EXAMINING THE EFFECTS OF KING COUNTY METRO CARPOOL INCENTIVE FUND

FINAL PROJECT REPORT

by

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16. Abstract

How should public transit agencies deliver mobility services in the era of shared mobility? Previous literature has recommended that transit agencies actively build partnerships with mobility service companies from the private sector, yet public transit agencies are still in search of a solid empirical basis to help envision the consequences of doing so. This study presents an effort to fill this gap by studying a recent experiment of shared mobility public-private partnership. The carpool incentive fund program launched by King County Metro in the Seattle region. This program offered monetary incentives for participants who commuted using a dynamic app-based carpooling service. Through descriptive analysis and a series of logistic regression models, we found that the monetary incentive to encourage the use of app-based carpooling generated some promising outcomes while having distinct limitations. In particular, it facilitated the growth of carpooling by making carpooling a competitive commuting option for long-distance commuters. Moreover, our evidence suggested that the newly generated carpooling trips mostly substituted for single-occupancy vehicles, thus contributing to a reduction of regional VMT. The empirical results of this research not only will help King County Metro devise its future policies but also highlight an appealing alternative for other transit agencies in designing an integrated urban transportation system in the era of shared mobility.

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SI* (Modern Metric) Conversion Factors

APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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List of Abbreviations

ACS:	American Community Survey
CIF:	Carpool Incentive Fund
ICT:	Information communications technologies
KCM:	King County Metro Transit
PacTrans:	Pacific Northwest Transportation Consortium
SOV:	Single occupancy vehicle
TNCs:	Transportation network companies
VMT:	Vehicle miles travelled

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Executive Summary

General Background

Shared mobility (especially transportation network companies (TNCs)) is quickly emerging in the U.S. and is having profound impacts on how people travel in cities. It is very likely to increase vehicles on the road and to add to congestion. It also substantially challenges traditional fixed-route transit and thus forces public transit agencies to rethink their roles in delivering mobility services. Public transit agencies should initiate policy responses to realize the potential benefits of shared mobility while reducing its negative effects. As one of various innovative policy experiments launched by King County Metro, the Carpool Incentive Fund program was launched in the Seattle region to offer incentives for commuters prone to drive alone to instead use carpooling.

Problem Statement

To date few studies have focused on the consequences of monetary incentives to encourage the use of app-based carpooling. This study was an attempt to fill this knowledge gap by analyzing the Carpool Incentive Fund program. Specially, this study answered the following questions: 1) Do app-based carpool trips show distinctive characteristics? 2) How does carpooling as a travel mode substitute for single-occupancy vehicles (SOVs)? 3) How do monetary incentives influence the use of carpooling for individual users? 4) How do monetary incentives for carpooling affect regional vehicles miles traveled (VMT)?

Methodology

We used both descriptive analysis and multinomial logistic regression on two sets of data, a trip-level data set from the app-based carpooling service provider, Scoop, and a survey data set collected from Scoop users. For descriptive analysis, we applied summary tables and GIS mapping to analyze the basic characteristics of app-based carpooling. For multinomial logistic regression, we developed two sets of models, one for Scoop's substitution effect on single occupancy vehicles and the other for the impacts of King County Metro's carpool incentive.

Major Findings and Their Implications

Findings

The main findings included the following:

(1) App-based carpooling showed a few desirable characteristics, e.g., a high level of occupancy and rapid growth during the program period.

(2) App-based carpooling mostly substituted for single-occupancy vehicles, and this effect was stronger on individuals with greater car access or stronger needs for driving.

(3) The incentive encouraged people to further switch to app-based carpooling, while the extent of the increase depended on the person's socio-demographic and judgmental characteristics.

(4) The incentive was effective at reducing regional VMT.

(5) However, current users of the app-based carpooling skewed toward high-income tech employees, raising the question of whether such a program could benefit the disadvantaged.

Impact on Future Research and Engineering Practice

This study indicates that the following:

(1) In the era of shared mobility, public transit agencies are recommended to actively partner with shared mobility service providers and to find innovative ways to supplement traditional transit.

(2) Incentivizing app-based carpooling, as one of the directions that public transit agencies can go, shows potentials to contribute to a sustainable and integrated transportation system.

(3) Future research should examine and compare different types of programs to gain a more comprehensive understanding of their relative strengths and challenges.

Chapter 1 Introduction

1.1 Emerging Shared Mobility and Public Transit Agencies

The transportation planning sector has been witnessing unprecedented changes in the way people travel in cities. With the rapid development of mobile information and communication technology, app-based, on-demand shared mobility has become one of the most quickly emerging forms of urban transportation (McCoy et al., 2018). Shared mobility includes ride services (often referred to as “ride-hailing” or “ride-sourcing”) offered by transportation network companies (TNCs), car-sharing, carpooling, bike-sharing, and others. More and more evidence suggests that shared mobility, especially TNCs, has grown beyond a niche market and has become one of the major players in the urban transportation sector (Schaller, 2018; Clewlow and Mishra, 2017).

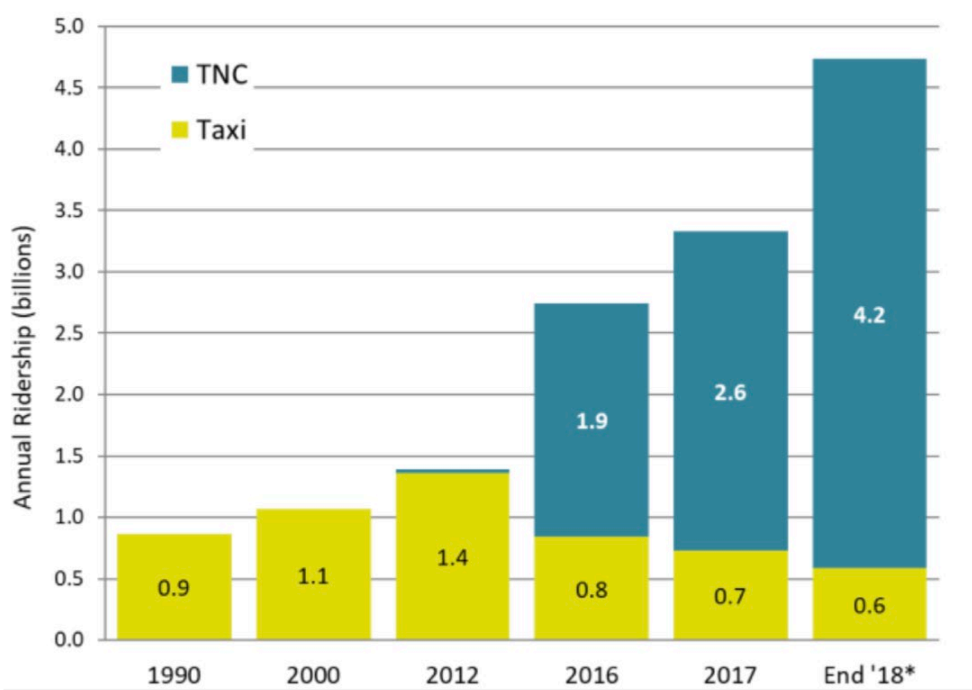


Figure 1.1 The exponential growth of TNCs in the U.S.
Source: Schaller, 2018

While shared mobility presents a new future in urban mobility, it challenges the current operations of public transit. Public transit ridership in the United States has been stagnating or even declining since the beginning of the 21st century despite a rapid growth in transit investments (Manville et al., 2018; Watkins et al., 2019). In comparison to fixed-route transit services, shared mobility provides appealing mobility options with great flexibility, comfort, and operational efficiency. Recent empirical evidence has suggested that shared mobility (especially TNCs) is very likely to further take customers away from already struggling transit (Clewlow and Mishra, 2017; Henao and Marshall, 2018; Schaller, 2018).

In addition, public transit agencies typically are not among the key drivers of technological advances of shared mobility, which usually happen in the research and development units within shared mobility companies. Therefore, unless transit agencies build direct collaboration with private mobility service companies, they have to respond reactively and passively to emerging shared mobility options, without adequate exposure to the operational details and protocols.

Fortunately, the emergence of new shared mobility options also provides new opportunities for public transit agencies to build partnerships. Many researchers have recommended that public transit agencies actively build shared mobility public-private partnerships that integrate shared mobility to serve as first-mile/ last-mile connections, fill in the gaps of existing networks, and even replace some low-demand, high-cost transit services (Circella and Alemi, 2018; Zhou, 2019; Feigon and Murphy, 2016; Shaheen and Cohen, 2020; Yan, et al., 2019). For example, the Federal Transit Administration has funded eleven Mobility on Demand (MOD) Sandbox projects of local transit agencies since 2016, many of which have explored the possibilities of integrating on-demand shared mobility services to supplement existing transit (Rodriguez, 2020).

However, such experiments from public transit agencies are still under development (Shaheen, Totte, and Stocker 2018). Moreover, few attempts have been made to empirically study existing experiments with rigorous analytical methods, and therefore evidence-based guidance for public transit agencies is largely missing. Therefore, much research is needed to identify best practices and to help transit agencies implement policy experiments in the era of shared mobility (Shaheen, Totte, and Stocker 2018; Watkins et al. 2019).

1.2 Research Questions

With the above-mentioned concerns and interests, this study aimed to conduct data-based research on one recent policy experiment of King County Metro Transit (KCM), the primary public transit agency in the Seattle region. As part of a holistic transition from a traditional service provider to a mobility facilitator, KCM has built a partnership with a dynamic app-based carpooling service provider, Scoop, and launched the King County Metro Carpool Incentive Fund (CIF) program. The program made available a fund that provided per-carpool trip incentives to carpool users. It aimed to encourage commuters who normally chose to drive alone to carpool instead, and thereby create cost-effective mobility options for certain travel demands. This study intended to answer four key questions to evaluate this policy experiment:

1) Do app-based carpool trips show distinctive characteristics?
2) How does carpooling as a mode choice substitute for single-occupancy vehicles (SOVs)?
3) How do monetary incentives influence the use of carpooling for individual users?
4) How do monetary incentives for carpooling affect regional VMT?

By answering these four questions, this research sought to deepen our understanding of the prospects of and barriers to incorporating on-demand carpooling and other types of shared mobility into an integrated public transportation system.

This report proceeds with a theoretical framework that draws upon relevant literature on revitalizing carpooling in the era of shared mobility, followed by detailed descriptions of the Carpool Incentive Fund program and the data and methodology for the research. Then it presents our models and findings to address the research questions. The report closes with generalizable lessons and conclusions.

Chapter 2 Literature Review

Much of the existing literature has addressed three related topics: first, how emerging shared mobility poses new challenges to public transit agencies; second, why app-based shared mobility creates new opportunities to revitalize carpooling; and third, demonstrations and evaluations of existing partnerships that incorporate app-based carpooling into transit. The following section reviews the literature on these three topics.

2.1 New Challenges for Public Transit Agencies in the Era of Shared Mobility

Although transit services, particularly bus and rail systems, remain the backbones of regional mobility in many U.S. cities, they have been struggling to attract users because of demographic shifts, new workplace policies, changes in service levels, and presumably, the emergence of new mobility options (Watkins et al., 2019). The automobile has consistently been the single most dominant travel mode. On average, a typical American household takes 2,592 person trips by private vehicle and only 80 person trips by transit in a year (Mcguckin et al., 2018, p. 23). Geographically, transit trips are highly concentrated in a few large cities, and within those cities they are disproportionally concentrated in dense and mixed-use central-city neighborhoods. Demographically, transit most commonly serves several distinct population groups who are not able to or do not want to drive.

In recent years, there has been speculation about a renaissance of public transit because of two new phenomena. First, many cities have voted to increase spending on their transit services, and second, we have seen an unprecedented decline in vehicle miles traveled in the U.S. for at least ten years starting in 2004 (Manville et al., 2017). However, as shown in figure 2.1, neither increasing transit spending nor decreasing driving has been associated with a surge in transit ridership (Manville et al., 2018, 2017; Manville and Cummins, 2015).

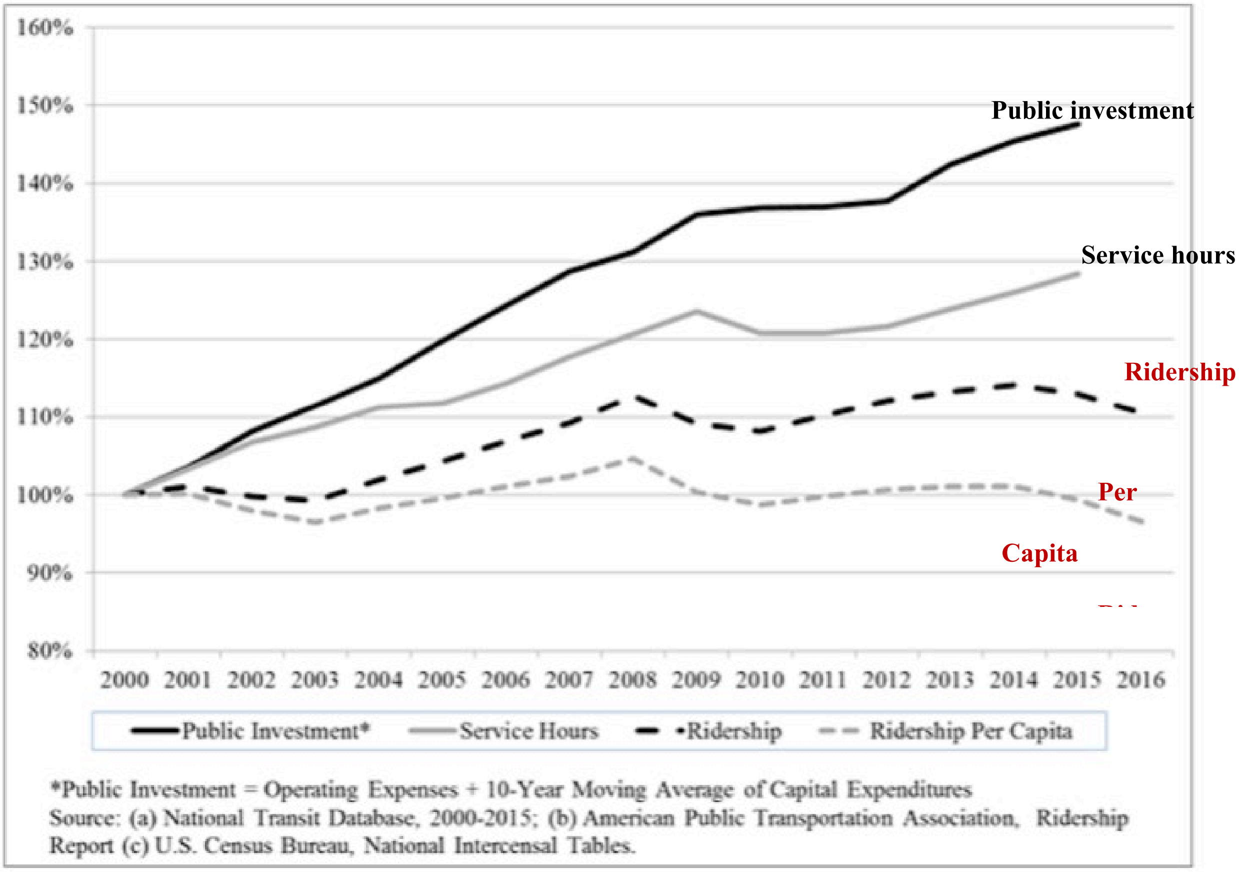


Figure 2.1 Stagnant transit ridership despite increase in the transit investment
Source: Manville et al. 2018

Emerging shared mobility, especially wide-spread services provided by TNCs, poses additional challenges to public transit agencies. There have been debates over whether TNCs substitute for or complement public transit (National Academies of Sciences, Engineering, and Medicine, 2018; Schaller, 2018). Some studies have reported evidence for a generally complementary relationship between public transit and TNCs (National Academies of Sciences, Engineering, and Medicine, 2016; Hall, et al., 2018). However, most available evidence has suggested that TNCs take a substantial number of riders away from public transit (Circella and Alemi, 2018; Clewlow and Mishra, 2017; Henao and Marshall, 2018; Schaller, 2018; Shaheen et al., 2018). As shown in figure 2.2, surveys from different regions in the United States have shown that when asked what alternative modes would have been used if TNCs were not available, respondents have frequently ranked public transit at the top of the list (Schaller, 2018; Shaheen et al., 2018). As more and more new studies have come out, academia has gained a relatively clear understanding that the heterogeneous effects of TNCs on public transit depend largely on the local context, the user group, and the specific transit mode (Circella and Alemi, 2018; Hall et al., 2018). The substitution effect of TNCs is most evident on the bus systems in large cities (Clewlow and Mishra, 2017; Hall et al., 2018). Moreover, TNCs tend to supplant transit in central-city neighborhoods and for young, single millennials (Circella and Alemi, 2018), thereby to a great extent overlapping with where and whom transit systems typically serve.

Another key question regarding the impacts of the emergence of shared mobility (especially TNCs) is its impacts on traffic congestion. Ride-sharing, the initial term that TNCs use, is indeed misleading because empirical evidence suggests that TNCs are mostly (74.3 percent) for single-passenger trips (as shown in figure 2.3). As a result of this low level of mobility sharing, instead of reducing the number of vehicles on the road, TNCs are very likely to exacerbate congestion, as shown in figure 2.4. Note that even in the most optimistic projected scenario (which is based on assumptions greatly divergent from reality), TNCs would still add 41 percent vehicle miles travelled (VMT). Because of these characteristics of TNCs, transportation researchers need to examine other types of innovative shared mobility services.

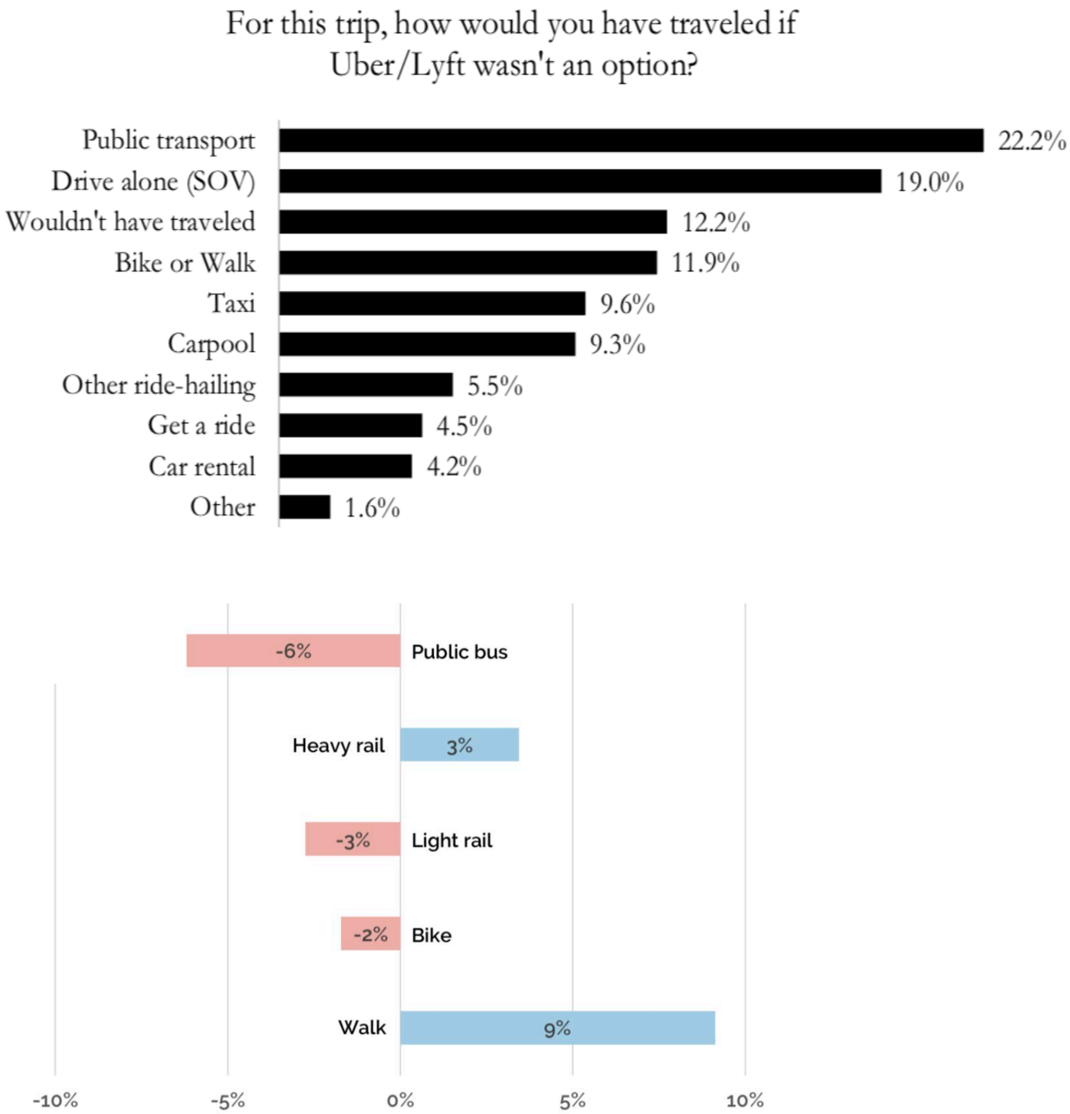


Figure 2.2 Survey results when respondents were asked about alternative travel options if TNCS are not available
Source: Henao and Marshall, 2018 (a); Clewlow and Mishra, 2017 (b)

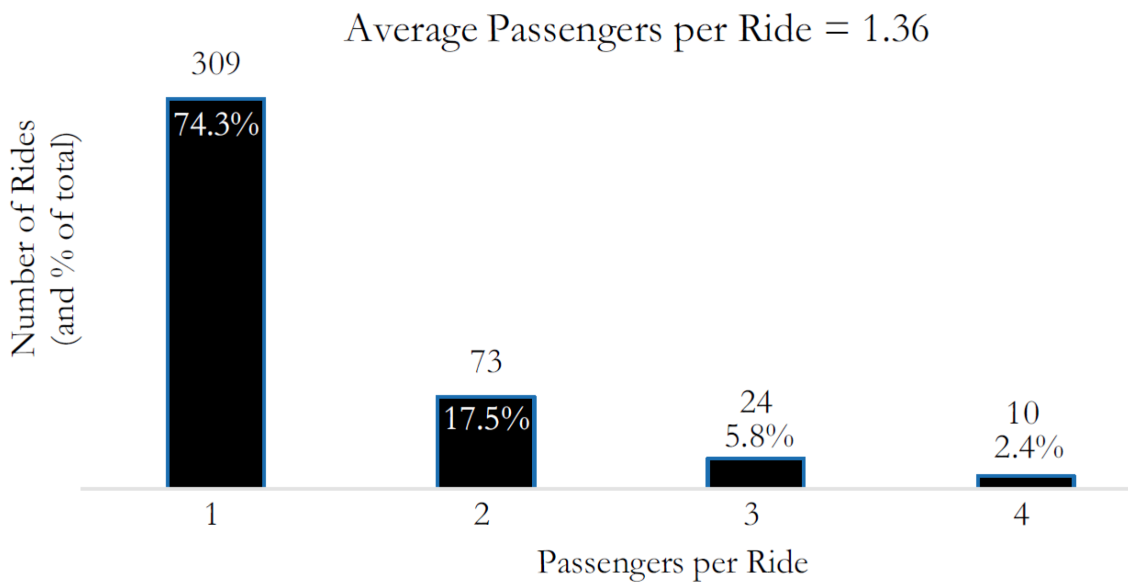


Figure 2.3 Number of passengers per ride for TNCs
Source: Henao and Marshall, 2018

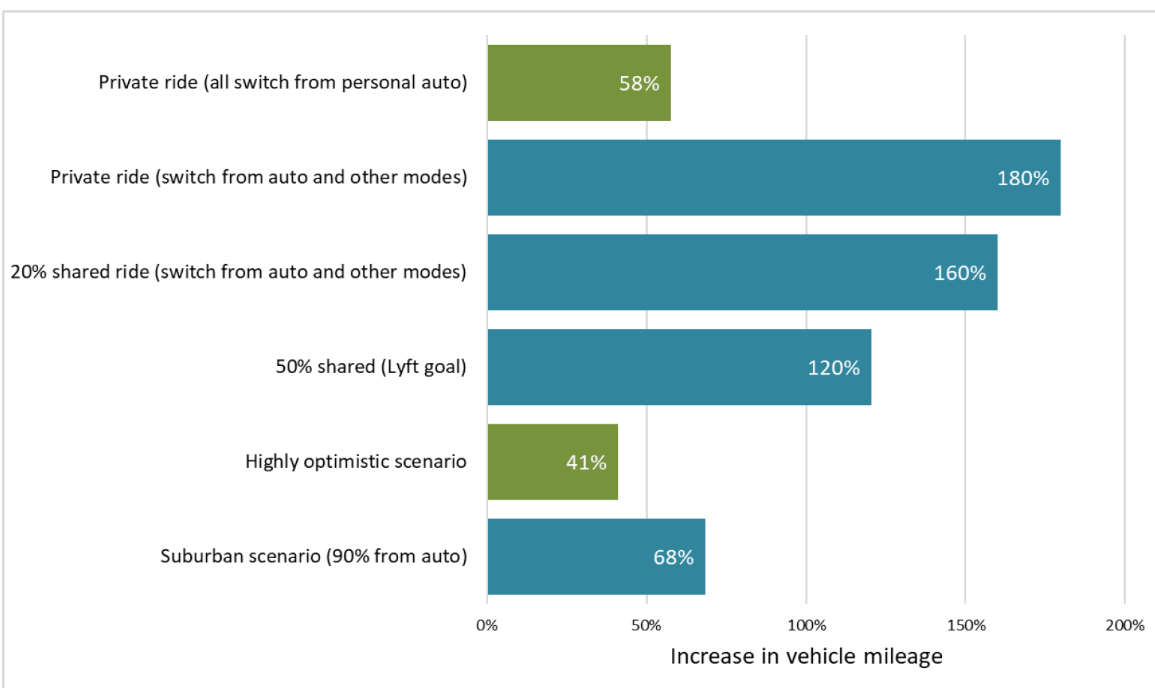


Figure 2.4 Changes in total VMT since the adoption of TNCs
Source: Schaller, 2018

Therefore, public transit agencies in the United States have recently been attracting funding and political support but not ridership (Manville et al., 2018; Manville and Cummins, 2015). In the era of shared mobility, it is reasonable to believe that the situation is unlikely to get any better without a fundamental shift in the way transit agencies operate and deliver mobility services. Our case, the Carpool Incentive Fund program in the Seattle area, shed light on one of many possible directions that transit agencies could take. The subsequent section will review the literature on carpooling, which provides some theoretical and empirical support for revitalizing carpooling in the era of shared mobility.

2.2 Revitalizing Carpooling in the Era of Shared Mobility

Carpooling inherently differs from TNCs. While both serve as components of shared mobility, in comparison to TNCs, carpooling reflects the nature of "true sharing" or "deep sharing," in which the driver does not just function as a service provider but instead shares both the vehicle and trips with other people. Carpooling has many social and environmental benefits because it reduces the use of private vehicles and the number of vehicle trips in comparison to SOVs and thus mitigates traffic congestion and emissions (Correia and Viegas, 2011; Delhomme and Gheorghiu, 2016). Historically in the United States, carpooling was a common travel option until the mid-1980s, when it started to decline as the SOV became more and more popular (Ferguson, 1997; Teal, 1987). Nevertheless, it is still the most common mode for commuting after SOVs (US Census Bureau, 2018). In recent years, carpooling has started to regain popularity with the rapid development of the internet and mobile information communications technologies (ICTs), which have made carpooling much more dynamic (Créno, 2016; Neoh et al., 2018; Shaheen et al., 2017).

Carpooling has drawn many research efforts because while it is environmentally highly desirable, asking commuters to switch from SOVs to carpooling is admittedly challenging (Ferguson, 1995, p. 1). Neoh et al. (2017) conducted a meta-analysis on factors affecting the use of carpooling, and they grouped factors identified in previous studies into four groups: social demographic (age, income, etc.), judgmental (attitude toward privacy, other preferences, mentality, etc.), situational (trip distance, travel time, vehicle availability, etc.), and intervention (matching program, HOV lane, etc.). Olsson et al. (2019) conducted a similar meta-analysis incorporating more recent literature. They applied groupings similar to those of Neoh et al. (2017) and found that judgmental variables were becoming more important to the propensity to join carpooling. However, most previous studies included in both meta-analyses had examined carpooling before the deployment of mobile communication technologies for transportation services. The factors affecting app-based carpooling in the context of shared mobility might be quite different. Also, recent studies (Créno, 2016; Griffin, 2018) have indicated that incentives such as travel cost reimbursements, parking cash out programs, and toll road discounts, along with recruitment tactics to attract more participants, are necessary enabling tools to make app-based carpooling competitive with SOVs.

The literature has provided additional rationale to incentivize carpooling for work trips. Previous research has found that work trips are more likely to be affected by instrumental factors rather than affective or symbolic factors (Neoh et al., 2018). Therefore, if a more cost-effective mode such as app-based carpooling is available, commuters are more likely to adopt it. Other advantages of adopting carpooling for work trips include a greater chance of matching because of a large number of employees at the same or close-by locations (Neoh et al., 2017); a shared commuting schedule (Buliung et al., 2010), potentially greater trust among co-workers (Correia and Viegas, 2011; Créno, 2016), and the possibility of less parking stress at the worksite (Neoh et al., 2017).

In addition, mobile ICT services create further opportunities to revitalize carpooling in the context of shared mobility. App-based carpooling is inherently more dynamic than traditional carpooling because it helps to match carpooling in a real-time, on-demand manner through algorithms instead of kinship or social network (Créno, 2016; Neoh et al., 2018). App-based carpooling reduces the searching and waiting costs of individual users by pooling a greater mass of users into the carpooling platform (Créno, 2016). The last advantage of app-based carpooling is less discussed, which is the institutional safeguard offered by the service itself. Specifically, shared mobility services designate roles and instruct users to execute carpooling according to rules and norms, provide potential solutions for disputes, and ask users to evaluate each other for a performance record. These mechanisms together attenuate uncertainty and possible opportunistic behavior and thus ensure a satisfactory carpool trip.

Thus, previous literature has identified the advantages of app-based carpooling and justified the CIF program from multiple theoretical perspectives. However, empirically, a solid basis for supporting transportation policymaking related to app-based carpooling is still missing. Data-based research is required to better understand the effects of various approaches for facilitating carpooling, as well as to understand the consequences of incorporating this type of shared mobility service through collaboration between the public and private sectors.

2.3 Incorporating App-Based Carpooling into Transit

There have already been efforts to incorporate app-based carpooling into an existing transit system to realize the advantages of app-based carpooling mentioned above. For example, Bay Area Rapid Transit (BART) recently implemented an Integrated Carpool to Transit Access

Program, a partnership with Scoop to provide access to and from BART stations with app-based carpooling (Nabti, 2020). The program incentivizes riders to form carpooling via Scoop by guaranteeing them parking space at the BART station. Martin et al. (2020) conducted a thorough evaluation of this program and reported many positive outcomes, such as increased utilization of parking spaces at stations, reduced SOV usage, and lower VMT.

Although the CIF program also built a partnership with Scoop, there are two salient differences between the CIF and BART's Integrated Carpool to Transit Access Program. First, instead of integrating Scoop to provide first-mile/last-mile access, the CIF program explores the possibility of using Scoop to replace transit to meet the demands of certain commuters. Second, instead of providing guaranteed parking space, the CIF program directly offers riders monetary incentives.

Aside from partnering with app-based carpooling service providers, public transit agencies in the U.S. have also launched policy experiments that have integrated other forms of shared mobility, including TNC companies (Pierce County, Wash.), micro-transit (Los Angeles, Calif., and King County, Wash.), bike-sharing (Chicago, Ill.), and other emerging options (Federal Transit Administration, 2019). Preliminary analysis has suggested that these programs generate promising outcomes (Rodriguez, 2020). However, much research is needed to comparatively examine the impacts of these new partnerships on travelers' mode choices, especially how and why different population groups choose different mobility options (Watkins et al., 2019). This study was an attempt to generate findings that could be useful for developing a synthetic view of various policy experiments.

Chapter 3 Research Design

3.1 The Carpool Incentive Fund Program

The Carpool Incentive Fund (CIF) program was a recent policy experiment to build a shared mobility public-private partnership. King County Metro, the primary transit agency in the Seattle region, worked with Scoop, a dynamic carpooling service provider, to incentivize the use of carpooling among commuters. The program offered up to a $2 incentive to every participant of each carpooling trip carried out through Scoop from December 2018 to April 2019. The amount of incentive for each carpooling trip was up to $2 multiplied by the driver and number of riders. All drivers and most of the riders received $2, while a small proportion of riders received $1 (mean = $1.87). A $2 incentive was likely to be a substantial amount because, in our data, the average cost for using Scoop was $6.10 per rider for each trip (with a median of $6 and a standard deviation of 1.42). This means that after the KCM incentive, riders paid about $4 on average, which was only slightly higher than the regular transit fare of $2.75 for adults in the Seattle region.

Scoop is a smartphone-based dynamic carpooling service provider that serves several cities in the United States, and it became available in the Seattle region in 2016. At the time of the CIF program, Scoop was available only for commuting trips and only at selected work locations in the Seattle area. It works by pairing up carpools the night before for morning commutes and in the afternoon for evening commutes on a daily basis. Scoop users can set up a pick-up time for each carpooling trip. Scoop allows users to select to be a rider, driver, or both, as shown in figure 3.1. This means that when the algorithm is not able to match the user as a rider or driver, it can attempt to match him or her with users in the other role. It also allows flexible pick-up times with a maximum range of 45 minutes. Riders with close-by origins and destinations may share the ride, together with the driver.

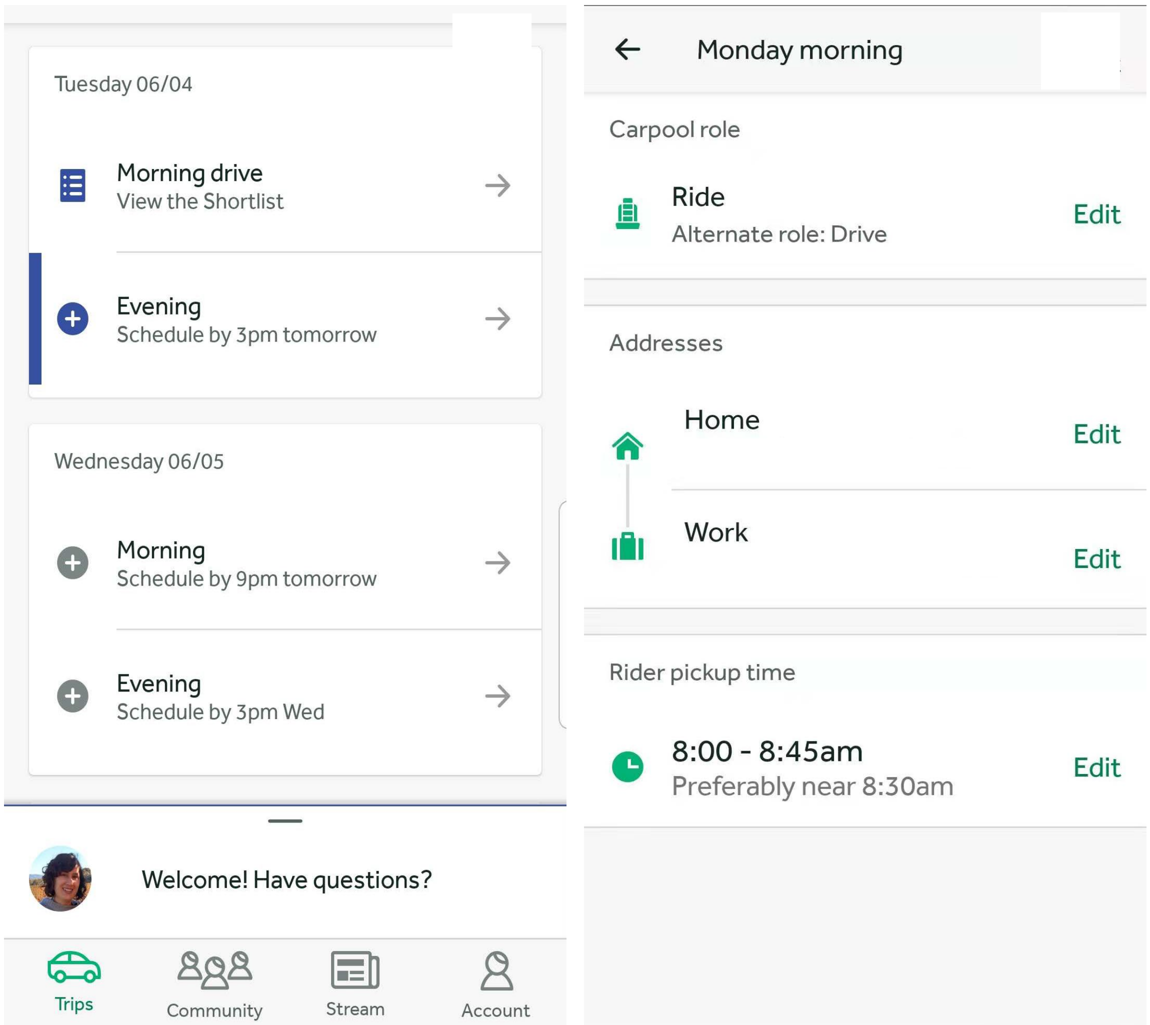


Figure 3.1 App interface of Scoop

3.2 Data Sources

This research integrated two types of data. The first was trip data from Scoop, which the partnership agreement required Scoop to submit to KCM every month. It included detailed data for each carpooling trip in the previous month, such as trip origin and destination at the census tract level, trip starting time, trip distance, vehicle occupancy, the original trip cost, and the amount of incentive. We acquired information for a total of 204,979 user trips throughout the entire five-month program. The second type of data was collected through an electronic survey of carpool participants. This survey contained 20 questions asking Scoop participants about their travel behaviors, socio-demographic characteristics, user habits, and user preferences, etc. The survey was distributed between February 2019 and May 2019. All users in the Seattle region who had already taken at least one Scoop trip were invited to participate in the survey. The advertisement for the survey showed up in the notification center on the Scoop mobile phone app, with a link directed to the actual survey questionnaire. KCM offered an incentive of a $25 Amazon gift card to five respondents randomly drawn from all respondents. We received 342 survey responses. These two data sets together contained rich information that enabled the research team to develop statistical models and assess the performance of the CIF program using quantifiable outcome measures.

3.3 Study Region

The study region, King County, includes Seattle and a large number of other municipalities. With approximately 2.2 million residents, it is the most populous county in the state of Washington. Based on the most recent American Community Survey (ACS) five-year estimates, 62.3 percent of the commuters in the region drive alone to work, 13.6 percent of them take public transit, and 7.0 percent choose to walk or bike to work (US Census Bureau, 2018). The median household income for the region is $89,418 (US Census Bureau, 2018). Additionally, several trends in the region are relevant to the implementation of the CIF program. First of all, the region has witnessed a booming tech industry in both Seattle downtown and suburban employment centers such as Redmond and Bellevue, which generates increasing commuting demands to and from these employment centers. The region's average commuting time increased from 26 minutes in 2010 to 30 minutes in 2018 (US Census Bureau, 2018).

Second, the state of Washington has a Commute Trip Reduction law that requires employers with more than 100 employees to implement travel demand management policies that reduce the use of SOVs (Washington State Commute Trip Reduction Board, 2017; Wu and Shen, 2019). Consequently, many employers in the region also offer various types of incentives for carpooling. Therefore, in our research, we explicitly controlled for this in our survey questionnaire and models. Third, HOV lanes are available on the highways in the region. Therefore, we asked the respondents to report whether HOV lanes are available on their commuting route.

3.4 Methodology

In the previous section, we identified four questions that this study aimed to address, including the general characteristics of the carpooling trips, the extent of substitution between carpooling and SOV, the impacts of the incentive fund on the travel behavior of individual users, and the impacts on regional VMT. For the first question, we used the information in the monthly reported data. To answer the second and the third questions, we developed a series of multinomial logistic regression models using information obtained from the travel survey. Because Scoop came to Seattle long before the King County Metro incentive program, we developed two models, one for the impact of Scoop on commuting mode choice, and the other for the impact of the incentive. Finally, for the fourth question, we combined the trip data with survey data and estimated the resulting changes in travel mode composition, with which we estimated the impacts of the incentives on regional VMT. These statistical analyses allowed us to test several hypotheses:

1) The emergence of Scoop has encouraged commuters who are prone to choose SOVs to carpool instead, and such an effect is conditioned on socio-demographic, judgmental, intervention, and situational factors.
2) The carpool incentive offered by King County Metro is effective in further encouraging the use of Scoop.
3) The implementation of the CIF program has contributed to a reduction in regional VMT.

One last thing to note is that we used multinomial logistic regression models that were suitable for categorical outcomes. We also tested an ordinal logistic regression model, and the estimated results were consistent. We chose to present the results of multinomial logistic regression in this report because the proportional odds assumption for the ordinal model might not be met for our data, and besides, multinomial logistic regression tells a richer story.

3.5 Conceptual Framework

The factors assumed to be associated with the level of Scoop's substitution effects are presented in the conceptual framework shown in figure 3.2. This framework is consistent with what previous literature has identified. Both internal factors (personal level) and external factors (environmental level) affect the extent of Scoop's substitution effects on SOVs. Internal factors include socio-demographic variables such as age, gender, race, income, and judgmental variables. External factors include situational variables and intervention variables. Last, the implementation of KCM's incentive may further attract individuals to use Scoop carpooling.

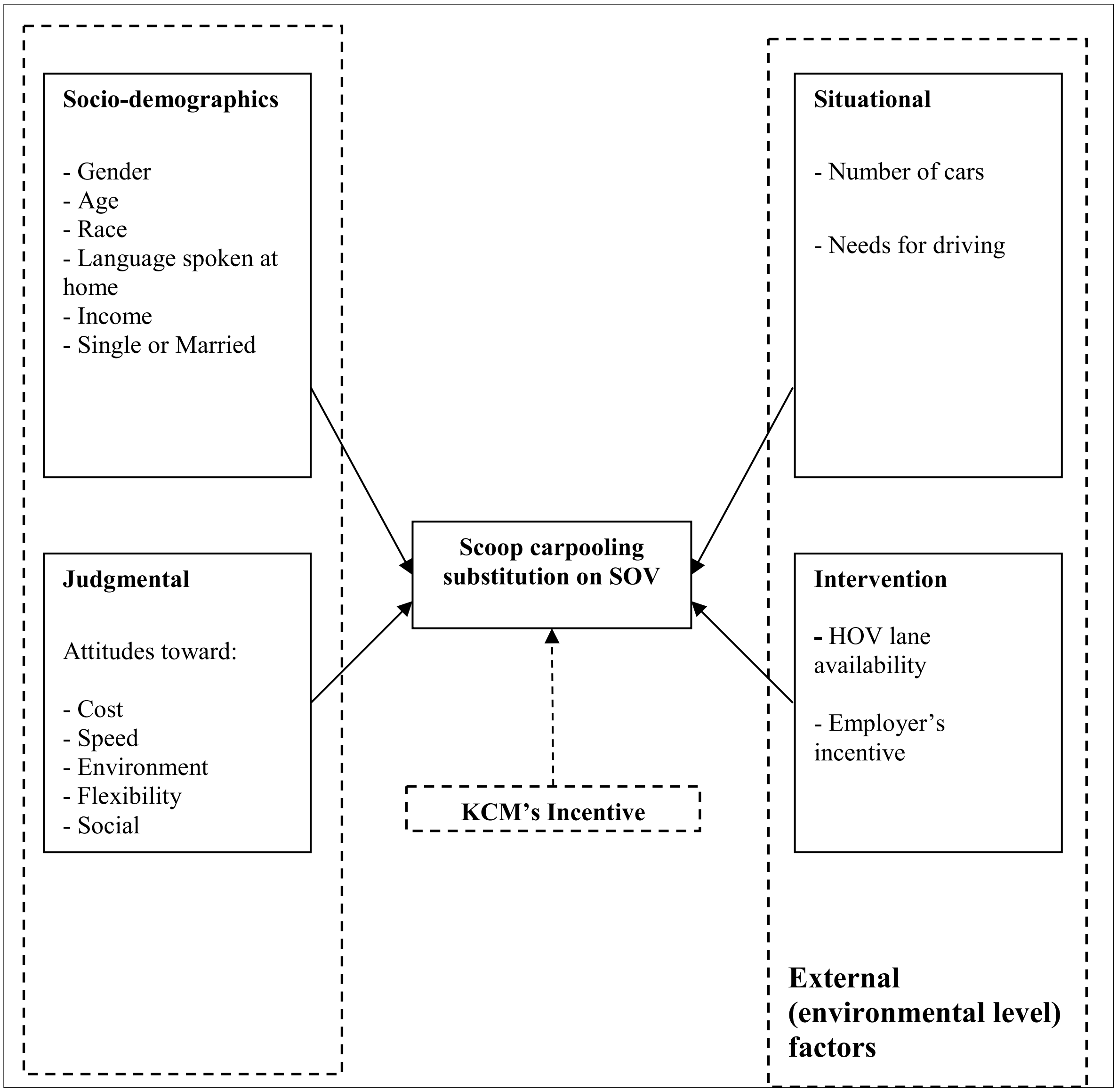


Figure 3.2 Conceptual framework for modeling Scoop's substitution for SOVs

Chapter 4 Results

4.1 General Characteristics of App-Based Carpooling Trips

There was rapid growth in the number of carpool trips during the time when the program was implemented (table 4.1). In April, the monthly person trips were more than twice as many as in December. The average carpool occupancy per trip was between 2.37 and 2.4 during the program period, indicating that a relatively large proportion of carpooling trips was shared by three or more people. In comparison, the estimated average passenger occupancy per trip for TNC services was 1.36 (Henao and Marshall, 2018). The significantly higher level of occupancy for Scoop confirmed our belief that carpooling is a form of "true sharing" and has a much greater potential to reduce vehicle use than TNCs. The average trip length was consistently greater than 11 miles while showing a gradual decreasing trend, indicating an expanding user base from long-distance commuters to shorter distance commuters.

Table 4.1 Overall CIF program performance

Metric	December	January	February	March	April
# of person trips/month	24,268	42,888	33,613	50,971	53,239
# of cumulative person trips	24,268	67,156	100,769	151,740	204,979
Carpool occupancy *KCM goal: >2.3	2.38	2.37	2.40	2.40	2.40
Average trip length (in miles)	12.63	12.33	12.08	11.76	11.54

We further examined the spatial distributions of Scoop trip origins and distributions using GIS. Figure 4.1 and figure 4.2 visualizes the home location and the work location, respectively, of every carpool trip during the experiment, where one dot represents 100 trips. Dots are randomly placed within a census tract. Between the two maps, the home locations are much more dispersed throughout the entire region while the work locations are concentrated in several locations, including downtown Seattle and several regional employment clusters. On the one hand, this spatial pattern of the carpool trips represents the characteristics of the Seattle region. Many large tech companies in the region employ a large number of employees, who generate a substantial amount of commuting. On the other hand, this pattern is also a reflection of Scoop's business model in which its service is currently available only for commuters traveling to certain locations.

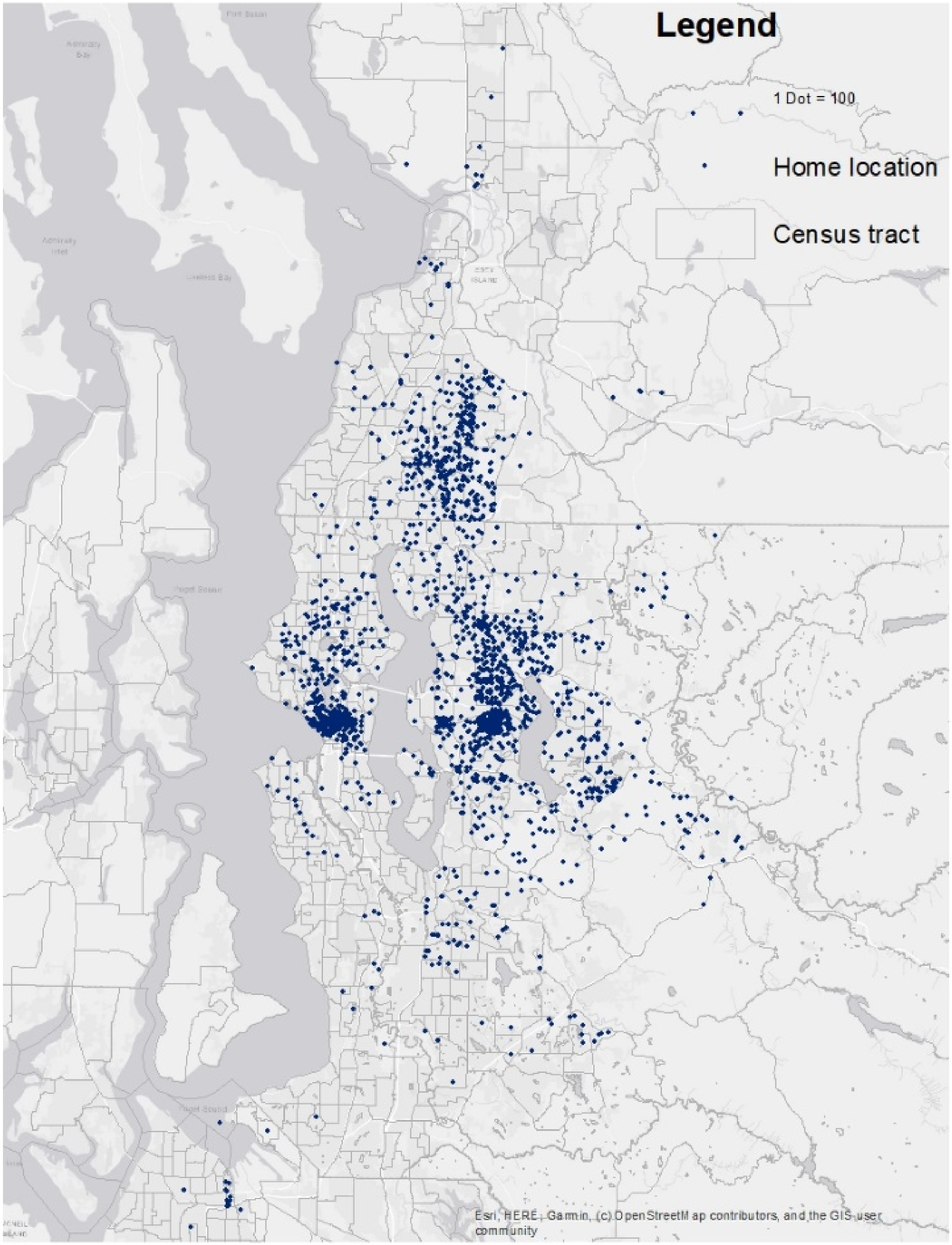


Figure 4.1 Spatial pattern of Scoop carpool trips: home location

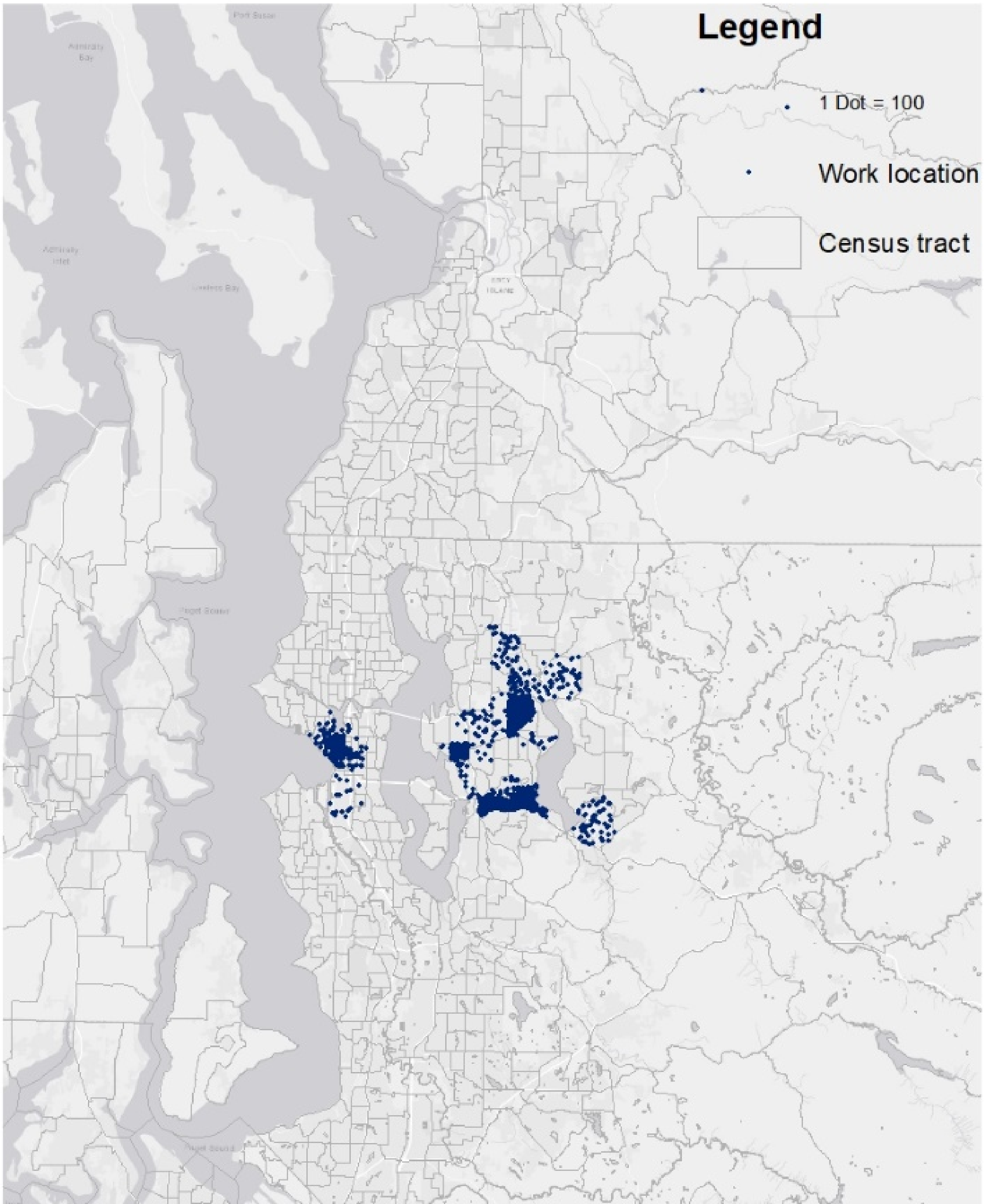
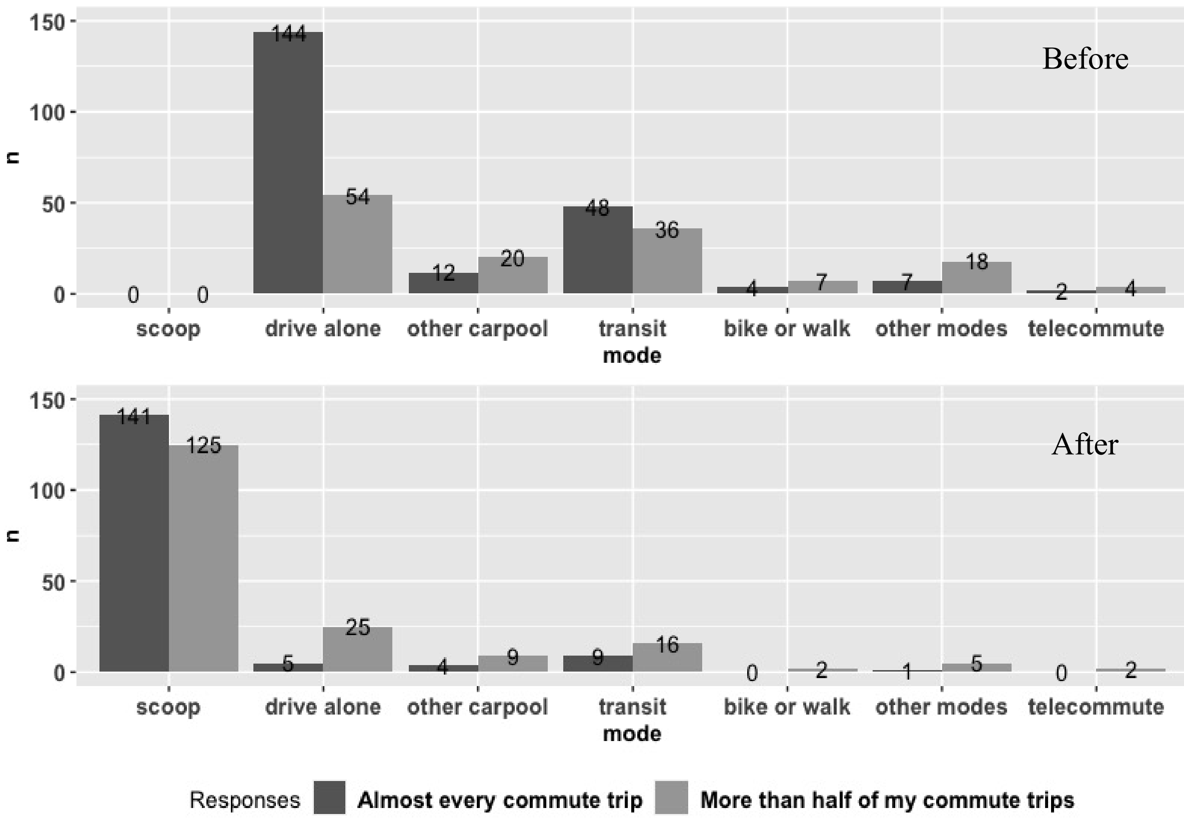


Figure 4.2 Spatial pattern of Scoop carpool trips: work location

4.2 Mode Substitution of App-Based Carpooling

Hypothetically, shared mobility, with its great flexibility and good service at a reasonable cost, would first attract users to switch from their previous travel mode and, second, generate new trips that would not have been made if the option of shared mobility were not available. In the case of the CIF program, the new carpooling participants may have been drawn from different modes: some may have previously been SOV drivers, others may have previously relied on public transit, biking, or walking. Therefore, the overall impact of this new mobility service was not pre-determined; instead, it was an empirical question to be answered on the basis of data.

Figure 4.3 visualizes the changes in the commuting mode indicated by the survey responses. The largest number of commuters used to drive alone, and transit ranked the second in mode share. However, after Scoop became available, most of the survey respondents switched to using Scoop. If primary commuting mode is defined as the mode chosen for more than 50 percent of a person's commuting trips, then 198 out of 342 (58 percent) respondents reported using SOVs as their primary mode before using Scoop, whereas only 30 (9 percent) reported doing so after using Scoop. For transit, the number was 84 (25 percent) versus 25 (7 percent). Scoop also supplanted other modes, such as other types of carpooling, biking, and walking. Therefore, among the commuters who adopted Scoop for carpooling, the substitution effect on other modes was strong. Note that although telecommuting was not as common a commuting option as SOVs or transit, its frequency also decreased after Scoop became available, indicating that Scoop could induce travel.



[a] The data were collected by asking two survey questions: “Before you started using Scoop, how frequently did you commute using the following types of transportation in a typical month?” and “After you started using Scoop, how frequently did you commute using the following types of transportation in a typical month?”

[b] The original survey offered four choice options: almost every commute trip, more than half of my commute trips, less than half of my commute trips, and never. For readability, we visualized the number of responses to the first two choices.

[c] Total n = 342.

Figure 4.3 Change in commuting mode: before and after Scoop

We further examined the substitution effect of Scoop on SOVs with regression modeling, which helped us to control for other factors that affect behavioral changes in commuting. Our model specification was guided by the conceptual framework for studying carpooling that was identified in our literature review. In the list of independent variables, we included variables that covered all four groups of factors identified by Neoh et al. (2017), i.e., social-demographical, situational, intervention, and judgmental factors. Table 4.2 lists all the variables we quantified on the basis of the survey and included in our regression analysis.

Table 4.2 List of variables in the SOV mode substitution model

Variable Name	Group	Description	Variable Type
Dependent variable			
Change in SOV		The change of commuter's SOV usage after Scoop became available, with three levels being: - No change or increase - Slight decrease - Substantial decrease	Ordinal (k=3)
Independent variables			
Age	Social-demographical	The age of the respondent	Ordinal (k=3)
Female		Whether the respondent is female (female = 1)	Binary
Race		The race that the respondent self-reported	Nominal (k=3)
English		Whether the respondent speaks English at home (yes = 1)	Binary
Income		The self-reported household income group	Ordinal (k=3)
Single		Whether the respondent is single (yes = 1)	Binary
Number of cars	Situational	Number of cars owned	Count
Needs for driving		Whether the respondent reported that they have mandatory needs to drive a car, including needs to pick up someone, to use a car for work, and to use a car for errands (yes = 1)	Binary
HOV	Intervention	Whether there are HOV lanes on the respondent's commuting route (yes = 1)	Binary
Employer incentive		Whether the employer provides an incentive for carpool (yes = 1)	Binary
Attitude: cost	Judgmental	Whether the respondent ranks the corresponding factor (cost, safety, speed, flexibility, environment and social) as one of the most important factors affecting the adoption of carpooling	Binary
Attitude: safety			Binary
Attitude: speed			Binary
Attitude: flexibility			Binary
Attitude: environment			Binary

Attitude: social			Binary

Table 4.3 presents the summary statistics. For categorical variables, we recoded them as a series of binary variables and present the mean value. The original survey sample size was 342 but about 50 people did not answer the socio-demographic questions. As a result, the effective sample size was 265 for the model because of missing values in some variables.

Table 4.3 Summary statistics of variables for Model 1

Variables	N	Mean
Change in SOV: (=1 if no change or increase)	285	0.347
Change in SOV: (=1 if slight decrease)	285	0.418
Change in SOV: (=1 if substantial decrease)	285	0.235
Age: (=1 if < 35 years old)	276	0.64
Age: (=1 if between 35 and 44 years old)	276	0.29
Age: (=1 if > 44 years old)	276	0.07
Gender: (=1 if female)	266	0.353
Race: (=1 if White)	245	0.257
Race: (=1 if Asian or Pacific Islander)	245	0.675
Race: (=1 if others)	245	0.069
English: (=1 if speaks English at home)	245	0.604
Income: (=1 if less than $75,000)	238	0.114
Income: (=1 if between $75,000 and $150,000)	238	0.500
Income: (=1 if greater than $150,000)	238	0.386
Single: (=1 if the respondent is single)	285	0.246
Number of cars	278	1.309
Needs for driving: (=1 if have mandatory driving needs)	285	0.544
HOV: (=1 if exists HOV lane)	285	0.611
Employer incentive: (=1 if received employer incentive)	285	0.453
Attitude: cost (=1 if scores 5 in cost, same for below)	285	0.523
Attitude: safety	285	0.418
Attitude: speed	285	0.474
Attitude: flexibility	285	0.372
Attitude: environment	284	0.411

Attitude: social	285	0.218

For the dependent variable, we recoded the survey response and derived a categorical variable with three levels that captured the change of SOV usage after Scoop became available. The baseline level of this dependent variable was survey respondents who reported no changes or increased SOV usage. For respondents who reported reduced SOV usage, we differentiated the extent of reduction into two levels, slight decrease and substantial decrease. Table 4.4 shows how we differentiated between slight decrease and substantial decrease.

Table 4.4 Coding the change of SOV usage associated with Scoop

Changes in the share of SOV after Scoop is available				Coded level
Almost every commute trip	More than half of my commute trips	Less than half of my commute trips	Never	
				Substantial decrease
				Slight decrease

Model 1 in table 4.5 illustrates how different groups of people changed their driving behavior when a new commuting option, Scoop, became available. We ran models using all the variables listed in table 4.2, but only present the statistically significant variables in the final model reported here. The results were robust when we tested alternative model specifications.

Table 4.5 Estimating mode substitution of Scoop for SOV

	Model 1: Scoop impact model Dependent variable: Change in SOV usage after Scoop came in	
	Slight decrease	Substantial decrease

	(ref. = no change or increase)			(ref. = no change or increase)		
	Est.	Std. Error	Sig.	Est.	Std. Error	Sig.
Gender (Female = 1)	-0.434	0.374		-0.710	0.322	**
Age: 35 to 44 years old (ref. < 35 years old)	1.090	0.414	***	-0.019	0.380	
Age: 45 years old and above (ref. < 35 years old)	0.264	0.670		-0.660	0.638	
Single (Yes = 1)	0.916	0.483	*	0.778	0.404	*
Number of cars	0.671	0.291	**	0.833	0.254	***
Needs for driving (Yes = 1)	0.804	0.385	**	0.689	0.327	**
Attitude: environment (Most important factor = 1)	0.530	0.366		0.740	0.316	**
Constant	-2.307	0.570	***	-1.374	0.460	***
N	265					
Pseudo R-squared	0.163					
AIC	543.827					
*Note: *p<0.1; **p<0.05; ***p<0.01*						

A positive estimate in Model 1 indicated a greater likelihood of reducing driving alone and joining or increasing the use of Scoop carpooling. As expected, the mode shift was conditioned on the commuter's socioeconomic status. Female drivers reported that they were less likely to substantially decrease driving, probably because of their family obligations or their concerns for carpooling safety. Commuters who were between 35 and 44 years old were more likely to slightly reduce their SOV usage than the reference group, commuters who were below 35 years old. However, commuters who were 45 or older were not significantly different from the reference group. Moreover, single people were more likely to reduce SOV usage and switch to Scoop. These results may indicate, respectively, the impacts of life stages and family constraints on the adoption of new app-based carpooling options. Interestingly, SOV reduction was associated with a higher number of cars owned by the household and stronger needs for driving. Having more cars in the household seemed to increase a commuter's flexibility to join carpooling, significant at the .05 level for a slight decrease in SOV use and at the 0.01 level for a substantial decrease in SOV use. Among people who had strong needs for driving (i.e., *Needs for driving =1*), some may not have considered driving alone to be a cost-effective choice and therefore took the opportunity to reduce their costs by serving as a driver for a carpool while still meeting their own transportation needs. And finally, people who cared most about the environment were more likely to switch from SOVs to Scoop carpooling and substantially decrease their driving. This relationship was significant at the 0.05 level.

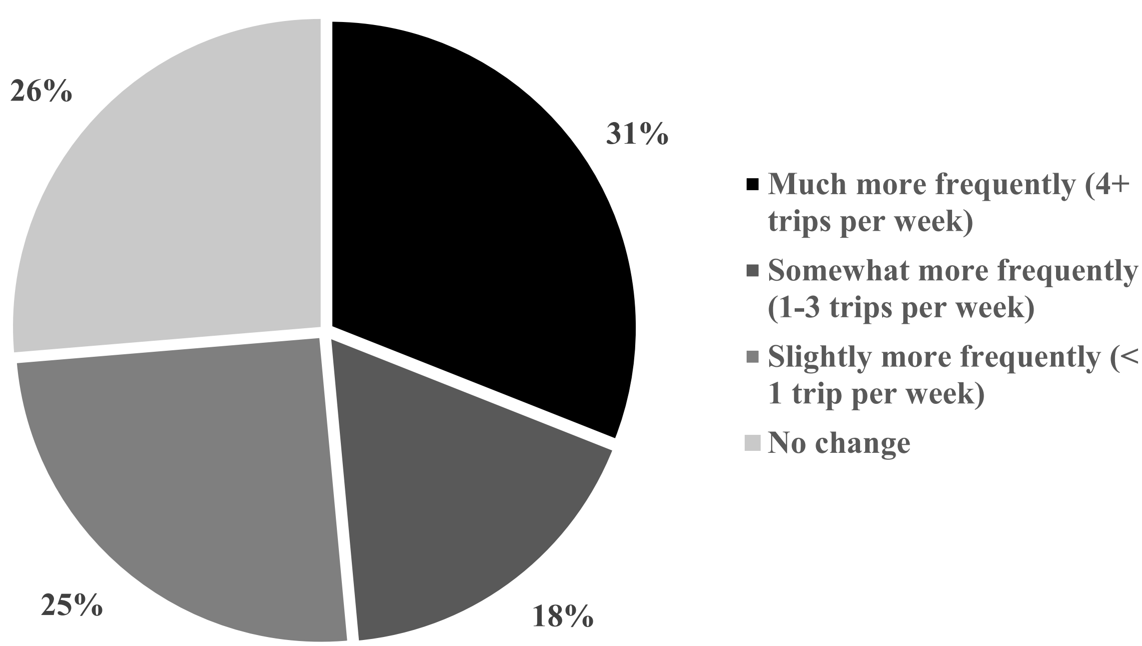
It is also worth mentioning that the estimated model showed that the extent of reduction in driving alone was not significantly different across income groups. This result was consistent with findings in previous literature, which have suggested that income level influences the usage of carpooling mostly through automobile ownership (Neoh et al., 2017, 2018). This was already controlled for in the model. It might also have been due to the fact that most Scoop users in our sample were middle-income or high-income. Therefore, this variable captured limited variation. Also, the results suggested that the availability of HOV lanes did not have positive effects on the propensity to join Scoop carpooling. This result was also broadly consistent with findings in several previous studies, which have indicated that HOV lanes have limited power to attract carpooling as they often offer little tangible timesaving to commuters (Buliung et al., 2010; Neoh et al., 2017).

Therefore, the mode substitution effect of Scoop was more evident for SOVs than for other modes (e.g., public transit, walking, biking). Similarly, Model 1 also indicated that Scoop was more appealing to people with more cars and greater driving needs. Therefore, the empirical results revealed the desirable characteristics of app-based carpooling make it a commute mode that competes with SOVs, which supports policies that promote this kind of shared mobility services.

4.3 Impact of the Monetary Incentive on Participants' Travel Behavior

Given the origin and destination of a trip, an individual usually chooses the travel mode that minimizes her/his generalized travel cost. Mobile ICTs reduce the time cost and uncertainty (both are components of generalized travel cost) of carpooling, which makes it more appealing as a travel option. The provision of monetary incentives for carpooling further reduces its generalized travel cost relative to other travel modes. These cost reductions were expected to increase the mode share for Scoop carpooling, as long as their value was greater than the transaction cost of shifting travel modes.

Our survey suggested that the monetary incentive offered by CIF attracted many survey respondents to increase their usage of Scoop carpooling, although there was heterogeneity related to the extent of increased use. Note that for this part of the analysis, we excluded the respondents who had already used Scoop for almost every commute trip before the incentive because there was no extra room for them to increase their usage of Scoop. Figure 4.4 visualizes the self-reported impact of the monetary incentive on survey respondents. Nearly one-third of the respondents (31 percent) reported that they increased their use of Scoop more than four trips per week. A substantial number of respondents showed an increase of one to three trips per week (18 percent) or a slight increase with less than one trip per week (25 percent). The rest of the respondents were insensitive to the incentive. From the perspective of transportation policy making, it is of great relevance to investigate factors that affect such heterogeneous responses to the same amount of incentive offered. Therefore, we ran another series of multinomial logistic regression modeling. This time, the dependent variable was a three-level categorical variable indicating the extent of increased usage of Scoop due to the incentive. It used the group that reported no change in figure 4.4 as the level for the reference group and used the group that reported much more frequent use as another level, named “substantial increase.” For the third level, we combined slightly more frequent use and somewhat more frequent use in figure 4.4 and named this level “moderate increase.” The independent variables were the same as those in table 4.2 plus the variable “Scoop,” indicating whether the respondent had used Scoop as his or her primary commuting mode before the KCM incentive.



[a] The data were collected by asking the survey question “How has the average $2 incentive provided by King County Metro on your Scoop trip changed your commuting behavior?”

[b] Total n =171

Figure 4.4 Change in the frequency of Scoop usage after the incentive

Our model confirmed that users' sensitivity to the monetary incentive was conditioned on a variety of factors. Model 2 in table 4.6 presents the estimation results, in which only significant variables are included. First of all, the incentive had a stronger impact on those who had adopted Scoop as their primary commuting mode, and the effect was significant at the 0.01 level. We found that people's reactions to the monetary incentive depended on their age. In particular, people who were 45 years old and above were less likely to moderately increase (significant at the 0.05 level) or substantially increase their Scoop usage (significant at the 0.1 level). People with strong needs for driving were more sensitive to the incentive, which confirmed our previous finding that Scoop functioned as a viable means for those who had to drive to share the cost of driving. Finally, people who cared about cost were more easily incentivized. They were likely to moderately increase their Scoop usage (significant at the 0.05 level) or substantially increase their usage (significant at the 0.01 level).

Table 4.6 Estimating the impacts of the monetary incentive on the usage of Scoop

	Model 2: Impact of the carpool incentive Dependent variable: Change in Scoop usage after the incentive					
	Moderate increase (ref. = no change)			Substantial increase (ref. = no change)		
	Est.	Std. Error	Sig.	Est.	Std. Error	Sig.
Scoop	-0.033	0.415		1.421	0.515	***
Age: 35 to 44 years old (ref. < 35 years old)	-0.922	0.476	*	-0.389	0.496	
Age: 45 years old and above (ref. < 35 years old)	-1.646	0.769	**	-2.118	1.152	*
Needs for driving (Yes = 1)	0.773	0.438	*	0.443	0.475	
Attitude: cost (Most important factor = 1)	0.960	0.438	**	1.241	0.476	***
Constant	0.196	0.404	***	-1.296	0.536	***
N	166					
Pseudo R-squared	0.127					
AIC	345.924					
*Note: *p<0.1; **p<0.05; ***p<0.01*						

4.4 Impact of the Monetary Incentive on Regional VMT

Aside from the impact of the monetary incentive on individual travel behavior, this study was also interested in the effects of the incentive on regional mobility, as measured by quantifiable aggregated metrics such as total vehicle miles traveled. Particularly, we wanted to know whether, among all the travel demand management options available to a typical public transit agency, the shared mobility public-private partnership, as illustrated in the case of the CIF program, was a cost-effective option. Therefore, we combined the information from the trip data and the survey data and used the following steps to estimate the impacts of the incentives on total regional VMT and the average cost of VMT reduction:

1) For each survey response, we asked the respondent about 1) the number of increased Scoop trips as a result of the KCM incentive and 2) the share of different modes replaced by those increased Scoop trips. Using information obtained from these two questions, we calculated the number of trips being replaced by Scoop for each mode as a result of the incentive.
2) We aggregated the numbers to get the share of trips of different modes that were replaced by new Scoop trips in the entire survey sample (N = 342), as shown in the left half in table 4.7.
3) We applied this share to the trip data (N = 204,979) and estimated the net change of trip numbers for each mode throughout the pilot period, as shown in the right half in table 4.7. This process assumed that the survey respondents were representative of all users in the trip data.
4) By applying an estimated trip distance (as shown in table 4.8) for each travel mode and assuming the corresponding changes in vehicle occupancy, we estimated the change in VMT for each mode as a result of the KCM incentive, and then the total net impact on VMT. For example, a switch from SOV to Scoop would result in a net decrease in VMT because Scoop had an average occupancy of 2.4. However, a switch from walking/biking or transit would lead to a net increase in VMT.

Table 4.7 Calculating the number of trips replaced by Scoop as a result of the incentive

Aggregated from travel survey			Apply to trip data		
Column	**A**	**B**	**C**	**D**	**E**

	Survey results: # of trip replaced	%	Trip replaced	Net change formulas	Net trip number change
Note	*Number of trips replaced in a typical week from survey data*		*= Column B * total # of Scoop trips*	*Applying occupancy to Column C Average Scoop carpool = 2.4 (from data) Average Uber/Lyft occupancy = 1.36 (Henao and Marshall, 2018 in Denver)*	*= Applying Column D on Column C*
Drive alone	366	69.1%	141,628	= - (trips*/1 - trips/2.4)	-82,617
Public transit	55	10.5%	21,454	= +(trips/2.4)	8,939
Uber/Lyft	31	5.8%	11,906	= - (trips/1.36 - trips/2.4)	-3,794
Other carpool	63	11.9%	24,365	no change	0
Employer bus	3	0.5%	988	= +(trips/2.4)	412
Walk/bike	12	2.2%	4,577	= +(trips/2.4)	1,907
Total	530	100.0%	204,979		-75,152

Table 4.8 Estimating the net impacts of the monetary incentive on regional VMT

Column	A	B	C	D
	Net trips number change	**Scenario 1: base scenario**	**Scenario 2: considering heterogenous trip lengths**	**Scenario 3: considering extra travel distance of carpooling**
Notes:	*Same as Column E In Table 4.7*	*= Column A * trip length Assuming all modes have an equal travel distance = 12.37 miles*	*= Column A * trip length Assuming different modes have different travel distance*	*= Column C with extra travel distance Carpooling may add additional VMT to pick-up and drop-off the riders*
		Change in VMT	Change in VMT	Change in VMT
Drive alone	-82,617	-1,016,184	-1,107,062	-948,916
Public transit	8,939	109,953	25,851	31,020
Uber/Lyft	-3,794	-46,662	-18,472	-15,395
Other carpooling	0	0	0	0
Employer bus	412	5,065	1,628	1,955
Walk/bike	1,907	23,455	2,250	2,700
Total	-75,152	-924,373	-1,095,805	-928,635
Cost per VMT reduced		$0.41	$0.35	$0.41

When aggregating the impacts of the incentive on individuals, we presented three different scenarios to account for various sources of uncertainty. The second row in table 4.8 shows our assumptions for each scenario. Scenario 1 assumed that all modes being replaced by Scoop had an equal trip length, which tended to underestimate the total VMT reduced. Scenario 2 instead assumed heterogeneous trip lengths for different modes. The scenario assigned the longest Scoop trips in the trip data to replace driving alone and other carpooling, assigned the shortest to replace walking/biking and public transit, and assigned the ones in between to the rest of the modes. By doing so, we tended to overestimate the total VMT reduced. Scenario 3 further accommodated the extra travel distance (i.e., over-heading) resulting from carpooling, as the drivers would need to pick up and/or drop off passengers at different locations. We do not claim that any of our scenarios offer a precise calculation of total VMT reduction, but together they give a reasonable range of estimations. The results were quite similar, suggesting the robustness of this analysis. The incentive provided by King County Metro contributed to a reduction of approximately 900,000 to 1,000,000 vehicle miles traveled during the experiment period, and the cost per VMT was estimated to be around $0.4. Note that this number only measures the net impact of the incentive on VMT during the pilot period. It does not capture long-term VMT reduction, which would come from individuals who would continue to use Scoop carpooling even after the incentive was discontinued. Such long-term effects have been reported for previous carpooling incentive programs (Shaheen et al., 2018). Even with obvious limitations, the estimated numbers in this study can serve as a benchmark for comparing the effectiveness of different policy strategies.

Chapter 5 Conclusions and Policy Recommendations

5.1 Conclusions

The adaptation of public transportation agencies in the era of shared mobility is an ongoing process with many uncertainties. Shared mobility, on the one hand, poses tremendous challenges to the public sector traditionally tasked with delivering mobility services in cities, which is typically achieved through the operation of fixed-route transit systems. On the other hand, shared mobility also creates opportunities for public transit agencies to design an integrated system that incorporates cost-effective, dynamic shared mobility services to supplement the transit system. The carpool incentive fund program of King County Metro in the Seattle region was therefore an exciting case to investigate.

This study presented a series of quantitative analyses to thoroughly evaluate the CIF program, and the estimated models indicated promising results. Such a program can lead to rapid growth of app-based carpool trips. App-based carpool trips were found to be more powerful in substituting for SOVs rather than for transit. In addition, app-based carpooling was found to be frequently used by car owners and people with mandatory needs for driving, and therefore it would provide an environmentally more sustainable option for those who usually choose to drive alone. Therefore, our findings provided evidence-based justifications for transportation policies to support app-based carpooling.

Regarding the performance of the monetary incentive in facilitating carpooling, we found that generally speaking, monetary incentives were effective, but such effects were heterogeneous for different population groups, conditioned on social-demographical and judgmental factors. We also estimated the VMT reduction achieved with the monetary incentives. The estimated reductions based on three alternative scenarios were generally consistent, and all suggested a substantial effect.

5.2 Limitations and Directions for Future Research

Several limitations of this type of incentive manifested as our analysis proceeded. First of all, early adopters of the shared mobility technology are unlikely to be a representative group of the whole population; those who are traditionally marginalized from the digital world are most likely to be excluded. The sample of app-based carpool participants in this study, consisting largely of high-income professionals, offered limited insights into how such programs would affect disadvantaged groups.

Secondly, although our analysis suggested that the CIF program would be a promising policy to encourage commuters who normally choose to drive alone to carpool instead, the incentive admittedly would also take customers away from public transit. Therefore, unless more strategically designed and implemented, such a program could undermine traditional public transit service.

Finally, this type of incentive policy could interfere with the market competition of the shared mobility industry, thus stretching the domains of the public sector into the private sector. Any full-fledged implementation of such a program should collaborate with an extended group of service providers.

Despite these data and program limitations, this study added to the relatively thin literature on the collaboration between public transit agencies and private shared mobility companies. On the basis of the empirical evidence obtained in this research, we encourage public transit agencies to think beyond their traditional role of a fixed-route service provider in the era of shared mobility. Our analysis illustrated that instead of passively watching the shared mobility companies (especially TNCs) encroach on the market base of transit systems, public transit agencies should actively take initiatives and strategically partner with selected shared mobility companies. Such proactive efforts could achieve desirable outcomes, including delivering new mobility options suitable to certain population groups, reducing SOV driving and regional VMT, and potentially mitigating traffic congestion, carbon emissions, and auto dependency.

Transit agencies are not profit-maximizing entities. They are expected to provide affordable transportation services for all. When designing shared mobility public-private partnership programs in the future, transit agencies need to orient the services toward mobility-challenged population groups. The CIF program examined in this study is only one of the many possible directions that public agencies could take to make use of emerging shared mobility for the public good. Paratransit, micro-transit, and first-mile/last-mile connection are some other examples of promising areas for policy innovation. Future research should examine and compare these different types of programs to gain a more comprehensive understanding of their relative strengths and potential challenges.

Chapter 6 References

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