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ABSTRACT
In this study, we present exploratory evidence of how “ridesourcing” services (app-based, on-demand ride services like Uber and Lyft) are used in San Francisco. We explore who uses ridesourcing and for what reasons, how the ridesourcing market compares to that of traditional taxis, and how ridesourcing impacts the use of public transit and overall vehicle travel. In spring 2014, 380 completed intercept surveys were collected from three ridesourcing “hot spots” in San Francisco. We compare survey results with matched-pair taxi trip data and results of a previous taxi user survey. We also compare travel times for ridesourcing and taxis with those for public transit. The findings indicate that, despite many similarities, taxis and ridesourcing differ in user characteristics, wait times, and trips served. While ridesourcing replaces taxi trips, at least half of ridesourcing trips replaced modes other than taxi, including public transit and driving. Impacts on overall vehicle travel are unclear. We conclude with suggestions for future research.

KEY WORDS: On-demand transport; taxis; transportation network companies (TNCs); shared mobility; ridesharing; flexible transport

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1. INTRODUCTION

The recent emergence of app-based, on-demand ride services has sparked great debate over their role in urban transport. We refer to these services—provided by companies like Uber and Lyft—as "ridesourcing." Ridesourcing dynamically matches supply and demand by allowing travelers to request car rides in real-time from potential suppliers using a smartphone application. Distinct from ridesharing, ridesourcing drivers operate for-profit and typically provide rides not incidental to their own trips. Ridesourcing is distinguished from traditional taxicabs by its use of smartphone technology and a dynamic matching algorithm—which some taxis have also adopted. It is also distinct because ridesourcing in the U.S. has not been subject to taxi regulations, which in many cities limit supply, determine fares, and set safety standards. Bolstered by support from customers, ridesourcing companies have grown quickly and received regulatory support across the U.S. However, they have also provoked the ire of the taxi industry and generated concern among many regulators.

Ridesourcing raises a number of public interest questions. Supporters view ridesourcing as part of a suite of transport options that provides fast, flexible, and convenient mobility in urban areas. By providing an attractive alternative to driving and filling gaps in the public transit network, these services can potentially reduce auto use, ownership, and associated environmental impacts (e.g., see Laurent and Katz, 2013; Metcalfe and Warburg, 2012; Silver and Fischer-Baum, 2015). However, critics charge that ridesourcing services increase congestion, compete with public transit, mislead consumers through opaque pricing practices, cater only to the young and well-to-do, and endanger public safety (Flegenheimer and Fitzsimmons, 2015; Laurent and Katz, 2013; Sabatini, 2014). Regulations may be needed to counteract negative externalities and other market failures inherent in the sector.

Ridesourcing has attracted significant criticism from its most direct competitor, the taxi industry, which views ridesourcing as an illegal service that flouts existing laws and competes unfairly. Ostensibly, taxis would fill the role played by ridesourcing services (Austin and Zegras, 2012; Gilbert and Samuels, 1982; King et al., 2012; Wohl, 1975), but in many cities they have not, due to regulations and monopolistic behavior that restrict supply and give rise to reliability and service quality problems (Cervero, 1997; Gilbert and Samuels, 1982; Hara Associates, 2013; Wohl, 1975). Some also argue that ridesourcing differs from traditional taxis due to the efficiency and reliability of the matching platform and pricing mechanisms, along with the accountability of the rating system. On the one hand, proponents maintain that ridesourcing, unlike taxis, enables more efficient use of vehicles that drivers already own. On the other hand, ridesourcing's apparent efficiency advantages may also be explained by its exemption from the supply restrictions that often govern taxis.

As city leaders deliberate policies on ridesourcing, there is an urgent need for independent data on their use and analysis of their environmental impacts. To date, little data on travelers' use of ridesourcing has been publicly available. The only studies of ridesourcing's impacts, to our knowledge, have been in the popular media (Bialik et al., 2015; Silver and Fischer-Baum, 2015), conducted by the companies themselves (Hall and Krueger, 2015), based on qualitative interviews with drivers (Anderson, 2014). In this exploratory study, we aim to fill this research gap and provide initial evidence on the use of ridesourcing in San Francisco. We focus on three questions: (1) Who uses ridesourcing and for what reasons? (2) How does the ridesourcing market compare with that of traditional taxis? (3) How does ridesourcing impact the use of public transit and overall vehicle travel?

We begin the paper by describing how ridesourcing operates in San Francisco and reviewing related literature. After explaining the survey methodology, we discuss results and conclude with a discussion on policy implications and suggestions for future research.

1.1. Background

Ridesourcing allows travelers to request a ride in real-time through a smartphone application, which communicates the passenger's location to nearby drivers. After a driver accepts a ride request, the passenger can view the vehicle's real-time location and estimated arrival time. The app provides GPS-enabled navigation, which helps non-professional drivers find destinations and reduces the chances of them taking a circuitous route. The payment—and sometimes tips—are automatically charged to the passenger's credit card. The driver keeps a portion of the fare, with the balance going to the ridesourcing company. Prices can respond dynamically to demand, which could increase the likelihood of finding a ride at peak times, but this can also make prices less predictable. Drivers and passengers rate each other at the ride's completion, creating an incentive system that rewards polite behavior. Unlike taxis, ridesourcing services like uberX, Lyft and Sidecar typically use drivers who lack a commercial vehicle license, drive their personal vehicle, and work part-time. Because of these characteristics, these services are considered "pure" ridesourcing compared to Uber's other options like UberBlack and UberSUV, which use dedicated vehicles and drivers with a for-hire license.

Much debate has gone into terminology for these services. Other names currently include: "Transportation Network Companies (TNCs)," "real-time ridesharing," "parataxis," "ride-hailing," and "on-demand rides." We chose to use "ridesourcing" because we believe it succinctly conveys the essential technology—a platform used to "source" rides from a driver pool. However, definitions are elusive, especially as these services continue to evolve. Taxi companies have also adopted app-based dispatch, some before the advent of Uber and Lyft.[1] App-enabled ridesharing (i.e., carpooling) also preceded Uber and Lyft. More recently, options like UberPOOL and Lyft Line allow unrelated passengers whose routes overlap to split rides and fares. Moreover, ridesourcing is not a new idea (e.g., Wright and Curtis, 2005); it falls into broader, more familiar categories, such as paratransit (Cervero, 1997) and demand-responsive or flexible transport (Brake et al., 2007; Davison et al., 2014). What is new about recent ridesourcing by Uber, Lyft, and others is the combination of a model that leverages GPS-enabled smartphone technology and exemption from traditional taxi regulations, which allows more flexibility in supply and service characteristics.

That combination appears enormously successful among consumers. According to the San Francisco Municipal Transportation Agency's (SFMTA) annual travel survey, in 2014, ridesourcing served an estimated 47,000 trips per day in San Francisco, or 1% of all trips, while taxis made about 22,000 trips per day. The same survey found 25% of San Francisco residents used ridesourcing at least monthly, compared to 19% for taxis (SFMTA, 2014a). A 2015 poll of registered voters in the U.S. found 12% used Uber or Lyft at least once a month, compared to 13% for taxis (Morning Consult, 2015). Among voters aged 18-44, that proportion jumped to 26% for Uber or Lyft, slightly edging out the 25% for taxis. Ridesourcing is indeed proving tough competition for taxis—in San Francisco, the number of taxi trips per month dropped by more than half between March 2012 and July 2014 (SFMTA, 2014b).

1.2. Related literature

Because independent research on the use of ridesourcing is very limited, we turn to related research on ridesharing (carpooling/vanpooling) and taxis to provide insights into expected usage characteristics and potential impacts. Compared to driving alone, ridesharing reduces vehicle miles traveled and for this reason federal and local policies have for decades promoted ridesharing (Altshuler et al., 1979). Individually, ridesharing participants benefit from shared travel costs, travel-time savings from high occupancy vehicle lanes, and reduced commute stress

1 For example, as of October 2014, 80% of San Francisco's 1,450 taxis were using the e-hail app Flywheel, according to the company.

(Chan and Shaheen, 2012). Despite its benefits, increased ridesharing use has faced several barriers, including reluctance to sacrifice the flexibility and convenience of the private automobile (Dueker and Levin, 1976), desire for personal space and time (Bonsall et al., 1984), and personal security concerns about riding with strangers.

Taxis have historically accounted for a very small share of urban travel and are much less extensively studied than other transport modes. Past surveys have shown taxis to serve several markets—older residents, higher-income groups, and lower-income households without a car (Webster et al., 1974). Despite their small modal share, taxis fill a critical gap by providing transportation when driving or other public transit modes are not possible (Gilbert and Samuels, 1982; Wohl, 1975). Notably, authors have found taxis to be both complements and substitutes for public transit (Austin and Zegras, 2012; King et al., 2012). Shared taxis can potentially bring benefits, including increased efficiency, lower costs for passengers, and reduced congestion and overall vehicle travel (Cervero, 1997; Enoch et al., 2004; Santi et al., 2014; Wohl, 1975). However, most cities in the U.S. prohibit unrelated passengers from sharing a taxi.

Research suggests unregulated taxi services can create public costs, and almost all large- and medium-sized cities have regulated taxis since the 1930s (Dempsey, 1996; Gilbert and Samuels, 1982). The taxi industry has at various times suffered from numerous market failures, providing the rationale for regulation (Dempsey, 1996; Gilbert and Samuels, 1982; Schaller, 2007). Lack of information is a problem in street-hail and cab-stand markets—riders cannot compare information on price or service quality before choosing a vehicle, often resulting in poor service quality. Low barriers to entry in these markets tend to enable over competition, leading to aggressive and unsafe driver behavior, poor vehicle maintenance, and congestion (Schaller, 2007). Regulatory responses include restrictions on market entry and supply (i.e., medallion systems); fare regulation; and vehicle and driver safety standards. The taxi industry in San Francisco is particularly heavily regulated, especially in terms of supply—a 2013 report concluded that the existing supply of 1,585 taxis needed to be increased by at least 50% to meet demand (Hara Associates). Technological advances, moreover, bring into question how the need for regulation may have changed. Hailing a for-hire vehicle no longer requires standing on a street corner or placing a telephone call, and rating systems might resolve the lack-of-information problem. With characteristics similar to taxis, but also the potential to realize some of the benefits of both taxis and ridesharing, ridesourcing poses a challenge for regulators. Addressing these challenges clearly requires better data on how ridesourcing is actually used in cities.

2. METHODOLOGY

To collect data on ridesourcing users and trips, we conducted an intercept survey in San Francisco during May and June 2014. The survey was conducted by intercepting ridesourcing customers on the street in key locations expected to have a high concentration of such users. We identified potential locations based on conversations with drivers and our own observations. After conducting pretests at these locations, we chose the three with the highest response rates (see Figure 1):

1) The Mission District (Valencia Street between 16th Street and 19th Street, and 16th Street between Mission Street and Guerrero Street);
2) The Marina District (Chestnut Street between Pierce Street and Laguna Street); and
3) North Beach (Columbus Avenue between Broadway and Union Street).

The pretests yielded an acceptable response rate (of roughly 4-5 completed responses per hour) only in evenings and during peak hours—Thursdays from 5:30-8:30pm, Fridays 6:30-9:30pm, and Saturdays 7:30-10:30pm. In June, surveying on Wednesdays from 6:30-9:30pm was added, and Saturday surveying was shifted to 6:30-9:30pm in response to surveyor feedback from the field. While ridesourcing companies and drivers advised that many trips are taken throughout

the day, including the AM and PM commute, pretesting conducted downtown during commute times yielded an extremely low response rate; hence, we did not attempt to survey at these times and locations.

Surveyors recruited two types of potential respondents: individuals who had just completed a ridesourcing trip ("intercept trips"), and individuals passing on the street who had used ridesourcing within the last two weeks ("previous trips"). Both groups responded to identical surveys. Surveyors were instructed to prioritize intercepting anyone exiting a ridesourcing vehicle, which were identifiable either by a sign (e.g., the company's logo or Lyft's pink mustache), passengers riding in the backseat, or a driver using the company's smartphone app. Our pretests suggested it was relatively easy to distinguish ridesourcing vehicles and passengers from those getting a ride from a friend or family member simply based on the passenger and driver behavior. The intercepted respondents were asked about the trip they just completed (i.e., an intercept trip). For the "previous trips," surveyors were instructed to intercept every fifth person encountered on the sidewalk. These individuals were asked if they had taken a ridesourcing trip within the past two weeks. If not, they were not eligible to complete the survey. If so, they were asked to recall their most recent trip. Those approached who did not have time to complete a survey were given a link to an equivalent online survey, which they could complete later on a computer or smartphone.

Of the 757 approached to participate in the survey over two months, 380 completed the questionnaire (i.e., response rate of 50.2%). Of the n=380 completed responses, 294 (77%) were about trips within San Francisco, but 21 (6%) had at least an origin or destination elsewhere in the Bay Area, and 24 (6%) answered about trips entirely outside of San Francisco. Another 41 (11%) were discarded due to missing data (e.g., missing origin/destination, unintelligible locations). This analysis focuses mainly on trips taken within San Francisco. Of the 380 trips, 316 (83%) were "previous trips," while 64 (17%) were "intercept trips." For analysis of demographics and non-location-specific topics, we include all Bay Area trips, as noted in the findings.

The survey asked 18 questions regarding trip origin and destination, trip purpose, previous and alternative modal choice, car ownership, and basic demographics. After survey completion, respondents received a US$5 gift card to a local coffee vendor. Survey instruments were pre-tested and modified slightly based on user feedback.

We compared ridesourcing intercept survey data with data from three other sources: (1) a survey of taxi users conducted for the SFMTA, (2) GPS trip logs from one medium-sized taxi company in San Francisco, and (3) the American Community Survey (ACS) 2013 one-year estimates. The SFMTA taxi user survey, completed in early 2013, was a telephone survey of a representative sample of San Francisco households. This survey asked questions about respondents' typical taxi usage and opinions about taxi service, but did not ask about specific trips and did not include detailed location information (Hara Associates, 2013). The taxi trip log data included origins, destinations, fare, distance, and number of passengers for all trips provided by the company's vehicles in October 2013. To enable a matched comparison between taxis and ridesourcing, a random sample of taxi trips was generated to match the day of the week and time of day of surveyed ridesourcing trips. For example, for each surveyed ridesourcing trip that took place on Fridays between 7:00-8:00pm, one taxi trip was randomly selected from the same Friday, 7:00-8:00pm time period. From the approximately 150,000 logged taxi trips, 290 trips overlapped with ridesourcing trips. While the dates of the ridesourcing survey did not align with the taxi trip logs, all observations excluded summer vacation and rainy seasons, which are factors that can influence travel behavior. The ACS data provided information on demographic characteristics of the San Francisco population for comparison.

2.1. Limitations

Like all intercept surveys, this survey was not completely representative of the ridesourcing market. Data were collected from three neighborhoods, capturing primarily evening trips to

dining and entertainment venues. While these social, evening trips likely comprise a large—and perhaps the largest—part of the ridesourcing market, other types of trips are underrepresented. Informal conversations with drivers tell us many people use ridesourcing services for their commute, airport trips, and other errands. Thus, the survey does not adequately capture these trips. Respondents did not represent all ridesourcing users in San Francisco or the greater Bay Area. The survey oversampled users who were likely to be in the survey locations in the evenings. A further limitation is that, while the ridesourcing survey data are roughly comparable to data from the existing taxi survey and sampled taxi trip data, these three sets were collected via different methods with different sampling strategies, and thus rigorous statistical comparisons between them are not meaningful.[2] Given these limitations, we intend this as an exploratory study on which future research can build.

3. RESULTS

3.1. Ridesourcing Market Share

Of all surveyed trips, uberX provided the majority (53%), while other Uber services (black car, SUV) represented another 8%. Lyft provided 30% of trips, Sidecar 7%, and the remainder was other services. This is consistent with anecdotal information on the market share of each service.

3.2. Respondent Demographics

Ridesourcing survey respondents were generally younger and better educated than the average population in San Francisco (see Table 1). The age distributions for both ridesourcing and those who use taxis at least once a week skew younger than that for the city as a whole. Ridesourcing survey respondents were generally even younger than frequent taxi users, although this difference may be influenced by the sampling method—individuals surveyed may be younger on average than the actual ridesourcing user base.

2 Surveyed ridesourcing trips were matched with logged taxi trips based on time and day, but the intercept nature of the ridesourcing survey likely biased the sample toward trips made by people likely to be on the street in certain neighborhoods, whereas that bias was not present for the taxi sample.

TABLE 1 Demographics of ridesourcing survey respondents compared to taxi survey

	Ridesourcing		*Taxi*[a]		
	Responses	*%*	*Uses taxis at least once a week (%)*	*Uses taxis less than once a week (%)*	*San Francisco population*[b] *(%)*
Age					
15-24	50	16%	3%	11%	10%
25-34	178	57%	43%	23%	22%
35-44	59	19%	27%	21%	16%
45-54	20	6%	13%	17%	14%
55-64	3	1%	9%	15%	12%
65-74	0	0%	4%	8%	7%
75+	0	0%	2%	9%	7%
N	*310*		*95*	*369*	
Gender					
Female	124	40%	42%	48%	49%
Male	184	60%	56%	53%	51%
N	*308*		*95*	*378*	
Vehicle availability					
No vehicle at home	139	43%	35%	20%	19%
N	*323*		*95*	*375*	
Household Income					
$30K or less	28	9%	n/a	n/a	24%
$30-70K	74	23%	n/a	n/a	22%
$71-100K	56	18%	n/a	n/a	13%
$100-200K	86	27%	n/a	n/a	25%
$200K+	35	11%	n/a	n/a	16%
No response	37	12%	n/a	n/a	n/a
N	*316*				
Education					
Less than a bachelor's degree	51	16%	n/a	n/a	47%
Bachelor's degree	173	54%	n/a	n/a	31%
Graduate degree	87	27%	n/a	n/a	22%
Other degree	10	3%	n/a	n/a	n/a
N	*321*				

Sources: [a] 2013 SFMTA taxi user survey; [b] 2013 ACS one-year estimates, City of San Francisco. Household income and education were not included in the taxi survey.

Respondents were relatively well educated–84% of ridesourcing customers had a bachelor's degree or higher, more than for the general San Francisco population. Surveyed ridesourcing customers matched the income profile of San Franciscans fairly closely, with the prominent exception that households making less than US$30,000 were underrepresented. However, a high percentage of respondents (12%) refused to answer, and these individuals may not have the same distribution as the rest of the sample. Income and education data for taxi users

are not available. While the majority of respondents said they had a vehicle at home, the proportion that was car-less (43%) was greater than that for frequent taxi users (35%) and for the overall city population (19%).

Measured by home zip code, survey respondents reflected most of the spatial distribution of the population in the city, except respondents were more likely to live in the centrally located Russian Hill, Nob Hill, and Castro neighborhoods, as well as the Marina, a neighborhood known for poor public transit connections. Neighborhoods in the outlying southern part of the city, like Outer Mission and Bayview, were underrepresented. In all, the survey data do not refute the claim that ridesourcing disproportionately serves younger residents of higher socio-economic status; however, it is not clear whether or not the findings are biased by the sampling method and whether the ridesourcing market differs from taxis.

3.3. Trip Origins and Destinations

The survey captured trips from across San Francisco and elsewhere in the Bay Area, as did the sampled taxi trips. The spatial distribution of trip origins and destinations within San Francisco is shown in Figure 1. As expected, the ridesourcing destinations were concentrated in the three survey locations, while the taxi origins and destinations were heavily concentrated in the downtown area. Still, both cover similar areas: in comparing the two samples, more than half (58%) of ridesourcing trips began within 200 m of the taxi trip, and 81% within 400 m (the same numbers for destinations were 51% and 86%, respectively). Since we lack data on the overall spatial distribution of ridesourcing trips, we cannot say how representative our data are.

[Insert figure 1 here]

FIGURE 1 (*a*) Sampled ridesourcing trip origins, (*b*) ridesourcing trip destinations, (*c*) sampled taxi trip origins, and (*d*) taxi trip destinations in San Francisco. Heavier shading indicates a higher concentration of trips. Several trips for both services also began or ended at San Francisco International Airport, which is not shown. (Ridesourcing n = 294, taxi sample n = 290)

While the vast majority of both ridesourcing and taxi trips served San Francisco's central area, a smaller number of trips began or ended in lower density areas outside of San Francisco or in the city's outer neighborhoods. Figure 1 suggests that taxi trips were more likely to begin in the downtown core, even if they ended in outlying neighborhoods, whereas ridesourcing trips outside of the downtown might begin or end in outlying neighborhoods.

3.4. Trip Purpose

Table 2 presents reported trip purposes from the ridesourcing survey and from the taxi survey. The two sets of responses are not directly comparable because the ridesourcing survey asked for the nature of the trip's origin and destination, whereas the taxi survey asked respondents for the "most common reason" they use taxis. Of all ridesourcing responses, 67% were social/leisure (e.g. bar, restaurant, concert, visit friends/family). A smaller 16% were commuting to or from work, 4% were to or from the airport, and 10% were other (e.g. doctor's appointment, volunteer). A large percentage (47%) of trips began somewhere other than home or work—a restaurant, bar, gym, etc.—and 40% were home-based. Although the survey did not specifically request it, 5% of ridesourcing respondents named a specific public transit station as their origin or destination, suggesting they used ridesourcing to access transit. Almost half (48%) of ridesourcing trips occurred on Friday or Saturday. While evening hours are heavily represented, the survey did capture trips at times throughout the day and night. Given that we oversampled nighttime and social trips, it is unsurprising that the majority were social/leisure trips. Perhaps more notable is that 16% were work trips, implying the true of proportion of work trips is higher. In comparison, 27% of frequent taxi users, or 5% of all taxi users, said commuting to work was one of the most common reasons they used taxis. These figures suggest ridesourcing is not merely used for

"going out at night," as sometimes believed, and it may be a more common commute mode than taxis.

Table 2: Trip purpose for ridesourcing and taxi surveys[a]

Ridesourcing survey			**Taxi survey**		
Trip purpose	*Responses*	*Percent*	**Most common reasons to use taxis**	*Uses taxis at least once per week*	*Uses taxis less than once per week*
Social/leisure	213	67%	Going out at night	45%	46%
Work	52	16%	Work	27%	7%
To/from airport	13	4%	To/from airport	23%	34%
Shopping/errands	8	3%	Shopping/ daytime activities	14%	15%
School	3	1%	Other business or employment needs	11%	9%
Other (medical, volunteer)	16	5%	Medical	6%	4%
To/from transit	15	5%	Avoid parking	3%	1%
N	*320*		Transit not running/ inconvenient	2%	1%
			Car trouble/ car not available	1%	2%
			n	*94*	*376*

[a] *Ridesourcing and taxi responses are not directly comparable due to differences in survey questions. The ridesourcing survey asked, "What was your reason for coming here (or going there)?" and accepted only a single response. The taxi survey asked, "What is the most common reason you use taxis?" and accepted multiple responses.*
[b] *Includes all taxi users*

3.5. Reasons for Choosing Ridesourcing

When asked why they chose ridesourcing, variations on speed and convenience were the main attractions (Figure 2), but other reasons were important too. More than 20% said they wanted to avoid drinking and driving. Only 2% said they could not get a taxi, and only 6% said public transit was not available.

Reasons for using ridesourcing varied by alternative mode. Among those who would have taken the bus, the most common responses were: fastest way to get there (24%) and short wait time (12%). For those who would have taken a taxi, the top reasons were about convenience —25% said ease of payment, 17% said short wait time, and 11% said easy to call car. These particular respondents did not consider ridesourcing to be generally cheaper or more reliable— only 3% said they chose ridesourcing due to cost and only 7% cited reliability. Users who would have otherwise driven appeared to want to avoid driving hassles. Of these respondents, the greatest number (25%) said: "don't need to park," and 19% "didn't want to drive after drinking." Overall, speed (shorter wait times and travel times) and convenience appear to make ridesourcing more appealing than the alternatives.

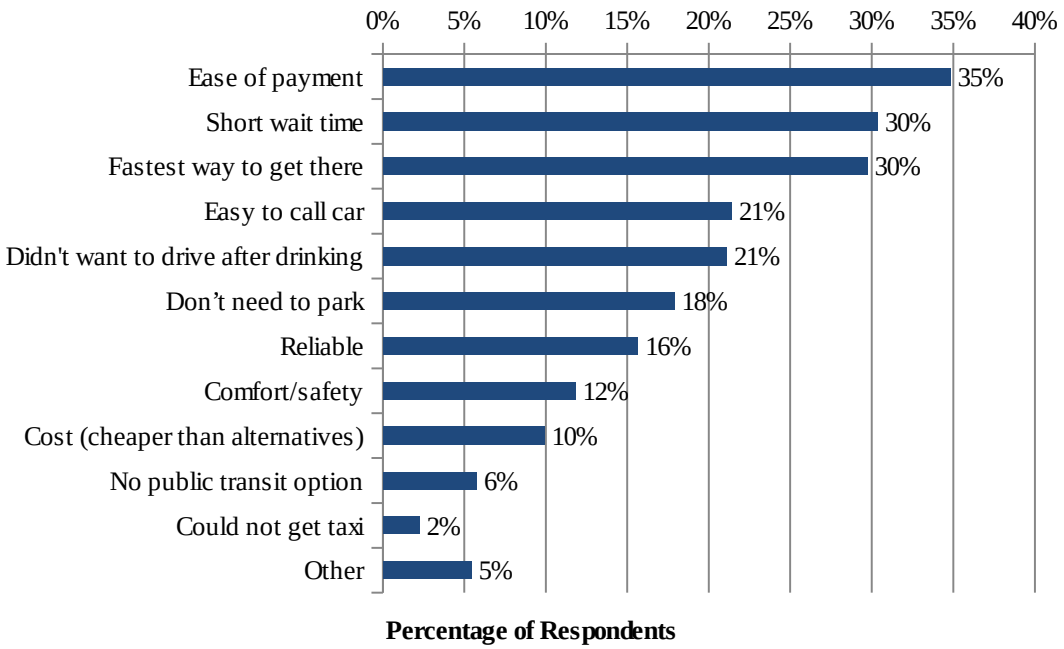

FIGURE 2 Responses to "What are the top two reasons you used uberX/Lyft/Sidecar for this trip? (n = 313). “Other” included, for example, need to carry stuff, friendly driver, car being repaired, and company pays for it.

3.6. Wait Time

Ridesourcing wait times are dramatically shorter than typical taxi dispatch and hail times (see Table 3). When calling a taxi to their home, only 35% of San Francisco residents said they usually waited less than ten minutes on a weekday during the day; on nights and weekends, this figure dropped to 16%. By comparison, close to 90% of ridesourcing respondents said they waited ten minutes or less at all times, and 67% waited five minutes or less. Ridesourcing wait times are also much more consistent across day of week, time of day, and area of the city. Ridesourcing customers could expect a wait of ten minutes or less any time and anywhere in the city. In contrast, taxi wait times varied considerably by time, day, and location and were notably longer in the city’s outer neighborhoods (Zones 2, 3, 4 and 5; see Figure 3).

TABLE 3 Ridesourcing Wait Times Compared with Taxi Dispatch and Hail Times

	Ridesourcing[a]						**Taxi Dispatch to Home**[b]						**Taxi Hail Near Home**					
	All	Zone[d]					**All**	Zone					**All**	Zone				
		1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
Mon-Fri 4am-6pm																		
	93	88	100			100	**35**	43	42	23	25	36	**39**	53	46		24	30
<= 10 mins	**%**	%	%	n/a	83%	%	**%**	%	%	%	%	%	**%**	%	%	6%	%	%
		12					**41**	41	42	41	48	38	**29**	32	27	17	29	36
10-20 mins	**7%**	%	0%	n/a	17%	0%	**%**	%	%	%	%	%	**%**	%	%	%	%	%
							23	16	16	36	27	26	**32**	15	27	78	48	33
> 20 mins or never[c]	**0%**	0%	0%	n/a	0%	0%	**%**	%	%	%	%	%	**%**	%	%	%	%	%
N	***97***	*43*	*24*	*n/a*	*6*	*14*	***282***	*79*	*57*	*39*	*56*	*47*	***226***	*81*	*48*	*18*	*42*	*33*
Mon-Fri 6pm-4am																		
	92	89	100			100	**16**	17	16	14		27	**33**	38	40		24	36
<= 10 mins	**%**	%	%	n/a	93%	%	**%**	%	%	%	6%	%	**%**	%	%	0%	%	%
		10					**47**	43	54	45	54	35	**31**	39	21	17	31	38
10-20 mins	**6%**	%	0%	n/a	7%	0%	**%**	%	%	%	%	%	**%**	%	%	%	%	%
							37	40	30	41	40	38	**36**	23	38	83	44	26
> 20 mins or never	**1%**	2%	0%	n/a	0%	0%	**%**	%	%	%	%	%	**%**	%	%	%	%	%
N	***144***	*61*	*30*	*n/a*	*15*	*23*	***254***	*77*	*56*	*29*	*52*	*37*	***230***	*82*	*42*	*18*	*45*	*39*
Sat-Sun																		
	88	85	100		100		**16**	23	16	12		17	**25**	33	18		20	32
<= 10 mins	**%**	%	%	n/a	%	89%	**%**	%	%	%	7%	%	**%**	%	%	0%	%	%
	12	15					**39**	28	36	54	50	37	**35**	43	36	19	33	32
10-20 mins	**%**	%	0%	n/a	0%	11%	**%**	%	%	%	%	%	**%**	%	%	%	%	%
							45	49	47	35	43	46	**39**	24	45	81	48	37
> 20 mins or never	**0%**	0%	0%	n/a	0%	0%	**%**	%	%	%	%	%	**%**	%	%	%	%	%
N	***75***	*39*	*13*	*n/a*	*8*	*9*	***251***	*75*	*55*	*26*	*56*	*41*	***232***	*86*	*44*	*16*	*46*	*38*

[a] *The ridesourcing survey question read: "About how long did you wait for your ride (from the time you made the request to the time the vehicle arrived)?"*

[b] *Taxi survey questions read: "Thinking about the times you've used a San Francisco taxi in the past 6 months, approximately how long does it take…" "…for a cab to arrive to your home after you've called taxi dispatch?" and "… to hail a cab in a street near your home?"*

[c] *The taxi survey included the response option: "Often never arrives." This was not included in the ridesourcing survey.*

[d] *See Figure 3 for zone definitions.*
n/a indicates there were too few observations available to calculate percentage.

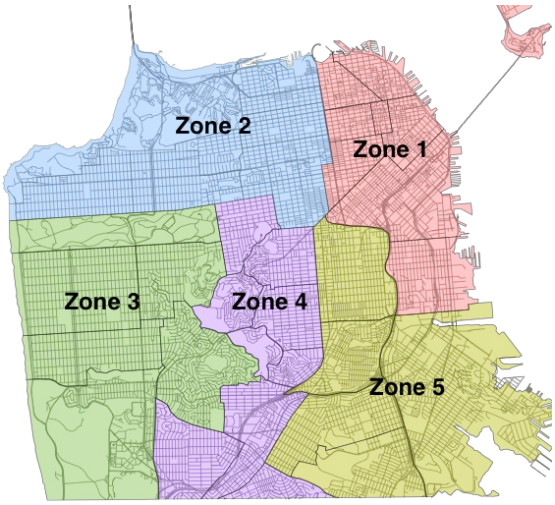

FIGURE 3 Definition of zones for wait time analysis. Downtown San Francisco is located in Zone 1.
Source: City of San Francisco

The discrepancy in wait times might result from location biases in our sample, since most surveyed ridesourcing trips did not begin at home, while the taxi survey asked about home location. However, when we analyzed the data by city zone, as defined in the taxi survey, the pattern of shorter and more consistent wait times held. Ridesourcing response times were longer in Zone 1 (which includes downtown) than other parts of the city, but the difference was very small compared with the variation in taxi times. For instance, on a weekday before 6pm, 88% of ridesourcing wait times in Zone 1 were ten minutes or less, whereas only 43% of taxi dispatches were as quick. Wait times for taxi street hails show the same pattern of longer and less consistent wait times relative to ridesourcing. The lowest wait times for street hails were in Zone 1 during weekdays; even then only 53% of respondents said they could hail a taxi in ten minutes or less.

Bias and inaccuracy in respondent perception or recollection of wait time might partially account for the difference between modes. For instance, ridesourcing apps provide the user with an estimated wait time, but the actual wait time may be longer—without the user noticing or recalling the longer wait. In contrast, respondents may overestimate taxi wait times; for example, they may recall one negative experience more than several positive ones. Even so, ridesourcing's short wait times and consistency across time and location—or at least perceptions of quick, consistent response—represent an important difference between ridesourcing and traditional taxis services from the user's perspective

3.7. Trip Distance and Vehicle Occupancy

Comparing surveyed ridesourcing trips with taxi trip logs, we found that ridesourcing trips were slightly shorter than matched taxi trips, but they carried more passengers. Trip distances for ridesourcing trips were calculated by entering the geocoded origins and destinations into Google Directions API; trip lengths therefore reflect the street network distance. For surveyed ridesourcing trips, the average length was 5.1 km (3.2 miles), while equivalent taxi trips were on average 6.2 km (3.8 miles).

Vehicle occupancies were somewhat higher than for taxi trips and about the same as for driving journeys-to-work. Half of ridesourcing trips had more than one passenger (not including the driver), and the average number of passengers was 2.1. For the matched taxi sample, the average was only 1.1. The difference is likely due to the fact that the ridesourcing trips overrepresented social trips. Considering work trips alone, according to the 2011 ACS, the average vehicle occupancy for work trips of San Francisco workers was 1.15. For surveyed

ridesourcing journeys-to-work trips within San Francisco, the average occupancy was nearly the same, 1.14.

3.8. Vehicle Ownership and Driving Frequency

As previously noted, ridesourcing survey respondents were less likely to have a car at home than both taxi users and the general population. Ninety percent of vehicle owners said they had not changed their ownership levels since they began using ridesourcing and those who did change ownership were as likely to own more cars as fewer cars, so the presence of ridesourcing probably did not influence car ownership behavior. However, ridesourcing users who did have a car drove it relatively infrequently—38% of car-owners said they typically drove once or twice per week, while only 24% said they drove every day. In addition, ridesourcing appears to have allowed some people to drive less frequently. Of the respondents who owned a car, 40% said they drove less often "as a result of using Lyft/Uber/Sidecar," while 58% said they had not changed how often they drove.

3.9. Modal Shift and Induced Travel

Respondents were asked if they still would have made the trip had ridesourcing services not been available and, if so, how they would have traveled. The vast majority (92%) replied they still would have made the trip, while 8% said they would not have made the trip at all, suggesting that ridesourcing induces a small but not inconsequential amount of travel. Of those who still would have made the trip even if ridesourcing were not available, a large number (39%) said they would have otherwise used a taxi, while 33% said bus or rail, and 6% drive their own car (Table 4).

TABLE 4 Ridesourcing survey responses to "How would you have made this trip if UberX/Lyft/Sidecar were not available?"

	All respondents	Do you have a car at home?	
		Yes	No
Taxi	39%	41%	35%
Transit (bus or rail)	33%	24%	43%
Walk	8%	9%	6%
Bike	2%	2%	3%
Drive my own car	6%	10%	0%
Get a ride with friend/family	1%	1%	2%
Other*	11%	12%	10%
n	*302*	*175*	*124*

** The majority of responses in the "Other" category include another ridesourcing service, even though they were instructed not to, followed by carsharing (i.e., City CarShare, Zipcar). One respondent noted Flywheel and another a local shuttle service.*

Notably, responses of car owners differed from those of non-car owners. As Table 4 shows, car owners were more likely to say they would have otherwise driven themselves, unsurprisingly, but compared to non-owners, they were also more likely to have otherwise taken a taxi. Respondents without a car at home, however, were more likely to substitute ridesourcing for public transit (43% of non-car owners vs. 24% of car owners).[3] These differences indicate car owners were generally more inclined toward car use, whether a private car, taxi, or ridesourcing vehicle. Non-car owners, in contrast, were more inclined toward public transit, and they seemed to consider ridesourcing a replacement for transit as much as a replacement for taxis.

3.10. Comparison with Public Transit

We investigated the extent to which ridesourcing complements or competes with public transit by examining whether or not the surveyed trips were accessible by transit. We considered two measures of transit accessibility: proximity to transit stops and relative transit travel time. For proximity to transit, we defined a trip as transit-accessible if it began and ended within a typical walking distance, 400 m (1/4 mi) of a rail transit station (streetcar, subway, or commuter train), or 200 m (1/8 mi) of a bus stop, during service hours. Of the ridesourcing trips, 28% began and ended within 400 m of rail transit (Table 5). Thus, just over a quarter were plausibly rail transit substitutes. Many more (81%) were accessible by bus, although fewer (63%) of these did not require a transfer. We observed similar values for the sampled taxi trips (Table 5).

TABLE 5 Public transit accessibility indicators

	Ridesourcing trips	**%**	**Taxi trips**	**%**
<400m of rail station	79	28 %	85	31%
<200m of bus stop	230	81 %	213	77%
Requires transfer	78	28 %	64	23%
<200m of bus stop, no transfer	177	63 %	166	60%
N	*283*		*277*	

Next, we estimated travel time for the surveyed trips by public transit and by driving, using the Google Directions API. Departure time was defined using the survey response for time and day. Transit wait time required estimation because Google Directions calculates the travel duration as the sum of in-vehicle time, walking time to and from the public transit stop, and, if there are transfers, the transfer wait time. The trip duration does not include wait time for the first trip leg, but directs the traveler exactly when to depart so as to minimize wait time. In reality, most travelers will not time their departures so precisely, so to estimate wait time, we calculated the difference between the given departure time as defined by the survey response time and the suggested departure time returned by Google Directions. This method may slightly overestimate

3 Tests of statistical significance comparing car owners and non-car owners on all responses to this question are meaningful because the variables are not independent: the "drive my own car" category is dependent on whether the respondent has a car at home. But, a pairwise Fisher's exact test comparing the two groups on taxi and public transit is significant at the 0.05 level (p-value=0.0128).

wait time, since some travelers may time their departures more carefully. The estimated total transit travel time equals the travel duration returned by Google plus the estimated wait time.[4]

For ridesourcing trips, we estimated the wait time as the midpoint of the interval provided in the survey response (e.g., 1 to 5 minutes, 6 to 10 minutes). The taxi trip log did not include wait times, so we conservatively assumed a wait time of five minutes, at the low end of the wait times suggested by the taxi user survey. The estimated total travel time by ridesourcing (or taxi) equals the travel duration by driving returned by Google plus the estimated wait time. This method may underestimate actual driving times because it cannot account for traffic conditions at the trip time. Of trips that began and/or ended in San Francisco, we were able to obtain public transit and driving directions for 283 observations (the remainder were missing departure time information).

TABLE 6 Estimated travel times for the surveyed ridesourcing trips, sampled taxi trips, and comparable transit travel times.

	Ridesourcing trips	**Taxi trips**
Average total time by transit (mins) (wait + travel)	32.5	31.0
Average total time by ridesourcing/taxi (mins) (wait + travel)	22.1	23.7
Average travel time by transit (mins) (in-vehicle + walk access + transfer wait)	27.8	26.6
Average travel time by ridesourcing/taxi (mins) (in-vehicle only)	17.0	18.7
Average wait time by ridesourcing/taxi (mins)	4.9	5.0
Average wait time by transit (mins)*	5.7	5.5
Trips that are twice as long by public transit	185 (66%)	169 (61%)
Trips that are 50% or longer by public transit	243 (86%)	242 (88%)
N	*283*	*277*

**Excludes "transit" trips that are walking only.*

Not surprisingly, estimated total travel times, including wait and in-vehicle times, were consistently greater for public transit than ridesourcing, although a few trips would have been faster by transit (Table 6 and Figure 4). The estimated average total travel time was 22 minutes for ridesourcing trips, while the same trips would have taken on average 33 minutes by public transit; a typical ridesourcing trip saves about 10 minutes of travel time. These figures do not appear to be significantly different for taxis. Overall, 66% of ridesourcing trips would have been at least twice as long in minutes, if taken by public transit.

4 In the few cases in which walking was faster than public transit, we assumed the trip would be made by foot, with the corresponding walking time as travel time.

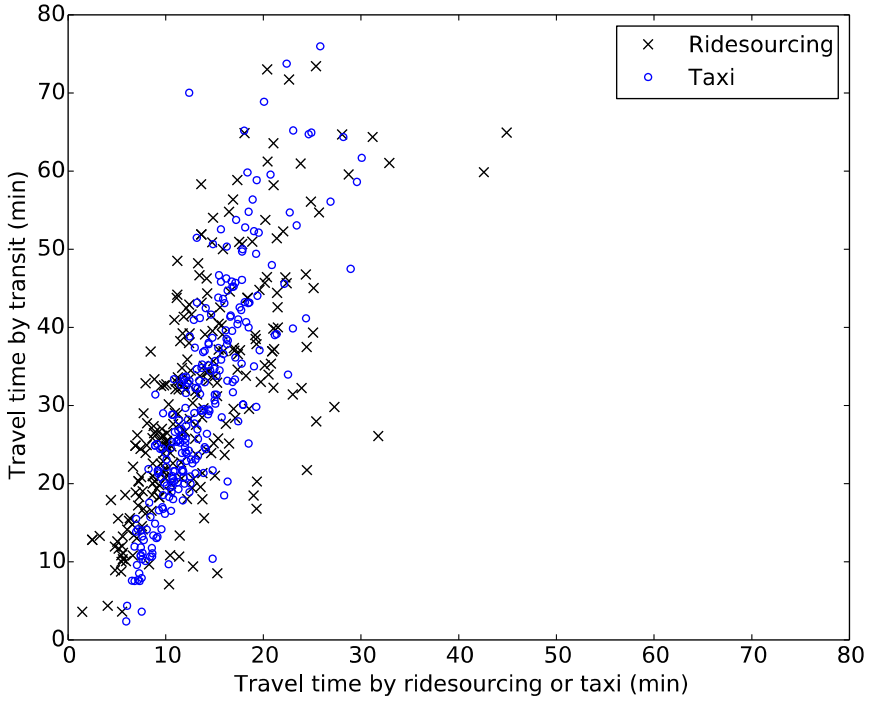

FIGURE 4 Comparison of transit travel time with ridesourcing travel times (total travel time = wait + in-vehicle time)

4. DISCUSSION

Ridesourcing is often seen as catering specifically to a young and smartphone-equipped population. Indeed, ridesourcing survey respondents were younger and better educated than the general population, and were younger than frequent taxi users. In all, the survey data do not refute the claim that ridesourcing disproportionately serves younger residents of higher socio-economic status; however, it is not clear whether or not the findings are biased by the sampling method and whether the ridesourcing market differs from taxis. A larger and more representative survey would be needed to address this question. Whether ridesourcing becomes popular among a more diverse population as it expands is a question for future research as well.

The survey data suggest that ridesourcing services and taxis serve a similar market demand— the plurality of ridesourcing users said they would otherwise have used a taxi for the same trip, and the two types of services covered similar areas and trip lengths. Yet our data suggest ridesourcing is doing more than just replacing taxi trips. Approximately half of the ridesourcing trips we surveyed replaced modes other than taxi, including public transit, walking and biking, and driving. Non-car owners were even less likely to have used ridesourcing in place of a taxi; instead, they were most likely to have shifted from transit. We expect this observation holds even when we consider that our survey oversampled nighttime and social trips. Compared to trips for other purposes and at other times of day, nighttime and social trips are probably more likely to be made by taxi, so we would expect taxi replacement trips to be overrepresented in our sample. It is quite probable, therefore, that more than half of all San Francisco ridesourcing trips substitute for modes other than taxi, and thus lie outside the traditional taxi market.

One reason ridesourcing is drawing more customers than taxis may be that users of each service apparently experience very different wait times. Reported ridesourcing wait times were not only much shorter overall, but they were also markedly more consistent across day, time, and

location. While there may be some bias in respondent recall of wait time, it is unlikely this would affect the consistency across time or space. Previous studies have found short wait times and real-time arrival information to be critical for public transit (Evans, 2004; Turnbull and Pratt, 2003), and these factors are likely equally critical for ridesourcing users, as noted by the respondents themselves. Notably, wait times appear to be reliably short in outer parts of the city, where public transit and traditional taxi service are sparser and auto dependency is higher. Ridesourcing's gap-filling role may be especially important in improving access to these neighborhoods. It is unclear whether ridesourcing's wait-time advantage arises from technological efficiencies (i.e., smartphone-enabled matching rather than telephone dispatch) or a greater vehicle supply (i.e., ridesourcing is not subject to regulations that restrict supply). Identifying the source of each advantage is a task for further research and will be essential as cities consider revised regulations.

In addition to replacing taxi trips, ridesourcing also draws from public transit. The survey provides evidence that ridesourcing both complements and competes with public transit, at least with respect to individual trips. The majority of trips were accessible by bus or rail; however, they would have taken more than twice as long using those modes. Respondents confirmed they often chose ridesourcing due to travel time savings, indicating a potentially competitive relationship. If ridesourcing mainly serves mass transit's core demand, offering faster alternative to trips that could be made by transit, ridesourcing could "skim the cream" from public transit ridership and erode transit's ridership base. At the same time, our survey offers tentative evidence that ridesourcing sometimes serves a niche demand that mass transit inherently does not serve well, like connections to transit, trips to or from low-density areas, or late-night trips when waiting for transit might feel unsafe. Moreover, in San Francisco transit is often overcrowded at peak times. Travelers may use public transit for a trip in one direction and ridesourcing for the return trip, as observed in taxi use (King et al., 2012). Habitual transit users might rely on ridesourcing in specific situations—e.g., in bad weather or when carrying heavy items. In these cases, ridesourcing would serve as a gap-filling mode that allows a generally car-free lifestyle. Future research to investigate whether the "gap-filling" or "cream skimming" effect dominates would have important implications for policymakers. Such research could be done with more representative survey data, as well as with data on the time and location of ridesourcing trips.

This study provides some insights into ridesourcing's influence on vehicle miles traveled (VMT), but the full impact remains unclear. The survey does provide tentative evidence that ridesourcing enables lower levels of driving among vehicle owners. A small proportion of respondents said they used ridesourcing rather than driving their own cars. Notably, several car owners used ridesourcing to avoid drinking and driving—clearly a positive effect—although we cannot say if taxis would have performed this function equally. However, ridesourcing seems to have had little impact on auto ownership to date, which is not surprising given the newness of these services. We also found a small induced travel effect from people who took trips they otherwise would not have, accounting for 8% of all trips. The data may underestimate this effect. San Francisco contains several neighborhoods with poor transit access, poor taxi availability, or scarce parking. Travelers who previously avoided these neighborhoods might now consider them accessible, perhaps without being conscious of the effect. Without ridesourcing, they may have chosen a different destination or forgone the activity altogether; our intercept survey may not have captured this decision-making process. Thus, our results should be interpreted as a lower bound on the induced travel effect. To the extent that these induced trips represent improved mobility, they are a positive effect, but they also add to VMT.

Compared with taxi users, surveyed ridesourcing customers appear to own fewer vehicles and travel with more companions. Both of these findings might be associated with less vehicle travel—ridesourcing might allow users to own fewer cars, and passengers get more mobility for fewer VMT—at least for the surveyed trips. However, these findings might be a consequence of the sampling method, ridesourcing user age, or both. People at the survey locations might be younger and more social than average and hence might be less likely to own a car and more likely

to travel in groups. Moreover, we lack data on the extent to which drivers cruise for passengers, which would clearly added to VMT. Ridesourcing drivers may tend to circulate less than taxi drivers because they do not rely on street hails. However, anecdotal accounts suggest the high demand in San Francisco attracts ridesourcing drivers from more distant suburbs, whereas this effect for taxis is limited by regulation.

Future research into the impacts of ridesourcing on VMT should take into account the induced travel effect, travel made by drivers when no passenger is present, potential substitution from public transit, and the impact of ridesourcing on users' driving. A comprehensive assessment of VMT impacts would require both more representative user survey data and data on drivers' behavior. Effects on users' driving behavior and vehicle ownership may require longer-term study.

To reiterate, the survey was not representative of the ridesourcing market, but oversampled social and leisure trips, likely underrepresenting trips made for work purposes, airport trips, and other errands. Despite this limitation, our intercept survey provides the best data available in our study area on this emerging service. At present, ridesourcing is a new and controversial subject, and access to industry and membership data for research purposes is limited. Since data on ridesourcing market size and user characteristics are unavailable, we are unable to describe the sample relative to the larger user population.

San Francisco may not be a typical market for ridesourcing. As the birthplace of these services, San Francisco probably has the highest adoption rate, implying a greater density of drivers and users, and hence efficiency, compared with other cities. The city is well-suited for ridesourcing for several other reasons: it has a restricted taxi supply (Hara Associates, 2013), scarce parking, a limited and underfunded public transit system, an urban form that lies somewhere between walkable and car-oriented (Henderson, 2013), and a large population of highly paid young professionals. Cities like Boston, Seattle, and Washington, D.C. share these traits, although other cities in which ridesourcing operates do not.

5. CONCLUSIONS

In this paper, we presented exploratory evidence of ridesourcing's role in urban transportation using an intercept survey of ridesourcing users in San Francisco and comparing the survey results with data from a previous taxi survey and taxi trip logs. The findings suggest ridesourcing meets a latent demand for urban travel, appealing to generally younger, well-educated users looking for short wait times and fast point-to-point service, while avoiding the inconveniences of driving like parking and having to drink and drive. Despite similarities, ridesourcing differs from taxis in important ways, especially in consistently shorter waiting times. We found that at least half of ridesourcing trips replaced a mode other than taxi, indicating the two services have overlapping but different markets. Ridesourcing competes with public transit for some individual trips, but it may sometimes serve as a complement. The majority of ridesourcing trips would have taken more than twice as long if made by public transit. Finally, ridesourcing might replace some private automobile use, but because it might also induce travel, the impacts on overall VMT are uncertain. These findings fill an important gap in our understanding of this emerging travel mode on which publicly available data remains scarce.

Although exploratory, these findings nevertheless indicate that ridesourcing expands mobility options for city dwellers, particularly in large, dense cities like San Francisco where parking is constrained and public transit is insufficient. Thus, outright bans on ridesourcing would negate these mobility gains. Ridesourcing may also have negative aspects not addressed in this study—such as increased congestion, labor abuses, and access for the disabled—that might call for regulation.

The popular media often pits ridesourcing against taxis.[5] Ridesourcing undeniably poses direct competition to the incumbent taxi industry; however, our study suggests the narrative of ridesourcing *vs.* taxis is only half the story. Ridesourcing appears to allow car owners to drive less, which should leave policymakers cautiously optimistic about its impact on vehicle use and ownership. Future research should assess these impacts over time. At the same time, the fact that ridesourcing often draws travelers, and especially non-car owners, from public transit suggests that researchers and policymakers should pay more attention to its impact on transit use.

Future research should investigate the potential hypotheses outlined in this study using more complete and representative data. Access to ridesourcing trip and user data would provide a much more detailed and representative picture, and researchers and policymakers should advocate for policies that require ridesourcing companies to make such data publicly available. Data from ridesourcing companies on trip times and locations will likely be insufficient to answer questions such as vehicle ownership changes, thus publicly sponsored travel surveys should be designed with these questions in mind. As ridesourcing and similar travel modes continue to rapidly evolve, other questions will surely emerge.

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5 Examples are countless. See, e.g., Flegenheimer and Fitzsimmons (2015) and Green (2015).

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