Seattle's Expanded Mobility Portfolio: an evaluation of two commute-focused pilot programs

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Abstract

Seattle's Expanded Mobility Portfolio: an evaluation of two commute-focused pilot programs

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This thesis explores two cases of private enterprise in the Seattle commuter mode share market: UberHOP and the Employer Shared Transit Stop (ESTS) pilot program. UberHOP is a service similar to vanpooling with fixed pick-up and drop-off locations in the primary commute direction during peak hours, but leverages Uber's ridesourcing platform to replace fixed departure schedules with riders matched in real time. The results of an intercept survey and count data found that many UberHOP riders made UberHOP their primary form of commute mode, and riders predominantly replaced public transportation modes rather than personal vehicles. Although UberHOP services were cancelled in Seattle in August of 2016, with larger rider densities per trip, the UberHOP model can be profitable and environmentally sustainable. Through the ESTS pilot program, the Seattle Department of Transportation (SDOT) and King County Metro (KCM) identified nine bus stops within the City of Seattle for stop-sharing with private shuttles that serve employees of (and are operated by) Microsoft and Seattle Children's Hospital. Through an analysis of real-time transit performance data, the study found that, on average, bus transit reliability has not been impacted by the ESTS pilot program. Based on these cases, it is recommended that public transit agencies engage with private transportation services to ensure quality, sustainable commute options for citizens.

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TABLE OF CONTENTS

List of Tables

List of Equations

LIST OF FIGURES

1. Introduction

In a city with significant geographical constraints and a rapidly growing population (1), traffic congestion has become a major issue; in 2015, Seattle tied with New York City for the fourth worst traffic congestion in the US which is astonishing given that the population of Seattle was just over 650,000 compared to NYC's 8.4 million according to the 2013 American Community Survey (2). To combat this gridlock, the City of Seattle is constantly looking for ways to manage roadway congestion and maintain equitable, quality access to citizens (3). To this end, goals for reducing drive-alone rates during commute hours have been adopted at a state level through the Commute Trip Reduction (CTR) Law (4). CTR requires cities and counties in Washington state "to reduce the number and length of drive-alone commute trips" by working with major employers in their jurisdiction to develop and implement employee commute programs (4). These efforts are incentivized through commuter tax benefits which allow employers to "receive tax benefits for providing certain types of transportation benefits" to employees that encourage non-drive alone commute patterns (5). Additionally, tremendous public initiatives to improve public transit and non-motorized travel options within the city have resulted in the passage of Sound Transit packages and the Move Seattle Levy (6,7).

In addition to the public sector in Seattle, the private sector is also working to provide alternative transportation options to commuters. ReachNow in Seattle has attempted to increase its commute mode share during the AM peak with special flat rates for drivers (8,9). Uber recently offered discounts to commuters who started or ended their trip at a light rail station south of the urban core (10). Beyond simple discounts, however, both Uber and Lyft along with new companies such as Via and Chariot are offering new types of services for commuters. Uber unveiled UberHOP (a service similar to a vanpool) in Seattle, Toronto and Manila and UberCOMMUTE (a service similar to a carpool) in Chicago in 2015 (11). In 2017, Lyft launched Lyft Shuttle (a fixed route, requested stop service) in Chicago and San Francisco (12). Both Via and Chariot are fixed rate, shared ride commute options with Via SUVs starting operations in Chicago, NYC, and Washington DC in 2016, and Chariot Ford Transit passenger vans in San Francisco and Austin in 2016 along with NYC and Seattle in 2017 (13–16). All of these services are branded with the goal of reducing drive alone commutes in order to reduce the congestion and emissions they produce.

This expansion of private services for commuters is generally supported in the City of Seattle. The Downtown Transportation Alliance, while predominantly comprised of public sector executive leadership, also includes private sector representation to support the Commute Seattle initiative (17). Within their resources for individuals and employers, they recommend ride- and carsharing services (collectively referred to as rideshare by Commute Seattle) as a drive alone alternative and count rideshare commutes (9%) towards total, non-drive alone percentages (70%) of commute mode share terminating in Seattle's urban core (18,19). Additionally, while applicable commuter tax benefits include transit passes in most cities, employees at participating companies can also use pre-tax income to pay for UberPool and LyftLine commute trips (20,21). More broadly, employers are also encouraged to provide shuttle services for employees, particularly shuttle services for first mile/last mile links to transit and for routes underserved by transit.

This thesis explores two cases of efforts within the City of Seattle to reduce drive alone commutes: the introduction of a new, private service to the city's commute choice portfolio, and partnerships between local employers and transportation agencies to share transit right-of-way. The first study explores the mode shifts and rider preferences through questionnaire and count data to determine the sustainability and impact of UberHOP, and the second study uses King County Metro (KCM) bus tracking data to determine whether or not the Employer Shared Transit Stop (ESTS) pilot program had a negative impact on transit reliability.

Taken together, these studies suggest that new, private commuter services, if they wish to truly reduce congestion and emissions, must be developed and implemented with some level of public transit partnership. Furthermore, while public agencies should not simply accept any and all service configurations put forward by private transportation companies, it is ultimately in the best interest of public agencies to work with private companies and employers to expand commute service alternatives.

2. UberHOP in Seattle: who, why, and how?

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2.1 Introduction & Overview of UberHOP

Since the introduction and rapid adoption of the smartphone, entrepreneurs have taken increasing advantage of the new business models and service opportunities provided by this technology. Companies such as Uber pioneered the app-based platform for ridesourcing in 2010 and have continued to flourish in this new age of smartphone-enabled transit services; from 2010 to 2014 they expanded from services that solely served the City of San Francisco to services that reach 64% of the entire US population (22). A U.S. PIRG (the federation of U.S. non-profit Public Interest Research Groups) study in 2015 found that ridesourcing services were offered in 59 out of the 70 cities reviewed (23).

As Uber continues to grow, they have tried different variations of and expansions on the basic platform that made them famous, such as UberSUV and UberPOOL. A recent adaptation that looks to meet the needs of commuters specifically is UberHOP. The service operates along designated commuter routes within a city during AM and PM peak periods and charges riders a flat fare to share a ride with up to five other UberHOP riders (24). On December 10, 2015, Seattle, USA became the first city globally to pilot UberHOP with $5 fares for rides along three of "the city's most popular routes" (25). Shortly thereafter, UberHOP also launched in Toronto, Canada with more routes and even cheaper fares than those initially offered in Seattle (26). Shortly after the initial launch, the routes offered in Seattle expanded to twelve and changed again in June, 2016 to the final studied eleven with varying rates for riders (Figure 1). The pricing range also changed during this time: instead of a flat fare for all routes, prices ranged from $2.50 - $4.50 depending on the route (Figure

1) with an added promotion of $1 rides during the month of February, 2016 (27). In April, 2016, the City of Manila in the Philippines became the third city worldwide with UberHOP services (28).

According to the Toronto press release, the goal of UberHOP is to provide citizens with an alternative to single occupancy vehicles (SOVs) so that they can "rely more on ridesharing and less on their personal vehicles to help reduce traffic and congestion" (26). While this is a common goal for cities worldwide, dissenting voices are concerned that UberHOP is "simply one more step towards the Uber-driven privatization of public transit" (29). At the 2016 Transportation Research Board (TRB) meeting, representatives from the public, private, and academic research sectors attended multiple workshops to discuss the present and future effects of shared-use mobility on transportation networks; among other things, the group recognized that "additional research is needed to understand the impact of shared-use mobility modes, in particular on-demand ridesourcing (e.g. uberX, Lyft, Sidecar, etc.)" (30). Given the dramatic growth of ridesourcing services and the disparity between intentions and outcomes, the need for studies that explore all varieties of ridesourcing services and the people who use them is clear.

UberHOP services were cancelled in Toronto at the end of July 2016 (25) and in Seattle in mid-August 2016 (27). Services in Manila were still running as of the end of October 2016 (31). Further, Uber announced in October 2016 that they plan to launch a new service of minivans and buses entitled UberEverything in India which will operate similar to UberHOP but with larger vehicles (32).

Based on an economic analysis of the UberHOP model, having 4 riders per trip or a lower expected driver hourly wage could make UberHOP profitable (see the Discussion section of this paper for further details). Therefore, while the UberHOP model did not succeed in Seattle or Toronto, it may still be a viable model in the correct market. Given this, the exploration of commuter ridesourcing is relevant, especially since it highlights important differences in rider choices compared to existing studies.

One of the most thorough previous studies of ridesourcing users is an intercept survey completed in May and June of 2014 in San Francisco, which revealed a great deal about the demographics and motivations of ridesourcing users. In that study, two of the top three reasons for choosing a ridesourcing platform over another mode were related to trip time (33). The study found that in most cases, ridesourcing or taxi services provided faster trip times than comparable transit services and that riders predominantly utilized the ridesharing service in place of a taxi trip (33). The survey was completed during late afternoon and evening hours in three areas of the city (The Marina, North Beach, and The Mission) and provides a look at the implications of ridesourcing mode shifts primarily for evening, leisure activities of young professionals. This is consistent with a recent study by the American Public Transportation Association (APTA), which found that standard ridesourcing services (Uber and Lyft); are mainly used for "social trips between 10pm and 4am" (34). Both reports clearly demonstrate the competition between ridesourcing and taxi services, and both reports conclude that ridesourcing services, in general, replace personal vehicle trips and complement existing public transit services.

UberHOP, however, focuses on applying "real-time ridesharing" (35) smartphone capabilities to commute trips. In 2011, multiple companies tried to leverage real-time ridesharing application technology to provide "formalized flexible carpooling" (35) within the Seattle Metro Area (SMA). The state funded a pilot program that targeted commuters crossing the I-520 toll bridge with a real-time ridematching application developed by a company called Avego; Zebigo was a start-up within the SMA that launched a similar, less targeted app; and the Washington State Department of Transportation (WSDOT) also invested in a ridesharing website for the state (36). Neither Avego nor Zebigo were able to recruit a "critical mass" of drivers and riders, and while Avego attempted to narrow its focus to more-targeted I-520 commuter pick-up and drop-off locations (specifically those frequented by "tech-savvy" Microsoft employees) to obtain necessary rider density, neither company appears to have lasted more than a year (36). Despite the failure of these real-time ridematching services, WSDOT still maintains the ridesharing website as a state-wide, formalized, carpooling program in an attempt to provide commuters with an online, pre-arranged ridematching option for those looking to carpool (37).

UberHOP is a ridesharing service that bears resemblance to (but is not) a vanpool or carpool service. While the pick-up location is pre-established, the departure time is not (35). Additionally, while it bears some similarities to real-time ridesharing, the service relies on paid drivers rather than fellow commuters to provide the ride. Furthermore, UberHOP is an inherently different form of ridesourcing service that is distinct from baseline ridesourcing services (e.g. UberX) and serves different trips than those highlighted by existing studies; it only operates during commute hours, along designated commuter routes, and only in the direction of the majority of commuter traffic. This is a new type of ridesourcing service, and as a result, there are no studies to date that consider its effects.

This study addresses the present lack of information relative to the types of people and vehicles of which this service is composed in order to begin to understand the implications of the new, unique form of urban mobility that is UberHOP.

2.1.1 UberHOP: What it is and how it works

Within the classification scheme presented by Chan and Shaheen in 2012 (35), UberHOP is a vanpool hybrid; it functions within the context of commuting centers, but breaks the traditional rigidity of prearranged departure times with the use of real-time ridesharing application technology (35). UberHOP in Seattle brought commuters from various neighborhoods within the city to major employment centers in Downtown, South Lake Union (SLU where the Amazon campus is located), and SODO (where the Starbucks Headquarters are located).

The app promises a ride every 10-min along any route within the UberHOP network. To achieve this, when a rider requests a trip along a HOP route, the app will either match that rider with an existing HOP trip or will request a new vehicle for that rider. To do this, the app assumes that the rider will walk to the pick-up location from his/her existing location, calculates the walk time necessary for the rider to reach the pick-up location, and determines whether or not the rider can make it to an existing HOP ride. This, of course, assumes a previously-requested HOP trip is in progress. If no other rider has requested a HOP ride within the past 10-min, a new request is generated and the 10-min clock begins. In this way, HOP trips do not run with pre-determined departure times, headways, or riders, but only when requested.

The Uber smartphone app only offered the option to request an UberHOP ride in Seattle during the hours of operation (7AM-10AM and 4:30PM-7:30PM) and during those hours, routes were only presented in the primary commuting direction. The user interface and the multi-step process that was required to request an UberHOP trip are shown in Figure 2-1.

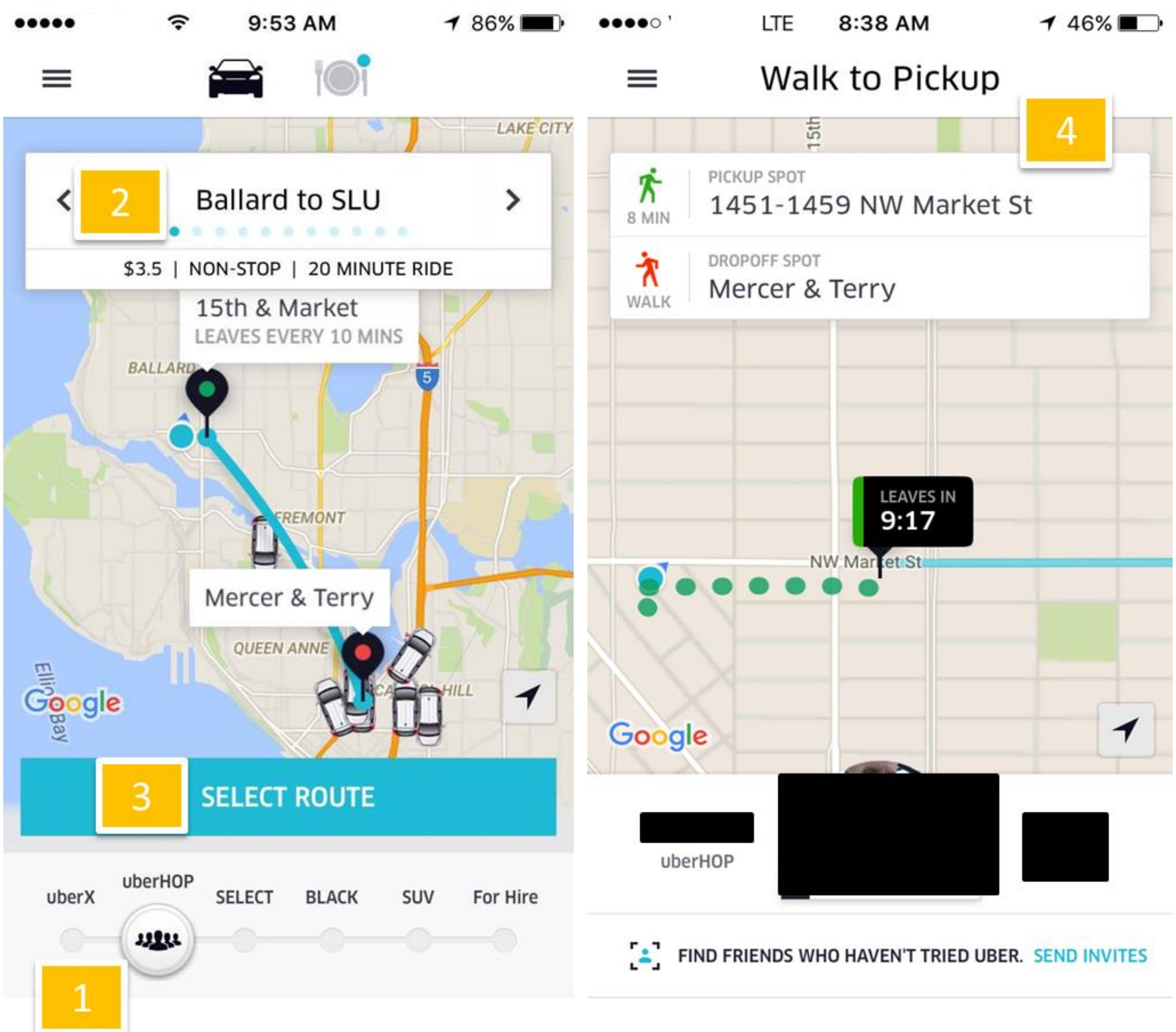

Figure 2-1. The user interface and steps to request and UberHOP ride during the AM peak commute period

2.2 METHODS AND DATA

The primary source of data regarding UberHOP riders and their preferences was obtained via a questionnaire administered through an intercept survey. In the process of administering this survey, additional data was collected regarding the total population of riders and vehicles in a trip log count sheet. Data were collected over the course of 16 UberHOP shifts (AM and PM) in order to administer surveys along all 22 routes (11 routes during AM and PM). This yielded 83 survey responses and observations of 133 trips carrying 165 riders; of the UberHOP riders approached, 83% completed and returned the survey and those respondents, 37 (45%) of rider trips were observed twice or more. Each respondent only completed the questionnaire once; when approached, a rider was asked to identify whether he/she had taken the survey previously and all responses along with total ridership and trips were logged in the count sheet.

2.2.1 SURVEY INSTRUMENTS

The survey instrument was a two-page paper questionnaire that covered the respondent's transportation habits, preferences, and demographic information. Respondents were asked the purpose of the present UberHOP trip, the origin and destination of the trip and how they traveled to/from the HOP pick-up and drop-off locations; respondents were asked to provide the nearest cross-streets, not addresses. Beyond this, respondents were asked their usual mode for the given route as well as the mode they would have used if UberHOP were not an option that day. Questions were worded without technical jargon and focused on the present situation (the ride they were taking at that moment) to maintain clarity and simplicity and to reduce hypothetical bias.

Respondents then rated each of 16 factors on a scale of 1 (not at all important) to 5 (very important) for how important each factor was when considering whether to ride UberHOP or an alternative mode. These factors were based on those previously identified in the 2014 San Francisco ridesourcing study, but were adapted to make them more relevant to commuters (33).

Demographic questions and response options mirror those given in the American Community Survey (ACS) and the Puget Sound Regional Council (PSRC) Regional Travel Study.

Additionally, a count sheet was developed to track HOP trips observed during data collection. This sheet considered the make and model of each HOP vehicle, the number of male and female HOP riders, and the departure times for any given HOP route. Notes for each trip were also maintained such as when a rider refused a questionnaire and if a rider had previously completed a questionnaire.

2.2.2 Data Collection

Two main types of data were collected: count data on vehicle trips and ridership for *all* routes starting from the same origin on a given day; and a survey of riders on a *specific* route (the "study route"). Data were collected on Mondays, Tuesdays, Wednesdays, and Thursdays during the AM and PM UberHOP operating hours between June 8th and July 12th, 2016 for a total of 10 observation days. Fridays were excluded from the study to control for summer riders leaving the city early for weekend activities. The 22 total routes (11 in the AM and 11 in the PM) were studied over the course of 9 morning shifts and 7 afternoon shifts.

To survey riders, a graduate student researcher approached potential riders at the route's pickup location with a questionnaire on a clipboard and invited them to complete it during their trip. An undergraduate research assistant waiting at the drop-off location met the HOP vehicle and retrieved the completed questionnaire(s) at the end of the trip.

Count data were collected for the study route plus all other HOP rides that originated at the same pickup location as the study route; because many of the stops served multiple routes (see Figure 2-2), the count data includes riders who confirmed their HOP route but were not asked to complete a questionnaire.

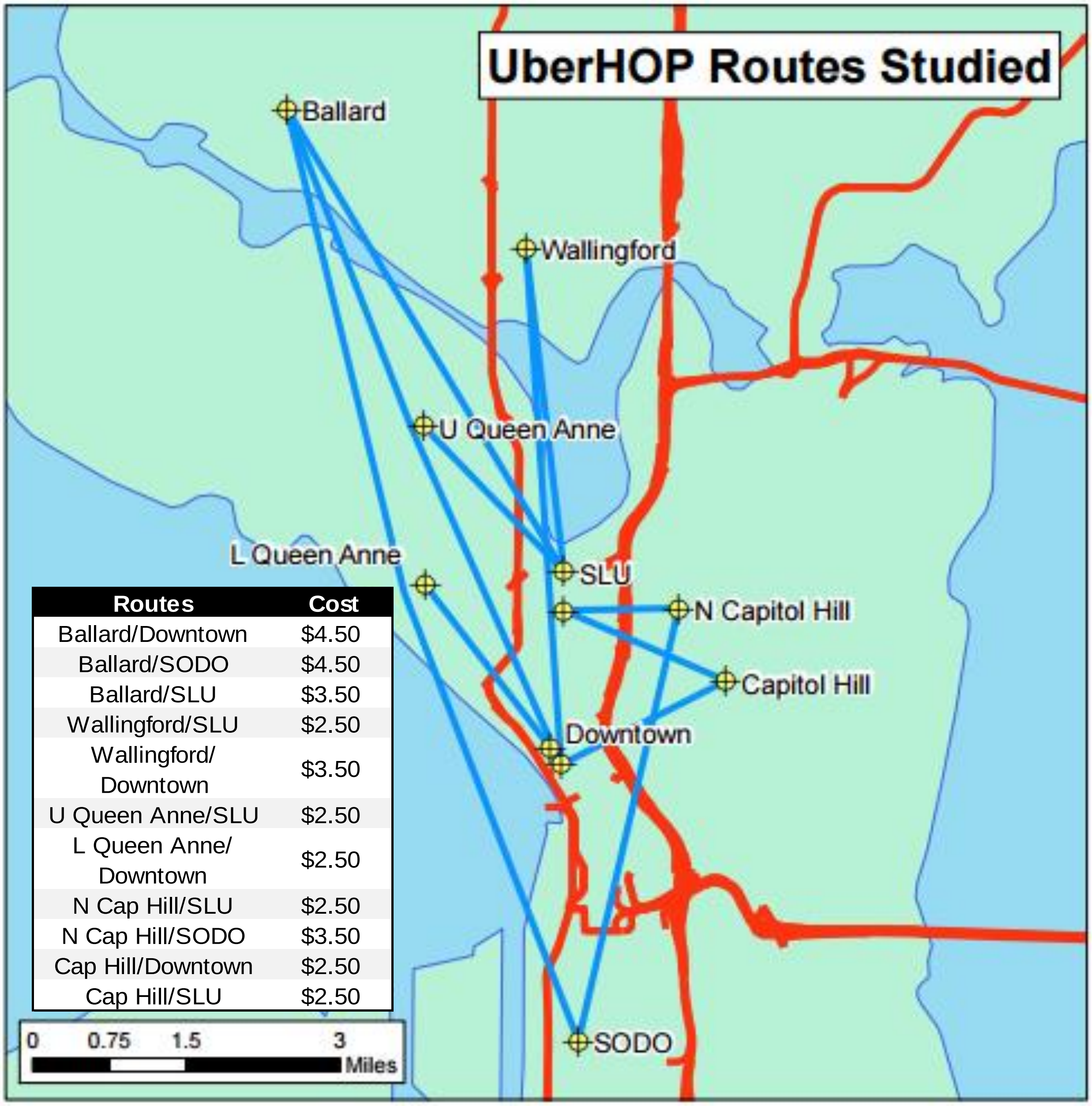

FIGURE 2-2. June 13, 2016 - Present UberHOP routes considered in study
Basemap generated from publically available geospatial data files from WSDOT (38) and the PSRC (39)

With this method, 100 out of the 127 unique riders were invited to complete the questionnaire; of these, 86 accepted the questionnaire and 83 completed questionnaires were returned, corresponding to a response rate of 83% (See Table 2-1); the disparity in accepted and completed questionnaires is due to three surveys that were lost en route. Of the 14 riders on a study route who did not accept a survey, these were generally riders who arrived at a car shortly before it departed and the graduate student researcher either did not have time to approach, or the rider was in a rush and unreceptive to the survey. As the research team gained experience, it was possible to study multiple routes (originating at the same location) in a single shift.

TABLE 2-1. Summary of count and survey data for UberHOP vehicles, trips, & riders by route

Routes	Days Counted (AM or PM = 0.5)	Count Data							Survey Data	
		Vehicles				Total Veh. Trips	Total Rider Trips	Unique Riders	Completed Questionnaires	Riders Asked to Participate**
		Hybrid	Pick-up	S/C/M*	Sedan					
Ballard/ Downtown	2	4	0	12	0	16	17	13	9	10
Ballard/ SODO	1.5	0	0	4	1	5	6	4	1	3
Ballard/ SLU	2	3	0	23	6	32	45	32	21	27
Wallingford/ SLU	1.5	0	0	2	3	5	5	5	2	2
Wallingford/ Downtown	2	2	0	4	3	9	12	10	7	9
U Queen Anne/ SLU	1.5	1	0	7	3	11	12	9	7	7
L Queen Anne/ Downtown	1	0	0	3	2	5	5	4	4	4
N Cap Hill/ SLU	1.5	1	0	8	2	11	12	10	6	7
N Cap Hill/ SODO	1.5	1	1	5	3	10	12	8	5	7
Cap Hill/ Downtown	2	1	0	2	1	4	5	4	2	2
Cap Hill/ SLU	1.5	1	0	23	1	25	34	28	19	22
TOTAL		14	1	93	25	133	165	127	83	100

*SUV/Crossover/Minivan

**Riders who were asked to complete a questionnaire along the route studied during that shift (rather than all riders observed on study and non-study routes)

Note: since HOP riders logged O/D cross-streets as opposed to specific addresses, many O/Ds fall in the same location, thus the differentiation by density of O/Ds rather than by points alone

Basemap generated from publically available geospatial data files from WSDOT (38) and the PSRC (39)

Census tract attributes referenced from the KCM Spring 2015 Service Guidelines Report (40) with low-income as defined by KCM (41).

In order to differentiate HOP trips from regular Uber or Lyft or regular carpooling trips, the graduate student researcher spent each shift at the pick-up location approaching anyone near the stop who looked like he/she might be a HOP rider or a driver; anyone waiting near the stop was approached and any drivers who stopped and did not exit their vehicles near the stop were approached. Drivers were approached to avoid the issue of a late rider arriving just before (or sometimes just after) the 10-min countdown finished and missing the opportunity to log a trip. This led to a highly comprehensive trip log data set and high percentage of study route survey coverage. Moreover, this trip log tracked repeat riders.

Finally, real-time trip time data for driving and for transit along each of the designated HOP routes was collected during AM and PM shifts using Google Maps to compare actual travel time options for HOP riders along all routes on multiple days during the study.

Limitations

Although the research team approached virtually all UberHOP passengers using a route on a given day, and obtained completed questionnaires from 83% of travelers along study routes, the overall size of our sample is relatively limited (*n*=83). Nevertheless, the quality of the data set is high and it is highly representative of the total population of HOP trips and riders. Thus, although the sample size is too small to support estimation of regression models (e.g. mode choice models) with large numbers of parameters, we can be confident that the descriptive statistics are highly representative of the population of UberHOP users in Seattle during the study period.

2.3 Discussion of Results

2.3.1 Who rides and How they meet the HOP vehicles

First, the survey responses confirmed a few core assumptions relative to UberHOP as a service: 96% of respondents walked from their trip origin to meet their HOP, 94% walked to their destination from their HOP, and 96% of respondents used HOP for a commute trip. In addition, HOP riders are predominantly white, highly educated, high-income, male millennials (Table 2-2). This is consistent with the neighborhoods of operation and origin/destination (O/D) sheds surrounding HOP stops as shown in Figure 2-3. While the commute destinations of SLU, Downtown, and SODO are located in/near both low-income and minority-dense areas, the income and racial makeup of riders is established by their neighborhoods of origin; with the exception of the Capitol Hill stops, UberHOP only operated in higher-income, predominantly white neighborhoods of Seattle. While these neighborhoods draw some of the lower-income HOP riders, the lowest reported income range by a HOP rider was 50K-74.9K; King County Metro (KCM) defines income status by household size, and a household income in that range would need to house five to seven people to be considered low-income (41). According to Forbes, in 2015 the median household income in Seattle was $73,561 (42); as Table 2-2 shows, the majority of survey respondents fall above this amount.

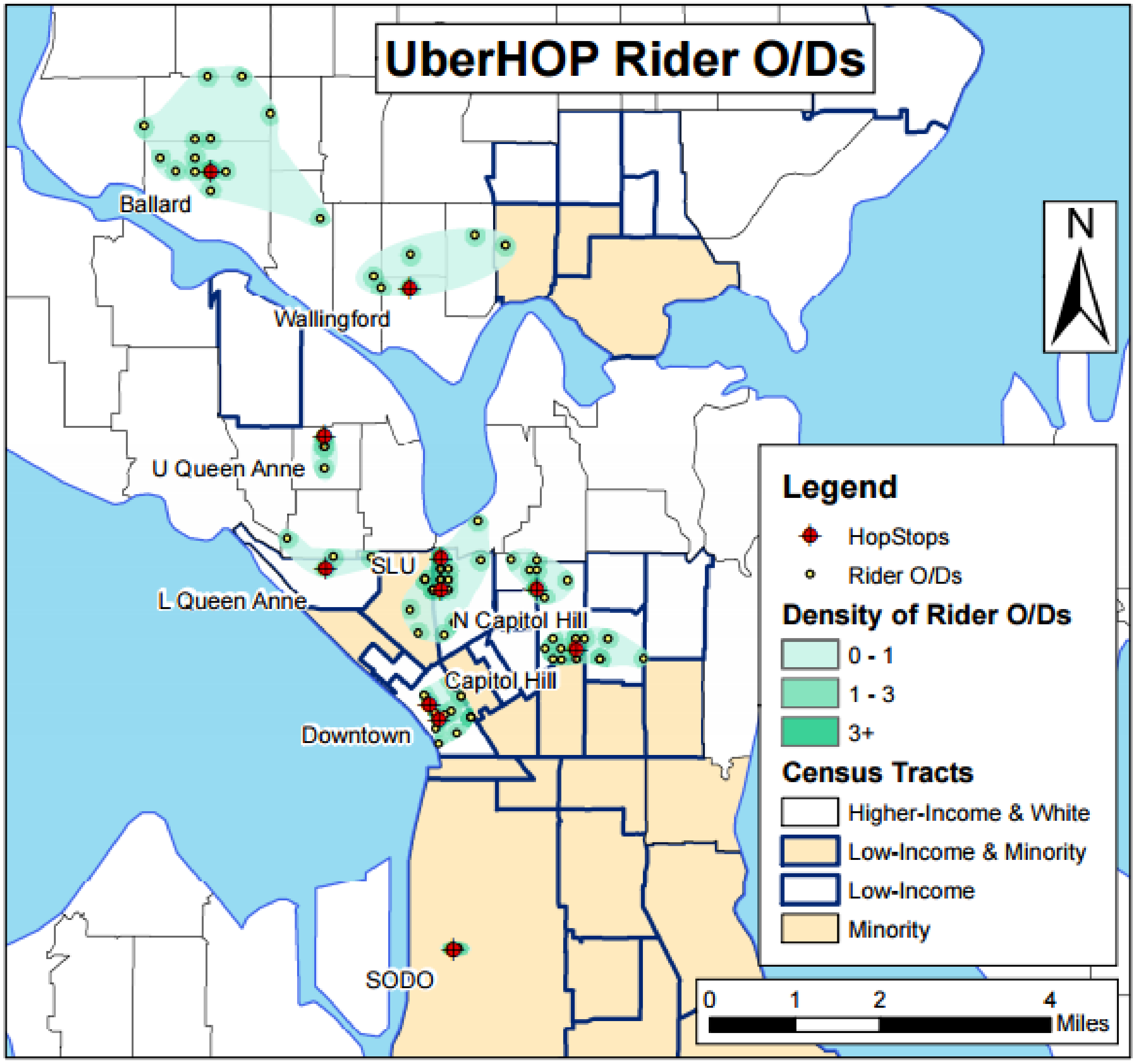

FIGURE 2-3. Origin and Destination (O/D) distributions and densities for UberHOP riders

TABLE 2-2. Demographic attributes and associated primary mode used by UberHOP rider respondents

	Respondents		Primary Form of Transit for UberHOP Route				
	Total	%	UberHOP	Non-Mot.	Transit	SOV/HOV	Other
Gender							
Male	51	68%	28%	11%	17%	4%	8%
Female	24	32%	12%	4%	3%	4%	9%
n	*75*						
Age							
20-24	6	8%	4%	3%	0%	1%	0%
25-30	34	45%	19%	4%	12%	3%	12%
31-34	14	19%	9%	1%	4%	1%	4%
35-40	10	13%	6%	3%	3%	1%	1%
41-44	3	4%	1%	1%	1%	0%	0%
45-50	1	1%	0%	1%	0%	0%	0%
51-54	0	-	-	-	-	-	-
55-60	1	1%	1%	0%	0%	0%	0%
n	*69*						
Race							
White	46	61%	24%	8%	15%	5%	9%
Hispanic, Latino or Spanish origin	5	7%	0%	4%	1%	1%	0%
Black or African Am.	1	1%	0%	0%	0%	0%	1%
Asian	17	23%	11%	3%	4%	1%	4%
Pacific Islander	0	-	-	-	-	-	-
Am. Indian or AL Native	0	-	-	-	-	-	-
M. Eastern or N. African	0	-	-	-	-	-	-
Other	6	8%	5%	0%	0%	0%	3%
n	*75*						
Education Level							
HS/GED	2	3%	1%	0%	0%	0%	1%
2yr Deg.	2	3%	0%	1%	0%	0%	1%
4yr Deg.	34	45%	19%	7%	12%	3%	5%
Graduate Deg.	36	48%	20%	7%	7%	5%	9%
Other	1	1%	0%	0%	1%	0%	0%
n	*75*						
Household Income							
less than $50K	0	-	-	-	-	-	-
$50-74.9K	9	12%	4%	1%	4%	0%	3%
$75-99.9K	19	25%	4%	5%	5%	3%	8%
$100-200K	29	39%	19%	4%	8%	3%	5%
more than $200K	8	11%	5%	1%	3%	1%	0%
No Response	8	11%	8%	1%	0%	0%	1%
n	*73*						

Note: Not all sections sum to 100% due to rounding

2.3.2 *WHY PEOPLE RIDE: STATED MODE CHOICES AND RELATED PREFERENCES*

While the demographics of UberHOP riders are similar to other ridesourcing services, their substitution between modes is different than in previous studies. The APTA study (34) found that ridesourcing services complement public transit, and the study in San Francisco found that 45% would have otherwise used a taxi or driven while 33% said bus or rail (33). Comparatively, as Figure 2-4 shows, if UberHOP were unavailable, 45% said that they would have taken the bus, and a total of 66% would have relied on public transit or non-motorized modes if UberHOP were not available. Just 25% would have used another ridesourcing service or a personal vehicle. Given that the APTA study (34) focused on the recreational nature of the majority of ridesourcing trips, these user trends suggest that UberHOP was replacing rather than complementing public transit for commute trips in Seattle. Beyond this, 40% of respondents reported that UberHOP was their primary commute mode. The trip log data shown in Table 1 corroborate this value and show that, of the 165 total rider trips counted, 74 (or 45%) were taken by riders who were observed twice or more.

The distances that riders were willing to walk in order to reach some of the UberHOP stops (Figure 2-3) along with the stated preferences of HOP riders help to explain the substitution of UberHOP for transit. For HOP locations that were well-connected by public transit such as North Capitol Hill, Upper Queen Anne, and Downtown, riders walk a mile or less from/to their O/Ds. In contrast, Ballard and SLU (the routes with the most riders per Table 2-1) riders walked one to two miles to reach UberHOP services. Given that SLU is difficult to reach without at least one transfer or a long walk, the relatively high stated preferences for "reliability" and "few(er) transfers" support these observations (Figure 2-5).

Traveling by car with UberHOP offered a significant time and financial savings over transit. Figure 2-6 plots the travel times by transit and by driving for the UberHOP origins and destinations. While shorter routes provided transit travel times comparable to travel times for cars, as the distance increases, so does the disparity between the travel time required for the two modes, with some transit times 2.5 to 3 times greater than their equivalent vehicular counterpart. Given this, it makes sense that the "short(er) time spent traveling" ranks as the second most important factor for individuals who choose to ride UberHOP (Figure 2-5). Most importantly, the most important factor for HOP riders was "the low(er) cost of the trip" (Figure 2-5). Since bus fares are $2.75 during peak periods, this makes 6 out of 11 UberHOP routes (including 4 out of 5 SLU routes) less expensive than their public transit alternative. This paired with the lower commute time, reliability, and no transfers made UberHOP a high-quality, desirable commute option.

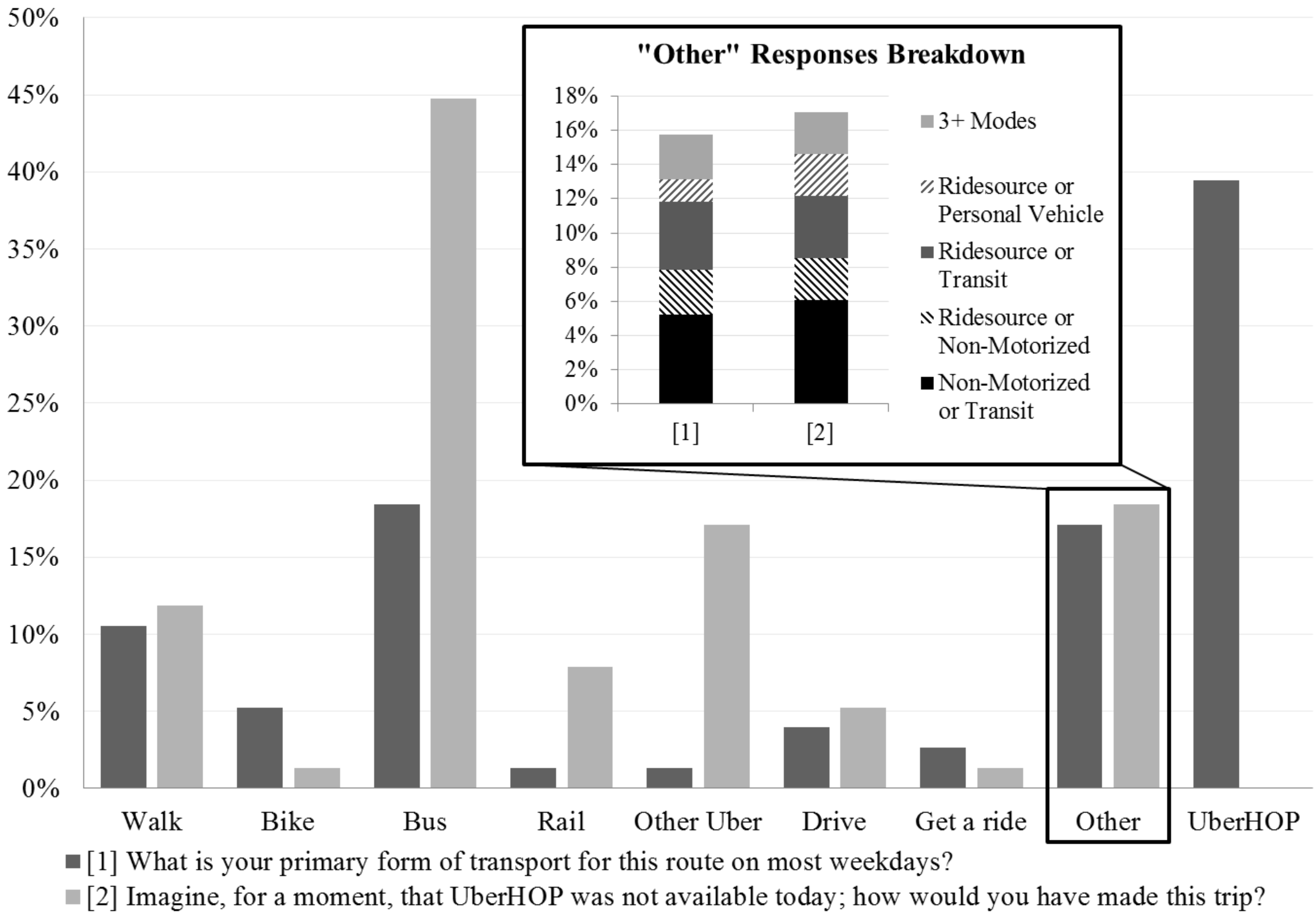

FIGURE 2-4. Stated, regular mode choice in scenarios with or without UberHOP

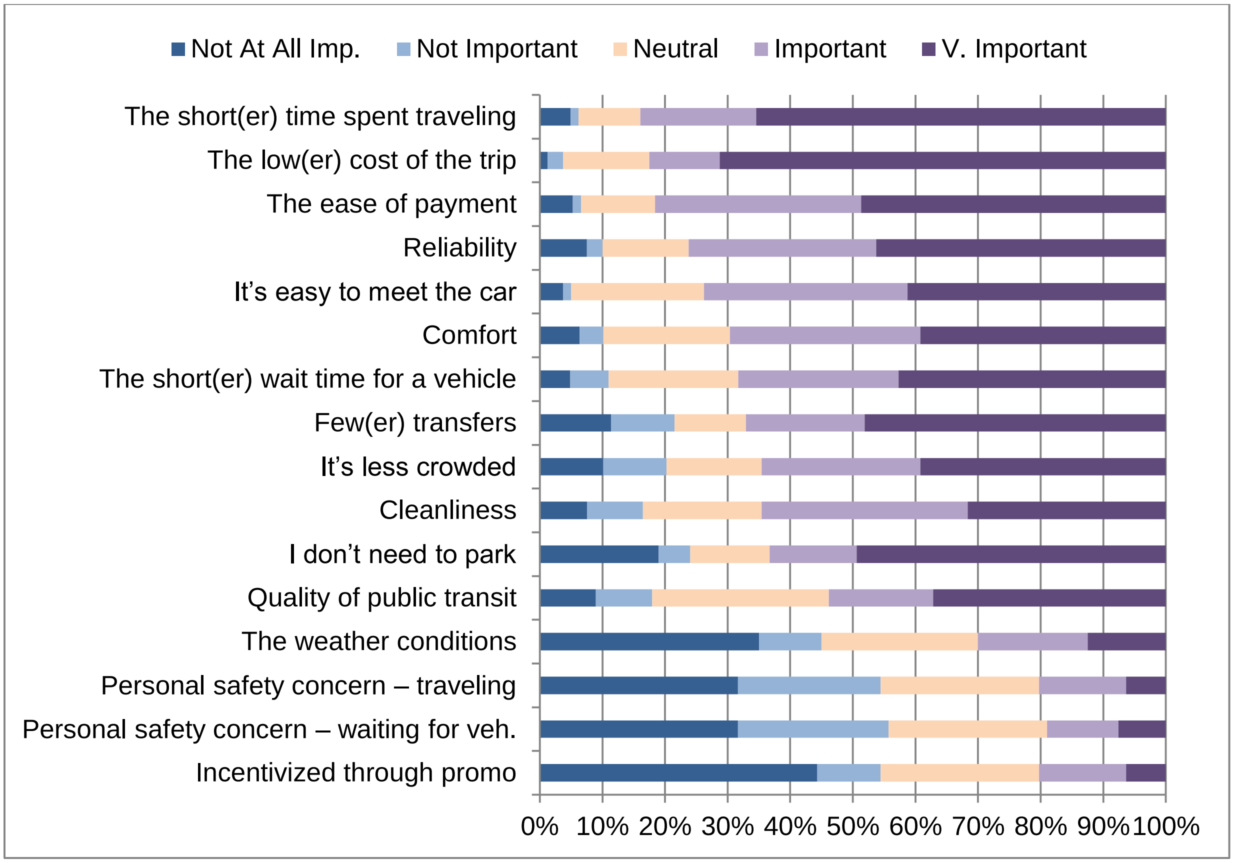

FIGURE 2-5. Stated importance of various reasons for choosing UberHOP.

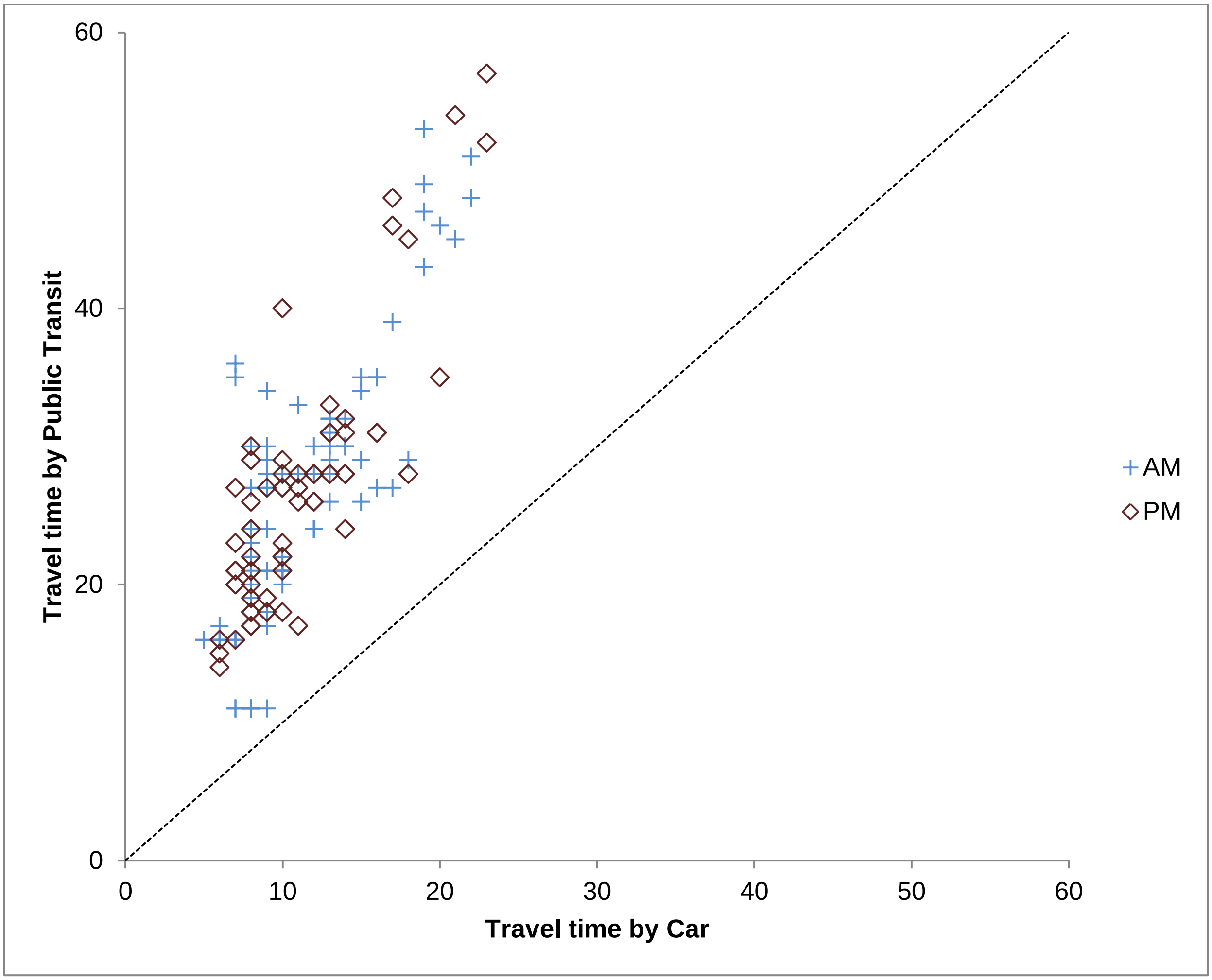

FIGURE 2-6. Travel times along UberHOP routes during hours of operation
Travel times taken from Google Maps during hours throughout multiple HOP shifts

Additionally, KCM has recognized SLU and Downtown as regional growth centers, Ballard (near the existing HOP stop) as a major transit activity center, and generally recognizes that most bus routes in the City of Seattle require additional hours of service to meet present demand (40). Relative to their primary, alternative mode of transit, the HOP attributes of "comfort", "the short(er) wait time for a vehicle" and "it's less crowded" fall in the top half of importance for respondents (Figure 2-5). Given these rider values combined with the top concerns for travel time and cost among current HOP riders, the present appeal and subsequent shift of riders from public transit services to HOP makes sense; commuting in a private vehicle with a guaranteed seat for less time and less money (in many cases) is simply more attractive to riders.

General UberHOP Observations

Given the high rate of return riders and relatively small collection of regular drivers, UberHOP established a small community of commuters familiar and happy with the service; HOP drivers consistently enjoyed the guaranteed hourly wage and HOP riders added many positive, exclamatory remarks to the "other" sections of the rider perceptions portion of the survey. However, beyond this core community of HOP riders and drivers, both UberX users and drivers remained generally unaware of or confused by UberHOP.

Over the course of the survey, on occasions when UberX drivers provided a HOP ride, drivers were often perplexed and upset by the 10-min wait time associated with a HOP ride and also had a tendency to pick-up or drop-off at locations slightly different than those designated by the app. Since most pick-up locations are in large parking lots or along a busy street, the lack of physical definition led to confusion on many occasions. The SODO stop is particularly susceptible to this issue, because while the designated location is in a specific corner of the Starbucks headquarters parking lot, it happens to be next to a collection of tables typically used for smoke breaks. Additionally, the presence of many different Uber, Lyft, and taxi services in the same, large parking lot make this location confusing for all parties.

2.3.3 Environmental and Economic considerations

Beyond the present and potential loss of KCM ridership, the relative emissions related to UberHOP travel at present are concerning. Given that 68% of HOP trips were taken in an SUV/Crossover/Minivan (S/C/M) (Table 2-1) and that 79% of trips were taken by solo riders, for the majority of respondents (52%) who would have otherwise commuted via public transit (Figure 2-4), their UberHOP commute increases their carbon footprint significantly as shown in Figure 2-7. Further, the 16% of individuals who replaced a solo UberX trip in a sedan or hybrid with a solo HOP trip in a S/C/M also increased their carbon footprints. If UberHOP were to achieve its intended goal of reducing SOV commuter travel, it could reduce emissions with 3 or more riders per trip, even compared with SOV commuting in a Prius. With 4 or more riders per trip, UberHOP's minivans and SUVs could even emit less than a KCM bus with average peak-hour ridership along the city's top 25% busiest routes that correspond to the HOP routes (40).

While UberHOP services were cancelled in Seattle and Toronto, the model itself can be economically viable as well as environmentally beneficial. A quick economic analysis of the most popular route studied, Ballard to SLU, serves to illustrate this. Assuming Uber subsidizes HOP drivers for their time up to the amount of revenue they would expect to receive as an UberX driver (43), as Table 2-3 demonstrates, the UberHOP model can generate positive cash flow for Uber with four or more riders per trip. Furthermore, it can operate without Uber subsidizing the driver's earnings with five or more riders per trip, yielding greater revenue than the UberX model for both Uber and the drivers. For comparison, in 2015 KCM subsidized even its top 25% most productive routes in the city core during peak commuting hours by $0.01 per passenger on average (40,44).

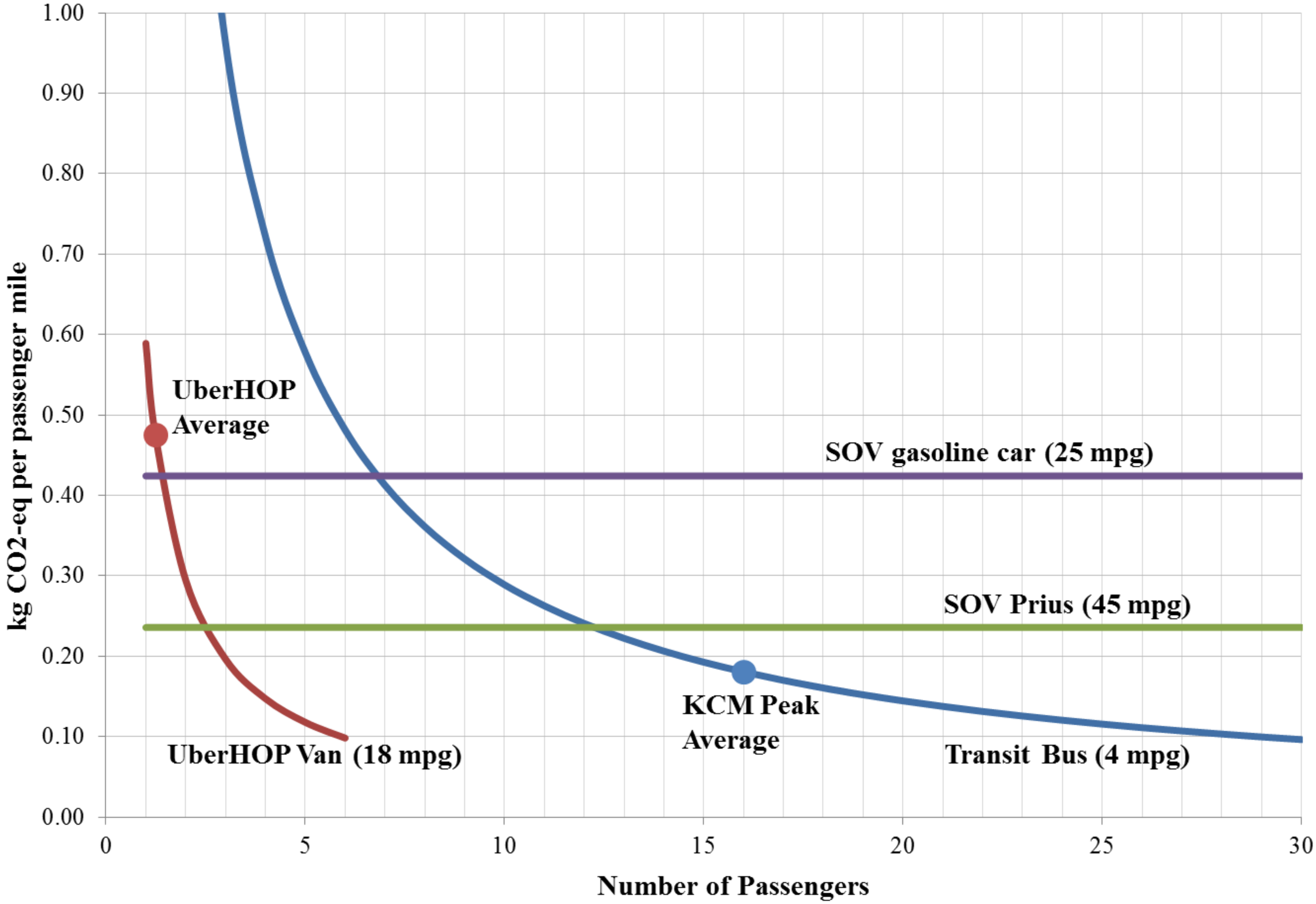

Figure 2-7. GHG emissions and average ridership for commute modes
Curves based on emissions values (45) and 2015 KCM peak hour ridership data (40) along the same routes served by HOP

Table 2-3. Economic viability analysis of the UberHOP model along the Ballard/SLU route

# Riders	Revenue per Trip		Revenue per Hour		Hourly Subsidy (from Uber to Driver)		Net Hourly Revenue for Uber
	to Driver	to Uber	to Driver	to Uber	Total	per Rider	
1	$ 2.80	$ 0.70	$ 5.60	$ 1.40	$ 20.90	$ 20.90	**$ (19.50)**
2	$ 5.60	$ 1.40	$ 11.20	$ 2.80	$ 15.30	$ 7.65	**$ (12.50)**
3	$ 8.40	$ 2.10	$ 16.80	$ 4.20	$ 9.70	$ 3.23	**$ (5.50)**
4	$ 11.20	$ 2.80	$ 22.40	$ 5.60	$ 4.10	$ 1.03	**$ 1.50**
5	$ 14.00	$ 3.50	$ 28.00	$ 7.00	Not Req'd	NA	**$ 7.00**
6	$ 16.80	$ 4.20	$ 33.60	$ 8.40	Not Req'd	NA	**$ 8.40**

Assumptions
Average of three route options given by Google Maps = 4.6 mi
Average of travel times collected in the study during peak periods = 13.7 minutes
Maximum possible given trips only in the direction of commute = two paid trips per hour
Uber commission per trip = 20%
Average driver hourly wage = $26.50
Uber provides an hourly subsidy to guarantee average UberX hourly wage for UberHOP drivers

Values for Uber commission and average driver hourly wage in Seattle from source (43).

2.4 UberHOP Conclusions & Recommendations

UberHOP is a unique take on vanpooling made possible by modern, real-time ridesourcing platforms. For Seattle residents who knew about it, it provided a fast, comfortable, on-demand, and relatively inexpensive commute alternative. While this made it an attractive alternative for those who already relied on public transit and Uber services for commuting purposes, it did not reach its target audience of SOV commuters. Beyond that, while a few routes had consistent ridership (those connected to SLU and Ballard), all routes would need to increase ridership to avoid the present, high rates of solo riders in large vehicles. However, if the growth mirrored current usage patterns, this ridership increase would likely take riders predominantly from public transit modes such as KCM bus routes.

To provide a service that does deliver on the ideals of decreased congestion and emissions, more targeted marketing to SOV drivers would be necessary. Given the on-demand nature of UberHOP, it provides users with a heightened sense of reliability and control and, while similar to a bus, is more intimate and comfortable than a bus. Because of this, it could serve as an excellent gateway alternative to get people out of their personal vehicles for commuting and other trips.

Given that trip cost is the number one factor for the current population of HOP riders (Figure 2-4), developing a rider base from SOV drivers also has the potential to be more stable from an economic perspective. Although the general patterns in traveler response given by the TCRP suggest that ridership in higher-income areas is "typically most sensitive to frequency changes" and that lower-income service areas are typically "more sensitive to fare changes" (46), this rule of thumb likely does not apply to HOP riders. Since current, transit-alternative HOP riders rank "the low(er) cost of trip" as their second most important mode choice factor, even though they are predominantly high-income riders, the existing rider base is likely sensitive to fare increases.

Policymakers facing decisions about whether and how to accommodate UberHOP (or similar services) in their jurisdictions may wish to consider its sustainability in economic, environmental, and equity terms. For the levels of ridership observed in Seattle (1.24 passengers per vehicle), UberHOP's GHG emissions per passenger mile were higher than driving alone in a standard car or riding the bus, and we estimate that Uber would have had to subsidize each UberHOP driver at the rate of about $17 per hour. This suggests that as implemented in Seattle, the service was neither economically nor environmentally sustainable. However, averaging 4 or more passengers per trip would yield positive cash flow for Uber, driver earnings comparable to those available from UberX, and GHG emissions 40% lower than driving alone in a Prius and slightly lower than riding the bus at average, peak occupancy levels (18.4 passengers per vehicle). And while the low cost per trip and time savings were attractive benefits of UberHOP, these benefits were not being captured by low-income or minority riders, likely because UberHOP routes served primarily wealthier and less diverse areas of the city.

Policymakers and regulators may want to work collaboratively with private sector service providers to identify how UberHOP or similar services can best complement and strengthen existing transportation services. In this study, a majority of UberHOP passengers surveyed indicated that they would have taken transit (bus or train) if UberHOP had not been available, while only 5% would have driven. Thus it appears that the service was not achieving to its stated goal of reducing SOV commute trips. And while UberHOP can be economically and environmentally competitive with bus travel at average occupancy rates, its application to high-demand routes in the city core during peak hours means that it was most likely displacing KCM bus trips with the highest ridership. A more collaborative approach might involve [1] looking for opportunities to use UberHOP on routes that are poorly or inefficiently served by public transit, [2] servicing of neighborhoods with a wider range of socioeconomic characteristics, and [3] efforts to ensure that UberHOP vehicle occupancy is relatively high (4 or more passengers per trip) in order to improve economic and environmental sustainability, preferably through targeted marketing to SOV commuters.

While UberHOP failed to develop the ridership necessary to support it in Seattle, the model has the potential to be both economically and environmentally sustainable. As a result, UberHOP and similar commuter-focused ridesourcing models will likely continue to grow in cities around the world. Therefore, more detailed analyses regarding the impact of these services on existing transit networks should be pursued to support educated policy responses to services such as these in future.

3. Private Shuttles and Public Transportation: Effects of Shared Transit Stops on Travel Time and Reliability in Seattle

This chapter is based on a paper jointly authored with Don MacKenzie and Regina Clewlow, pending publication in *Transportation Research Record: Journal of the Transportation Research Board*, in press. Material in this chapter is reproduced with permission of the Transportation Research Board. None of this implies endorsement by TRB of a product, method, practice, or policy.

3.1 Introduction & Overview of Shared Transit Stops

In an attempt to improve private shuttle services provided by major employers for their employees in the City of Seattle, the Seattle Department of Transportation (SDOT) and King County Metro (KCM) began the Employer Shared Transit Stop (ESTS) pilot to "test the feasibility of allowing employer-provided shuttles to use public transit stops while minimizing impacts to public transit operations" (47). On April 24th, 2017 the pilot began, allowing private shuttles operated by Microsoft and Seattle Children's Hospital (SCH) to share nine of eleven bus stops throughout the city of Seattle that were identified for the pilot program (47). Employers pay a monthly fee for each stop in exchange for special signage and permission to use of the public right of way (ROW) as a pick-up and drop-off for employees (48).

Microsoft and SCH both provide private shuttles to employees through their Commute Trip Reduction (CTR) programs. Shuttle fleets are comprised of community buses and motor coaches as defined by the Transportation Capacity and Quality of Service Manual (TCQSM) (49). Microsoft Connector Buses provide an alternative to personal vehicle commuting to their campus in Redmond, Washington located 13 miles from downtown Seattle (50). SCH's 22-shuttle system provides both first mile/last mile connections to the University of Washington (UW) LINK light rail transit hub as well as along underserved routes (51). SCH's CTR program has been particularly aggressive, earning multiple awards for excellence (52).

The ESTS pilot program was met with mixed public opinions. The potential positive benefits include: 1) cost-sharing in the maintenance and upgrades to transit stops, which could result in better quality stops overall; 2) employees using shuttle buses can more easily transfer between private and public transit; 3) formal loading and unloading is safer for all users of the right-of-way; 4) existing transit facilities would have higher overall utilization and improve pedestrian-oriented investments nearby; and 5) sharing facilities could put less pressure on limited curb space throughout the transportation network (53) (54). Negative concerns are mostly related to the existence of such shuttles in general, namely related to their potential to enable gentrification (55) (56). Beyond this, concerns about the shuttle's impact on transit have also been raised in response to the announcement of the ESTS pilot program specifically (48).

The ESTS pilot is a trial to determine what the impacts of allowing private shuttles to utilize public transit ROW will have on transit services. In a review of literature related to bus transit service reliability, reliability was consistently held as a critical passenger priority; arguably only second in importance to "arriving safely at destinations" and that passenger patronage of bus transit is directly correlated to service reliability (57). Moreover, from an operator's perspective, low reliability not only impacts patronage but can contribute "to increased operating costs" as it "impacts the schedule recovery component of cycle time" (49).

Reliability, however, is an ambiguous attribute that is subsequently difficult to quantify and measure. In current practice, reliability is typically quantified as on-time performance (OTP). However, while OTP is an easy metric to calculate, it does not adequately represent reliability as perceived from a passenger's perspective. Given that the TCQSM recognizes not only reliability explicitly in its five key concepts, it also identifies it as a passenger-perspective quality of service performance measure (49). To address this, recent efforts by innovative transit agencies are currently seeking to identify more effective ways to measure reliability from a passenger's perspective (58).

Though identifying a single metric for reliability is difficult, it generally relates to time (57). Many agencies nationally, including KCM, maintain access to General Transit Feed Specification (GTFS) and APIs of real-time transit performance data (59). The company Swiftly has collected this data and aggregated it into a format that can be easily queried by tools through its advanced analytics platform as well as downloaded in CSV format for further analysis.

To determine the ESTS pilot impacts, this paper first reviews practical metrics and analysis methods for reliability, then applies these methods to the Swiftly data set of KCM bus schedules and adherence. The three analyses presented in this paper include a standard on-time performance (OTP) runtime performance assessment per KCM guidelines, a fixed effects panel regression of schedule adherence at the stop level, and a quantile regression of schedule adherence at the stop level.

3.2 Measuring Reliability

While the definition of reliability varies, it consistently involves time, from how actual bus times relate to scheduled times, to consistency of travel time and minimized waiting times (57). The most basic and most commonly used metric for reliability is on time performance (OTP) (57). While "most agencies define reliability in terms of OTP," the exact time range that constitutes an on-time bus arrival/departure vary widely depending on the operator, though on average operators consider a bus on-time if it arrives within the window of 1 min early to 5 min late (60). At KCM, schedule reliability is measured with an OTP window that only considers late bus arrivals; routes that experience arrivals more than 5 min late 35% of the time during PM peak periods or 20% of the time on average are considered non-compliant (61). Any early arrivals are considered on-time.

In a 2016 OTP service review, KCM found 60 routes that needed "service-hour investments to improve reliability" (61).

Percent on-time OTP, though widely used by operators, is considered a sub-par metric throughout the research literature because it does not adequately capture time reliability from a passenger perspective. For passengers, waiting time at bus stops is valued "more than any other time component of their trip" (57). In fact, studies have found that passengers can value waiting time at a rate of 3 to 5 times their time in-vehicle and that the quality of waiting locations can also be valued in in-vehicle time equivalents up to 1.3 minutes for a stop shelter (49). Furthermore, passengers tend to overestimate waiting time, particularly if that waiting time is unpredictable (57). Therefore, beyond seeking to reach a set percentage of trips/arrivals that are on-time, looking at the arrivals that fall outside of the "on-time" range and the severity of deviation better captures the passengers' perception of reliability. Additionally, analyzing schedule adherence at the stop level rather than at the route runtime level further focuses on the most critical time component of the trip from a passenger reliability perspective.

Based on this, multiple analyses of reliability were considered to determine the impact of the ESTS pilot on KCM service reliability. These methods attempt to capture not only the impact of company shuttles on transit performance from a planning perspective, but also from a user perspective. In a percent on-time OTP analysis (based on KCM standards), the dependent variable is schedule adherence of runtime for each of the impacted routes. For the panel regression comparisons, the dependent variable is schedule adherence at the stop level.

3.3 Data

3.3.1 Swiftly's Data and Analytics Platform

Swiftly, Inc. is a software company that specializes in developing accurate real-time passenger information and robust data analytics for transit operators. Swiftly Insights is a cloud-based platform that processes and archives GPS data from the computer aided dispatch (CAD) and automated vehicle location (AVL) systems of transit agencies. The platform allows transit agencies, planners, and researchers to quickly access and analyze GPS data points, both for real-time monitoring and for analysis of historical data.

Swiftly Insights generates aggregate variables such as schedule adherence in addition to presenting the basic data pulled from the agency AVLs. Schedule adherence is calculated as the difference between scheduled bus times and actual bus departure times. These variables can then be analyzed both through the visualization tools provided within the Swiftly Insights dashboard or through analyses of CSV downloads of the data.

3.3.2 Data Set Development

To determine appropriate date and time ranges for the data, KCM press releases and route revisions since the start of Swiftly data records (3/23/2016) were reviewed to determine potential scheduling/routing impacts. For analyses considering before and after effects of the ESTS program, data was considered from the Monday of 3/13/17 after the implementation of a March 11th, 2017 semi-annual KCM schedule change and until 6/04/17, providing 6 weeks of data on either side of the 4/24/17 pilot start date. Multiple study stops fall near the University of Washington Seattle campus, so it should be noted that classes were in session throughout the study period with the exception of week 2 of the study when classes were out for spring break.

To determine the routes needed for analysis, the OneBusAway online browser was used to identify impacted stops and related routes based on the SDOT press release announcing the ESTS pilot program. According to this release, all but two Children's stops were introduced on the 4/24/2017 pilot start date (47). These two stops were removed from the study, resulting in a total of nine shared stops considered as the treatment stops in the study. As shown in the Table 3-1 summary of treated stop and route information for the study, all of the study stops are low-volume, with only one initial stop (A) serving five routes. The majority (7/9) of study stops only serve one to two routes and all of the study stops are simple curb-side (rather than bus bay) stops.

TABLE 3-1. Treated stops and routes identification and labeling for the study

	Stop Identification			Direction	Company	Implem.	Routes that				
Study Label	KCM ID #	KCM Street	KCM Cross-street	of Travel	Shuttle	Date	utilize the stop				
A	2180	Queen Anne Ave N	W Harrison St	S	Microsoft	4/24/2017	1	2	8	13	32
B	10562	Sand Point Way NE	40th Ave NE	N	SCH	4/24/2017	75				
C	11420	15th Ave E	E Mercer St	S	Microsoft	4/24/2017	10				
D	12340	E Madison St	25th Ave E	SW	Microsoft	4/24/2017	8	11			
E	13250	19th Ave E	E Harrison St	S	Microsoft	4/24/2017	12				
~~F~~	~~25200~~	~~NE 45th St~~	~~Union Bay Pl NE~~	~~W~~	~~SCH~~	~~Later~~	~~31~~	~~32~~	~~67~~	~~75~~	~~78~~
G	25765	Montlake Blvd NE	NE Pacific Pl	N	SCH	4/24/2017	65	78			
H	29720	NW Market St	20th Ave NW	W	Microsoft	4/24/2017	44				
~~I~~	~~29920~~	~~NE 45th St~~	~~Mary Gates Memorial~~	~~E~~	~~SCH~~	~~Later~~	~~65~~	~~75~~			
J	31970	California Ave SW	SW Spokane St	S	Microsoft	4/24/2017	50	55	128		
K	37920	NE 65th St	39th Ave NE	W	Microsoft	4/24/2017	62	71	76		

To develop the control group, schedule adherence reports from the previous year were avoided given the rapid growth in Seattle. Instead, two types of stops were identified as potential control stops: upstream (US) stops and different route (DR) stops. US stops are stops located upstream or before a treated stop whereas DR stops are located in the same geographic area but not along the same route as a treated stop. US stops were selected because, of a wide variety of factors that have been found to impact bus reliability, many are directly tied to a given route; factors include driver experience, length and complexity of route, operating environment, and other route conditions such as on-street parking, signalized intersections, and direction of travel (62). For both control group stop types, only low-volume, curb-side bus stops were considered. All stops by type are plotted in Figure 3-1 for reference.

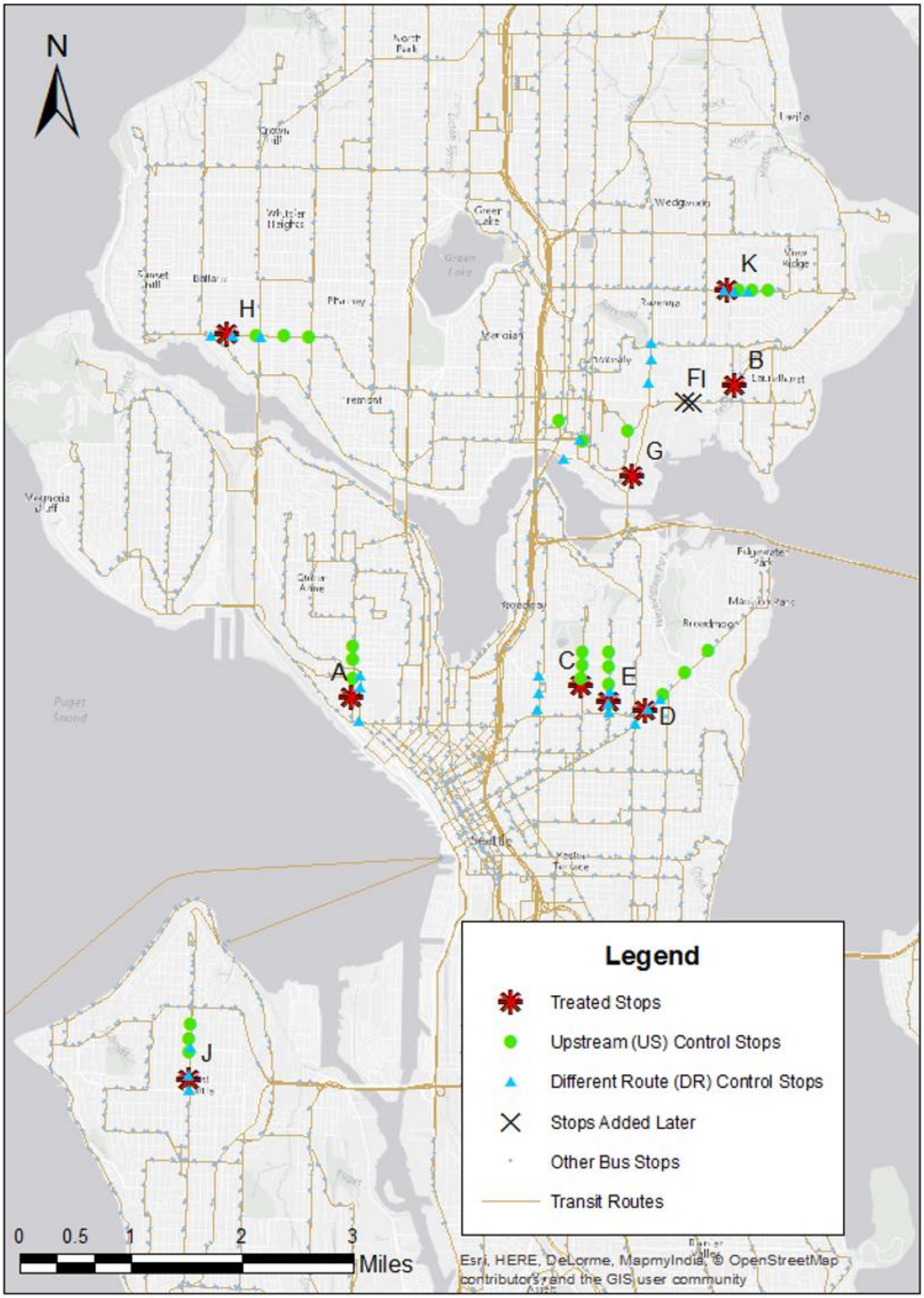

FIGURE 3-1. ESTS Pilot Study Stops and Control Stops considered within the analysis

While stops along nearby streets with comparable surrounding land use and parking patterns as well as number and type of routes utilizing the stops were held as the ideal for DR control stop selection, such stops exist for only two of the nine treated stops. As a result, the majority of DR stops identified were nearby stops in the opposite direction of travel of treated routes/stops, i.e. stops across the street from treated stops. To try to control for the impact of the differing directionality, DR stops in the opposite direction of travel from treated stops were only selected if they experienced similar weekday peak congestion per the Google Maps Typical Traffic™ function.

Based on these requirements, the CSV data download feature in the Swiftly Insights platform was used to extract the historical KCM data for all potentially impacted routes. The data was disaggregated into AM and PM peak sets per KCM guidelines: AM peak from 6am to 9am and PM peak from 3:30pm to 6:00pm (63). All routes in the vicinity of the treated stops operate within mixed traffic environments as defined by the TCQSM (49). Cumulative Distribution Function (CDF) plots were used to compare the distributions before the implementation of the ESTS program of the potential control stops vs the treated stops to determine the best control group for the study. As shown in Figure 3-2, the DR stops have a different distribution of schedule adherence compared to the treated stops, especially in the PM peak. In contrast, the US stops have a similar distribution before the start of the ESTS stop sharing pilot in both the AM and PM peak as shown in Figure 3-2. Based on this, US stops at a ratio of 3:1 control:treated stops were selected as control stops for the analysis with one exception.

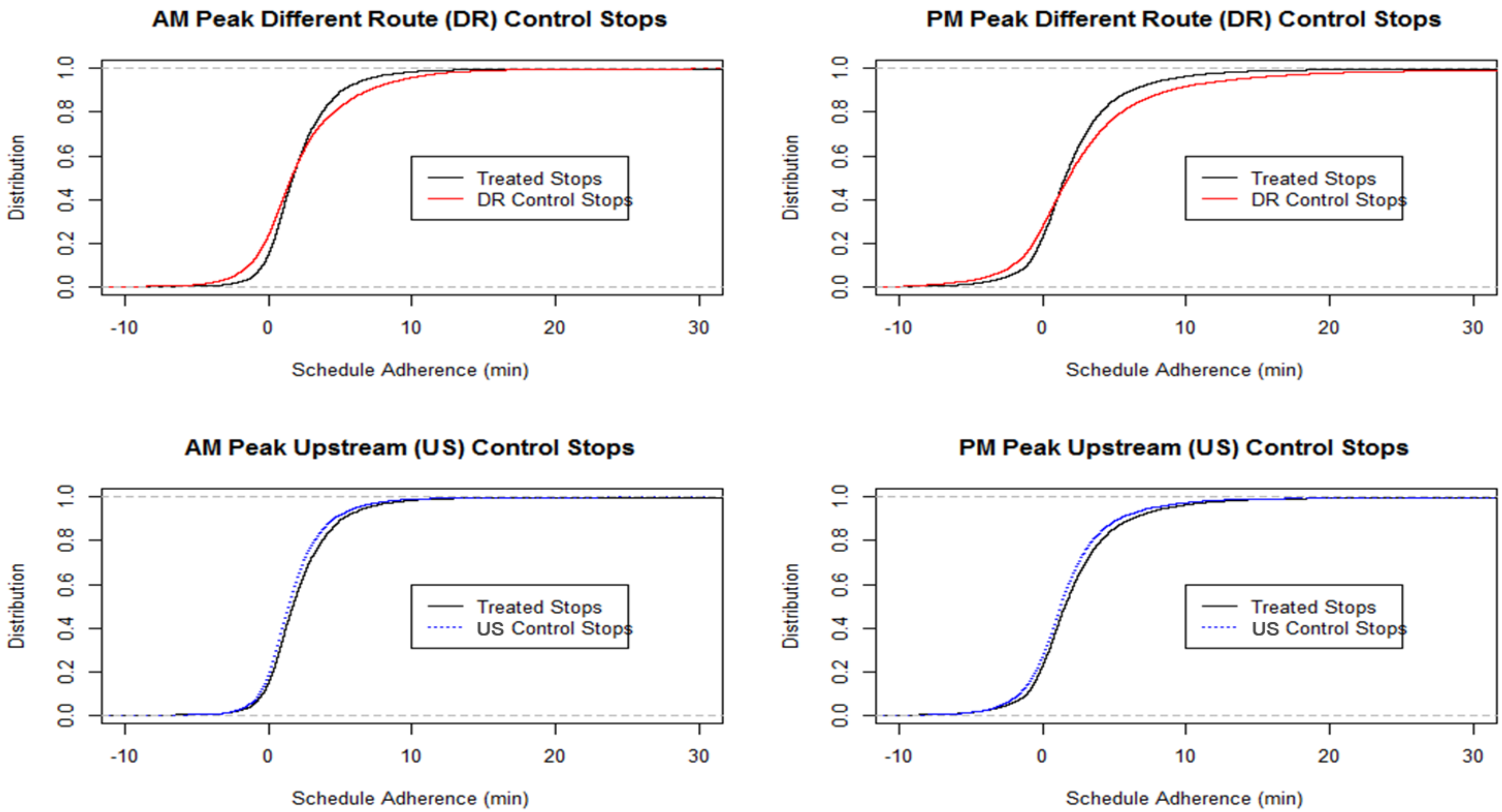

FIGURE 3-2. CDF Plots comparing the schedule adherence distributions of potential collections of Control Stops Upstream (US) or along Different Routes (DR) to Treated Stops before the ESTS program began

As shown in Figure 3-1, treated stop B is downstream of treated stop G. Additionally, stops along the west and southwestern edges of the University of Washington serve as major transfer hubs for buses within the region. As a result, control stops for either stop B or G could not be identified immediately upstream. Control stops for treated stop G were selected from US stops west (or further upstream of) the transfer hubs that border the University campus. Because stop B is located near the start of route 75, a route that runs through multiple bus transfer hubs on UW's campus, only one US stop could be identified. As a result, stop B has a ratio of 1:1 control:treated stops. However, because the US control stop serves a second route in addition to the 75, observations are roughly 2:1 control stop:stop B.

3.4 Analysis Methods

Four analysis methods were selected to determine ESTS impacts on KCM reliability from the Swiftly schedule adherence data set. The first analysis most closely adheres to the KCM guidelines for reliability measurement. It considers the route runtime level and analyzes the data using the tools provided by the Swiftly platform. From this, percentage of late run times along each route before and after the ESTS start date are identified.

The second analysis method utilizes panel regression which considers all treated stops along with US control stops along the same impacted route. Panel regression is a widely-used method in social sciences and econometrics to analyze a data set in terms of identity and time to consider cross-sectional and longitudinal relationships and impacts (64). Specifically, a fixed effects panel regression was utilized to determine the average difference between treated and control stop types, between weeks within the study, and between stops impacted by the ESTS pilot shuttles and non-treated stops. A total of 12 study weeks were considered with the ESTS pilot beginning at the start of the 7th study week. Stops impacted by the ESTS pilot shuttles are the treated stops during weeks 7 to 12, and non-treated stops are all stops in the control group and stops in the treated stop group during weeks 1 to 6. This model ultimately identifies the average waiting time at the stop caused by the introduction of ESTS pilot shuttles. Given that "unreliable transit service will increase average waiting time," the model provides a good metric to determine whether the ESTS pilot impacted transit reliability (49).

The third analysis method considers quantile panel regressions of the 0.90 and 0.95 quantile of schedule adherence. Because quantile regression focuses on a user-specified portion of a data distribution rather than fitting an average to the distribution as a whole, it generates models that more robustly estimate the effect of outliers in a data set (65). It is therefore ideal for assessing the frequency of severe bus delays and therefore more closely approximates the frequency of low reliability from a passenger perspective. The quantile regression R package is "quantreg" (66).

Finally, to separate and further investigate individual treated stops, CDF plots were utilized to identify different distributions of schedule adherence before and after the ESTS pilot start date. First, the quantiles of schedule adherence at each of the treated stops before and after the ESTS pilot start date were compared to identify a subset of stops with increased arrival delays after the start of the ESTS pilot. Quantile regression at the median (0.50 quantile) as well as in the 0.90 and 0.95 quantiles were fitted to the subset of stops to determine if the increase in bus delays was the result of the ESTS shuttles or some other factor.

3.5 Discussion of Results

The results of the four analysis methods are discussed below.

3.5.1 Analysis 1 - OTP measurement following KCM guidelines

KCM guidelines for reliability identify routes experiencing >35% late arrivals (i.e. arrivals more than 5 mins past the scheduled time) in PM peak as unreliable and in need of remedial attention (61). Per these guidelines, Figure 3-3 was generated using the Schedule Adherence by Route feature on the Swiftly Insights platform to look at the percent on-time OTP of routes impacted by ESTS shuttle stops before and after the pilot start date (4/24/17). As Figure 3-3 shows, the percent of late arrivals increased in most study routes with four (rts 8, 11, 50, 62 which stop at A & D, D, J, and K, respectively) of the eighteen routes passing the KCM threshold of 35% late arrivals, Comparatively, only one (rt 8 which stops at A) of the eighteen routes passed the 35% threshold before the ESTS start date.

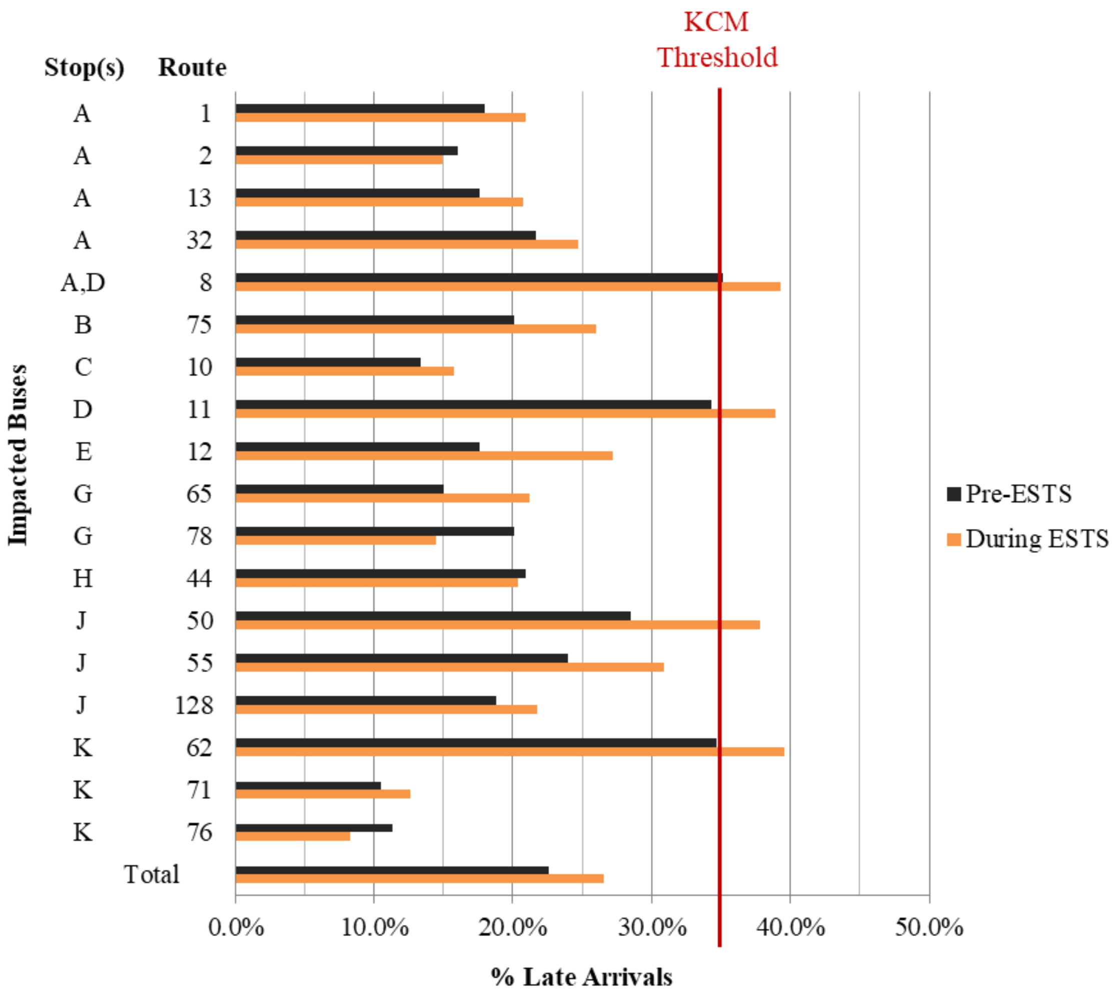

FIGURE 3-3. Schedule Adherence by Route for routes with Shared Stops before and after the ESTS Pilot Start Date during the PM Peak

While this suggests a potential impact on routes, it does not indicate whether these increased delays are the result of the ESTS shuttles or some additional factors. For example, the 8 is the only bus that runs along a highly congested east-west thoroughfare near the Amazon campus with a portion of the roadway under construction. Additionally, the 62 has been receiving remedial attention since it was created as a combination of two routes discontinued after the LINK light rail extension in March of 2016. The 50, however, has remained constant in schedule with no published concerns since early 2016, as has the 11 beyond minor routing changes in September 2016. Therefore, while this percent on-time OTP route-level analysis suggests the possibility that ESTS shuttles are affecting on-time performance, additional analysis is necessary.

3.5.2 Analysis 2 - Fixed Effects Panel Regression

To better identify whether the ESTS shuttles impact bus performance, this second analysis not only focuses more acutely on the point of impact (the stops), but also introduces a set of control observations. Additionally, both AM and PM peak periods are considered. Once US control stops were identified (as explained in the "DATA" section), control and treated stops were compared in a fixed effects panel regression as specified in Equation 3-1.

$$y_{iwt} = \propto_i + \gamma_w + \beta D_{iw} + \epsilon_{iwt} \qquad (3\text{-}1)$$

i = stops
w = weeks
t = observations

The model specification includes fixed effects both for stops ($\propto_i$) and for weeks (γ_w). The stop-level fixed effects capture average schedule adherence at each stop, while the week-level fixed effects capture area-wide variations between weeks such as those caused by seasonality and UW sessions. A treated dummy variable (D_{iw}) is used to specify when treated stops are subjected to the ESTS pilot program treatment, and the coefficient β represents the average treatment effect. The dummy variable D_{iw} has a value of 1 from weeks 7-12 at the treated stops (since week 7 marks the start of the ESTS pilot program) is 0 otherwise. Table 3-2 shows the results of the regression analysis. The estimated treatment effects of the ESTS pilot program are small, and not statistically significant. This suggests that, on average, sharing stops with private shuttles did not affect schedule adherence for King County Metro buses at the studied stops. Further, the "Constant" for the models represents the average schedule adherence in the data set; for both AM and PM peaks, the average arrival time for buses occurs on-time, only ~2min after the scheduled arrival time.

TABLE 3-2. Fixed Effects Panel Regression of Schedule Adherence in the AM and PM Peak at All ESTS Study Stops

	Dependent variable:	
	Schedule Adherence (min)	
	AM Peak	PM Peak
Week 2	−0.256**	−0.582**
	(0.063)	(0.094)
Week 3	−0.116	0.542**
	(0.066)	(0.091)
Week 4	−0.015	−0.107
	(0.066)	(0.092)
Week 5	−0.653**	−0.837**
	(0.066)	(0.092)
Week 6	−0.365**	−0.116
	(0.067)	(0.093)
Week 7	−0.270**	−0.401**
	(0.069)	(0.095)
Week 8	−0.063	1.235**
	(0.070)	(0.098)
Week 9	−0.246**	0.016
	(0.069)	(0.096)
Week 10	−0.227**	0.174
	(0.068)	(0.096)
Week 11	−0.054	0.532**
	(0.069)	(0.097)
Week 12	−0.245**	0.426**
	(0.070)	(0.100)
Treated Dummy	0.001	0.102
	(0.060)	(0.087)
Constant	2.534**	1.880**
	(0.069)	(0.095)
Stop Fixed Effects	Yes	Yes
Observations	37,477	37,155
R^2	0.100	0.077
Adjusted R^2	0.099	0.076
Residual Std. Error	2.641 (df = 37431)	3.763 (df = 37109)
F Statistic	92.904** (df = 45; 37431)	69.227** (df = 45; 37109)
Note:		*p<0.05; **p<0.01

3.5.3 *Analysis 3 - Quantile regressions of stop schedule adherence*

While the fixed effects panel regression considered the average impact of ESTS shuttles on the treated stops, or impact at the mean, quantile regressions provide a shifted focus. Quantile regressions of the fixed effects panel data were performed on all stops at the 0.90 and 0.95 quantiles (i.e. the 90th and 95th percentiles) in order to look more closely at the severity of later bus arrivals. Models were fitted per the same specifications given in Equation 1 and the resulting coefficients for the intercept and treatment dummy variable are presented in Table 3-3. As shown, results in the 0.95 quantile are not statistically significant, while results for the 0.90 quantile have a p-value of 0.028 in the PM peak. The estimated treatment effect implies that schedule adherence improved as a result of the ESTS pilot. This is an unreasonable causal impact and suggests that additional factors not present in this analysis impacted the results. To seek further clarification, a fourth analysis of each stop individually was considered.

TABLE 3-3. Fixed Effects Quantile Regression in the AM and PM Peak for All ESTS Study Stops

	Dependent variable: Schedule Adherence (min)			
	AM Peak		PM Peak	
	0.90	0.95	0.90	0.95
Treated Dummy	−0.147	−0.141	−0.376*	−0.226
	(0.085)	(0.135)	(0.171)	(0.229)
Constant	5.846**	7.314**	5.512**	7.798**
	(0.142)	(0.164)	(0.186)	(0.240)
Weekly Fixed Effects	Yes	Yes	Yes	Yes
Stop Fixed Effects	Yes	Yes	Yes	Yes
Degrees of Freedom	140116 total; 140041 residual		149170 total; 149095 residual	
Note:				*p<0.05; **p<0.01

3.5.4 Analysis 4 - Quantile comparisons and regressions of stop schedule adherence

While the results at both the mid and upper quantiles did not indicate an effect of the ESTS program on transit performance, an additional analysis was conducted to determine whether or not individual stops have been impacted. Rather than relying exclusively on the first analysis of an increase in late runtimes after the start of the ESTS program, schedule adherence before and after the start of the ESTS program at the stop level were assessed by comparing distributions. Figure 3-4 presents the cumulative distribution function (CDF) plots of schedule adherence times before and after the start of ESTS at the treated stops. Most of the stops show little to no difference, as the CDF curves overlap almost perfectly. Plots B and G, however, represent the stops that have experienced clear disparities between the distribution of schedule adherence at the stop before and after the start of the ESTS program. At both stops, buses are consistently later after the start of the ESTS program, with significantly later arrivals occurring at stop B after the start of the ESTS program. Based on these variations, treated stops B and G were identified as stops that required additional attention.

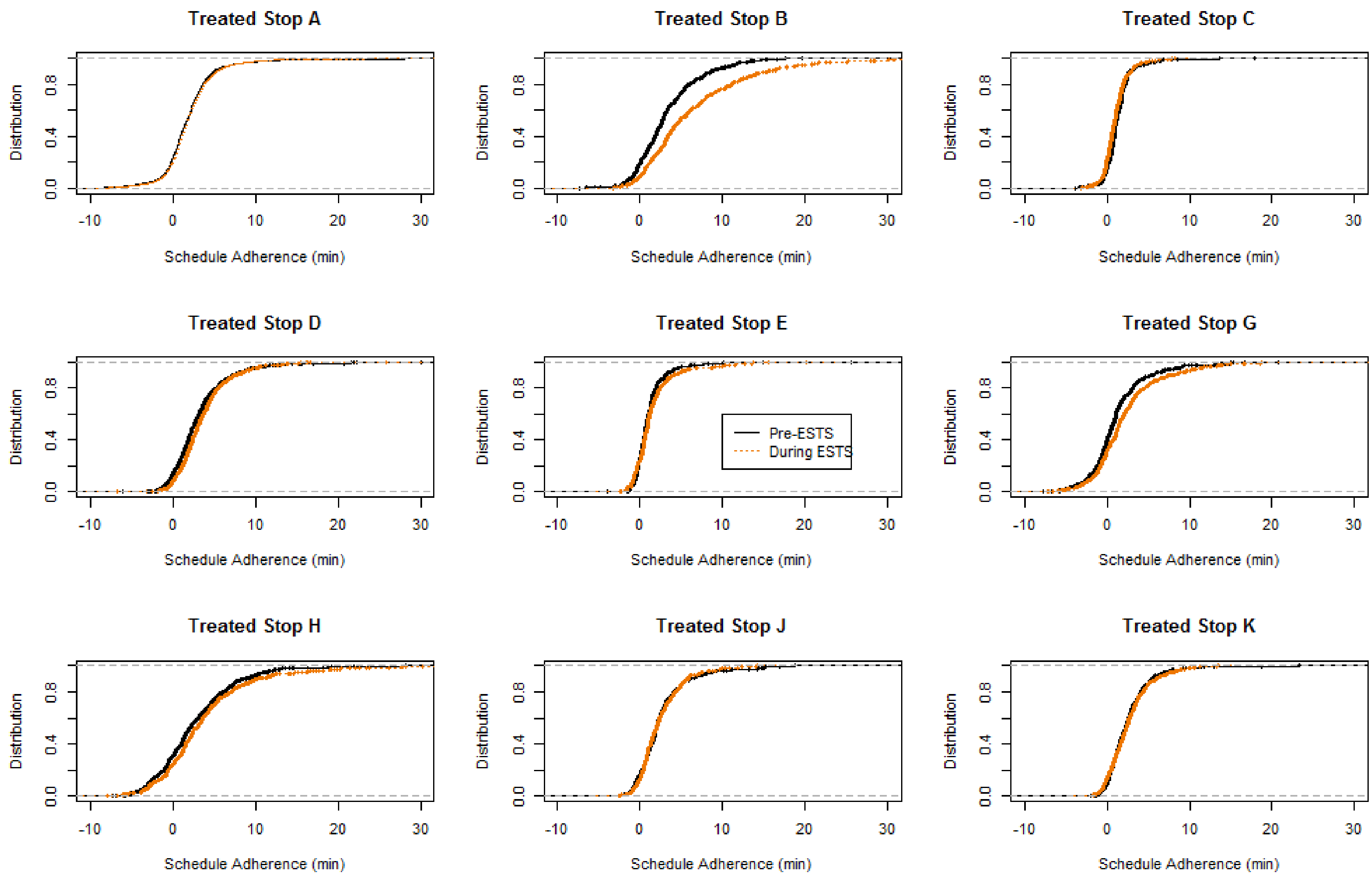

FIGURE 3-4. CDF Plots of Schedule Adherence for Treated Stops Before and After the start of ESTS

To determine whether these disparities are the result of the presence of ESTS shuttles or simply the result of other factors not considered in the analysis, fixed effects panel regressions at the median (0.50), 0.90, and 0.95 quantile comparing the treated stops to their corresponding control stops were considered. Table 3-4 presents the estimated treatment effects for stops B and G. Quantile regression models for stop G failed to reject the null hypothesis that the ESTS shuttles had no impact on bus schedule adherence during both peak periods and at all quantiles tested.

The models for stop B, however, reject the null hypothesis at the median (0.50) and 0.90 quantile during the PM peak. As Figure 3-5 shows, an increase in delays at the treated stop B compared to the US control stop occur after the ESTS pilot begins. The differences between stops are very statistically significant, many with p-values < 0.0001. Based on this, the model suggests that, while arrival times at stop B are consistently later than arrival times at the control stop throughout the study period, buses began arriving even later at stop B after the start of the ESTS pilot. In the aggregate, these results suggest that the introduction of ESTS shuttles at stop B may have impacted schedule performance.

TABLE 3-4. Treated Dummy Coefficients for Schedule Adherence at the 0.50 (median), 0.90, and 0.95 Quantile of Stops B & G during the AM & PM Peak

	Treated Dummy Values for Dependent Variable: Schedule Adherence (min)					
	AM Peak			PM Peak		
Models	0.50	0.90	0.95	0.50	0.90	0.95
Stop B	0.395	0.791	1.382	1.864**	2.756*	1.644
	(0.311)	(1.130)	(0.957)	(0.457)	(1.386)	(0.991)
Stop G	−0.165	−0.629	−0.748	0.178	−0.889	−1.874
	(0.125)	(0.378)	(0.585)	(0.226)	(0.764)	(1.284)
Weekly Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Stop Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Deg. of Freedom Stop B	5187 total; 5173 residual			7146 total; 7132 residual		
Deg. of Freedom Stop G	18039 total; 18023 residual			17946 total; 17930 residual		

Note: *p<0.05; **p<0.01

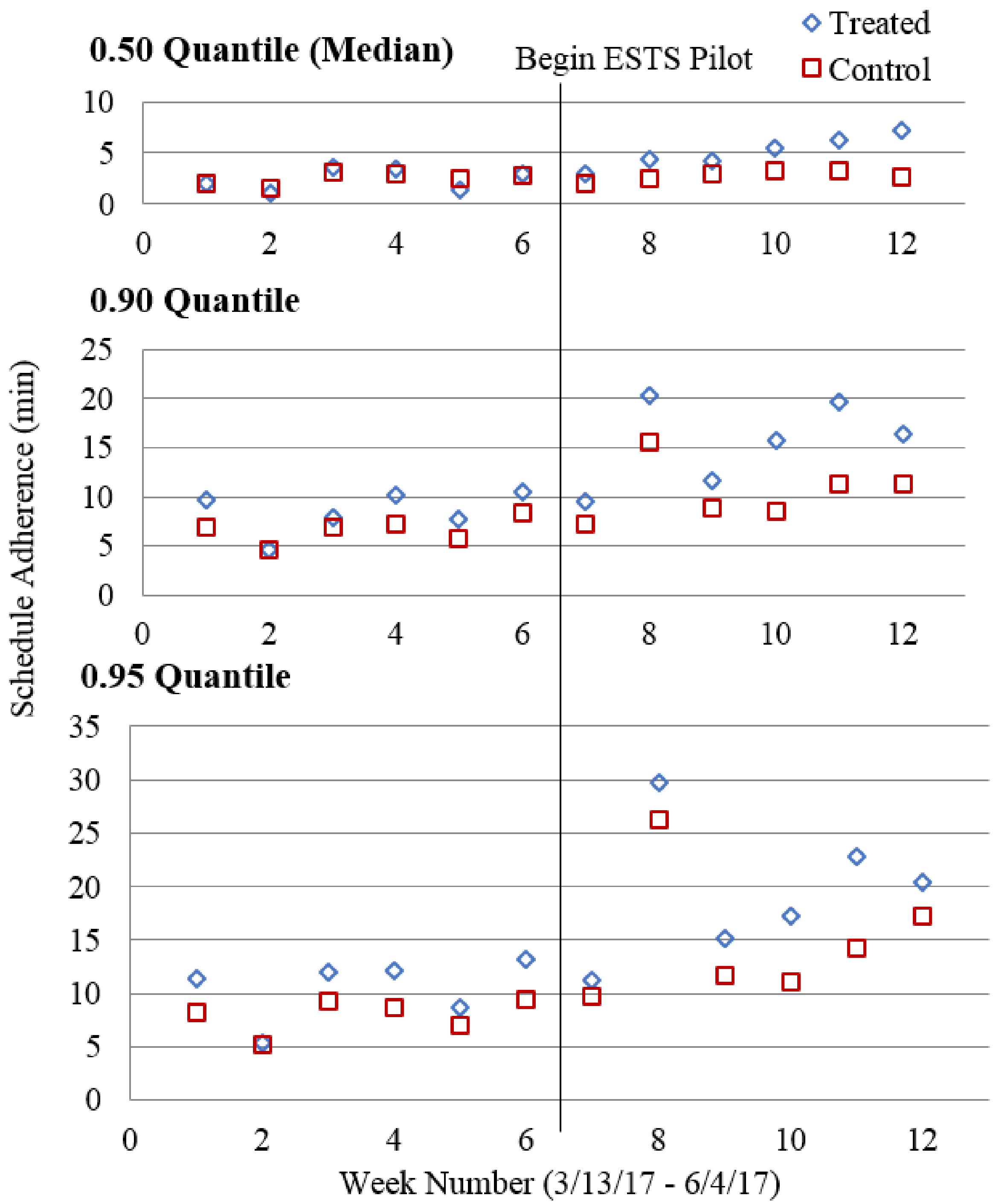

FIGURE 3-5. Stop B Treated vs. Control Stop Schedule Adherence in the PM Peak by Quantile

3.6 Shared Stops Conclusions & Recommendations

Many factors impact bus schedule adherence. This study attempts to control for a multitude of factors through a robust control group development effort in order to study the impact of the introduction of private shuttles sharing bus transit stop ROW through the ESTS program with schedule adherence (time) information. While standard KCM reliability analysis methods looking at OTP at the route level were considered, they were ultimately too zoomed out from the study locations. Moreover, discrepancies were found at the stop level that did not appear at the route level and vice versa. Furthermore, stop-level analysis is more likely to capture the perceived reality of impact caused by ESTS shuttles by better representing what passengers experience and would consider to be unreliable service.

An aggregate analysis of all nine stops selected for the ESTS pilot study paired against control stops and considered at the mean as well as at the 0.90 and 0.95 quantile in fixed effects panel regressions did not suggest a negative impact on public transit performance. At the stop level, however, one model suggested a potential relationship. Stop B that serves only one route (route 75) may have been impacted. Stop B is a low capacity bus facility with only one loading area. Given that capacity and reliability are inherently linked, it is possible that the addition of shuttles stopping at this low capacity location is the sole cause of the increased bus arrival delays (49). However, given that none of the other low-volume, single loading zone stops exhibit statistically significant impacts, the presence of multiple loading areas at a stop should not necessarily be a prerequisite for shared stop selection.

Based on this analysis, further investigation is needed to determine whether ESTS shuttle sharing is the sole cause of these delays, and if so, why this stop is the only adversely impacted stop while others are not. Further, because low-volume pilot stops were selected, results from these stops may not provide a clear indication of the potential impacts if a wider-spread program made use of busier stops. Given the apparent minimal to no impact caused by the ESTS shuttle stops sharing ROW with transit buses at lower-volume stops, an expansion of the program at similar, low-volume stops is recommended at this time.

Before a full expansion to busier stops, additional analysis is recommended. For example, if data from the shuttles in addition to bus data was available, arrival and departure times could be compared to identify how often actual bus and shuttle times overlap. This would not only serve as a more detailed analysis of the impacts of shuttles on buses, but would allow for more careful management of the sharing efforts. If stop sharing expands to larger, more heavily-utilized stops, interaction with bus riders will increase. Not only that, but with this greater exposure, greater scrutiny is inevitable. Agencies will need to remain sensitive to public opinion, but ongoing data analysis and management would make it easier to track and mitigate concerns. Ultimately, real-time GPS data makes tracking, analyzing, and managing fleet interactions possible. This paired with the potential for positive utilization of public curb space ROW and the added revenue that a stop sharing program such as ESTS provides outweigh the minimal negative impacts and warrant further investigation into expansion options.

4. Summary & Final Recommendations

As the City of Seattle has continued to grow and become denser in recent years, congestion during peak commute hours has risen as well. Public transit service providers such as King County Metro (KCM) that share the congested streets of Seattle with personal vehicles have established service guidelines in order to measure and pursue the goal of quality transportation alternatives for all Seattle residents (67). A wide variety of new, private companies that harness the power and convenience of smart phone applications have entered the commute mode market with the stated goals of reducing drive alone commutes. Given the consistent trend of longer travel times for public transit over private alternatives, public transit agencies are advised to recognize the need and the opportunity to partner with new, private commute service providers in order to provide the best quality of transportation possible. Private companies in turn should also look to partner with public agencies to establish a symbiotic relationship between alternative services and public transit to meet their goals of reduced congestion and emissions.

The UberHOP case provides an example of a private service that was designed and implemented without public partnership. While the stated goals of the service were to reduce congestion and emissions by shifting drive alone commuters to UberHOP, the service ultimately failed on all counts. Knowledge of the service's existence was minimal, resulting in a small ridership. This ultimately led to a majority of single riders in larger, lower fuel-efficiency vehicles and significant driver dead-heading. Additionally, many routes overlapped directly with bus routes and the service drew predominantly from transit riders, not drive alone commuters. While it failed every metric of sustainability in its implemented form, the UberHOP model has the potential to be sustainable with a larger ridership.

It is possible for public entities to try and deal with the potential loss of ridership to private companies by forcing them out through policy initiatives; this, however, is an unreasonable response that does not ultimately address the root issue. While City of Austin policy makers were concerned with safety rather than transit ridership, the result of a ballot measure passage resulted in the exodus of Uber and Lyft (68). Because the ridehailing services were meeting a demand that public transit did (and seemingly could) not, new ridehailing services adapted to the new measures and entered the market to fill the void in transportation services; ultimately, a law was passed at the state level overturning the ballot measure in question which eventually led to the return of Uber and Lyft and an even more competitive transportation market (69).

In contrast to examples such as UberHOP or the City of Austin ballot measures that have ultimately pitted private vs. public entities, the ESTS pilot program studied a partnership between private companies and public transportation agencies. The real-time bus data used in the study was cleaned and easily accessed through the Swiftly platform and provided a relatively easy method for assessing bus service impacts to monitor the public-private relationship. Through this analysis, a general lack of private shuttle impact on bus schedule adherence was determined. Moreover, the shuttles are part of programs known to reduce drive alone commute trips and are operated as first/last mile connections to light rail and/or along routes with significantly longer travel times by bus. Ultimately, the ESTS pilot program provides a good example of a way in which public agencies can partner with private companies to provide an improved commute trip for citizens and an additional source of revenue for the city.

In an attempt to address the issue of congestion from the private sector, companies such as Amazon, Expedia, Microsoft, Zillow, and others (totaling 17 of the city's top companies) led by former Washington State Gov. Christine Gregoire recently launched the Challenge Seattle initiative (70). While this has the potential to be a step in the right direction, given that KCM, SDOT and Sound Transit do not appear on the list of Challenge Seattle organizations (while Puget Sound Energy does), the level of public-private transportation collaboration needed to achieve a successful program seems unlikely. Presently, all of the private sector companies are in competition with each other as well as with the public transit agencies – everyone is competing for ridership. Ultimately, policies and economics that promote some form of collaboration between these public and private providers is highly recommended to facilitate a symbiotic relationship, such as the ESTS case, rather than a competitive relationship, such as the UberHOP case.

REFERENCES

1. Puget Sound Regional Council. Population grows at fast pace in 2017 [Internet]. Puget Sound Regional Council. 2017 [cited 2017 Jul 13]. Available from: https://www.psrc.org/whats-happening/blog/population-grows-fast-pace-2017

2. Molly Brown. Report: Seattle one of the worst U.S. cities for traffic congestion, tied with NYC [Internet]. GeekWire. 2015 [cited 2017 Nov 21]. Available from: https://www.geekwire.com/2015/report-finds-seattle-is-one-of-the-worst-u-s-cities-for-traffic-congestion-tied-with-new-york/

3. Puget Sound Regional Council. Transportation 2040 Executive Summary [Internet]. Puget Sound Regional Council; 2010 May [cited 2017 May 26]. Available from: https://www.psrc.org/sites/default/files/4web_finalt2040es.pdf

4. King County Metro. About the Commute Trip Reduction (CTR) Law [Internet]. 2017 [cited 2017 Jul 18]. Available from: http://www.kingcounty.gov/transportation/CommuteSolutions/About.aspx

5. Commute Seattle. Tax Free Transportation: Utilizing Commuter Benefit Programs to Save Your Business Money [Internet]. 2016 [cited 2017 Nov 22]. Available from: https://www.seattle.gov/waytogo/docs/Tax-Free-Transportation-Utilizing-Commuter-Benefit-Programs.pdf

6. Sound Transit. History: what voters approved [Internet]. Sound Transit. 2015 [cited 2017 Nov 21]. Available from: https://www.soundtransit.org/Projects-and-Plans/Developing-Regional-Transit/History-what-voters-approved

7. Seattle Department of Transportation. Levy to Move Seattle [Internet]. seattle.gov. 2016 [cited 2017 Nov 21]. Available from: http://www.seattle.gov/transportation/about-sdot/funding/levy-to-move-seattle

8. ReachNow. Refresh your morning commute, Seattle [Internet]. ReachNow. 2017 [cited 2017 Nov 22]. Available from: https://reachnow.com/en/newsroom/refresh-your-morning-commute-seattle/

9. ReachNow. Upgrade your commute: $6 drives + rides every weekday morning in Seattle [Internet]. ReachNow. 2017 [cited 2017 Nov 22]. Available from: https://reachnow.com/en/newsroom/6dollarcommuterpromo/

10. Monica Nickelsburg. Uber offers discounts to commuters traveling by light rail in Seattle area [Internet]. GeekWire. 2017 [cited 2017 Nov 22]. Available from: https://www.geekwire.com/2017/uber-offers-discounts-commuters-traveling-light-rail-seattle-area/

11. Ken Yeung. Uber is testing a new commuter transit service in Seattle and Chicago [Internet]. VentureBeat. 2015 [cited 2017 Nov 22]. Available from: https://venturebeat.com/2015/12/08/uber-is-testing-a-new-commuter-transit-service-in-seattle-and-chicago/

12. Etherington D. Lyft adds more routes and commute scheduling to Shuttle service [Internet]. TechCrunch. [cited 2017 Nov 22]. Available from: http://social.techcrunch.com/2017/09/14/lyft-adds-more-routes-and-commute-scheduling-to-shuttle-service/

13. Via. Via | Smarter shared rides [Internet]. Via. 2017 [cited 2017 Nov 22]. Available from: http://ridewithvia.com

14. Alyse Whitney. I took Via to work every day for a month. Here's what I learned [Internet]. Brick Underground. 2016 [cited 2017 Nov 22]. Available from: https://www.brickunderground.com/live/commute-via

15. Chariot. Chariot - Your Commute, Solved [Internet]. Chariot. 2017 [cited 2017 Nov 22]. Available from: https://www.chariot.com/

16. Hawkins AJ. Ford's on-demand bus service Chariot expands to Seattle [Internet]. The Verge. 2017 [cited 2017 Nov 22]. Available from: https://www.theverge.com/2017/6/22/15854376/ford-chariot-seattle-expand-on-demand-shuttle

17. Commute Seattle. About Us [Internet]. Commute Seattle. 2016 [cited 2017 Nov 22]. Available from: https://commuteseattle.com/who-we-are/

18. Commute Seattle. Rideshare [Internet]. Commute Seattle. 2016 [cited 2017 Nov 22]. Available from: https://commuteseattle.com/commuteportal/rideshare/

19. Commute Seattle. How Do You Get There, Seattle? [Internet]. Commute Seattle. 2016 [cited 2017 Nov 22]. Available from: https://commuteseattle.com/modesplit/

20. Commuter Benefits for uberPOOL [Internet]. Uber. [cited 2017 Nov 22]. Available from: https://www.uber.com/info/uber-commuter-benefits/

21. Inc L. Line Commuter Benefits [Internet]. Lyft Help. [cited 2017 Nov 22]. Available from: http://help.lyft.com/hc/en-us/articles/115002073608--Line-Commuter-Benefits

22. Uber's Global Expansion In Five Seconds [Internet]. Forbes. [cited 2016 Jan 13]. Available from: http://www.forbes.com/sites/ellenhuet/2014/12/11/ubers-global-expansion/

23. Hallock L, Inglis J. The Innovative Transportation Index: The Cities Where New Technologies and Tools Can Reduce Your Need to Own a Car [Internet]. U.S. PIRG Education Fund & Frontier Group; 2015 Feb. Available from: http://www.uspirg.org/sites/pirg/files/reports/Innovative_Transportation_Index_USPIRG.pdf

24. FAQs for uberHOP [Internet]. Washington. 2015 [cited 2016 Jul 17]. Available from: https://newsroom.uber.com/us-washington/uberhop-faq/

25. Meet uberHOP: A New Way to Commute [Internet]. Seattle. [cited 2016 Jan 13]. Available from: https://newsroom.uber.com/canada/meet-uberhop/

26. Introducing uberHOP: A New Way to Commute [Internet]. Toronto. [cited 2016 Jan 13]. Available from: https://newsroom.uber.com/toronto/meet-uberhop/

27. Everything you need to know about uberHOP [Internet]. Washington. 2015 [cited 2016 Feb 17]. Available from: https://newsroom.uber.com/us-washington/seattle-uberhop-routes/

28. Also A. Get Around the Metro with uberHOP [Internet]. Uber MNL Tips. 2016 [cited 2016 Jul 17]. Available from: http://ubermanilatips.com/uberhop-manila-routes/

29. UberHop is Uber's latest idea for killing mass transit [Internet]. The Verge. [cited 2016 Jan 13]. Available from: http://www.theverge.com/2015/12/8/9873544/uber-hop-commute-mass-transit-seattle-chicago

30. Shared-Use Mobility: What Does the Future Hold? Workshop Synopsis [Internet]. Innovative Mobility Research. 2015 [cited 2016 Mar 2]. Available from: http://innovativemobility.org/?project=shared-use-mobility-what-does-the-future-hold-workshop-synopsis

31. #uberhop hashtag on Twitter [Internet]. [cited 2016 Nov 4]. Available from: https://twitter.com/hashtag/uberhop

32. Raj A. Uber plans bus, mini-van ride sharing service in India [Internet]. http://www.livemint.com/. 2016 [cited 2016 Nov 4]. Available from: http://www.livemint.com/Companies/DdIguNHRQvrtb7iUtlzhGM/Uber-plans-bus-and-minivan-ride-shares-in-India.html

33. Rayle L, Dai D, Chan N, Cervero R, Shaheen S. Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco. Transp Policy. 2016 Jan;45:168–78.

34. Murphy C. Shared Mobility and the Transformation of Public Transit [Internet]. Shared-Use Mobility Center; 2016 Mar [cited 2016 Jul 18]. Report No.: TCRP J-11. Available from: https://trid.trb.org/view.aspx?id=1401765

35. Chan N, Shaheen S. Ridesharing in North America: Past, Present, and Future. Transp Rev. 2012 Jan;32(1):93–112.

36. Gutierrez S, Staff S com. Carpooling a click away with online ridesharing [Internet]. seattlepi.com. [cited 2016 Jul 26]. Available from: http://www.seattlepi.com/local/transportation/article/Carpooling-a-click-away-with-online-ridesharing-1458815.php

37. WSDOT - RideshareOnline.com [Internet]. [cited 2016 Jul 26]. Available from: http://www.wsdot.wa.gov/transit/rideshare/rideshareonline/

38. WSDOT GeoData Distribution Catalog [Internet]. [cited 2016 Jul 28]. Available from: http://www.wsdot.wa.gov/mapsdata/geodatacatalog/

39. Puget Sound Regional Council GIS Shapefiles [Internet]. [cited 2016 Jul 28]. Available from: http://www.psrc.org/data/gis/shapefiles

40. 2015 Service Guidelines Report [Internet]. King County Metro Transit; 2015 Oct [cited 2016 Jul 28]. Available from: http://metro.kingcounty.gov/planning/pdf/2011-21/2015/service-guidelines-full-report.pdf

41. ORCA LIFT reduced fare - Metro Transit - King County [Internet]. [cited 2016 Jul 28]. Available from: http://kingcounty.gov/depts/transportation/metro/fares-orca/orca-cards/lift.aspx#qualify

42. Seattle, WA [Internet]. Forbes. [cited 2016 Aug 1]. Available from: http://www.forbes.com/places/wa/seattle/

43. How much do Uber drivers make in Seattle? • I Drive With Uber [Internet]. I Drive With Uber. 2016 [cited 2016 Nov 4]. Available from: http://www.idrivewithuber.com/how-much-do-uber-drivers-make-in-seattle/

44. Financial - Annual Performance Measures [Internet]. King County Metro Online: Accountability Center. 2016 [cited 2016 Nov 14]. Available from: http://metro.kingcounty.gov/am/reports/annual-measures/financial.html

45. Schäfer A. Transportation in a climate-constrained world [Internet]. MIT press; 2009 [cited 2016 Nov 15]. Available from: https://mitpress.mit.edu/sites/default/files/titles/content/9780262512343_sch_0001.pdf

46. United States, National Research Council (U.S.), Transit Development Corporation, Transit Cooperative Research Program, editors. Chapter 9 - Transit Scheduling and Frequency. In: Traveler response to transportation system changes. 3rd ed. Washington, D.C: Transportation Research Board; 2003. (TCRP report).

47. Seattle Department of Transportation. Seattle Department of Transportation: Employer Shared Transit Stop Pilot [Internet]. [cited 2017 Jun 23]. Available from: http://www.seattle.gov/transportation/SharedTransitStopPilot.htm

48. Bruce Nourish. Pragmatism, Efficiency, and Who Shares [Internet]. Seattle Transit Blog. 2017 [cited 2017 Jul 18]. Available from: https://seattletransitblog.com/2017/05/04/pragmatism-efficiency-and-who-shares/

49. Kittelson & Associates, Inc., Parsons Brinckerhoff, K. F. H. Group, Texas A&M Transportation Institute, Arup. Transit Capacity and Quality of Service Manual [Internet]. Transportation Research Board of the National Academies; 2013. (Transit Cooperative Research Program). Report No.: 165. Available from: https://www.nap.edu/download/24766#

50. Brian Crockford. Microsoft's Commute Program Keeps Employees Moving | NAIOP [Internet]. 2016 [cited 2017 Jul 13]. Available from: http://www.naiop.org/en/Magazine/2016/Winter-2016-2017/Development-Ownership/Microsofts-Commute-Program-Keeps-Employees-Moving.aspx

51. Association for Commuter Transportation. Getting to Work: Spotlight on employer-sponsered commuter programs [Internet]. 2017 Jan [cited 2017 Jul 13]. Available from: http://actweb.org/wp-content/uploads/2017/01/Getting-to-Work-Jan-2017-Final.pdf

52. Seattle Department of Transportation. Seattle Commute Trip Reduction Employer Profile [Internet]. 2015 [cited 2017 Jul 13]. Available from: http://www.seattle.gov/waytogo/docs/CTR_Profile_Boards_seattlechildrens.pdf

53. Stephen Fesler. Seattle Launches Shared Transit Stops With Microsoft And Children's Hospital » The Urbanist [Internet]. The Urbanist. 2017 [cited 2017 Jul 13]. Available from: https://www.theurbanist.org/2017/04/24/seattle-launches-shared-transit-stops-microsoft-childrens-hospital/

54. Jessica Lee. A first-of-its-kind program: Microsoft, Seattle Children's shuttles are now using Metro stops. The Seattle Times [Internet]. 2017 Apr 30 [cited 2017 Jul 18]; Available from: http://www.seattletimes.com/seattle-news/transportation/a-first-of-its-kind-program-microsoft-seattle-childrens-shuttles-are-now-using-metro-stops/

55. Jordan Crucchiola. SF's Tech Bus Problem Isn't About Buses. It's About Housing [Internet]. WIRED. [cited 2017 Jul 13]. Available from: https://www.wired.com/2016/02/sfs-tech-bus-problem-isnt-about-buses-its-about-housing/

56. Alison Grande. Microsoft Connector shuttles targeted by protestors [Internet]. KIRO. 2014 [cited 2017 Jul 13]. Available from: http://www.kiro7.com/news/microsoft-connector-shuttles-targeted-protestors/81833193

57. Diab EI, Badami MG, El-Geneidy AM. Bus Transit Service Reliability and Improvement Strategies: Integrating the Perspectives of Passengers and Transit Agencies in North America. Transp Rev. 2015 May;35(3):292–328.

58. TransitCenter. To Improve Transit, Be Smart About Delays [Internet]. TransitCenter. 2016 [cited 2017 Aug 2]. Available from: http://transitcenter.org/2016/05/17/improve-transit-smart-delays/

59. King County Metro. Developer resources [Internet]. 2010 [cited 2017 Aug 2]. Available from: http://www.kingcounty.gov/transportation/kcdot/MetroTransit/Developers.aspx

60. Bates JW. Definition of practices for bus transit on-time performance: Preliminary study. Transp Res Circ [Internet]. 1986 Feb [cited 2017 Jul 13];(300). Available from: https://trid.trb.org/view.aspx?id=276035

61. King County Metro. 2016 System Evaluation: Annual Service Guidelines Report Attachement A [Internet]. King County Metro Transit; 2016 Sep [cited 2017 Jul 18]. Available from: http://metro.kingcounty.gov/planning/pdf/2011-21/2016/service-guidelines-full-report.pdf

62. Strathman JG, Hopper JR. Empirical analysis of bus transit on-time performance. Transp Res Part Policy Pract. 1993 Apr 1;27(2):93–100.

63. King County Metro. Fares & ORCA passes: What to pay [Internet]. [cited 2017 Jun 23]. Available from: http://kingcounty.gov/depts/transportation/metro/fares-orca/what-to-pay.aspx

64. Maddala GS, Lahiri K. Introduction to Econometrics. 4 edition. Chichester, U.K: Wiley; 2009. 654 p.

65. Ijsmi E. Application of Quantile regression in clinical research: An overview with the help of R and SAS statistical package. Int J Stat Med Inform. 2017 Mar 26;2(1):1–6.

66. Koenker R, Portnoy S, Ng PT, Zeileis A, Grosjean P, Ripley BD. Package "quantreg." Quantile Regres In [Internet]. 2017 [cited 2017 Aug 2];5. Available from: ftp://ftp.ussg.iu.edu/pub/CRAN/web/packages/quantreg/quantreg.pdf

67. King County Metro. King County Metro Strategic Plan: Service Guidelines [Internet]. King County Metro Transit; 2013 [cited 2017 Jun 23]. Available from: http://metro.kingcounty.gov/planning/pdf/Metro_ServiceGuidelines_2013.pdf

68. Hern A. Uber and Lyft pull out of Austin after locals vote against self-regulation. The Guardian [Internet]. 2016 May 9 [cited 2017 Nov 22]; Available from: http://www.theguardian.com/technology/2016/may/09/uber-lyft-austin-vote-against-self-regulation

69. Sisson P. Uber and Lyft return to Austin: What's changed, and why it's important [Internet]. Curbed. 2017 [cited 2017 Nov 22]. Available from: https://www.curbed.com/2017/6/14/15803138/austin-uber-lyft-transportation-ride-hailing-return

70. Challenge Seattle [Internet]. 2015 [cited 2017 Nov 21]. Available from: http://www.challengeseattle.com/