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Exploring partnership between transit agency and shared mobility company: an incentive program for app-based carpooling

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Abstract

How should public transit agencies deliver mobility services in the era of shared mobil- ity? Previous literature recommends 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 paper 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 offers monetary incentives for participants who commute using a dynamic app-based carpooling service. Through descriptive analysis and a series of logistic regression models, we find that the monetary incentive to encourage the use of app-based carpooling generates some promising outcomes while having distinctive limitations. In particular, it facilitates the growth of carpooling by making carpooling a competitive commuting option for long-distance commuters. Moreover, our evidence suggests that the newly generated carpooling trips mostly substitute single-occupancy vehicles, thus contributing to a reduction of regional VMT. The empirical results of this research will not only 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.

Keywords Shared mobility · Public–private partnership · App-based carpooling · Incentive fund · Transit agencies

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Introduction

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). It 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 become one of the major players in the urban transportation sector (Schaller 2018; Clewlow and Mishra 2017).

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 twenty-first century despite the rapid growth of transit investments (Manville et al. 2018; Watkins et al. 2019). Compared to fixed-route transit services, shared mobility provides appealing mobility options with great flexibil- ity, comfort, and operational efficiency. Recent empirical evidence suggested that shared mobility (especially TNCs) is very likely to further take customers away from already struggling transit (Henao and Marshall 2018; Clewlow and Mishra 2017; Schaller 2018).

On the other hand, 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 should actively build shared mobility public–private partnerships that integrate shared mobility to serve as first-and-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 11 Mobility on Demand (MOD) Sandbox projects from 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).

Such experiments from public transit agencies, however, are still under development (Shaheen et al. 2018b). Moreover, few attempts have been made to empirically study existing experiments using rigorous analytical methods, and thus 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 et al. 2018b; Watkins et al. 2019).

This paper is aimed at filling this gap by conducting data-based research on one of the recent policy experiments of King County Metro Transit (KCM), the primary public transit agency in the Seattle region. As part of the 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 provides per-carpool trip incentives to carpool users. It aimed at encouraging commuters normally prone to driving alone to carpool instead, and thus creating cost-effective mobility options for certain travel demands. This paper intends to answer four key questions to evaluate this policy experiment: (1) Do app-based carpool trips show distinctive characteristics? (2) How does the carpooling as a travel mode substitute single-occupancy vehicles (SOV)? (3) How do monetary incentives influence the use of carpooling for individual users? (4) How do monetary incentives for carpooling affect total VMT of Scoop users? By answering these four questions, this research deepens 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 paper 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 article closes with generalizable lessons and conclusions.

Literature review

Much of the existing literature addresses 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, demonstration and evaluation of existing partnerships that incorporate app-based carpooling into transit. The following section reviews the literature on these three topics.

New challenges for public transit agencies in the era of shared mobility

Although transit services, particularly the bus and rail systems, remain the backbones of the regional mobility in many US cities, they have been struggling to attract users due to 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 2592 person trips by private vehicle and only 80 person trips by transit in a year (Mcguckin et al. 2018). In recent years, there have been speculations of a renaissance of public transit as two new phenomena being observed. First, many cities have voted to increase the spending on their transit services, and second, we have seen an unprecedented decline in vehicle miles traveled in the US for at least 10 years starting 2004 (Manville et al. 2017). However, neither the increasing transit spending nor the decreasing driving has been associated with a surge in transit ridership (Manville et al. 2017, 2018; Manville and Cummins 2015).

Emerging shared mobility, especially wide-spreading new services provided by TNCs, poses additional challenges to public transit agencies. Although some studies have reported evidence for a generally complementary relationship between public transit and TNCs (Feigon and Murphy 2016; Hall et al. 2018), most available evidence has suggested that TNCs take a substantial number of riders away from the public transit (Circella and Alemi 2018; Shaheen et al. 2018b; Clewlow and Mishra 2017; Henao and Marshall 2018; Schaller 2018). Surveys on different regions in the United States show that when asked what alternative modes would have been used if TNCs were not available, respondents frequently rank public transit at the top of the list (Schaller 2018; Shaheen et al. 2018b).

Therefore, 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, sheds 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.

Revitalizing carpooling in the era of shared mobility

While both serve as components of shared mobility, compared to TNCs, carpoolingreflects the nature of 'deep sharing'. In most TNC trips, the driver is simply a service provider and hence any economies of sharing are limited to the shared use of vehicle. In contrast, the driver in a carpooling trip not only provides service to the rider(s), but also accomplishes her/his own trip purpose along the way. Conceptually, this form of sharing tends to have a higher occupancy rate and lower vehicle miles per person. It has many social and environmental benefits, because for a given set of required trips,it reduces the use of private vehicles and the number of vehicle trips compared to SOV and TNCs, and thus mitigating traffic congestion and emissions (Correia and Viegas 2011; Delhomme and Gheorghiu 2016). Historically in the United States, carpoolingwas a common travel option until the mid-1980s, when it started to decline as the SOV became more and more popular (Teal 1987; Ferguson 1997). Still, it is the most com- mon mode for commuting after SOV (US Census Bureau 2018). In recent years, car- pooling started to regain popularity with the rapid development of internet and mobile Information Communications Technologies (ICTs), which have made carpooling much more dynamic (Créno 2016; Shaheen et al. 2017; Neoh et al. 2018).

Carpooling has drawn many research efforts because while environmentally highly desirable, it is admittedly challenging to ask commuters to switch from SOV to carpool- ing (Ferguson 1995). Neoh et al. (2017) conducted a meta-analysis on factors affecting the use of carpooling, and they grouped the factors identified by the previous literature into four groups: social demographical (age, income, etc.), judgmental (attitude towards 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 the similar grouping as Neoh et al. (2017) did and found that judgmental vari- ables are becoming more important to the propensity to join carpooling. However, most prior studies included in both meta-analyses examined carpooling before the deploy- ment of mobile communication technologies for transportation services. The factors affecting app-based carpooling in the context of shared mobility might be quite differ- ent. Also, recent studies (Créno 2016; Griffin 2018; Shaheen et al. 2018a) indicate that incentives such as travel cost reimbursement, parking cash out program and toll road discount, along with recruitment tactics to attract more participants, are necessary ena- bling tools to make app-based carpooling a competitive option to SOV.

Literature has provided additional rationale to incentivize carpooling on 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). Thus, 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 on work trips include a greater chance of matching due to a large number of employees at the same or close-by locations (Neoh et al. 2017), a shared commuting schedule (Buliung et al. 2010), poten- tially greater trust among co-workers (Créno 2016; Correia and Viegas 2011) and the possibility of releasing parking stress at the worksite (Neoh et al. 2017).

Besides, mobile ICT services create further opportunities to revitalize carpooling in the context of shared mobility. App-based carpooling is inherently more dynamic compared to 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 also reduces the searching-and-waiting costs of individual users by pooling a greater mass of users into the carpooling platform (Créno 2016).

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

Incorporating app-based carpooling into transit

There have already been efforts to incorporate app-based carpooling into the existing transit system to realize the advantages of app-based carpooling mentioned above. For example, Bay Area Rapid Transit District (BART) recently implemented an Integrated Carpool to Transit Access Program, a partnership with Scoop to provide access to and from BART stations using 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 partnerships 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-and-last mile access, the CIF program explores the possibility of using Scoop to replace transit to meet the demand 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 US have also launched policy experiments that integrate other forms of shared mobility, including TNC companies (Pierce County, WA), microtransit (Los Angeles, CA, and King County, WA), bike-sharing (Chicago, IL), and other emerging options (Federal Transit Administration 2019). Preliminary analysis suggests that these programs generate promising outcomes (Rodriguez 2020). However, much research is needed to examine comparatively the impacts of these new partnerships on traveler's mode choices, especially how and why different population groups choose different mobility options (Watkins et al. 2019). And this study is an attempt to generate findings that could be useful for developing a synthetic view of various policy experiments.

CIF program, data, study region, and methodology

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 agencyin the Seattle region, worked with Scoop, a dynamic carpooling service provider, to incen-tivize the use of carpooling among commuters. The program offered up to $2 incentive to every participant of each carpooling trip carried out through Scoop from December 2018 to April 2019.[1] A $2 incentive is likely to be a substantial amount because, in our data, the average cost for using Scoop is $6.1 per rider for each trip (with median = $6 andSD = 1.42). It means that after the incentive, riders pay about $4 on average, which is onlyslightly 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 only available for commuting trips, and only at selected work locations in the Seattle area. It matches carpool trips among participating commuters 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. This means that when the algorithm is not able to match the user as a rider or driver, it can attempt to match users in the other role. Riders with close-by origins and destinations may share the ride, together with the driver.

This research integrates two types of data. The first is 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 to 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 the incentive of a $25 Amazon gift card to five respondents randomly drawn from all respondents. We received 342 survey responses. These two datasets together contain rich information that enabled the research team to develop statistical models and assess the performance of the CIF program using quantifiable outcome measures. One important thing to note is that both trip data and survey data capture the early adopters of the app-based carpooling. Therefore, we do not claim that our findings from the two datasets are necessarily representative of all the commuters in the Seattle region. The research findings should be interpreted with caution.

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 ACS 5-year estimates, 62.3% of the commuters in the region drive alone to work, 13.6% of them take public transit, and 7.0% 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 employer centers. The region's average commuting time went up from 26 min in 2010 to 30 min in 2018 (US Census Bureau 2018). Second, the state of Washington

[1] The amount of incentive for each carpooling trip = (up to $2) * (driver + number of riders). All drivers and most of the riders received $2, while a small proportion of riders received $1 (mean = $1.87).

Table 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

has a Commute Trip Reduction law that requires employers with more than one hundred employees to implement travel demand management policies that reduce the use of SOV (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. Thus, we asked the respondents to report whether HOV lanes are available on their commuting route.

In the previous section, we identified four questions that this paper aims to address, including the general characteristics of the carpooling trips, the extent of substitution between carpooling and SOV, the impact of the incentive fund on the travel behavior of individual users, and the impact on total 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. Since Scoop came to Seattle long before the King County Metro incen- tive program, we developed two models, one for the impact of the 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 estimate the impact of the incentives on regional VMT. These statistical analyses allow us to test several hypotheses:

1. The emergence of Scoop has encouraged commuters who are prone to choose SOV to carpool instead, and such an effect is conditioned on the 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 total VMT of Scoop users.

Results

General characteristics of app-based carpooling trips

There was a rapid growth in the number of carpool trips during the time when the program was implemented (Table 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 is shared by three or more people. This level of occupancy is likely to be substantially higher than that for TNCs. For example, in their study of over 400 TNC trips in Denver, Henao and Marshall (2018) estimated the average vehicle occupancy to be 1.36. If the level of occupancy observed in Denver were representative for all TNC trips, it would strongly support our belief that carpooling is a form of 'deep sharing' and has a greater potential to reduce vehicle use than TNCs. The average trip length is consistently greater than 11 miles while showing a gradual trend of decreasing, indicating an expanding user base from long-distance commuters to shorter-distance commuters. We further examined the spatial distributions of Scoop trip origins and distributions using GIS. The spatial patterns are visualized and discussed in Appendix 1 in the supplementary material.

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 secondly, 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 participants of carpooling may be drawn from different modes: some may previously be SOV drivers, others may previously rely on public transit, biking, or walking. Therefore, the overall impact of this new mobility service is not pre-determined; instead, it is an empirical question to be answered based on data.

Figure 1 visualizes the changes in the commuting mode from 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 use Scoop. If we define primary commuting mode as the mode chosen for more than 50% of one's commuting trips, 198 out of 342 (58%) respondents reported using SOV as their primary mode before using Scoop, whereas only 30 (9%) reported so after using Scoop. For transit, the number was 84 (25%) versus 25 (7%). Scoop also supplanted other modes such as other types of carpooling, biking, and walking. Therefore, among the commuters who adopted Scoop carpooling, the substitution effect on other modes was strong. Note that although telecommuting was not as common a commuting option as SOV or transit, its frequency also decreased after Scoop became available, indicating that Scoop could induce travel.

We further examine the substitution effect of Scoop on SOV with regression modeling, which helps us to control for other factors that affect behavioral changes in commuting. Our model specification is guided by the conceptual framework for studying carpool-ing that was identified in our literature review. Table 2 lists all the variables we quanti-fied based on the survey and included in our regression analysis. Most of the variablesare either binary or categorical. We presented the summary statistics in Appendix 2 in the supplementary material.

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 is survey respondents that reported no changes or increased SOV usage. For respondents that reported a reduced SOV usage, we differentiated the extent of reduction into two levels, *slight decrease* and *substantial decrease*. Table 3 below shows how we differentiated *slight decrease* and *substantial decrease*.

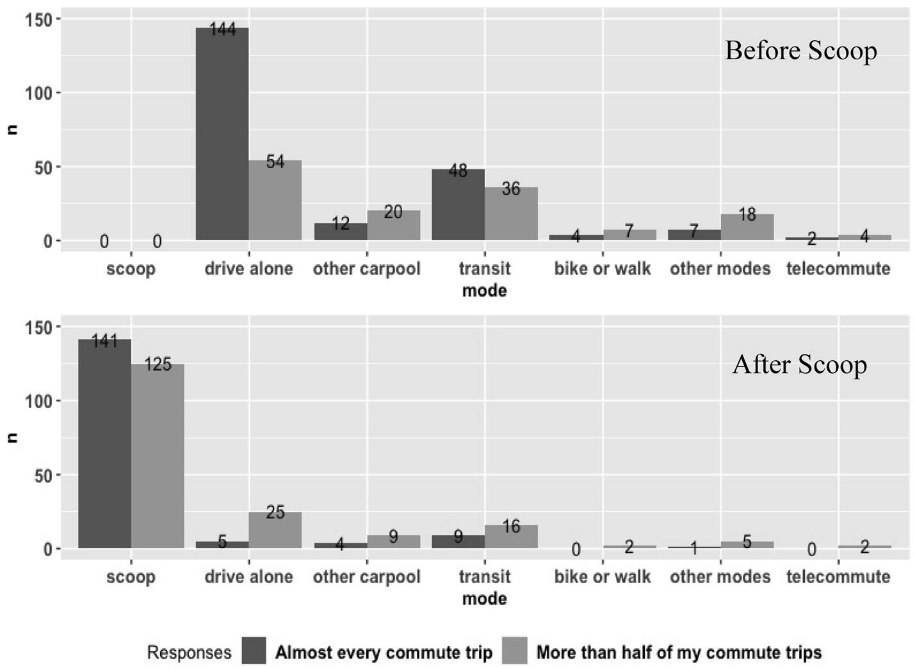

Fig. 1 Change in commuting mode: before and after the Scoop (n = 342). *Note* The data is collected by asking the survey questions "before you started using Scoop, how frequently did you commute using the following types of transportation in a typical month?" and "after you started using Scoop, how frequently did you commute using the following types of transportation in a typical month?" (The original survey offers 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 visualize the number of responses to the first two choices.)

For the independent variables, we included variables that cover all four groups of factors identified by Neoh et al. (2017), i.e., social-demographical, situational, intervention, and judgmental factors. The effective sample size is 265 for the model because of missing values in some variables. We adopted the multinomial logistic regression that is well-suited for categorical outcomes. We present our estimated Model 1 in Table 4, which shows how these independent variables are associated with Scoop's substitution for driving alone. We ran models using all the variables listed in Table 2, but only presented the statistically significant variables in the final model reported here. The results were robust when we tested alternative model specifications.[2] We also present the estimated odds ratio for each coefficient in Appendix 3 in the supplementary material for easier interpretation.

Model 1 illustrates how different groups of people change their driving behavior when a new commuting option, Scoop, became available. A positive estimate in Model 1 indicates a greater likelihood to reduce driving alone and join or increase the use of Scoop carpooling. As expected, the mode shift is conditioned on the commuter's socioeconomic status. Female drivers reported that they are less likely to substantially decrease driving, probably due to their family obligations, or due to their concerns for carpooling safety. Commuters

[2] We also tested an ordinal logistic regression model, and the estimated results are consistent. We choose to present the multinomial logistic regression here because the proportional odds assumption for the ordinal model may not be met, and besides, multinomial logistic regression tells us a much richer story.

Table 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	Ordinal (k=3)
		No change or increase	
		Slight decrease	
		Substantial decrease	
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 3 Coding the change of SOV usage associated with Scoop (black arrow indicates the change of SOV usage before and after the Scoop was available)

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
	————	——→		
		————	——→	

Table 4 Estimating mode substitution of Scoop for SOV

	Model 1: Scoop impact model					
	Dependent variable					
	Change in SOV usage after Scoop came in					
	Slight decrease (ref. = no change or increase)			Substantial decrease (ref. = no change or increase)		
	Est.	SE	Sig.	Est.	SE	Sig.
Gender (female = 1)	– 0.434	0.374		– 0.710	0.322	**
Age: 35–44 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					

*$p<0.1$; **$p<0.05$; ***$p<0.01$

who are between 35 and 44 years old are more likely to slightly reduce their SOV usage compared to the reference group, commuters who are below 35 years old. However, commuters who are 45 or older are not significantly different from the reference group. Moreover, single people are 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 is associated with a higher number of cars owned by the household and stronger needs for driving. Having more cars in the household seems to increase a commuter's flexibility to join carpooling, significant at the .05 level for a slight decrease of SOV and the 0.01 level for a substantial decrease of SOV. Among people who have strong needs for driving (i.e., *Needs for driving = 1*), some may not consider driving alone as a cost-effective choice, and thus tend to take the opportunity to reduce the cost by serving as a driver for carpool while still meeting her/his own transportation needs. And finally, people who care most about the environment are more likely to switch from SOV to Scoop carpool and substantially decrease their driving. This relationship is significant at the 0.05 level.

It is also worth mentioning that, the estimated model shows that the extent of reduction in driving alone is not significantly different across income groups. This result is consistent with previous literature, which suggests that income level influences the usage of carpooling mostly through automobile ownership (Neoh et al. 2017, 2018), which has already been controlled for in the model. It might also be due to the fact that most Scoop users in our sample are middle-income or high-income. Thus, this variable captures limited variation. Also, the results suggest that the availability of HOV lanes do not have positive effects on the propensity to join Scoop carpooling. This result is also broadly consistent with several previous studies, which indicate that HOV lanes have limited power in attracting carpooling as they often offer little tangible time-saving to commuters (Neoh et al. 2017; Buliung et al. 2010).

As shown in Fig. 1, the mode substitution effect of Scoop is more evident on SOV than on other modes (e.g., public transit, walking, biking). Similarly, Model 1 also indicates that Scoop is more appealing to people with more cars and greater driving needs. Therefore, the empirical results reveal the desirable characteristics of app-based carpooling as a competing commute mode to SOV, which supports policies that promote this kind of shared mobility services.

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 uncer-tainty (both are components of generalized travel cost) for 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 are expected to increase the mode share for Scoop carpooling, as long as their value is greater than the transaction cost of shifting travel mode.

Our survey suggests that the monetary incentive offered by CIF attracts many survey respondents to increase their usage of Scoop carpooling, though there is heterogeneity regarding the extent of increased use. Note that for this part of the analysis, we exclude the responses that had already used Scoop for almost every commute trip prior to the incentive, because there is no extra room for them to increase the usage of Scoop. Figure 2 visualizes the self-reported impact of the monetary incentive on survey respondents. Nearly one-third of the respondents (31%) reported that they increased the use of Scoop more than 4 trips per week. A substantial number of respondents showed an increase of 1–3 trips per week (18%) or a slight increase with less than 1 trip per week (25%). 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 affect- ing such heterogeneous responses to the same amount of incentive offered. Thus, we ran another series of multinomial logistic regression modeling. This time, the dependentvariable is a three-level categorical variable indicating the extent of increased usage of Scoop due to the incentive. It took the group that reported *no change* in Fig. 2 as the

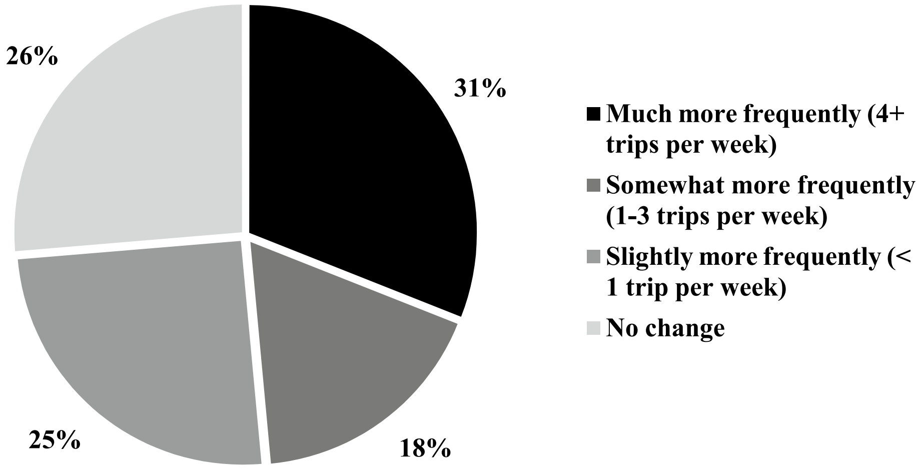

Fig. 2 Change in the frequency of Scoop usage after the incentive (n = 171). *Note* The data is collected by asking the survey question "How has the average $2 incentive provided by King County Metro on your Scoop trip changed your commuting behavior?"

Table 5 Estimating the impact 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.	SE	Sig.	Est.	SE	Sig.
Scoop	– 0.033	0.415		1.421	0.515	***
Age: 35–44 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					

*$p<0.1$; **$p<0.05$; ***$p<0.01$

level for the reference group and took the group that reported *much more frequently* as another level, named as *substantial increase*. For the third level, we combined *slightly more frequently* and *somewhat more frequently* in Fig. 2 and named this level as *moder- ate increase*. The independent variables are the same as those in Table 2 plus a variable *Scoop* indicating whether the respondent used Scoop as his or her primary commuting mode prior to the KCM incentive.

Our model confirms that users' sensitivity towards the monetary incentive is conditioned on a variety of factors. Model 2 in Table 5 presents the estimation results, where only significant variables are included. Again, we present the estimated odds ratio for each coefficient in Appendix 4 in the supplementary materials for easier interpretation. First of all, the incentive has a stronger impact on those who had adopted Scoop as their primary commuting modes, and the effect is significant at the 0.01 level. We find that people's reactions towards the monetary incentive depend on their age. In particular, people who are 45 years old and above are less likely to moderately increase (significant at 0.05 level) or substantially increase their Scoop usage (significant at 0.1 level). People with strong needs for driving are more sensitive to the incentive, which confirms our previous finding that Scoop functions as a viable means for those who have to drive to share the cost of driving. Finally, people who care about the cost are more easily to be incentivized. They are likely to moderately increase their Scoop usage (significant at 0.05 level) or substantially increase the usage (significant at 0.01 level).

Impact of the monetary incentive on total VMT of the Scoop users

Aside from the impact of the monetary incentive on individual travel behavior, this paper is also interested in the group-level effects of incentive measured by quantifiable aggregated metrics such as total vehicle miles traveled. Particularly, among all the travel demand management options available to a typical public transit agency, is the shared mobility public–private partnership, as illustrated in the case of the CIF program, a cost-effective option? Therefore, we combine the information from the trip data and the survey data, and used the following steps to estimate the impact of the incentives on total VMT and the average cost per VMT reduced:

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 these increased Scoop trips. Using information obtained from these two questions, we calculate the number of trips being replaced by Scoop for each mode as a result of incentive;
2. We aggregate the numbers to get the share of trips of different modes that are replaced by new Scoop trips in the entire survey sample (N = 342);
3. We apply this share to the trip data (N = 204,979) and estimate the number of trips being replaced by Scoop for each mode throughout the entire pilot period. This process assumes that the survey respondents are representative of all users in the trip data;
4. By applying an estimated trip distance (as shown in Table 6) for each travel mode and assuming the corresponding changes in vehicle occupancy, we estimate 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 will result in the net decrease in the VMT because Scoop has an average occupancy of 2.4. However, a switch from walking/biking or transit will lead to a net increase in VMT.

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 6 shows our assumptions for each scenario. Scenario 1 assumes that all modes being replaced by Scoop have an equal trip length, which tends to underestimate the total VMT reduced. Scenario 2 instead assumes heterogeneous trip lengths for different modes. The scenario assigns the longest Scoop trips in the trip data to replace driving alone and other carpooling, and assigns

Table 6 Estimating the net impact of the monetary incentive on regional VMT

	Scenario 1: base scenario	Scenario 2: considering heterogenous trip lengths	Scenario 3: considering extra travel distance of carpooling
Notes	Assuming all modes have an equal travel distance	Assuming different modes have different travel distance	Carpooling may add additional VMT to pick-up and drop-off the riders
Mode replaced	Change in VMT	Change in VMT	Change in VMT
Drive alone	− 1,016,184	− 1,107,062	− 948,916
Public transit	109,953	25,851	31,020
Uber/Lyft	− 46,662	− 18,472	− 15,395
Other carpooling	0	0	0
Employer bus	5065	1628	1955
Walk/bike	23,455	2250	2700
Total	− 924,373	− 1,095,805	− 928,635
Cost per VMT reduced	$0.41	$0.35	$0.41

the shortest to replace walking/biking and public transit, and the ones in between to the rest of the modes. By doing so, we tend to overestimate the total VMT reduced. Scenario 3 further accommodates the extra travel distance (i.e., over-heading, estimated 20% of the original trip distance based on Henao and Marshall 2018) resulting from carpooling, as the drivers now need to pick up and/or drop off passengers at different locations. We do not claim that any of our scenarios offers a precise calculation of total VMT reduced, but together they give a reasonable range of estimations. The results are quite similar, suggesting the robustness of this analysis. The incentive provided by King County Metro contributes to approximately a reduction of 900,000–1,000,000 vehicle miles traveled during the experiment period, and the cost per VMT is estimated to be around $0.4. Note that this number only measures the net impact of the incentive on total VMT of Scoop users during the pilot period. It does not capture long-term VMT reduction, which comes from individuals who still use Scoop carpooling even after the incentive is discontinued. Such long-term effects have been reported in previous carpooling incentive program (Shaheen et al. 2018a). Furthermore, this calculation does not account for possible triple convergence, where the congestion reduced by the CIF program may lead to other commuters increasing their SOV usage because the road conditions now get better. Even with obvious limitations, the estimated numbers in this study can serve as a benchmark for comparing the effectiveness of different policy strategies.

Conclusion

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 is thus an exciting case to investigate.

This paper presents a series of quantitative analyses to thoroughly evaluate the CIF program, and the estimated models indicate promising results. Such a program leads to rapid growth of app-based carpool trips, and these trips are more powerful in substituting SOV rather than transit. Besides, app-based carpooling is frequently used by car owners and people with mandatory needs for driving, and thus it provides an environmentally more sustainable option for those who are usually prone to drive alone. Therefore, these results confirm our first hypothesis, and provide evidence-based justifications for transportation policies to support app-based carpooling.

Regarding the performance of the monetary incentive in facilitating carpooling, we find that generally speaking, monetary incentives are effective, but such effects are heterogeneous on different population groups, conditioning on the social-demographical and judgmental factors. We also estimated the VMT reduction achieved with the monetary incentives. The estimated reductions based on three alternative scenarios are generally consistent, and all suggest a substantial effect. These findings strongly support our second and third hypotheses.

However, it is important to note that these findings are based on the assumption that the respondents of the survey are representative of the Scoop users who benefited from the CIF program in the region. It is possible that our survey is prone to response bias, as people who use Scoop more are more likely to respond to the survey. It is practically impossibleto test if such a bias exists because Scoop, like any other private mobility service provid- ers, does not include user's socioeconomic characteristics in its trip data, and Scoop only allowed us to ask a limited number of questions in the survey. Future research on this topicshould aim at collecting more information to help validate the survey representativeness when using both trip data and survey data for analysis.

Several limitations of this type of incentive manifested as our analysis proceeded. First of all, the 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, offers limited insights about how such programs would affect the disadvantaged groups.

Secondly, although our analysis suggests that the CIF program is a promising policy to encourage commuters who are normally prone to drive alone to carpool instead, the incentive admittedly also takes customers away from public transit. Therefore, unless more strategically designed and implemented, such a program may undermine the traditional public transit service.

Finally, this type of incentive policy may 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 paper adds to the relatively thin literature on the collaboration between public transit agencies and private shared mobility companies. Based on 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. Instead of passively watching the share mobility companies (especially TNCs) encroaching the market base of transit systems, our analysis illustrates that public transit agencies should actively take initiatives and strategically partner with selected shared mobility companies. Such proactive efforts can 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 emission, 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 towards mobility-challenged population groups. The CIF program examined in this paper is only one of the many possible directions that public agencies could take to make use of the 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.

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Compliance with ethical standards

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