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Charging infrastructure requirements to support electric ride-hailing in U.S. cities

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Introduction

The number of electric vehicles that have been sold globally is well into the millions. Ride-hailing services, such as Uber and Lyft, also have seen substantial growth. These developments have remained largely separate trends: Less than 1% of the vehicles used in ride-hailing fleets were electric in 2017. As governments at city, state, and national levels act to stabilize the climate and reduce pollution from transportation, ride-hailing fleets could potentially be leaders in the transition to zero-emission mobility.

In cities where more than 20% of residents use ride-hailing services, there are tens of thousands of drivers, and ride-hailing rivals local transit use. Ride-hailing vehicles are often driven three to four times more miles per year than privately owned cars, so their electrification offers greater relative per vehicle fuel-saving and emission-reduction benefits and could significantly accelerate the share of electric vehicle miles traveled.

Many governments are implementing policies to address ride-hailing fleets' traffic and environmental externalities and steer them toward adopting more electric vehicles. Regulations in California, London, and Shenzhen require ride-hailing companies to reduce their emissions and increasingly adopt electric vehicles in future years. Policymakers in Boston and San Francisco have proposed levying taxes or fees on ride-hailing trips and incentivizing electric vehicles by making them fully or partially exempt. New York City restricts the number of ride-hailing vehicle licenses available and exempts electric vehicles from the cap. Various other policy support measures, including financial incentives, infrastructure deployment, preferential vehicle access, and free charging, are in place in many markets across China, Europe, and North America.

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Despite these efforts, the pace and scale of electric vehicle adoption in ride-hailing fleets lag those of the private vehicle market (Slowik, Fedirko, & Lutsey, 2019). Several barriers persist that hinder widespread electric ride-hailing adoption, including model availability and supply, higher upfront cost, driver awareness and education, and availability of charging infrastructure that is convenient and affordable. Charging infrastructure availability is critical, and governments and industry stakeholders alike are motivated to provide charging solutions to eliminate infrastructure as a barrier to electric vehicle adoption for ride-hailing. To do so, much greater availability of infrastructure is needed, including Level 2 charging at driver residences and rapid public charging in urban locations.

This working paper assesses the charging infrastructure needs to support the growth of electric ride-hailing in the 2020–2030 time frame in U.S. cities. The analysis quantifies the amount and type of infrastructure needed and specifically analyzes the extent to which electric ride-hailing fleets can take advantage of underutilized public charging infrastructure capacity. Based on this analysis, the paper identifies pathways to overcome the infrastructure barrier to the electrification of ride-hailing.

Background on electric ride-hailing infrastructure

The use of ride-hailing in the United States has proliferated within major metropolitan areas over the last decade. The two largest ride-hailing companies, Uber and Lyft, together have more than 1 million drivers completing several million trips each day nationwide, which are heavily concentrated within dense urban areas. Several studies estimate the number of ride-hailing vehicles in major U.S. cities in 2017 and 2018: According to Marshall (2019) there were about 80,000 ride-hailing drivers in New York City and Channick (2018) came up with 67,000 in Chicago. At the same time there were about 45,000 Uber and Lyft drivers in San Francisco, with those vehicles representing approximately 20% of intracity vehicular travel (San Francisco County Transportation Authority, 2017, 2018).

Early pilot programs, research literature, and government programs identify the importance of having sufficient charging infrastructure available for electric ride-hailing. Uber's electric vehicle pilot in London identified the lack of an extensive public charging network as the key roadblock to electric vehicle adoption (Hartley, 2017). California data indicate that electric ride-hailing puts substantially higher charging usage on public fast chargers than personal electric cars do, and that additional infrastructure installation, utilization, and management are critical for success (Jenn, 2019a). California's Clean Miles Standard, a regulation requiring the reduction of ride-hailing companies' greenhouse gas emissions per passenger mile, includes an evaluation of infrastructure needed to support an expanding fleet of zero-emission ride-hailing vehicles (California Air Resources Board, 2019).

Charging needs can be greater for ride-hailing drivers for a variety of reasons. Ride-hailing is a commercial business and time spent charging at, driving to, or queuing near charging stations can amount to lost driver revenue. Given high weekly and annual driving distances and the need to minimize downtime, public rapid charging is critical. However, public rapid charging frequently is more expensive than other charging options, including Level 2 overnight charging in residential areas. Charging electric ride-hailing vehicles at home can lower the total cost of operation by 25% compared to using public rapid charging (Pavlenko, Slowik, & Lutsey, 2019).

Despite the favorable economics, home charging for electric ride-hailing has its own challenges. Many drivers live in apartments or multiunit dwellings without detached garages which adds significant complications and costs to charging at home. Additional challenges arise for drivers who rent their homes or move frequently. Some drivers commute several hours before starting a shift (Said, 2017), so home charging alone is insufficient to serve their daily needs. Many drivers have short-term weekly and monthly vehicle leases specifically for ride-hailing and thus may be less inclined to invest in purchasing home charging equipment. Public rapid charging is therefore a critical complement to home charging to enable more electric ride-hailing vehicles.

There are few quantitative estimates of how much public urban fast charging is needed to fuel an electric ride-hailing fleet. Maven Gig, a subsidiary of General Motors that offers short-term electric vehicle leases to ride-hail drivers, reported that one direct current (DC) fast charger typically supports about 10 to 12 high-mileage vehicles per day (Seki & Nigro, 2018). A key factor in the number of battery electric vehicles (BEVs) that DC fast chargers can supply is the utilization of chargers: One DC fast charger can supply about 10 electric ride-hailing vehicles under a utilization scenario where a charger is used for 4 hours per day; however, under higher rates of utilization of up to 6 hours and 8 hours, the ratio of BEVs to DC fast charger increases to about 16 and 22, respectively (Slowik, Wappelhorst, & Lutsey, 2019).

A 2018 study analyzed the charging infrastructure needs of an optimized ride-hailing fleet of electric vehicles simulated to meet travel demand in Columbus, Ohio based on 2016 INRIX GPS trip data (Wood et al., 2018). The researchers modeled the number of home, workplace, public Level 2, and public DC fast chargers needed to support a mix of 2,417 battery electric and 2,417 plug-in hybrid electric ride-hailing vehicles that each average 37 daily miles. The simulation identified a total need for 5,040 chargers, including 4,469 Level 1 and Level 2 home chargers, 547 Level 2 workplace and public chargers, and 24 DC fast public chargers. A key assumption was that all drivers have access to charging at home and prioritized charging there over public locations.

Other studies have investigated the charging infrastructure needs for other on-demand mobility fleets, including taxis and shared autonomous electric fleets (e.g., Moniot, Rames, & Burrell, 2019; Loeb, Kockelman, & Liu, 2018; Hu, Dong, Lin, & Yang, 2017; Chen, Kockelman, & Hanna, 2016). The temporal and spatial driving profiles of these fleets can differ substantially from those of typical ride-hailing fleets in major U.S. cities today. More targeted investigation into the infrastructure needs to electrify today's high-volume ride-hailing fleets is warranted.

Despite electric vehicles accounting for a very small share of all vehicles in ride-hailing in 2018, there is evidence that electric ride-hailing has led to increased public charging infrastructure utilization and has led to saturation at some charging stations in some markets (Jenn, 2019b). Significantly increasing the share of electric vehicles in ride-hailing services will require major infrastructure investments. More shared use (i.e., ride-hailing and non-ride-hailing cars) of public charging stations, as well as the expansion of charging stations exclusively for ride-hailing use, are potential solutions going forward. Among the key underlying questions for governments and industry stakeholders are how many electric ride-hailing vehicles can be supported by the existing public charger network, and how many additional chargers might be needed.

Infrastructure analysis

This analysis uses data from ride-hailing drivers to construct four driver types for whom we determine the number of chargers needed to serve each. The four driver types are part-time drivers with home charging, part-time drivers with no home charging, full-time drivers with home charging, and full-time drivers with no home charging. The varying use of DC fast and Level 2 home charging is quantified, based on a 240-mile electric range BEV being used in each situation in 2020, rising to 300 miles by 2025.

MILES DRIVEN PER ELECTRIC RIDE-HAILING VEHICLE

The first steps in determining infrastructure needs are to define how many miles are driven by ride-haling drivers, and whether those miles can be met with home charging or whether additional public fast charging is needed. Ride-hailing vehicle data from the California Air Resources Board (2019) and Jenn (2019a) are applied to estimate the distribution of daily miles for electric ride-hailing vehicles. The California Air Resources Board estimates there were more than 600,000 ride-hailing vehicles in California in 2018 traveling 4.3 billion miles, which is an average of approximately 7,000 annual miles per vehicle. Detailed ride-hailing data from Jenn (2019a) indicate that including all ride-hailing vehicles results in a mean daily driving of 30–40 miles, whereas full-time ride-hailing vehicles average approximately 180–190 miles, with both driver types exhibiting wide distributions.

These data are used to define the driver types for this analysis. Part-time drivers average 5,000 annual miles and are estimated to make up 94% of the drivers. Full-time drivers average 40,000 annual miles and are estimated to be 6% of the ride-hailing drivers. For context, the short-term vehicle rental company Maven offers rentals for ride-sharing services through its Maven Gig program, and these vehicles are anecdotally reported to be driven 40,000 to 50,000 miles annually. Similarly, full-time Uber and Lyft drivers often drive similar distances annually, roughly matching our full-time driver assumption.

Figure 1 depicts the assumed part-time and full-time ride-hailing vehicle daily mileage applied in this analysis. These daily distance profiles show what percentage of total days in the year the vehicles travel a certain distance. The vertical axis shows the frequency a certain daily mileage occurs within a five-mile bin and the horizontal axis shows the daily number of miles a ride-hailing driver travels while working. The distributions, in turn, help determine how many driving days can be completed with only home charging and how many days public charging would be needed to help supply the remaining miles. As shown, more than half of part-time driver-days involve less than 70 miles of driving, whereas most full-time driver-days entail 80–250 miles of driving.

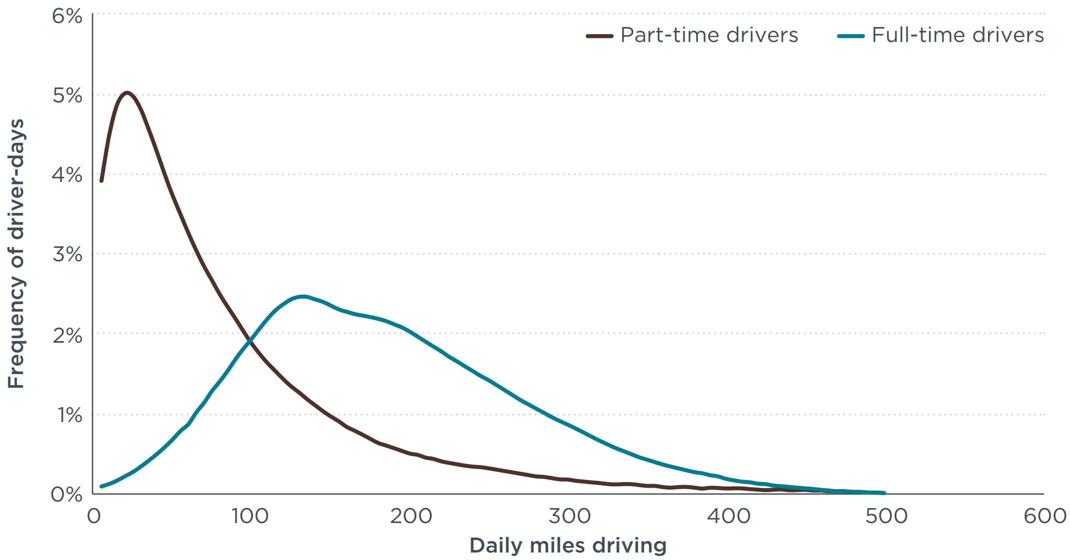

Figure 1. Assumed daily mile distributions for part-time and full-time ride-hailing battery electric vehicles (based on Jenn, 2019a).

Table 1 summarizes the average driving characteristics for the four electric ride-hailing driver types. Drivers are assumed to use a BEV with a 240-mile range, similar to the Chevrolet Bolt used in several ride-hailing services in California. Based on previous analysis (Pavlenko, Slowik, & Lutsey, 2019), the opportunity cost of using public charging more frequently for BEVs that have electric ranges less than 240 miles hinders the business case for electric ride-hailing. Based on the daily mileage distributions shown above, the full-time driver has many days during which the daily mileage exceeds the electric range, thus necessitating public charging even when they have regular access to home charging. The part-time driver has fewer such days. The breakdown of total annual miles powered by home charging and public DC fast charging is shown in Table 1. These values are based on the distribution shown above and the assumption that those with home charging will drive up to 150 miles before using DC fast charging. Even on driving days that exceed 150 miles, a significant portion of electricity used comes from home charging. When home charging is available, 71% (i.e., 28,500) of the full-time drivers' annual miles, and 80% (i.e., 4,000) of the part-time drivers' miles, are assumed to be from home charging. All miles driven by drivers without home charging are assumed to be attributed to DC fast chargers.

Table 1. Electric ride-hailing miles (total, home charging, DC fast) for four driver types

Driver type	Total annual miles	Home charging miles	DC fast-charging miles
Part-time with home charging	5,000	4,000	1,000
Part-time with no home charging	5,000	—	5,000
Full-time with home charging	40,000	28,500	11,500
Full-time with no home charging	40,000	—	40,000

ACCESS TO HOME CHARGING FOR ELECTRIC RIDE-HAIL DRIVERS

To determine how many chargers are necessary to support ride-hail operations, the potential access to home plugs must be assessed. Access to home charging is potentially challenging for ride-hail drivers. Although data are limited, anecdotally from practitioners in field only about 15% of Maven Gig rental, Uber, and Lyft drivers reportedly have access to at-home charging. However, it is not clear to what extent this represents barriers related to drivers not having overnight off-street parking and/or access to higher-power Level 2 charging, and also whether the lack of home charging access varies by region. By contrast, surveys show that general public (i.e., non-ride-hailing) long-range BEV owners have much greater access to home charging. The ride-hail drivers' lower home charging access may be a reflection of the types of housing in which they live, such as multiunit dwellings without dedicated off-street parking.

Our analysis relies on assumptions about housing type for ride-hail drivers and likelihood of encountering charging in those housing types. For our scenarios, we assume that ride-hail drivers are less likely to live in single-family houses. In the top 100 metropolitan areas, approximately 59% of the population lives in detached single-family housing. We reduce this by a third for ride-hail drivers, to 39%, and redistribute the remaining population to other housing types of apartments (typically with 5 or more housing units) and attached multiunit homes (typically 2-4 attached housing units). Surveys detail access to Level 2 charging for long-range BEVs for private vehicle buyers by housing type and this relative access to home charging is applied to the assumed housing types for ride-hail drivers (Tal et al., 2019). These percentages are summarized in Table 2.

Table 2. Access to Level 2 charging by housing type for private drivers, assumed housing type for ride-hail drivers, and implied access to Level 2 charging

	Apartments	Attached multiunit housing	Detached housing	Total
Level 2 home charging access potential in general public	17%	49%	68%	—
Assumed housing type of ride-hail drivers	37%	23%	39%	—
Estimated portion of ride-hail drivers with Level 2 access	6%	11%	27%	44%

Based on installation in similar housing types, an estimated 44% of ride-hail drivers could feasibly install Level 2 home charging. Additionally, this 44% could include those who can find charging off-shift near their home or at a workplace, but we make no distinction between these access options and assume they provide equivalent energy off-shift. The remaining 56% are assumed to have no access to home charging or rely on Level 1 charging—situations that would thereby need greater use of daytime public DC fast charging. Combined with the earlier assessment that 6% of ride-hail drivers are full-time, the breakdown of the four driver types is shown in Table 3.

Table 3. Summary breakdown of representative ride-hail driver fleet for four driver types

Driver type	Percentage of ride-hail fleet
Part-time with home charging	41%
Part-time with no home charging	53%
Full-time with home charging	3%
Full-time with no home charging	3%

Each of the driver types has a different charging profile. The part-time versus full-time designation affects the magnitude of total charging needed and the access to home charging affects the amount of charging done at public chargers as well as when that charging is needed as explained in the next section.

ASSESSING EXISTING CHARGER CAPACITY CONSTRAINTS

Charging infrastructure to support electric ride-hailing can come from adding new dedicated charging and from using existing underutilized capacity in public fast-charging infrastructure. Before estimating how much additional dedicated charging may be needed, the ability to take advantage of existing regional DC fast chargers is analyzed.

Theoretically, public chargers could be used 24 hours a day. In practice, though, chargers with 10–12 hours of daily usage are among the highest utilization rates, considering normal constraints on when and where people need charging, and 1–4 hours per day is more typical. As long as the excess charging capacity coincides with times of ride-hailing vehicle charging demand, ride-hailing can increase utilization of existing chargers. To assess the potential for such ride-hailing charging opportunities, charging capacity is estimated based on general public charging usage trends at the peak hour of the day.

Figure 2 shows the daily DC fast-charging demand by general public and ride-hailing electric vehicle users. The charging profile data are from Jenn (2019a) through 2018 and are based on EVgo and ChargePoint data in the Los Angeles area. The usage is distributed over a 24-hour period with the hour of charging occurrence on the horizontal axis. The vertical axis is the percentage of daily charging energy from the corresponding hour of the day. These charging patterns, taken from the U.S. region with the most electric vehicles by volume, are assumed to be representative of electric vehicle markets elsewhere in the United States as they grow in the years ahead. The general public DC fast electricity use shows the lowest use between midnight and 8 a.m., increasing throughout the day to a peak at 8 p.m. The electric ride-hail drivers with no home charging reveal a more even distribution throughout the day, showing the potential for greater utilization than the general public charging. The ride-hail drivers also show greater relative DC fast-charging demand, as compared to the general public, overnight from 10 p.m. to 5 a.m., presenting an opportunity for increasing utilization.

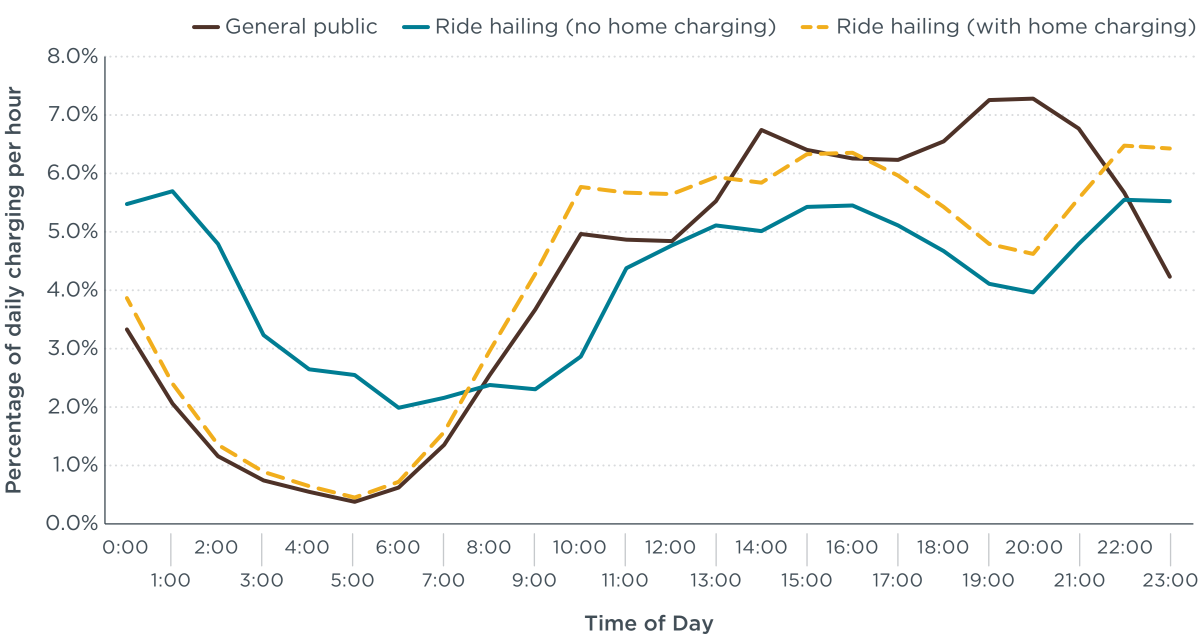

Figure 2. DC fast charger usage profiles for the general public and ride-hail drivers.

A third composite distribution is derived for electric ride-hail drivers with home charging (hashed yellow line in Figure 2), by mirroring the public distribution from midnight to noon and the ride-hailing distribution from noon to midnight. This profile reflects that ride-hail drivers with home charging are more likely to use charging later in the day as the electricity from their overnight home charging is depleted. It also reflects the relative dip from 5 to 9 p.m. as with the other ride-hail drivers. Because of the more even distribution of ride-hail charging throughout the day, approximately 20% more daily charging can be accomplished with combined ride-hailing-plus-general-public charging (for a given peak hourly utilization), compared to general public usage alone.

Determining how much public chargers can be used for ride-hailing requires that reasonable utilization constraints be applied to limit congestion at the chargers and ensure a reliable charging experience. Based on proprietary data and interviews with operators of chargers heavily used by the general public, we assume an average daily maximum of 36 minutes of charging time for any charger in any hour. This 36-minute maximum hourly usage constraint prevents congestion on general public chargers. Under real-world general public-only charger use, utilization has typically resulted in substantially less than this maximum use. As a result, we assume 18-minute maximum use as our lower-utilization case for charging in future years, with that peak occurring around 7 to 8 p.m., as shown in Figure 2. As our central estimate, we take the midpoint of 27 minutes for the assumption of some improved utilization with public and ride-hailing vehicles.

Figure 3 illustrates the combined usage of the chargers for the low, central, and high utilization cases. The vertical axis shows the number of minutes used per hour. The horizontal axis shows the time of day that the usage occurs. In each case, the preexisting general public charging level remains the same while increasing amounts of ride-hail demand are added. The top figure shows the low utilization case where general public usage represents the majority of charging and a smaller amount of ride-hail charging occurs on general public chargers. The middle and bottom figures include increasing amounts of ride-hailing vehicle charging, assuming the same overall general public usage on the chargers. The figure assumes 44% of future ride-hail drivers have access to home charging, which affects how the relative amount of each ride-hail driver profile from Figure 2 is applied to Figure 3. Several of these assumptions are further explored below.

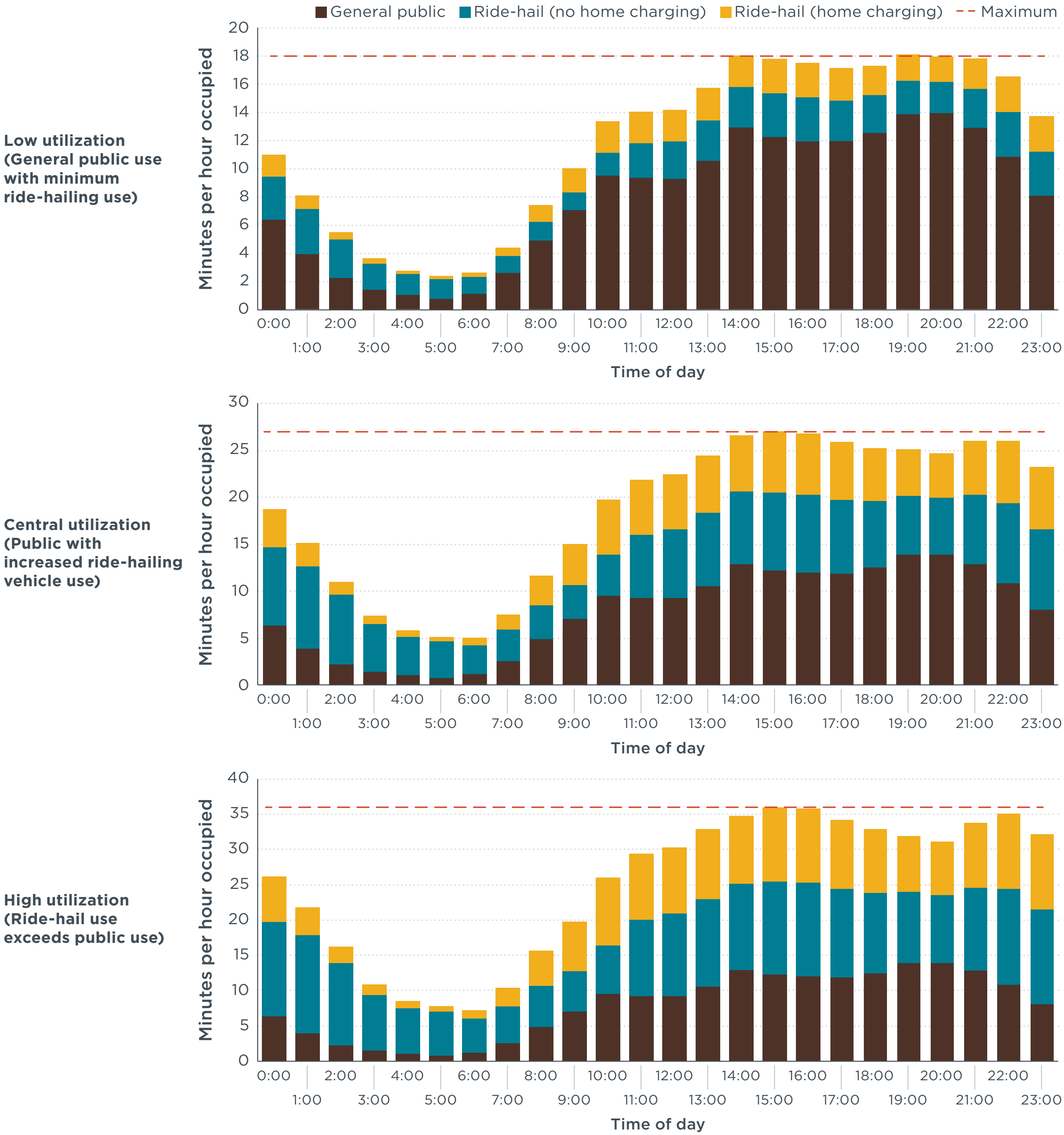

Figure 3. Charger usage for a public DC fast charger under three utilization cases, showing average minutes of implied usage per hour.

The combined use of general public and ride-hail charging as shown in Figure 3 allows for higher overall charger utilization by filling in the underutilized early morning charging capacity to distribute demand and keeps charging near the maximum use from 2 p.m.

through 10 p.m. This is also the case for ride-hail drivers without home charging, who do frequent charging after midnight (see Figure 2) and thus can increase station utilization over general public usage. The resulting average daily usage of these three cases is 5.1 hours for low utilization, 6.5 hours for the central case, and 9.5 hours for the high utilization case.

EXISTING CHARGER DIVERSITY OF USAGE

In order to examine the total extra capacity of the existing fast-charger system, a utilization rate is assigned to each charger and spare capacity is assessed in a manner similar to that shown in Figure 3 and summed to obtain a systemwide total. The range of utilization rates for all chargers is modeled as a truncated normal distribution as shown in Figure 4 such that some chargers are lightly used and some are heavily used. Public DC fast-charger station utilization independent of ride-hail usage is expected to increase between 2020 and 2025 so a distribution is shown for each year based on Nicholas, Hall, and Lutsey (2019). The vertical axis reflects the percentage of stations and the horizontal axis shows peak utilization thresholds in minutes per hour as described above.

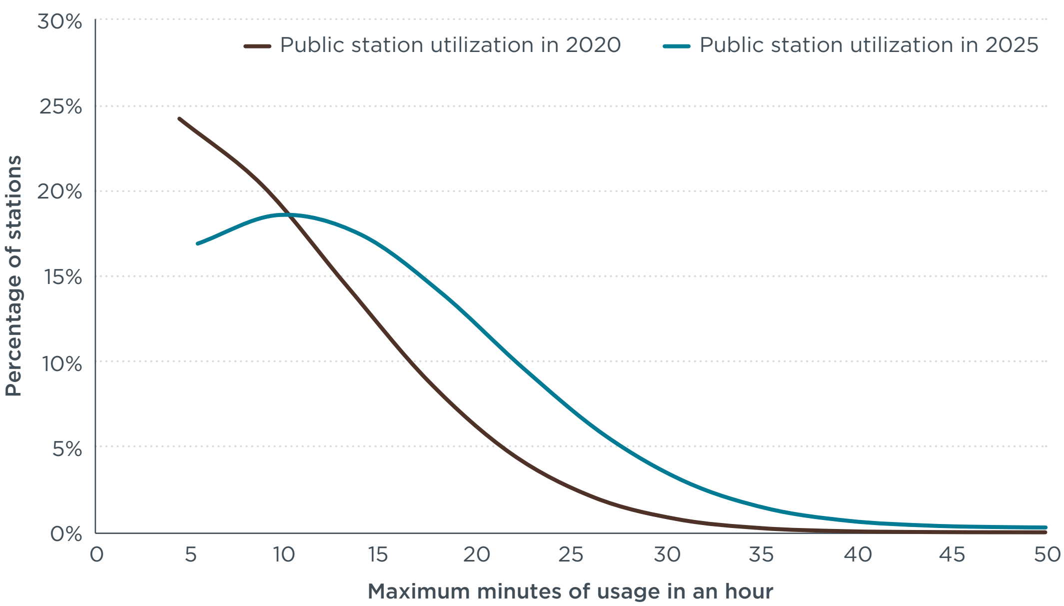

Figure 4. Distribution of preexisting public usage hours of private chargers in 2020 and 2025.

The station utilization shown by the blue line demonstrates that stations are expected to be more heavily used in 2025 than in 2020. This reduces the extra capacity for ride-hailing on public chargers in the future. The average utilization in 2020 is modeled at an average of 2.15 hours of general public charging over a 24-hour period. This leaves between 2.7 and 7.2 hours per charger on average available for ride-hail use. In 2025, the general public usage is expected to rise to an average of 3.19 hours, leaving between 1.9 and 6.3 hours available on average to ride-hail drivers, a reduction in extra capacity of between 10% and 30%.

TIME NEEDED TO CHARGE

With the overall time available to charge defined using the maximum hourly thresholds above, two additional factors determine the total time needed to charge: battery capacity, expressed as the vehicle range in electric miles, and the charging speed. The overall charging speed is determined through the combination of transition time and charging speed while plugged in. Transition time is added because even if drivers queue, there are times between charging sessions when a car is not plugged in. We estimate that the power while charging is 45 kW and the transition time is 3 minutes. We assume each fast-charging session supplies a total of 22 kWh (approximately 82 miles of range) and takes 29 minutes for energy transfer and 3 minutes of transition time for a total of 32 minutes. For 2025, we assume an average charging power of 80 kW and an average vehicle range of 300 miles. The average kWh per charge increases proportionally to 28 kWh. The time to charge is 21 minutes plus 3 minutes in transition time for total of 24 minutes per charge event.

Even though the model assumes a 22 kWh or 28 kWh charge in 2020 and 2025 respectively, dividing by the frequency of charging allows the calculation of an average charging time in minutes per day. These times can be allocated to spare capacity on existing public chargers and on dedicated ride-hail chargers. Based on charging speed and the kWh per charge, the average daily charging time per driver type and year is shown in Table 4. The table shows that the time spent per day charging is reduced between 2020 and 2025 even though the yearly miles driven is constant. The charging time is reduced by two factors. First, the charging speed increases and second, the range of vehicles increases resulting in less overall fast charging needed per car.

Table 4. Average daily fast-charging time demand by ride-hail driver type

Driver type	Minutes charging per day in 2020	Minutes charging per day in 2025
Part-time with home charging	0.88	0.33
Part-time with no home charging	5.43	3.17
Full-time with home charging	12.52	4.62
Full-time with no home charging	43.42	25.38

NUMBER OF RIDE-HAIL DRIVERS SUPPORTED PER FAST CHARGER

Using the breakdown of ride-hail driver types in Table 3, the spare capacity calculations in Figure 3, the distribution of station utilization in Figure 4, and the charging time demand in Table 4, it is possible to calculate the number of ride-hail drivers supported per charger in 2020 and 2025. Table 5 shows the number of drivers supported per public charger based on the spare capacity available for three different utilization cases in the first two rows. The last two rows show only the high utilization case for 2020 and 2025 for a dedicated ride-hail charger with no public usage. Only the high utilization case is used for dedicated stations because of the reduced conflict with general public usage. The conservative low utilization case represents an estimate that only allocates ride-hail drivers to lightly used stations, potentially reducing crowding and dissatisfaction among existing general public users. The high utilization case represents the same chargers but assumes that public chargers are more highly utilized by ride-hail drivers.

Table 5. Number of electric ride-hail drivers supported per public charger and dedicated ride-hail charger in 2020 and 2025

	Low-utilization case	Central-utilization case	High-utilization case
Ride-hail drivers supported per general public charger 2020	33	52	88
Ride-hail drivers supported per general public charger 2025	23	41	77
Ride-hail drivers supported per dedicated ride-hail charger 2020	—	—	122
Ride-hail drivers supported per dedicated ride-hail charger 2025	—	—	222

The top two rows in the table show that because of increasing general public utilization of fast chargers in 2025 compared to 2020, there is less spare capacity available for ride-hail drivers. However, for dedicated ride-hail fast chargers, the number of ride-hail drivers supported per fast charger increases as a result of increasing charger speed and a reduced need for charging due to vehicle range extension. The table represents a charging session weighted average number of drivers. To compare these values to the case with the greatest infrastructure needs, full-time drivers with no home charging, a single charger can support about 14 drivers in 2020 and 24 in 2025. For full-time drivers with home charging, the corresponding numbers would be 43 and 117 ride-hail drivers supported per charger due to lower public charging requirements.

To demonstrate the implications of the vehicle-to-charger relationships assessed above and shown in Table 5, several concrete examples are examined. First, the hypothetical case of an increasing California electric ride-hailing fleet reaching 600,000 vehicles by 2025 is analyzed, essentially matching the number of all California's ride-hailing vehicles in 2018. Second, the charging implications are similarly analyzed for increasing electric ride-hailing fleets to 50,000 all-electric ride-hailing vehicles each across various other U.S. metropolitan areas by 2025. The examination includes an incremental increase in available public chargers to match business-as-usual trends through 2025 based on Nicholas et al. (2019). These markets are selected due to their relatively high electric vehicle uptake and ride-hailing operations, as well as increasing programs and policies under consideration to promote electric ride-hailing.

Table 6 summarizes the number of additional dedicated ride-hail chargers that would be needed in 2025 to electrify ride-hailing vehicle fleets across California. The findings are shown for four large metropolitan areas, as well as a California summary assuming all the 600,000 electric ride-hail vehicles were deployed proportional to population in the state's 10 largest metropolitan areas. The actual public fast chargers in 2017 are shown for context, along with estimates for 2025 fast chargers, which incorporates 17% annual growth across major California metropolitan areas from 2017. The table's bottom two rows show the portion of electric ride-hail drivers that would need dedicated chargers, and the portion that would be able to use the existing public charging network. These estimates for the number of dedicated ride-hailing chargers needed vary according to the low, central, and high public fast-charger utilization cases described above. The central estimate indicates nearly 2,000 dedicated public chargers will be needed across California, and 72% of electric ride-hailing vehicles would use those dedicated chargers, compared with 28% being able to rely on the existing public network. If higher utilization of public chargers becomes a reality, 1,300 dedicated fast chargers would be needed for the 48% of electric ride-hail drivers who would require them. Additional data on the numbers of ride-hail drivers that could be supported by the public charging infrastructure without additional dedicated chargers is shown in the appendix.

Table 6. Additional ride-hail chargers needed to support a hypothetical all-electric ride-hail fleet based on three public charger utilization cases

Metropolitan area	Public fast chargers [a]		Additional dedicated ride-hail chargers needed in 2025, depending on overall utilization of public chargers		
	Actual in 2017	Assumed in 2025	Low public charger utilization	Central public charger utilization	High public charger utilization
Los Angeles	336	1,604	904	776	516
San Diego	70	329	185	159	106
San Francisco	192	901	508	436	290
San Jose	108	600	338	290	193
California major metropolitan area total	1,158	4,051	2,284	1,960	1,303
Percentage of a total California ride-hail fleet of 600,000 that would need dedicated charging			84%	72%	48%
Percentage of a total California ride-hail fleet of 600,000 supported by public charging			16%	28%	52%

[a] Nicholas, Hall, & Lutsey, 2019

Table 7 shows how many more DC fast chargers dedicated for ride-hailing would be needed if 50,000 electric ride-hail vehicles were electric in each of seven metropolitan areas by 2025. The selected markets have experienced relatively high ride-hailing service use through 2018, and 50,000 was selected to be roughly similar to the number of total ride-hailing vehicles operating in these cities around 2018. The metropolitan areas' actual 2017 and estimated 2025 public fast-charger counts are shown alongside the additional number of dedicated fast chargers that will be needed for the hypothetical emerging electric ride-hail fleet. The central estimate shows that between 55 (New York) and 193 (Denver) dedicated public chargers will be needed per area to support the transition to electric ride-hailing. With greater overall utilization of public chargers, about 40% fewer dedicated chargers would be needed; with lower utilization, about 20% more dedicated chargers would be needed. Additional data on the estimated numbers of ride-hail drivers supported by public charging infrastructure are shown in the appendix.

Table 7. Additional ride-hail chargers needed to support a hypothetical all-electric ride-hail fleet based on three public charger utilization cases

Metropolitan area	Public fast chargers [a]		Additional dedicated ride-hail chargers needed in 2025, depending on overall utilization of public chargers		
	Actual in 2017	Assumed in 2025	Low public charger utilization	Central public charger utilization	High public charger utilization
Boston, Mass.	63	351	189	161	104
Chicago, Ill.	94	240	200	181	142
Denver, Colo.	37	176	207	193	164
New York, N.Y.	149	924	129	55	0
Portland, Ore.	56	266	198	176	133
Seattle, Wash.	81	414	182	149	82
Washington, D.C.	102	333	191	164	110

[a] Nicholas, Hall, & Lutsey, 2019

Conclusions

This research analyzes two pressing questions that are highly relevant across major U.S. cities, namely, quantifying how many electric ride-hail vehicles can be supported by a growing public charging infrastructure network and how many additional dedicated chargers could pave the way for a fully electric ride-hailing fleet. Although there are limited data and many uncertainties on how the associated trends for ride-hailing and electrification will play out, this analysis allows for several conclusions and potential implications regarding electric ride-hail infrastructure needs through 2025 for major metropolitan areas.

Significant public fast-charging capacity exists to support electric ride-hailing. Approximately 28% of a California-wide 600,000-vehicle fleet could transition to electric and be supported on the public fast-charging system by 2025. Fast-charging needs for 23 to 77 ride-hail drivers could be accommodated per fast charger in 2025. Lower estimates correspond to reducing the potential for conflict with the general public by only assigning ride-hail usage to lightly-used public chargers. Overall it is clear that fast-charging use by the general public and ride-hail drivers have complementary timing. Because peak usage hours for ride-hail drivers and the general public are at different times of day (e.g., more ride-hail demand overnight), combined usage can increase utilization of a charger by up to about 20% on average over a public-only charger.

Utilization of public chargers could be increased with greater data sharing and coordination. This research reveals that the number of electric ride-hailing vehicles that could be supported by public chargers could increase greatly. Increasing the combined public-and-ride-hailing usage of public chargers could, in our high-utilization case, increase the electric ride-hailing vehicles supported from 165,000 to more than 300,000. This would become increasingly possible by the general public and ride-hail drivers having improved information on chargers in operation, in use, and queuing. To support this, governments and utilities could explore ways to maximize data sharing (e.g., toward universal data protocols, aggregated charger usage patterns, anonymized real-time charging usage) when using public funding, incentives, or policy on charging infrastructure to help shift ride-hail usage to ideal times. Public-private partnerships could allow selective data sharing between applicable charging providers, ride-hailing companies, and city government leaders to expedite permitting and provide incentives for deployment of chargers in areas where there is existing (and likely future) charger congestion.

Dedicated ride-hail fast charging can serve more demand if placed more strategically. Ride-hailing is often geographically focused, and not all public chargers are equally relevant to ride-hailing operations. Dedicated station locations can be placed in these areas. Often public chargers in popular ride-hail areas are congested, potentially driving away usage by the general public. In contrast to general public stations, dedicated ride-hail stations can see higher use with better management, potentially lower prices, and services targeted to ride-hail drivers. Although this work does not specifically analyze what the optimized geographic placement of chargers looks like in cities, our cases imply that strategically placed dedicated ride-hail chargers can be highly utilized and serve 4 to 10 times the number of ride-hail vehicles as public fast chargers for these reasons.

Home charging or other off-shift charging can reduce fast-charging needs. When home charging can be used, fast-charging needs can be reduced by 70% to 90% depending on the daily driving range of drivers. Based on the underlying assumptions, ride-hailing company and government programs to help install home charging could greatly reduce the need for additional fast charging as assessed here. When home charging is not available, other off-shift charging can be used, such as charging at work or at a public charger near home. However, more than half of ride-hail drivers are expected to not be able to use or install a home Level 2 charger, necessitating a fast or other off-shift charging solution.

This research provides an estimate of how many drivers can be accommodated on existing charging for both part-time and full-time ride-hail drivers with and without home charging, but many key research questions remain. This work does not address the cost of associated charging networks. Furthermore, much more work is needed to determine how companies and governments can better support the transition to electric ride-hailing with a combination of joint planning, policy, and financial resources. In addition, further research could include examining charger siting and the cost of electricity as well as the broader benefits of electrifying ride-hailing.

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Appendix

Table A1 complements Table 6 above by showing the total number of electric ride-hail drivers supported by the expected growth of public charging, without any increase in dedicated fast-charger deployment for ride-hailing fleets. The table shows the results for 10 large California metropolitan areas. Combining all 10 metropolitan areas, in the central case 28% of the California ride-hailing fleet of 600,000 electric vehicles could be supported by public charging infrastructure; the low public charger utilization case drops that share to 16% of ride-hailing vehicles, while the high utilization case increases the share to 52%.

Table A1. Electric ride-hail drivers supported by existing public charging infrastructure in California by 2025

Metropolitan area	Low public charger utilization	Central public charger utilization	High public charger utilization
Los Angeles	36,974	65,454	123,150
Riverside	5,279	9,345	17,582
San Diego	7,584	13,425	25,260
San Francisco	20,769	36,767	69,176
Sacramento	3,734	6,611	12,438
San Jose	13,831	24,484	46,066
Fresno	1,821	3,224	6,065
Bakersfield	668	1,183	2,227
Ventura	1,890	3,346	6,296
Stockton	830	1,469	2,764
California metropolitan area total	93,380	165,308	311,024
Percentage of total California ride-hail fleet of 600,000 supported by public charging	16%	28%	52%

Table A2 complements Table 7 above to show the number of electric ride-hail drivers supported by the expected growth of public charging infrastructure in each of seven U.S. metropolitan areas by 2025. In the central utilization case, as few as 7,000 (Denver) and as many as 37,000 (New York) electric ride-hail drivers could be supported by public charging infrastructure. The difference across areas is driven primarily by the absolute size of the metropolitan areas and their associated electric vehicle and infrastructure deployment. As shown, 44% fewer electric ride-hail vehicles are supported in the low-utilization cases, and 88% more vehicles are supported in the high-utilization cases, as compared to the central cases.

Table A2. Electric ride-hail drivers supported by existing public charging infrastructure in selected U.S. metropolitan areas by 2025

Metropolitan area	Low public charger utilization	Central public charger utilization	High public charger utilization
Boston, Mass.	8,091	14,323	26,949
Chicago, Ill.	5,532	9,794	18,426
Denver, Colo.	4,057	7,182	13,513
New York, N.Y.	21,299	37,705	70,942
Portland, Ore.	6,132	10,855	20,423
Seattle, Wash.	9,543	16,894	31,786
Washington, D.C.	7,676	13,589	25,567