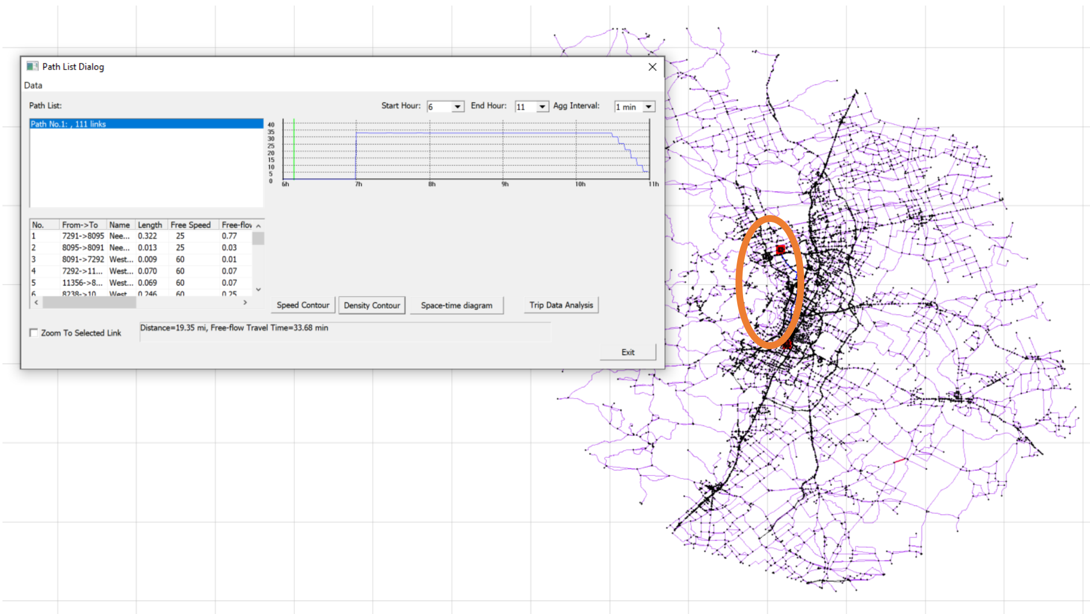
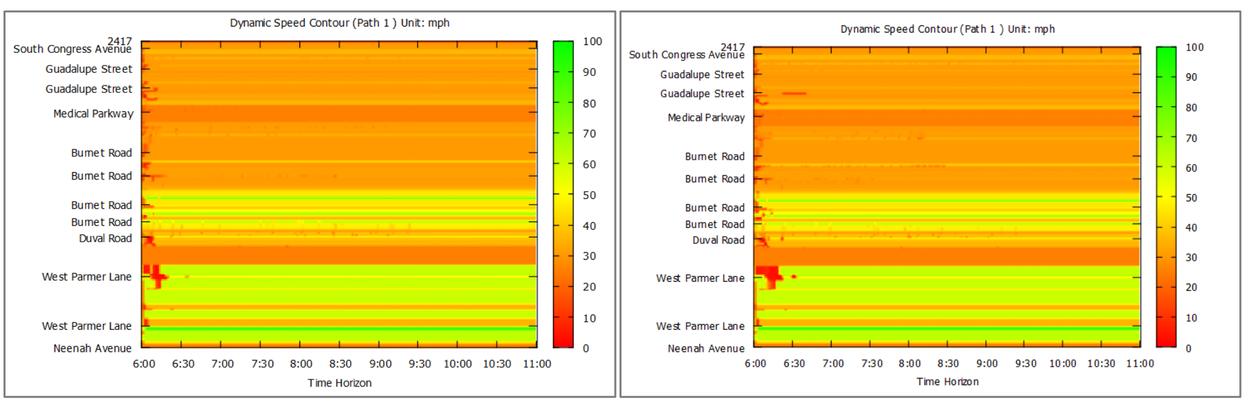


Figure 13. The path from one of the residential areas to the downtown Austin

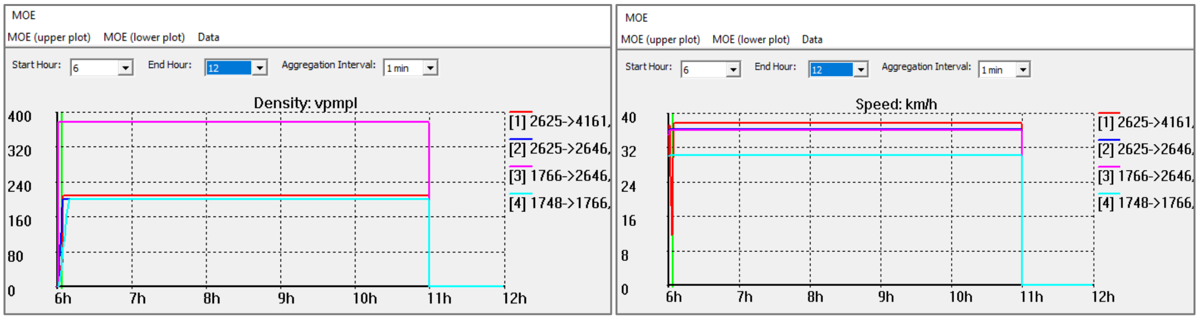
Figure 14 shows the speed contour for the selected path. The trip starting point at the bottom of the figure shows that the vehicle significantly slows down as you drive near the downtown area.



(a) (b)

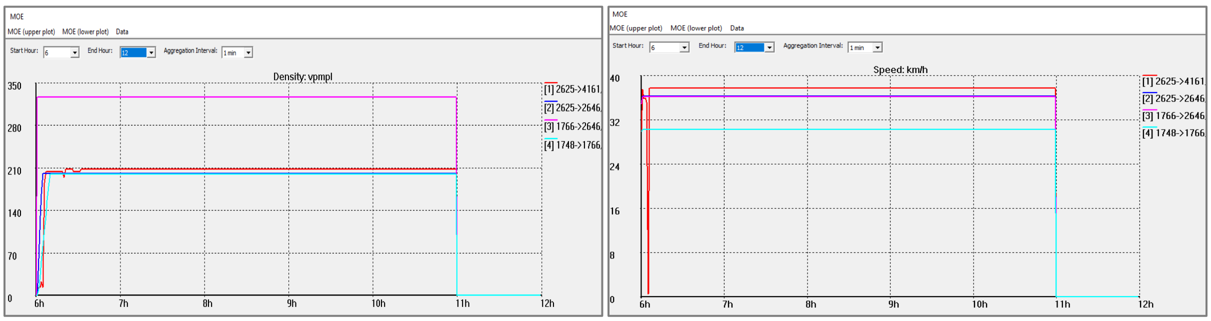
Figure 14. Speed contour for the selected path between 6 AM and 11 AM: (a) base scenario, (b) conversion scenario

Individual links can also be studied in detail. For example, the link from node 4161 to node 1748, from South 1st Street to South Congress Avenue, shows that the speed changes up to 38 mph for both scenarios. While the link density from node 1766 to node 2646 reaches 380 vpmpl in the base scenario, the conversion scenario for the same link shows less density up to 330 vpmpl.



(a) (b)

Figure 15. Simulated density and speed of four links near the terminal of the selected path under the base scenario[3]



(a) (b)

Figure 16. Simulated density and speed of four links near the terminal of the selected path under the conversion scenario[3]

Conclusion

Researchers investigated the impact of the regional scale of social carpooling on traffic mitigation by following four-step modeling and with the assistance of a dynamic trip assignment simulation tool. First, network data was prepared using OpenStreetMap. Then, the zonal trip generation for the entire CAMPO area and the potential social carpooling trips were distributed by OD pairs at the zonal level. Mode choice was not considered as it was assumed solo driving trips are converted to social carpooling trips that use the same mode, passenger vehicle. Compared to the base scenario, if social carpooling trips are incremented by 120,805 trips during AM peak hours, the AM trip demand would decrease to 4,621,908 trips in the conversion scenario, which is a 2.55% of decrement from the trips in the base scenario. Due to the low conversion rate, a dramatic improvement may not be observed in the study area's traffic flow. However, out of 29,567 links, 27,707 links' travel times were reduced or remained at the same level and 20,504 links' speeds were increased or remained at the same level in the conversion scenario. Technological improvements and demographic changes are contributing to the increasing usage of shared mobility (Shaheen et al., 2018). Therefore, more usage of social carpooling and more solo driving trips will likely be converted to trips with high-occupancy vehicles, which will further relieve congestion in the CAMPO area.

[3] Although the figure indicates the unit of speed as km/h, which is the default setting by the program, the unit of the speed is miles per hour.

Chapter 5. Qualitative Study: Interview Social-Carpooling Practitioners

Interview, as a qualitative research method, is often used as a complementary approach to quantitative analysis to provide a more nuanced and detailed understanding of a particular research problem or phenomenon. While quantitative analysis can provide statistical data on trends and patterns, qualitative research can help to uncover the underlying meanings, motivations, and experiences of individuals. Therefore, in this project, researchers interviewed two practitioners to investigate factors that are not been identified by our quantitative analyses to gain a deeper understanding of factors encouraging and discouraging social carpooling in Austin, Texas. The two interviewees are professionals, including a travel demand manager from TxDOT and a consultant from Movability.

Summary of the First Interview

The speaker discusses social carpooling initiatives in Austin, including a regional ride-matching program in partnership with the local Metropolitan Planning Organization and a private sector partner, as well as a nonprofit called Movability that promotes transportation challenges on social media. Unregulated services like Arcade City, which use Facebook and Craigslist, also play a role in carpooling. The speaker emphasizes the importance of social carpooling in supporting the elderly and the need for more incentives beyond pull-side or push-side options. The interviewee suggests using a tracking system to differentiate trips and encourage sustainable behavior. They propose a gamification approach with carbon offset rewards and incentives for millennials and younger generations through apps and digital currency. They believe these technologies can create a more sustainable ecosystem and marketplace. The speaker discusses changes in travel patterns due to COVID-19 and the promotion of personal benefits of owning a car. Construction workers share rides effectively due to their cultural competency related to sharing tools and rides. The interviewee is concerned about the impact of ongoing infrastructure projects on traffic congestion and plans to expand mobility pattern tracking with partnerships. The difficulties in changing transportation policies in Austin are discussed, with the need for better coordination among stakeholders. The interviewee suggests using a distributed ledger to track trips and promote sustainable transportation. Incentivizing the use of public transit and shared rides is challenging due to existing policies and financing strategies.

The discussion focuses on addressing traffic congestion through transit systems, park-and-ride facilities, and micro-transit. Development and land policies are also mentioned, with the importance of having overarching policies rather than individual project-based deals. Sexual offenses and discrimination are recognized as a concern for social carpooling, and safety measures like background checks and in-car cameras are proposed. The speaker acknowledges the challenges of implementing social carpooling and advocates for a community-driven approach specific to different neighborhoods. They highlight the potential for building community resiliency through such programs and efforts to promote alternative transportation modes during ongoing construction.

Summary of the Second Interview

The interviewee is the program manager at Movability, and their role involves the implementation of services for members, including technical assistance, grants, research and analysis, and promotion of services. The interviewee explains that GetThere, their ride-matching program, uses the RideAmigos platform and provides tools for carpooling, transit routes, and other mobility options. Commuters can sign up individually or through their employer, and those affiliated with a member business have access to incentives such as biweekly drawings, monthly contests, and an emergency ride home program. The interviewee notes that one frustration is encouraging users to log their trips to track metrics while also promoting the tool's usefulness for finding travel options. They also mention that many users start logging their trips but then stop, requiring constant engagement to keep them interested.

In the interview, the interviewee discussed the benefits of carpooling and the incentives provided to encourage it. They mentioned that people enjoy the simplicity of seeing all the different options for commuting and that logging their trips and tracking their performance is similar to tracking fitness goals. They also mentioned that there is a leaderboard that shows the top organizations and individuals who have logged the most trips. Currently, there are no other incentives provided besides discounts and sweepstakes, but the organization is planning to strategize on how to target different audiences with incentives that make an impact. The interviewee also mentioned a program called "Mobility Camps," where they offer hands-on learning experiences for different modes of transportation. The first one will be a bike trip, but they plan to do one for carpooling as well.

The interviewee discusses efforts to promote individual modes of transportation and increase awareness of incentives for carpooling and other options. They mention using motivational interviewing in one-on-one conversations and plan to offer a webinar on the technique in the future. When asked about Waze carpool and Metropia, the interviewee notes that they are familiar with both but believes that awareness of options is a significant barrier to their adoption. They suggest that agencies or organizations need to push these platforms to increase market penetration. The interviewee also identifies social barriers to carpooling, such as discomfort with riding with strangers and the need for social interaction in a carpool, as potential challenges to adoption.

The interviewee discusses Movability's promotion of transportation demand management (TDM) strategies and the challenges they face in encouraging carpooling. The interviewee mentions that there has been more buying from partners towards promoting the regional tool GetThere, which provides funding to help build it out. However, they express frustration with the difficulty of getting people to actively log their trips and express a desire to find ways to incentivize people to take sustainable modes of transportation instead. The MPO pays for the platform, and the city of Austin is using the data to build a larger data exchange to collect data from different transportation modes.

In the interview, the interviewee provides their pricing preferences for peer-to-peer carpooling. They suggest that the cost should be 15% cheaper than Uber or Lyft to be considered a viable option. They do not have a specific number for when carpooling becomes too cheap, but they would hesitate if the cost nears double digits for a five-mile trip. They consider two or three dollars for a trip to be a great bargain.

Chapter 6. Conclusions

Social carpooling is an innovative solution for transportation that offers numerous benefits for individuals and the community. With the growth of technology-assisted mobility services, it's likely that social carpooling will become an even more widespread and convenient option of transportation in the future. It is a growing trend in the transportation industry, providing a cost-effective and eco-friendly alternative to traditional transportation methods. To promote it to large-scale deployment, it is important for researchers to understand when and why people choose social carpooling, where carpooling trips are generated, and how a social carpooling platform can be operated that aligns with their needs and preferences.

Metropia considers an experiment aimed at testing and promoting the mode choice and usage of social carpooling. Despite it being operated at a small scale and involving biases when recruiting the users, it has provided valuable insights for the next step large-scale deployment and may create a profound impact on the social carpooling system, and largely the future transportation system.

In this project, binary choice between social carpooling and driving alone over time and the ratio of social carpooling trips for each individual were utilized as the dependent variables to give a more comprehensive understanding of the behavior of individuals. A panel binomial logit model and a generalized linear model were estimated in the individual analysis. Individual factors and trip characteristics were examined to correlate with social carpooling. Based on the modeling results, some mobility management strategies, such as providing tax incentives or subsidies for employers and app platforms, which were dedicated to promoting carpooling; creating dedicated carpool lanes, which can be the most desirable incentive for carpoolers during peak hours; differentiating tolls for different times of a day and different days of a week; promoting awareness about the benefits of carpooling through public campaigns.

The use of the number of carpooling trips as the dependent variable allows for a more comprehensive understanding of the behavior of individuals in the TAZs. By examining how various independent variables, such as area size, settlement types, income, employees in different industries, household car ownership, and household size, are correlated with the number of carpooling trips, the study can provide valuable insights into where carpooling promotion would be more cost-effective. This information can be used to inform mobility management strategies, such as promoting carpooling, designating carpool lanes, reducing the number of single-occupancy vehicle trips, with the goal of reducing traffic congestion and improving mobility services. These findings can also offer guidance for future transportation planning efforts in Austin and other similar cities.

The aim of this project was to determine the extent to which large-scale social carpooling could alleviate traffic congestion, and a system-level analysis was conducted to achieve this goal. To investigate the impact of social carpooling on traffic mitigation, a four-step modeling approach was adopted, and a dynamic trip assignment simulation tool was used. OpenStreetMap was utilized to prepare the network data, and OD pairs were distributed across the CAMPO area at the TAZ zonal level to represent zonal trip generation. The study assumed that solo driving trips would be replaced by social carpooling trips using the same mode (i.e., a passenger vehicle) without considering mode choice. The results suggest that as technology advances and population demographics shift, more solo driving trips will be converted to high-occupancy vehicle travel, thereby reducing traffic congestion in the CAMPO region. In conclusion, this study highlights the potential benefits of social carpooling in mitigating traffic congestion and improving the efficiency of the transportation system.

Researchers used binary choice and ratio of social carpooling trips as dependent variables and employed panel binomial logit and generalized linear models in individual analysis to identify factors influencing social carpooling behavior. Based on the modeling results, the study recommends mobility management strategies, including tax incentives and subsidies for employers and app platforms, dedicated carpool lanes during peak hours, differentiated tolls, and public campaigns promoting carpooling awareness. Additionally, a system-level analysis was conducted, using a four-step modeling approach and dynamic trip assignment simulation, to investigate the impact of social carpooling on traffic mitigation. The findings suggest that promoting social carpooling can potentially reduce traffic congestion and improve transportation efficiency in the CAMPO region and similar cities. The information obtained from the analysis can be used to inform future transportation planning efforts in Austin and other similar areas, making carpooling promotion more cost-effective in specific zones and enhancing overall transportation strategies.

Two limitations are presented in this project. The first limitation relates to the biased sampling presented by the users. As noticed, the sample represents adults with good education and high income. The findings identified from this research to some extent can be biased. Also, riders who have no car were excluded from the sample; the insights drawn on this group of carpoolers can be limited. The second limitation relates to incentives and the experimental settings. The data cannot allow controlling various incentives due to issues of endogeneity and data availability. Regarding the locality, the state of Texas has a limited number of HOV lanes, while the usage priority of HOV lanes is a major incentive for carpooling. Alternatively, individuals are not highly incentivized to carpool in Texas. If the experimental setting is changed, the results can be significantly different. Future research may consider local settings with different types of incentives.

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Appendix

Interview I

Q: I know right now many people are not willing to share a ride because of the social distance, especially if people cannot gain much from this ride match or sharing experience. I think that's why, maybe, Metropia, changed to another app called Smart Mobility. I think in the mid of 2019, they ceased the operation. What would be the most frustrating part when you see when people operating this program? Because Metropia is not quite successful. Even right now I'm not exactly sure what's going on with RideAmigos if you don't tell me that. So, I think there must be something quite frustrating here. Can you share some experience with that?

A: There is always the gap between registered users when you are doing campaigns to get people on board with the application, and then how much they do, how much they use the application, and how trips they try to share. And when we first got started, and this is partially my, I've only been with the city since 2018, and so, some of what I'm saying is my interpretations of the past. But we didn't have our TMA, Movability, they are focused on connecting and keeping those connections, so starting about five years ago, the TMA's role began to increase. They can, they are member-based organizations so large employers became members of that organization, took on executive roles and executive boards for that organization, and then major companies like Google and others made promises on how much they were going to do. And they've been able to manage that through this triangle of Movability piece, city piece, and then the MPO piece. It does take building out a network of stakeholders in each region. Those stakeholders in each region are contact-sensitive to the region. The way that we are doing here in Austin might not be exactly how Houston or Dallas would do. It has a lot to do with who is your major traffic generators, especially at AM and PM commute times, at least in the past, keeping all things related to the travel patterns related to COVID aside. That is a unique thing happening right now. I think a lot of it may stay. We are going to see hyperlocal trips happening a lot more often than in the past, for instance. The AM peak in Austin is very distributed now. People are changing their AM commute times, but the PM peak is very solid again. Everybody wants to leave work and get back home at the same time, regardless of when you get there. Just looking at the different travel patterns, and keeping performance indicators, we've noticed that there are changes. The AM peak people are choosing when they can come in to work, I think a lot of that is based on their at-home childcare and educational needs amongst other things. So, we are seeing that, and a lot of that may, those trends may hold for longer than just the span of the response to this respiratory virus that's going to be with us for a while. That tells me that more than likely we'll see a lot of these unique behavioral shifts hold and maybe become permanent to some degree. Another frustration that we've seen is it's very difficult to create a Yi-Chang was trying to do with Metropia, to create sustainable incentives to have people change their behavior. And I believe that, again, if you go back to the trifecta of TMA that does most of the vocal social media push, a regional mobility authority or regional mobility MPO that's focused on the region and looking at all commute trips coming into this job center and then the city that represents that job center. It's hard for an app to buy itself to be the thing that makes humans change their behavior. Like, if I am not changing the price of my parking, if I am not reducing the amount of parking surplus, if I am not creating the right incentives or disincentives to take your single occupant vehicle downtown then how am I supposed to do it with just an app alone. It doesn't work that way. We all know it requires built conditions, and policy, which is the price thing.

Q: We need both push-side and pull-side tools. Pull side will provide but that incentive is very small. I know it's just like one-third of a quarter, that's a very small incentive. While for the push part, if we don't add anything to consider people's interest in driving alone, then that's very hard. So, what kind of incentives, because for Yi-Chang's Metropia, I know, is just like one-third of a quarter, but after people carpool, they have the privilege, can use the carpool lane. Do you have other incentives right now to provide for those social carpoolers?

A: So, as an employer, we are changing our incentive program. We used to provide an incentive for each city employee who is a part of this program if they did a certain number of carpooling trips, then they could receive two four-hour administrative leave benefits, a total of eight hours. It had to be used in two separate time periods. What we are still focused on here is we're beginning to change it, so that's where we are right now. I took over the travel demand management program this year. It used to be in our planning department, and now it's in the smart mobility office, for obvious reasons. First, we're going to be removing the administrative leave incentive. It's not an equitable incentive. It takes me and one of my employees. If I carpool, I get a total of eight hours, at my pay rate. That's a certain value. For a parking enforcement officer, who gets paid 15 dollars an hour, is this much? It's not an equitable benefit. And moreover, it has a lot of other inequities built into that because then you will start looking at car ownership, how far away they live from the city, where their home ownership is, and the cost of transportation. And then you are asking someone to essentially remove part of their economic vitality that they are trying to attain for the benefit of others who would benefit more from that incentive than you would. So, it's not something that we are looking to continue.

Q: Do you have any other suggestions when designing this kind of incentive?

A: We are very much looking towards going to a type of tracking system to start with. We use the tools that are already available to us, and we begin classifying those trips better than we are today. Right now, we are just classifying them as single occupants or a few heads in the car. We're not looking at the combination of adding a propulsion methodology. So, we are going to be really making a difference between ICE[4] and hybrid electric. That's going to be one thing. So, you can start to see their future. I am going to share with you some things that are really my vision that we are headed for, but we are not there yet. I believe that we will get to a point where we are really trying to track little carbon at them. To me, that's the most important thing. And then once we can track that accurately across multiple modes, multiple types of trips and people, whether you are driving alone, and get that level of information. Then we can begin monetizing that carbon or the carbon offset. Once we do that, we can do something like what the mayor was thinking about related to distributed ledger and city coin and begin tokenizing that to something that could be exchanged eventually into a type of digital currency. I believe that is the future of travel demand management. We must find a way to, there is only one thing that's a certain very proven methodology to change human behavior. And that's the cost. The money. So, we got a quick plan around TDM[5]. We've been playing around with this. I helped create a lot of the nation's TDM program, and programmatic elements way back when I was doing work for the feds. And we're stuck in this do-run loop of not innovating internally and not disrupting internally. The institutions have responded and forced us into a corner related to the way that we are doing it with the advent of distributed ledger technologies, the ability to tokenize, the ability to bring in the monetization of track the trips as carbon, track the behavior as carbon and then monetize that. Now we have a way to truly

[4] Internal Combustion Engine
[5] Transportation Demand Management

showcase to each human something that's more important than just whether it's an SOV[6] trip or not, but if that's an SOV trip that's only five miles of a 15 mile-commute, right? Because they are going to add a mobility hub and they are going to switch to transit. Then that person's trip, that portion trip gives incentives to people. It's a lot like our Vision Zero program we've launched to Safe 2 Save here in Austin where drivers who subscribe to the program, get tokens that they can exchange for digital currency to buy Big Macs at McDonald's, and other things like that. And we also have to look at the demographics. Are we trying to hit the current 35- to 55-year-old SOV driver or are we trying to find a way to, the strategy is different. If you are going after a millennial or lower population, find ways to incentivize it through app usage to where you are getting tokens. I mean, all of our kids, they play video games for how long where they can get the coin, on Xbox 360 and everything like that. They are already mentally there. They are habitually ready for that type of behavioral change. For us to not implement that now would be a very big misstep and not seeing the vision right in front of us. Because it is right there. It's time for us to make that move and to begin finding a way to monetize the carbon and present that as that new type of gamification that presents rewards for certain types of behaviors, something that's a lot more sustainable than me trying to cobble together a hundred thousand dollars to hand out a gift card with whatever extra money I'm able to find in our ever increasingly reduced budgets. We're asked to do this much now with this much money. In the past, it was here. Now, the need had risen, but the tax and the way we get money from the government haven't really changed. So, to create a more balanced and more sustainable ecosystem marketplace, for a marketplace of a rise, means taking on these new types of technologies. It's not technology. It's how you can piece together the technologies to create an outcome that's different, and hopefully if we do it right somewhat more sustainable than the way we've done it in the past.

Q: I know many people this year because many companies moved into Texas, to Austin in the last year. Then the property price is increasingly high, but people are moving to Austin. Do you see any change in the mobility pattern in Austin? And how would you see the likelihood of social carpooling in this background, in the past few years?

A: I would say more people moving and in fact, we are one of the cities that grew during COVID. There were about 165 people per day moving to Austin at the beginning of 2020, in January. Increased COVID to 184 per day in January of 2021. So, it was a net increase of quite a lot of folks. A lot of them are moving to the Austin area, primary states are California and New York. In fact, they usually are head-to-head, New York surpassed California by a good amount during the 2020 year. I think a lot of that has to do with the level of density in some cities. A new social construct around personal health and safety and density, which is the opposite of everything that we've been working on for the last 20 years. Our institution of travel management is going to continue to see more disruption, because of that. So, travel patterns have changed. We've seen very interesting things. A lot more local road usage, a lot more VMT[7] in the communities that are around Austin, and obviously during the stay-at-home orders, very few trips downtown. When the state of Texas changed their statewide policies and really kind of opened everything back up, we obviously saw the commute patterns come back but they were nowhere close to where they were pre-COVID, pre-pandemic. They were at most on even the highest demand days, only about 65 percent of what we had seen before. The time and spatial and temporal piece to this is probably the most interesting thing to study. We've done some focus group work ourselves talking to different communities and folks that are active participants and a lot of the different trip production or carpooling programs or electric vehicle programs to get an understanding from them of what they are

[6] Single Occupancy Vehicle
[7] Vehicle Miles Traveled

seeing and hearing themselves, what they are on behavioral patterns how they changed. And I think it's everything. We're seeing parents take two-hour-long trips in the middle of the day to just get away. It's personal time. The car has become the bathroom. In fact, car companies have already picked up on it. If you look two years ago, car companies were selling safety systems. They were selling the ADAS[8] systems. Nissan and Star Wars. The backup cameras and school buses. Now, the commercials are all about the personal things that you can do in the car. Have you seen the Volvo commercial where they arrive at the campsite and the kids run out and the husband looks over at the wife, and she goes 'just give me 15 minutes.' When the husband gets out, you see him run to the foreground with the kids, she hits a button, her seat reclines, the car lighting gets into mood lighting, and her favorite music comes on. And a lot of ways, a car is starting to become the Calgon commercial of giving me some relaxation, some time to myself. And that's not good for single-occupant driver trips. Right? We've seen a lot of inter-local. The interesting thing is we can't tell if it's actual people or it's that more delivery services. I think a lot of them are delivery services. Local delivery services from the local grocery stores to your home. That service is there to stay, and I don't see it going away. As I mentioned earlier, the AM and PM peak, and AM peak is very distributed now. We used to have a very, you could almost count it by numbers, very specific peaks. That's changed. One thing that is holding true, at least in Austin, is that Thursdays are still our highest peak day, especially around where you consider the traditional peak hours. Friday folks are choosing to leave work at different times, especially in the nicer weather months. On a Thursday, it's only up to just before 4 o'clock and then you'll see it. Come up. Friday, it starts around as early as noon sometimes. And you see that the entire demand just gets spread out over that time frame, much like the AM peak. So, Thursdays are still our heaviest PM peak day, which has been traditionally here for quite some time, I think that has a lot to do with the area and the surroundings and the level of opportunity that people have to start their weekends early and that kind of thing. There is an overall reduction in carpooling trips as a whole, because of personal health issues. We have a vanpool service that's run by CapMetro[9], where CapMetro provides the van and then residents sign up to be drivers, they have to go through some background checks, and they drive the van and pick up their neighbors, drop them off at work. That service also had an impact during COVID.

Q: Do you see any spatial difference, I mean of the clustering, of the social carpooling trips in Austin? My assumption would be like low-income people, because they may not be able to afford a car. So, maybe in those low-income neighborhoods, there may this kind of peer-to-peer ride match may happen more frequently. Another assumption is people drive to the downtown area because of the shortage of parking space also maybe because of the congestion, people are more willing to use the carpool lane, so I assume may be in the downtown area, there are more social carpooling trips. Will your observation be consistent with my assumptions?

A: The first assumption, for sure that low to moderate-income families find other mechanisms to share rides other than a ride for hire. Ride for hire is usually their last resort, for obvious reasons. We do not have an HOV[10] system. We don't have that yet. TxDOT[11] is rebuilding I-35 for the very first time since its inception during the Eisenhower era. So, there are still very short ramps on I-35. The interstate looks about the same as it did in 1950, only a little bit wider. So, part of it is, where the region is with a lot of it being transportation infrastructure improvements, Project Connect. So, we have an eight-billion-dollar rail initiative that just got started. That was board approved. That's going to add what I consider to be

[8] Advanced Driver-Assistance Systems
[9] Capital Metropolitan Transportation Authority
[10] High-Occupancy Vehicle
[11] Texas Department of Transportation

commuter and urban rail concepts into the unified light rail program. They are going to expand their bus rapid transit from that et cetera. We will eventually see, I think, more transit rides, but today, most of those single-occupant vehicle rides coming into town are your downtown workers. Folks that are still that work in the service industry support the downtown restaurants and other services. The office workers who still are coming downtown even though I mentioned that is lower than it was in the past, and then something that really hasn't changed very much and that's the downtown construction workers. So, there are a lot of construction workers, a lot of construction worker trucks. Now, those folks because of the communities that support, the demographic community that supports construction, are predominantly Hispanic and Latino. They already have a unique cultural competency related to how they share rides, share tools, and a lot of other things. So, we noticed that usually every construction worker trip coming downtown is bringing three construction workers per trip. Because they themselves are low to moderate income. They may only have one friend that has a truck, and they collectively share their tools and that's how they get jobs at construction sites. So, they are still moving back and forth, because they live pretty far out in the community typically to be able to afford a home. They are living further out than others and they are traveling every day for those very long construction worker shifts. They are usually starting, we see them as the front end of the AM peak, they are there before seven on job sites getting started, and usually aren't leaving until, well after five o'clock.

Q: So, this is based on your observation, for a specific industry, for the Latinos in the construction industry sector. Is any other this kind of regional, map, you mentioned about RideAmigos, also the TMA, monitored by Movability? Do they have this kind of more objective measurement or quantitatively see how mobility pattern is changing with the intervention of social carpooling?

A: Not yet. Something that we are expanding our contract with Movability to increase their capabilities to do some of that and then creating a partnership with UT[12] to begin studying it. Should we have been doing that before? Yes, of course. We should have been. But it seems like that with the advent of Project Connect and a lot of the other infrastructure programs that are going in now. If you add it, a lot, it's almost 20 billion dollars' worth of roadway construction, I-35, Project Connect, which is a major rail, and then we have mobility bond programs for new roads and creating new NACTO[13] Complete Streets kind of concepts of all of the major arterial corridors in Austin. And they are all going to be under construction in the next 15 years. So, for the next 15 years, it's going to be very hard to move around Austin in an SOV. Anything on rubber tires and wheels would be difficult because every one of your alternative routes is also under construction. My worry and being one of the lead executives at the transportation department whose job is to keep mobility moving is how we are going to keep mobility moving if we don't find a way to reduce the demand. Because you are going to see so many lane closures. It's going to be hard to move around the city if we don't reduce the total vehicle demand on our streets and roads. There are some other travel sheds, the MPO, for instance, is responsible for doing the normal MPO, macro-, meso-, and micro-modeling. It's the combination of the TDM program and some new contracts that will be standing up with our Movability partners. Part of that is really expanding the ride-matching program. Because it has a decent amount of registered active participants. But they are mostly, predominantly city staff, because of the old incentives that were there. Really that entire government TDM-based ride-matching, the carpooling program needs to become more socialized to a point where it is providing incentives for others that aren't employer-based. And that's really why we are focused on the monetization of carbon items and starting from there. The data that we do have is predominantly, pretty good for pre-pandemic, you'll see normal things of communities all accessing

[12] The University of Texas at Austin
[13] National Association of City Transportation Officials

the same top five roadways in the area and using those to move downtown. We still see a lot of travel patterns where folks are utilizing the interstate and other high-capacity roadways for short trips. So, there is still more education to do around, finding the appropriate roadway for your trip, right? That has a whole lot to do with navigation apps and other things on phones, so finding ways for us to have those meaningful conversations and create new partnerships with the folks like Waze, Google, and others give us the ability to hopefully begin if we are lucky. They'll understand what we are talking about and be willing to at least during certain times of the day, certain areas, and pockets of town, not send everybody onto the high-speed roadway to make a 2-mile trip. That's some of the issues that we still have is our road network in Austin, we do not have a loop around the city. We still have just I-35. There is not a lot of east-west movement. There are some issues there. Most of the things that I'm mentioning are of course anecdotal and I know that your research needs some good empirical evidence for that. I would take that as an action from this interview to connect you with the people who can help you and track down some of the information that we do have.

Q: Another concern of mine is why Austin, does it have any carpool lane with tolls, people can pay tolls to drive a more efficient toll lane on the left-hand side. Usually, I see many cities have that. If you have that, why do not change this to a carpool lane? Because I mean, especially as a carpooler, the incentive part, maybe what the city can provide is very limited. However, if people can drive on the carpool lane, the incentive, like three-dollar, four-dollar, I mean, that will be a much greater incentive for people to do really carpool.

A: It's not our roadway, not our policies. Those express lanes, managed lanes, are, in the state of Texas, managed by either the state or regional mobility authority, or toll authority.

Q: Is the city possible to talk to the state DOT and then initiate that?

A: In the past. We continue to try each opportunity we get. Most of those facilities are these days, built under a type of innovative financing strategy, where it may be a concessionaire. You can't go in and change the public policy in the middle of the contract. To do so would be detrimental to the contract. Or it would be incredibly costly on the side of the government to make that change because they bought that lane, and they need to make sure they get a return on investment out of it. So, it's been monetized already at a certain rate. We are dealing with that right now as we look at, the managed lanes we are part of the new I-35 build, for instance, one of the city policies that we are trying to get into the neap of purpose in need, that's where that project is, still in neap of phase. So, we do have some of it, instead of being something where you get carpool, you get half off your toll. We were able to get out of, there are regional toll partners and the state policies that enable transit to ride for free on those lanes. They aren't charging the buses. But that's not enough.

There is still enough whole supply and demand issue. The state continues to build more free-lane capacity. It's not like the Bay Area where you are trying to cross the only bridge that gets to San Francisco, and you are going to find a way to carpool so that you take advantage of it. The other thing that I've noticed here is the local conversation around this particular topic. The toll agency is concerned about misuse and leakage. How do you confirm that there is more than one person in the vehicle and how do you do that under current state law in Texas that doesn't allow you to use a camera to get a person's face? So, there are all these other policies that create the inability for government to unify itself on a common goal.

Every time you think you get a little, two-step forward, one-step back. You are making small incremental improvements, but at this pace, it's going to take five generations for us to get to where we need to be today. That's five times too late. So, that's the reason why we are so focused on trying to get the trips tracked down to use a distributed ledger to really track the trips, the number of people in the car, the vehicle type, the propulsion type, and then I'm looking at adding other things. When I came on board, the parking rate per hour in the city of Austin, for a city parking space, on the street or in a garage, was a dollar twenty an hour. It was the lowest in the nation. So, there is no incentive to not bring your car downtown and park it. So now, it took us, we wanted to go up to seven dollars. We wanted to create dynamic pricing to base it on demand. Council would not go for that. So, the policymakers did not approve of that. We got a lot of pushbacks. What we ended up on through negotiations with the policymakers was we could go up to five dollars, but it can't be dynamic. It can't be like a surge pricing thing. So, right now, what we've created instead is what we call, progressive pricing. So, if you park downtown, for the first two hours, it's a certain rate. And then, for any hour above three hours, you're paying a higher rate, up to five dollars an hour. That way, we are at least trying to incentivize the turnover of the parking space. That's step one. Open the parking space for more use. Make it a little bit more costly to drive your car and park. But now we need to add in, with CapMetro's help and Project Connect, different, we can still call it mobility hubs, mobility hubs to where we can intercept that trip and have them leave their SOV somewhere outside of the city center because most of the congestions are in the middle of the city and hopefully provide them with enough moss and toss and transit solutions so that they are taking a more sustainable shared ride for the, I want to say not the last mile, but last five miles, would be great, especially if they are coming from, most of the downtown workers don't live close to the downtown. Most of the downtown workers don't live in the CapMetro service area. They live in the bedroom communities where the nicer homes are. And it's also more affordable. And that's also where the better schools are.

We're using the regional context around how people live and work around here to try to find the right place to intercept their SOV trip and have them at least do the last five miles as a shared ride. And if I can make that more sustainable by adding electricity, great. In fact, if they want to take transit from that mobility hub for the last five miles to a transit stop downtown, their last mile might be on a scooter. What I want to have the ability to do is begin tracking that trip for them, turning that into carbon, giving them debits for their SOV piece, so they see it as soon as they park their truck, their diesel truck at the mobility hub, and they paid to park, and they see oh it's going to take twenty dollars to park here today. In addition to that, I got negative ten credits for carbon and negative ten tokens. Then they will go, if we are good with the app, it will present to them, electric transit and other things that will allow them to earn back even the positive tokens that they can use to pay for the parking of their truck. At the end of the day, it's zero-zero. But what we've done is we've educated the user. We've educated the transportation user. We are starting to not call them users. They are customers. Something that the government, and I, struggled with internally because my policymakers don't want me to call our residents customers. But we are all customers of our government. We pay a lot to them, taxes, property taxes, sales tax, and transit. People are customers of the government. The government needs to understand that we have a provider customer issue because mentally we're not looking at everyone as customers. There is no bidirectional symbiotic relationship.

Q: There is no equilibrium here. Usually, I just feel sometimes government is just too generous in the U.S. comparing it to Singapore and Hong Kong. They just push very hard, but they provide alternatives. The alternatives will be the transit system, and park and ride facilities, and you can have those micro-transit, and paratransit to serve the specific group. And that can really make this kind of carpooling.

Also, you just push hard for the park-and-ride system, parking pricing, and parking cash out and then that will mitigate congestion a lot.

A: We didn't need to get into development, and parking minimums, parking maximums for new hotels, and new residences downtown. When you add in land code and policy around development, again, it's much like the thing, the example with the state. We are not working together. Our different goals are pulling apart. That's where we are trying to make small incremental improvements. We are not getting policies across the board, but if we can create incentives within the developer code, for instance, where they are able to get more variable to expand into the public right of way with their promenade, where they would normally have to pay a license fee to take over some city right of way. If they are willing to go really low on their parking, then we will give what we can to make that deal. But it's not something that's overarching policy for everyone. Right now, it's very, the deal-making is happening at an individual deal level of each project. And some developers are able to take advantage of those incentives and reduce their overall parking strategy for that development. In other developers I've noticed, where the money is coming from, their investors are very focused on an old way of thinking, because the old investment models haven't changed. So, if you are a banker, or you are someone who funds developments, and you are looking to build a thousand apartment complex, the math is two parking spaces per apartment. If the banks are not willing to change how they fund projects, because if you don't have parking, then they will go no, the level of system-to-system interaction, goes all the way to the banking and finance component of things that are outside of the city's control. This is the post department's deciding what to do with whatever investors they have for whatever local project.

Q: For those things, if they, look at New York City. Definitely, I think they have this kind of parking maximum. I know in Canada, they have this kind of new code, California, and Seattle, WA. If you have this kind of code, I think the local city can still push them to fall out. It just needs time to change.

A: There is something very important is something why a lot of companies come to Austin with their launches and their go-to-market strategies. Why have Ford and Lyft and Argo picked Austin for their autonomous vehicle service? A lot of it has to do with, what I call the different colors of the fabric of the geopolitical situation across the United States. California is, a democratic state, all cities are democratic, but you have a democratic state government, and a democratic legislature, all unified around the particular cultural concept for their entire state and all their communities in that state, same thing for Oregon, and Portland. Although Oregon is different. Because Oregon has a lot of the same issues. If you live anywhere past the eastern seaboard of Oregon, it's very rural. It's very focused on incentivizing development and not looking at things the way that we're looking at them. Austin is a lot like that. Because the cities in Texas have the demand in the city, but the state policies haven't changed. While New York can create policies that affect the entire width of the state so that every investor knows 'Oh I'm not going to be able to do what I do in Texas in New York City.' The United States is not unified. We believe in state sovereignty, which means we have 52, that many different flavors of state and local policies that don't match. Unfortunately, because of the way, the United States is, the federal government can only do so much to create a level of unification. So, a lot of it does reside in the policy. And this is the reason why I think that's so important that we take advantage of the current administration and the kind of way that secretary Buttigieg is looking at trying to reinvent and transform at the same time our nation's transportation system. The feds understand what needs to be done, but they are also respectful that in order to get the votes at capitol hill, they need those state senators to vote yes. If you are a state like Texas, there is already a defined no. It's the Republican side.

Q: Last question is, for social carpooling, in another country, this is not really a sexual offense, but female riders just feel uncomfortable when they are sitting with the male riders based on how they look at them or this kind of discussion or talk they initiated. They are really discouraged, and there was also this kind of discrimination that male drivers tend to pick up female riders. How do you feel those things really impact social carpooling in Austin?

A: That's very real. As a father of a 16-year-old child, I would not allow my daughter to ride in a social carpooling thing that was not in any way regulated, did not provide any background checks of their drivers, and certainly did not have any licensing and enforcement on top of those drivers. There's no company. It's just a driver, it's an individual. So, if you are the father of a young daughter, you think about the world in a very different way. That's a unique construct that is an ugly part of humanity. That's everywhere. The fact that you can't even ride be a female and ride public transportation in Mexico City for fear of getting raped on the bus, the bus, with crowded bus, standing room only and women are getting raped on them. How are you going to fix everything else? Being able to, if it is a social carpooling concept, there must be some level of social justice. There is always that fear. Simple things like mandatory in-car cameras and other types of systems and technologies can help provide a construct of safety. We saw something come through in 2018 with the Ford City: One Challenge. A company decided to work with the Arcade City folks, who do Craigslist and Facebook to connect. What they were wanting to do was take that little bit further and have other female riders verify the driver. That's kind of a crowdsource validation or crowdsource trust and detriment of a particular driver.

Q: I see a lot of challenges. Right now, our proposal is just based on Yi-Chang's data, which has this kind of estimation from the individual level to the area level and zone level, then to the system level to see how much social carpooling is fully deployed and then we can see how much, we can help mitigate the congestion. But I know many issues cannot be observed from data. So that's why I think reaching out to the stakeholders is very important to give us the more complete picture.

A: I'd say one other thing that I didn't think about that's really what's happening with our NSF[14] Civic Innovation Challenge project. I'm noticing a unique opportunity to create community-specific community-driven approaches to where you are utilizing your community members. So, ours is in a neighborhood called Georgian Acres. It's low to moderate-income neighborhood. And that community is one that when we got in there started to talk with the community about the different community engagement opportunities, we noticed that they have a level of resiliency amongst their community. We are asking them questions about the winter storm Uri, issues with the freeze that happened here, and other things like that. What we found was that in times of greatest need, the community was able to come together and provide its own level of community resiliency. I think there are some secret opportunities in that. If we can find ways to create community ride-match programs that are community specific almost specific to the demographics and different cultures that reside in those communities. Georgian Acres is predominantly Hispanic, I have another one that's predominantly black, and another one is predominantly Vietnamese and connect to them through the Asian and cultural center and provide programming through there and they are able to go out to the community and have the community actually create the momentum. Then we are building something that I think truly can work in a social construct. And I think we are almost there with all these different construction projects. Our community, all of our different single-occupant drivers, are going to be forced. Because there is so much construction going on, you might as well be in California, and they are going to be like "I've got to find a

[14] National Science Foundation

different way." I think in a lot of ways, the city got started something way before the rest of the environment.

Interview II

Q: Could you describe a little bit about what your role is with Movability?

A: Yeah of course. So, I'm Movability's program manager. And essentially what I do is a lot of the implementation of the services we provide to members. So that can be from technical assistance, where we create a commute plan, a trip reduction plan, or a business, or a property, it could be our grants program, GoGrant, where we provide funding to businesses to implement different mobility strategies, TDM[15] strategies. It can be doing research and analysis on best practices and what other businesses are doing in the region and providing that to our members, so they have an idea of where they sit within the region. Or promotion of any of our other services we have a trip planning program, and ride-matching program, called GetThere, which is a standard ride-match program where people can find carpool matches, find transit routes, and things like that. Our work with businesses is to set that up for their organization.

Q: Is GetThere a particular brand of an existing vendor? And about how long have you been using RideAmigos?

A: It is using the RideAmigos platform. GetThere is a rebrand of the existing platform that has been in the region since 2018. And before that, we were using RideShark, since, I believe, 2012 or 2013.

Q: Can you walk me through the process that a commuter goes through? How to use your carpool service?

A: There are two options. They can go as an individual that's unaffiliated with a business that is joint. Essentially what they will do is sign up on the website. Well, technically they do not have to sign up at first. So, they can go on to the website, and look for carpool matches, or they can look at their different mobility options on the website. From there, if they see a carpool match, they can sign up to be able to email that person and then, if they are unaffiliated with a member business, a member that employer that's jointed to get there, they would join but they wouldn't see incentives that provide things like gift cards for logging trips or the emergency ride home program, and things like that. They would just get the tool of being able to find their matches. The other way is to go through an employer. So, we actively recruit employers to join the program. When they join, we provide them tools to distribute information about the program, so their workforce, which is their traveler base, and then those employees are individuals who sign up like how an individual would do it. The only difference is they would see that they are part of the network. They would also see that they have incentives. We do typically some biweekly drawings and we do monthly contests for people that log a certain number of trips, as well as an emergency ride home program.

Q: What are the prizes?

A: Typically, those are $25 gift cards. We allow the winners to pick what they want.

[15] Transportation Demand Management

Q: Biweekly drawings with a winner can pick. And then there was something else?

A: We do a monthly contest. Typically, it would be like a log of at least 15 qualifying trips within the calendar month. You can be entered into a contest to win a larger scale price. Typically, we choose a valued prize of around $200 per month. It can be less or more. It typically would be something like an experience around town, like going to a local resort, or it could be a pumpkin patch experience. It varies from month to month. We play around with what that incentive is each month. And the other one was the emergency ride home program.

Q: Do you get those prizes donated or do you use your funding to buy the prizes?

A: For the most part, we purchase them. But we do periodically request donations. It just depends if we have the time and staffing available to reach out to ask for donations.

Q: Is there anything particularly frustrating about the experience of signing up for the commuter or Movability?

A: It's interesting. This is something that we'd talk about quite a bit is the program a trip-planning tool. What we are telling people is you can find all your different options, and you can find a match, but then we really want them to log the trips, and the sign-ups, so that we can track metrics. So, we are getting to this pain point where we end up pushing the logging, pushing the registration, so that we have numbers showing how many people are using it rather than really just promoting the fact that they can carpool, the fact that they can find a vanpool, or they can find a transit route. It's a little bit of a frustration point where we are trying to find that balance of really encouraging people to log in and sign-ups so that we can see growth and see impacts, but also acknowledging of the tool is actually able to see other carpools in the area or see other travel options.

Q: Do you see people starting the logging and then stopping the logging?

A: Yes. One hundred percent. I think we get a lot of excitement, and a lot of interest at the start, and people sign up. They are probably good for a week or two logging their trips and then the follow-up. We need to engage and keep nudging, just constantly nudging people to remember to log their trips and stay interested in the program. One of the cases is that once you find a trip plan that you need you don't really go to that platform that often. You are not planning a new trip, monthly or weekly. Most people aren't. Typical employees are going to be finding, you know, 'I found a carpool match, I don't need the platform.'

Q: Does RideAmigos can track people like Strava and those other apps?

A: It allows you to integrate Strava and Waze carpool into the platform. There might be a couple of other ones, but those are the ones that I know for sure. If you log a trip on Strava or use Waze carpool, it will automatically log the trip onto RideAmigos, if they connect those, which is another hurdle.

Q: I was just curious, that's all. We find a very similar experience here in Tampa with logging that person, just, after a while, it doesn't matter what the prizes are, it seems to be. The prizes we are using are through adding the miles, which are basically discounts. There are few sweepstakes. What do you think that they like about the experience, not just what's frustrating?

A: One thing people really enjoy is just having the simplicity of seeing all the different options. Any time I've shown this up on one-to-one commuter chats with people, them going 'oh, this many people around me that I can carpool with, or I can vanpool, or I could take thirty minutes on transit versus 15-20 minutes driving. That's not too big of a difference. Maybe I'll do that.' I think people really enjoy being able to see all those different options that initially trip planning. From there I think people really enjoy that people that continue to log their trips, they really enjoy seeing their performance, and tracking their impacts. I think it is similar to people who use a fitness watch and track their steps or track their calorie burns. I found that maybe a few hundred people would just log their trips with no incentives. They are just doing it because they like seeing that impact.

Q: Do you share that on the website, like who is leading, who logged the most trips, or who logged the most miles?

A: Yes. We have a leaderboard. It will show the top organizations, and the next panel will show the individuals with just the first name and last initials of the people that are logging the most trips.

Q: Are there any other types of incentives you provide to help foster carpooling?

A: Nothing currently. Though, I will say that we are going through strategic planning for 2022 and beyond right now. We are talking about one of the key metrics that we want to strategize on is how to target different audiences with incentives that make an impact. We are going into grant things on how we incentivize carpool trips, how do we incentivize more transit or do we need to, because we have so many stakeholders that are already doing that, how do we incentivize biking, vanpools, all of that. So that's something that we are working on. There is nothing that we are doing activities for one mode versus the other. We have implemented a program called 'Mobility Camps,' where we are doing one-to-one, like a tri-transit type program, except for us, a little bit more mode. We are switching from maybe a bike trip to a carpool trip. We haven't done one for carpooling, but I imagine we will because we want to jump from mode to mode. And with that, we go to a business, and we say, 'hey what are you all interested in' and we will plan out some kind of hands-on learning demo experience for people. So, the first one is going to be a bike trip where we are going to bring some bikes and go from the business's location around the bike trail. We are excited about that, and hopefully, that helps get people more comfortable with using different modes.

Q: Are there any rewards or information that you would like to offer potential carpool customers, but don't offer today?

A: I'm not sure if there is anything off the top of my head that I can think of. I think we just need to do more individual mode pushes, and talk about the benefits of each different mode, so both the employer and the individuals. I know what we are working on trying to get better information about people knowing that 'hey there's preferential parking or there's some kind of incentive available for this mode.' We learn a lot of people just don't know. They don't know about the incentives that each different employer offers for the different modes. That's something that we are trying to get to see if we can build into one platform rather than people having to go on to their HR files or their bulletin board or something to find out there's incentives about this. Rather just have it all built-in to get their network where they can see 'Okay. I have a guaranteed parking spot if I carpool into the office rather than possibly having to go to another garage if I drive alone.' 'If I take transit, I get a free discount pass,' and things like that. There is an awareness, and that is kind of a work in progress. I wouldn't say something that we haven't been made aware of, but it is just something we haven't finished building yet.

Q: Are you still using motivational interviewing?

A: Yes. We use that mostly when we do one-to-one chats or when we talk to an employer, and say, 'Hey, this is a technique that we use, that we found, it's going to be official to employees.' And we give them tips and tricks on how to use it. We are planning in early 2022 to do a webinar, maybe an hour-and-a-half webinar on motivational interviewing that will probably be open to the public, I think. So that we can talk through those techniques with people, and possibly do another workshop here in the future where people can get trained on motivational interviewing.

Q: How familiar are you with Waze carpool and Metropia?

A: I would say I know of them. I used Waze carpool once that was many years ago. I know Metropia because I know a few people that were and are now staffed there. We talked about the program. I don't believe that Metropia is very active in the region at this point. But they used to be a little bit more. I know someone who works at the regional mobility authority here. She used to be part of Metropia, so we would talk about that from time to time, but she moved on from there maybe two or three years ago.

Q: What factors do you believe are significant predictors of individuals choosing to use something like Waze carpool or Metropia versus your current method of finding a ride match to get there?

A: I think the biggest thing is, let's just start with someone engaged and interested in finding a mobility solution. What I find as the biggest hurdle is just awareness of options. I would guess that maybe this might be optimistic, 10 percent of the population knows about Metropia, probably even less, I would guess less, of the commuting population I should say. Maybe a little bit more knows about Waze carpool, but the number that actually understands how it works is the fact that the driver can get paid. I don't know how many people know that. Especially here in this region. Whenever I'm talking to someone, I never hear them say 'oh I use Waze carpool or I'm using this.' I just don't think they have the market penetration, so I think that's a big hurdle or barrier from a buyer standpoint. I don't know if there is any agency or organization in the region that is bought into Waze or Metropia currently to push it and to increase that awareness and get more people to use those platforms. So, I think it would be to be strategy or somebody, might be Google or Metropia, who are really pushing those platforms or encouraging the city or the county or Movability to push those to really start getting a little bit of the market penetration, getting people to know about it before they can even be interested. I think it's an awareness issue, first and foremost. Beyond that, I think it's just standard issues of carpooling. Getting people comfortable with the possibility of reaching out to someone to take a ride or to hop in a car with someone rather than driving alone. They have a choice. They may be uncomfortable saying 'let me choose a carpool ride instead of driving,' and I find that barrier is larger than people are willing to hop into a Uber or Lyft because they feel like I'm paying that person to take me here, it's different, versus a carpool which seems a little bit more formalized and a little more social that people need to talk to each other, kind of having a relationship with the other, which is a standard issue in a carpool.

Q: Is there a reason that Movability doesn't push either of them?

A: I think we just haven't really talked too much about that at this point. GetThere is, there is a lot of buying from the MPO[16] and from the city. They provide us funding to help build that out. We discussed that logging trip frustration is a difficulty, and it would be great if we are able to collect metrics more passively than asking people to actively log their trips in a trip log online or on an application. But I think the biggest thing is that there has been buying from our partners, so we promote what the regional tool is, understanding that the more people that are using the same platform, the more likely everyone is to find a match. I think that would probably be the main reason, but we are open. At least from what I got from the rest of the team here, open to other ideas on how to promote TDM strategies, mainly because of those frustrations on, whether is it a trip logging program or is it a ride match program.

Q: If you could wave a magic wand and solve any of the problems associated with forming the carpools, the way you are doing it now. What would you like to solve?

A: I think the biggest thing is I would want ways to be able to incentivize people to take the trip rather than to log the trip. I think that's the biggest frustration that I tend to have. Here in the next few months, we are probably going to be actively looking for partners or vendors out there that have solutions where we feel like we are helping people take a different mode or use a more sustainable mode rather than logging the trips. Because the biggest frustration we have is getting people actively log different trips. So, it may be Waze or Scoop or depending on what modes you want to promote. It might be us bringing in one of those vendors and saying, we are buying in here whatever dollar amount, can you start incentivizing these trips in the region and let us know what that data looks like so that we are still collecting metrics and data, but we are not encouraging to log their trips.

Q: Who's the user of those metrics? Is it the MPOs, the funder?

A: The MPO pays for the platform, so they are using the metrics, but then on top of that, the city of Austin is paying for, I guess, more active outreach engagement through Movability. So, they are using the data. They have some big envisions to build a data exchange so that they can collect data from a number of different transportation modes from parking all the way to driving on the roadways. So, this is just like one small piece of the larger data lake that they are trying to build out.

Q: At what class could you consider peer-to-peer carpooling to be so expensive that you would not consider participating?

A: Probably if it is costing more than an Uber or Lyft trip, which probably is around, depending on the timing. I would probably want it to be 15% cheaper than the trip in Uber and Lyft would.

Q: At what cost would you consider peer-to-peer carpooling to be priced so low that you would be in the quality couldn't be very good because it's too cheap?

A: I don't know if there is a number. I would have to give more thought to figuring out the consequences of it being too cheap. But off the top of my head, I don't have a number.

Q: At what cost would you consider peer-to-peer carpooling starting to get expensive, so it's not out of the question, but you must give it some thought before applying.

[16] Metropolitan Planning Organization

A: If it's nearing double-digit dollar amount to take a carpool trip, let's say, for example, five miles or ten miles maybe. Let's go with five miles, if you are in the double digits, I may start to flinch at those numbers.

Q: At what cost would you consider peer-to-peer carpooling to be a bargain, a great buy for the money?

A: I think if I saw it, it was, two or three dollars to take a trip. I would probably consider that a bargain.

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