Shared EV Charging Stations for the Austin Area: Opportunities for Public-Private Partnerships

Lin Su
Department of Civil, Architectural and Environmental Engineering
The University of Texas at Austin
sulin@utexas.edu

Kara M. Kockelman, Ph.D., P.E.
(Corresponding Author)
Dewitt Greer Professor in Engineering
Department of Civil, Architectural and Environmental Engineering
The University of Texas at Austin
301 E. Dean Keeton St, Stop C1761, Austin, TX, 78712
kkockelm@mail.utexas.edu
Tel: 512-471-0210

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ABSTRACT

The global decarbonization and electrification has led to the shift towards sustainable transportation and increased adoption of electric vehicles (EVs). Developing sufficient EV charging stations (EVCS) is essential to alleviate range anxiety of EV users and prompt the widespread acceptance of EVs. Considering land use limitations and operational cost, co-locating private EVCS with/alongside public EVCS has emerged as a promising approach which leverages the collaboration between government entities and EV fleet operators. This study explores the potential sites for co-locating public-private (PP) charging hubs across the City of Austin area, considering both demand and supply aspects. Existing EVCS resources are examined by charging level, including Level 2 (240 volt) and DC fast charging (DCFC). On the demand side, POLARIS, an agent-based activity-based model, is used to simulate charging demand of EVs and agent's behavior. Additionally, the paper provides design draft and cost estimations for potential EVCS.

Key words: Electric vehicles, Charging infrastructure planning, Agent-based modelling, POLARIS

INTRODUCTION

The decarbonization and electrification of transportation are important parts of society's efforts to reduce greenhouse gas (GHG) emissions and improve air quality *(1)*. Recent years have witnessed rising purchases and use of electric vehicles (EVs) *(2, 3)*. There are now more than 3 million EVs on the road and over 130,000 public chargers across the U.S. *(4)*. By 2030, with an estimated 28.3 million EVs on U.S. roads, approximately 2.13 million Level 2 chargers and 172,000 Level 3 chargers will be needed in public locations, in addition to home EV chargers *(5)*.

Sufficient charging infrastructure play an integral role in the development of EVs. Researchers have pointed out that there is a chicken-egg dilemma between them *(6, 7)*: consumers are reluctant to buy EVs when they feel a lack of efficient access to charging facilities, yet the low usage of EVs tends to discourage charging station (CS) operators from investing in charging infrastructure. *(1)* suggested that financing and funding EV charging infrastructure can be private or public. Given EV charging infrastructure shares some good characteristics similar to public infrastructure, some public funding could be beneficial in the early stages of EV deployment. In the long run, with greater EV uptake, public investment is desirable and important, particularly in fast-charging infrastructure.

Private EV fleets may do well to share sites with public chargers. Co-locating private charging stations with/alongside public charging stations could maximize utilization, share installation and operation costs, and offer convenience for EV drivers. In this study, the City of Austin is used as study area. As of Jun, 2023, Los Angeles accommodated the largest number of EVCS compared to other cities in the U.S. Austin, on the other hand, ranks sixth among cities with the most EVCS in the country *(8)*. Our objective is to analyze current EVCS service and simulate charging demand across Austin. This will help us explore the opportunities of co-locating public-private charging station hub. Findings will serve as a reference for future charging stations operators.

The rest of paper is structured as follows. The next section details EV charging infrastructure, including charging components (like charging plugs, charging levels, and connector types), and provides an overview of EVCS service around the globe. The following section summarizes the distribution of EV charging stations by charging level across the City of Austin. Then, the siting EVCS section presents the simulated charging demand and suggests potential sites for co-locating PP EVCS, followed by a section provides the cost estimations for potential EVCS. The last section concludes the paper and proposes future research direction.

ELECTRIC VEHICLE CHARGING INFRASTRUCTURE OVERVIEW

In the North American market, EV chargers are categorized by power rate, into Levels 1, 2, and 3, as shown in Table 1. U.S. Level 2 are considered suitable and common for home and workplace charging *(9)*, if those with low-charge batteries can leave their vehicles parked for 5+ hours (or simply "top off" or add electrified miles with lower durations of parked time – like while shopping at a grocery store). In contrast, DCFCs replenish an EV battery to at least 80% SOC in just 30 minutes, enabling drivers to 'grab and go' *(10)*. They are becoming prominent in EV supply equipment (EVSE) configurations due to their advantaged efficiency of recharging and enabling long-distance travel *(11)*.

Table 1. Charging Details (with Hours and Distances for Passenger Vehicles)

Charging Level	Voltage (V) & Current Type	**Power Rate (kW)**	EV Range per Charging Hour (miles/hr)	Avg. Charging Time (Empty Battery)	Location

Level 1 (US wall outlets)	120 V AC	**1.3 to 2.4 kW**	3 to 5 miles per hour of charging time	40 to 50 hrs (BEV) & 5 to 6 hrs (PHEV)	Primarily home
Level 2 (standard in EU & China)	208 to 240 V AC	**7.4 to 22**	12 to 30 miles per hour of charging time	4 to 10 hrs (BEV) & 1 to 2 hrs (PHEV)	Home, work, & public stations
Level 3 (DCFC)	480 to 1000 V DC	**50+**	180 to 240 miles per hour of charging time	0.5 to 1 hr (BEV)	Public

Charging Connector Types

To provide clarity on the EVCS terms mentioned later, Figure 1 details the EVSE components. EV charging takes place via cables attached to the EVSE. One end of the cable, called the plug, interfaces with the socket outlet on the EVSE/wall, while another side of cable, the connector, will be plugged into the EV's socket/inlet by consumers *(12)*.

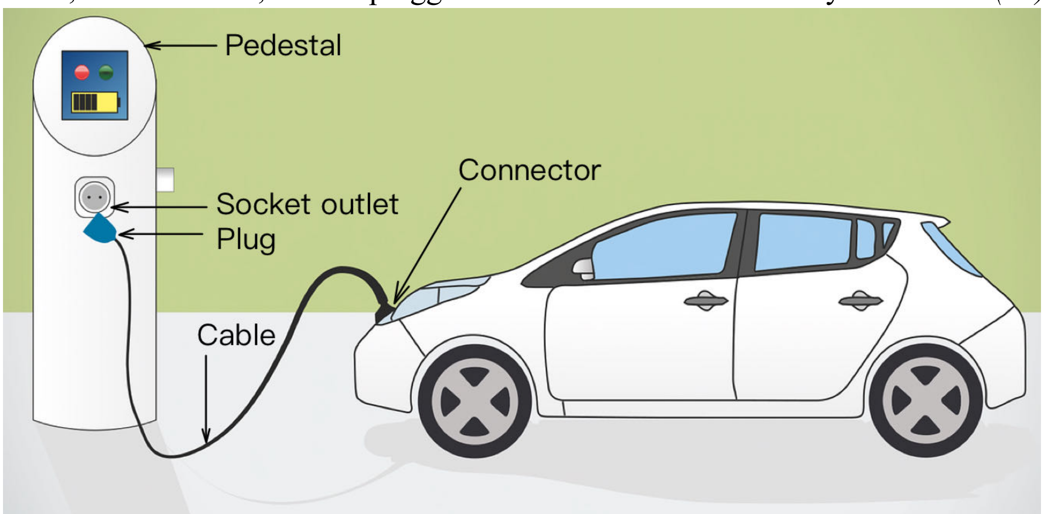


Figure 1. EVSE Components

EV charging pedestals with multiple plugs are available on the market for charging multiple EVs at the same time. For instance, some charging pedestals have two cables and two connectors enabling charge two EVs simultaneously *(13)*. With multiple EVs charging simultaneously, power consumption of the pedestal increases significantly. To avoid a power outage caused by exceeding the potential load of the entire property, the charging load can be limited and rebalanced between charging spots by utilizing dynamic load balancing. Specifically, DCFC pedestals may have 2 cables because different EVs have different connectors/technologies, but only one cable can be used at a time (just like a gas station pump has a diesel and gasoline line, but only one can be used at a time).

Figure 2 presents different EV charging connector types. Major regional markets (including North America, Japan, EU, and China) have their corresponding connector standards.

Figure 2. EV Connector Types *(source: 14)*

Global EVCS Service Performance

According to *(15)*, 61% of EV drivers in EU charged EVs at home, while 15% charged at workplace. *(16)* reported that out of approximately 225,000 public chargers available in the EU, only 25,000 are for fast charging, meaning that merely one in nine EU charging points can offer fast charging (with power more than 22kW). Between 2015 and 2020, the median ratio of BEVs and public charging points in European countries has increased from 1.6 to 7.2 *(17)*. By 2030, the EU is predicted to have an average of 5.7 public chargers per capita (1,000 inhabitants) *(15)*. Most of the EU (all Western and Northern Member States) would need at least 4 public chargers per capita (e.g., 8.7 for German, 8.6 for Sweden). On the other hand, the rest of EU need less than 3 charge points per capita.

Compared with slow charging, fast charging is being rolled out faster in China, where the number of fast chargers (power rating >22 kW) in 2021 increased by over 50% to 470,000, more than the 44% growth in 2020 *(18)*. As of 2021, China has a total of 1.15 million publicly available EV charging points, with 41% of them having fast-charging capability *(19)*. On average, one public charging point served around 14 EVs while one fast charger served 35 EVs in China. Comparably, there were about 18 EVs per charging point in US *(18)*. China's expanding charging market has lowered costs for manufacturing and constructing charging stations, particularly fast-charging stations. According to *(20)*, the cost of a 50 kW DCFC unit in China dropped by 67% to $3,000 from 2016 to 2019, compared to more than $20,000 for a DCFC unit in U.S.As of 2021, the Tesla Supercharge network led the DCFC field in the US, accounting for 58% of the total installed fast chargers (21,676), followed by the next three largest DCFC networks: Electrify America (14.4%), EVgo (7.9%) and ChargePoint (7.7%). These four major charging networks account for 88% of total DCFCs in US *(21)*. The US government plans to build a national network of 500,000 EV chargers along America's highway and by 2030 to promote EV adoption and have EVs make up more than half of new car sales *(4)*. As part of that, Tesla's network of Superchargers and Destination chargers in the US will be opened up with no less than 7,500 of its piles available to all EVs by the end of 2024. This includes at least 3,500 superchargers along highways and 4,000 slower destination chargers at locations like hotels and restaurants.

CURRENT EVCS DISTRIBUTION ACROSS AUSTIN

Level 2 Public Charging Stations

Spatial distribution of public charging stations across Austin is shown in Figure 3. The majority of the Level 2 chargers are concentrated in workplaces and parking spaces adjacent to transportation hubs and commercial areas.

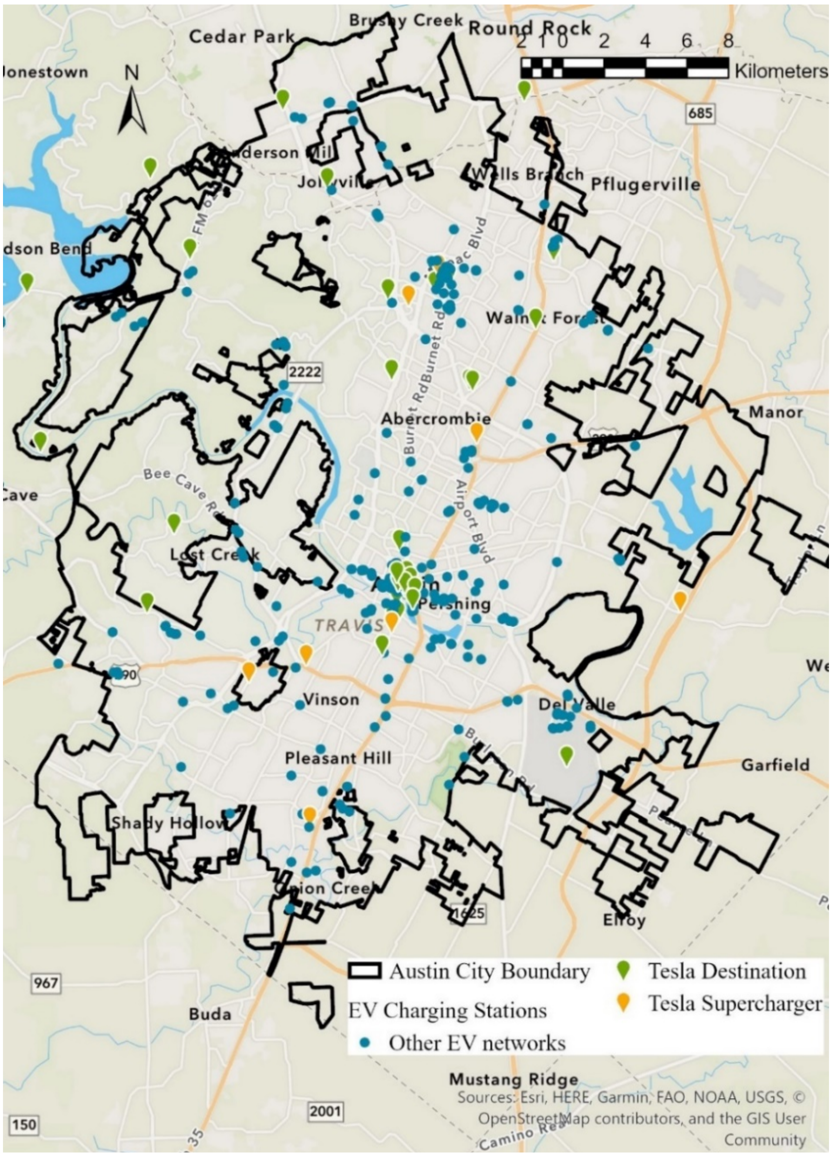


Figure 3. Public Charging Stations Within Austin *(Source: 22)*

Table 2 summarizes the number of charging stations and ports in Austin area, based on data from AFDC of the U.S.DOE (2023). Public charging stations in Austin are predominantly Level 2 and DCFC stations, with more Level 2 stations in service. Assuming all public charging stations in Austin are occupied, a total of 979 EVs can be charged simultaneously at Level 2, 125 of which are at Tesla Destination Chargers. Given there are nearly 17,000 registered EVs in the city *(23)* and 404,121 households *(24)*, each Level 2 charging port serves roughly 17 EVs and 413 households across the City of Austin. Destination charging stations operated by Tesla often provide more charging ports with higher power compared to other EV charging networks. On average, Tesla Destination charging stations can charge more EVs at once than non-Tesla EVCSs (3.47 vs 2). These charging stations are located in places where drivers may stop for reasons other than charging, such as hotels, restaurants, shopping malls, and other commercial areas.

Table 2. Descriptive Statistics for Public Charging Stations *(Source: 22)*

EVCS Type	# Stations	# Ports[a]	Average # Ports	Power Rate (kW)

Level 2	Non-Tesla Public charging	426 stations	854 ports	2 ports	6.48 to 21.6 kW
	Tesla Destination Charging	36	125	3.47	8 to 16
	Total	**462**	**979**	**-**	**-**
DCFC	Non-Tesla Public charging	29	29	1	50 to 125
	Tesla Superchargers	8	94	11.75	72 to 250
	Total	**37**	**123**	**-**	**-**

a. A single charging pedestal can accommodate one or more EVSE ports (or socket outlets) which provide power to charge EVs. Each port charges only one vehicle at a time *(22)*. The majority of charging networks now report the number of ports that can charge simultaneously *(21)*.

Austin Energy provides a more detailed description of the location categories for non-Tesla Level 2 public charging stations. Their Plug-In EVerywhere program network contains 439 charging stations and over 800 Level 2 charging ports in the City of Austin. Table 3 summarizes the charging stations and charging ports by location type. Level 2 charging stations in workplaces account for 36.9% of all service stations, ranking top among all location types, with an average of 1.88 charging ports. Charging stations in general workplaces provide the most ports (229) for charging, with parking lots in commercial areas (187) and residential apartment complexes (166) following behind, which is consistent with many studies that suggested charging stations could be co-located with parking lots and gas stations *(25, 26)*. Some of the charging pedestals built in these location types have only one charging port per pedestal, so these locations' average number of ports per pedestal is less than 2 (while the average number of ports for all other types is 2). There are relatively few charging resources near retail, education, and health areas. The 423.5-acre UT Campus is a charging station desert, with just two Level 2 charging stations available near the campus' west side, one of which offers four ports (6.48 kW) and the other two ports (8 kW each), provided by Tesla Services.

Table 3. Non-Tesla Public-Access Level 2 Stations by Location Type
(Source: 27)

Category	Sub-category	# Level 2 Charging Stations	% of Stations	# Ports	% of Ports	Average # Ports
Education	University / College	4 stations	0.91%	8 ports	0.94%	2 ports
	High School / Other	10	2.28%	20	2.36%	2
Healthcare	Hospital / Treatment Center	10	2.28%	20	2.36%	2
Hospitality	Hotel / Resort	5	1.14%	10	1.18%	2
Multi-family Commercial	Condominium	2	0.46%	4	0.47%	2
	Apartment	88	20.0%	166	19.5%	1.89
Municipal	Library	8	1.82%	16	1.88%	2
	Municipal Workplace	7	1.59%	14	1.65%	2
	Parks and Recreation (Public)	1	0.23%	2	0.24%	2
	Municipal Parking	3	0.68%	6	0.71%	2
	Municipal Fleet	21	4.78%	42	4.95%	2
Parking	Airport	10	2.28%	20	2.36%	2
	Commercial	95	21.6%	187	22.0%	1.97

Parks and Recreation	Parks and Recreation	7	1.59%	14	1.65%	2
Retail	Shopping Center	3	0.68%	5	0.59%	1.67
	Strip Mall	1	0.23%	2	0.24%	2
	Car Rental / Car Share	2	0.46%	4	0.47%	2
Workplace	General Employers	122	27.8%	229	27.0%	1.88
	"High-Tech" Employers	40	9.11%	80	9.42%	2
	Total	439	100%	849	100%	1.95

Level 3 (DCFC) Public Charging Stations

Level 3 charging stations are not as common as Level 2 (Figure 3). There are about 37 DCFC stations in Austin with power ranging from 50 kW-250 kW. Tesla Superchargers make up 76% of the 123 DCFC charging ports in the Austin area (Table 2). 17% non-Tesla DCFCs are co-located with Level 2 charging stations, each pedestal only houses one charging port. In contrast, Tesla Superchargers can simultaneously charge an average of 11.75 EVs at each site. Many public DCFC stations are within Downtown Austin, located in parking lots near restaurants and shopping malls. DCFC charging stations are also scattered along the I-35 freeway.

SITING EVCS: CURRENT ISSUES AND POTENTIAL SITES

Agent-based Simulation: POLARIS

The agent-based model, POLARIS, is used to fully simulate travel demand, network, and operations *(28)*. It relies on travel demand and supply models to synthesize and simulate agent travel and EV trips across large regions *(29)*. Regarding the demand inputs, POLARIS synthesizes a representative population of the given region with socio-economic information provided by region's metropolitan planning organization and the United States Census Bureau *(28)*. Within this simulation environment, travel demand models are used to simulate agent's behaviors and actions across the region on a single day *(30)*. POLARIS integrates an energy consumption model during runtime to simulate EVs appropriately, querying link-level consumption based on trajectory inputs provided to a machine-learning model *(31)*. When the SoC of the EV is identified to be below a specific threshold, it triggers the estimation of the energy demand considering nearby available charging resources, thus simulating the charging behavior.

Simulated Charging Demand Across Austin

Taking the charging demand derived from the charging behavior simulation, the output demand file contains comprehensive information such as location, timing, charging level and, duration of EV charging. Given the existing public charging stations, the 6-county Austin metropolitan region (5,300 square miles) is used as geofence to simulate the charging demand. Figure 4 visualizes the EV charging demand within the City of Austin.

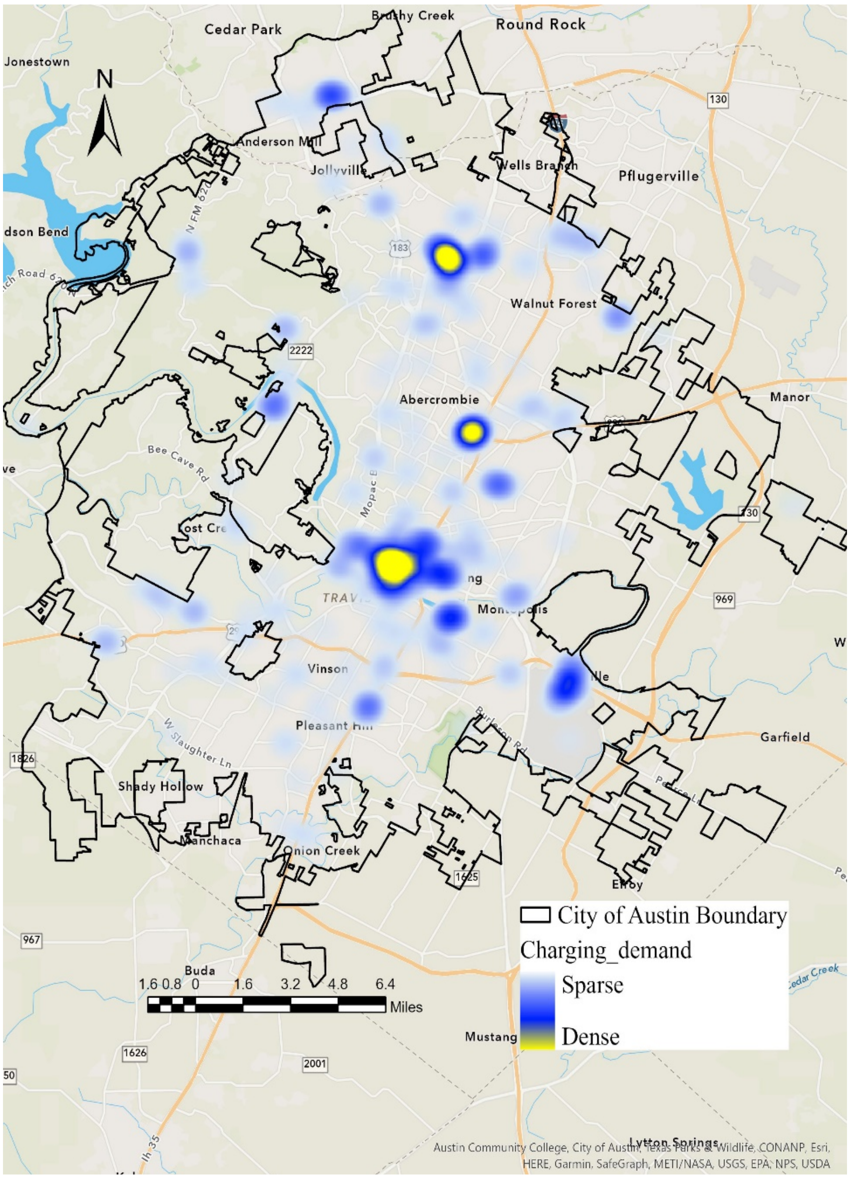


Figure 4. Charging Demand Across Austin Area

Three locations demonstrate notable concentration of charging demand: Downtown and Central Austin, the intersection of highway I-35 and US-290, and the Domain area. These areas align with previous studies which recommend placing EVCS along major highways where charging demand tends to be high, thus maximizing profitability *(2)*. In addition, parking lots attached to Austin-Bergstrom International Airport in the southeastern of Austin city exhibits relatively high charging demand.

Among private EV drivers, 87.8% prefer to charge their EVs at home while the remaining 12.2% get EV charged at public charging stations. EVs charged at home are predominantly relying on Level 2 charging. As for EVs head to EVCS for charging, 87.5% charged by Level 2 while 12.5% use DCFC.

The majority of charging activities occur between 15:00 and 18:00, accounting for 30% of total charging trips, as shown in Figure 5. Peak demand takes place specifically between 17:00 and 18:00 time slot. On average, the waiting time at charging stations is approximately 41 minutes, with 82% of the waiting trips occurring at Level 2 charging stations.

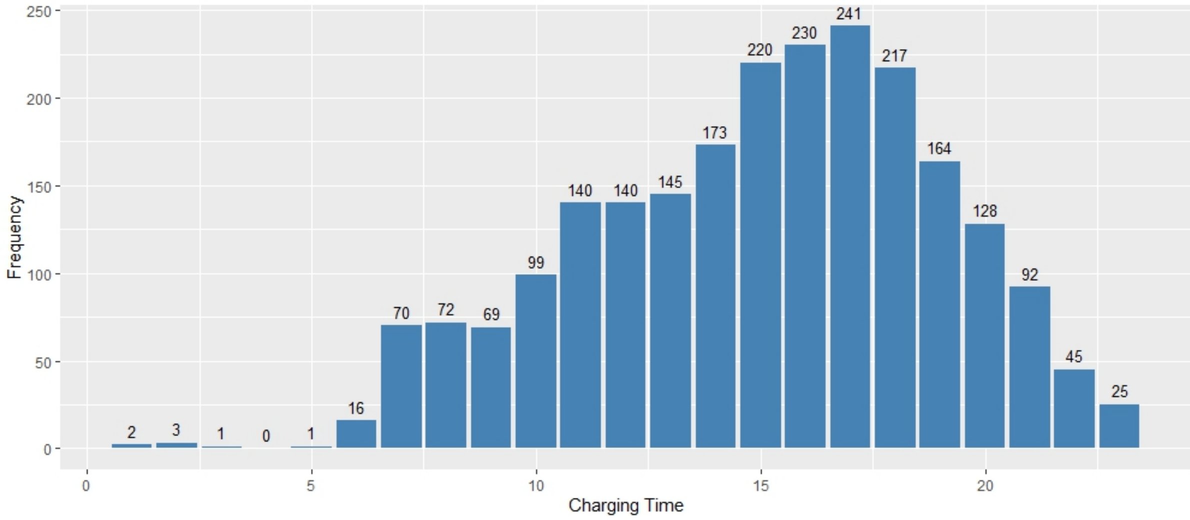


Figure 5. EV Charging Time Distribution

Potential Sites for Future EVCS

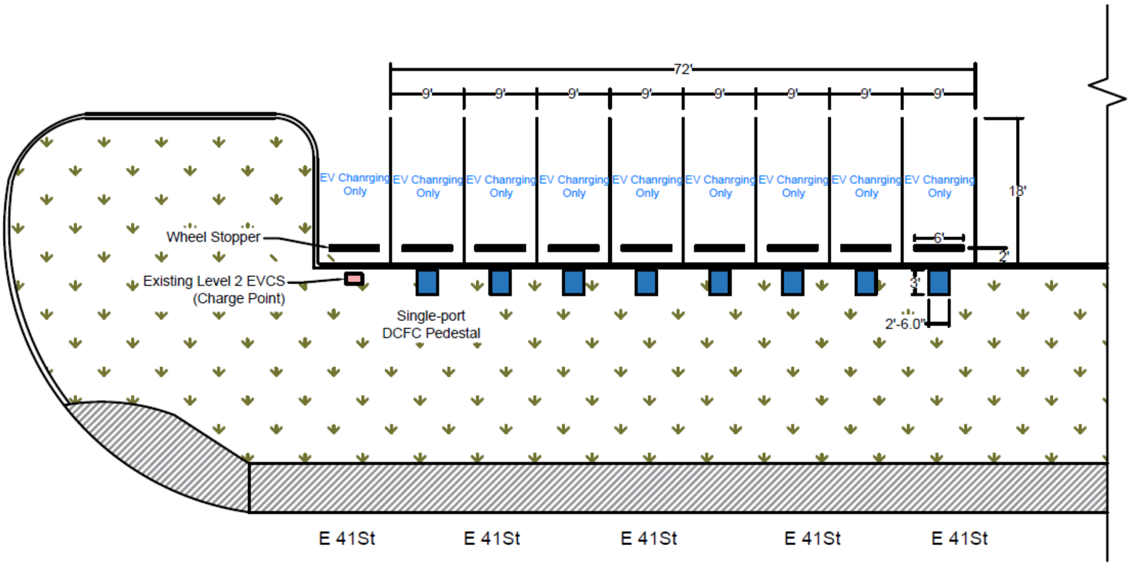
Downtown Austin and Central Austin have relatively higher charging demand (Figure 4), especially around the UT Austin campus which is almost a desert of charging stations. The campus has heavy daily traffic from students, faculty, staff and visitors, and there is a residential area just north of the campus, which could contribute to charging demand and offer potential sites for new EVCS. One potential site option includes UT garages, such as San Jacinto or San Antonio, as they can alleviate charging resources constraints and provide walkable distance to most of UT buildings and bus stops, effectively addressing last/first-mile concerns for travelers.

In the Central Austin, where charging demand is relatively high, numerous parking lots are connected to commercial zones. Some parking lots have already installed charging stations, but the scale is not large, with Level 2 chargers being predominant type. As shown in Figure 3, DCFC stations are scattered throughout Austin, but fewer stations are available in Central areas with higher charging demand compared to surrounding neighborhoods with lower charging demand. The HEB commercial area in Central Austin attracts a large volume of daily travel and possesses sufficient parking bays suitable for deploying new EVCS. When considering the co-location of public-private charging infrastructure, such parking lots or residential areas present promising potential sites, where existing EVCS operators can explore co-location and upgrading of charging power.

EVCS Sites Design Examples

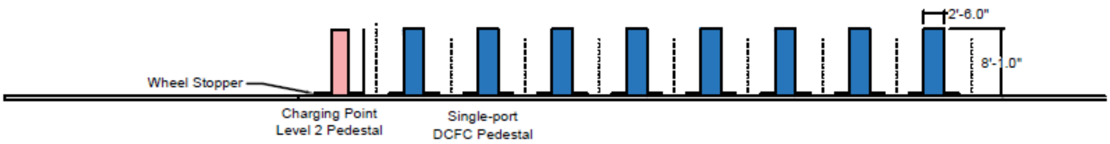
Taking the parking lot attached to HEB in Central Austin as a case, Figure 6 presents a sample design of arranging charging pedestals here. The design features 8 new DCFC pedestals alongside an existing public Level 2 charging station. It is worth noting that these new DCFC pedestals are not solely invested and installed by private fleets such as Tesla which only charge their own EVs. Rather, they are established through collaborations with public CS operators or public entities. This kind of public-private charging station hubs enables the charging infrastructures to be accessible by not only specific private EV fleets but private EV drivers, providing them certain public access to take advantage of these EVCS.

Given parking bays are arranged parallelly on one side of the lawn, each bay can accommodate only one EV to get charged in real time. However, it becomes possible for a single pedestal serves two parked EVs at parking lots with parking bays on both sides. This arrangement maximizes the utilization of charging infrastructure and optimizes the efficiency of available parking spaces.



EVCS Design at HEB Parking Lots (Plan View)

(a) Plan View



EVCS Design at HEB Parking Lots (Profile View)

(b) Profile View

Figure 6. EVCS Design at HEB Parking Lots

EVCS COST: MARKET AND ESTIMATION

The planning problem faced by many charging station investors is how to provide charging services to customers with random behavior and charging demand at a lower economic cost of charging facilities and practical operation *(25)*. Costs of owning and operating EVSE mainly includes: EVSE hardware cost, installation fee, operation and maintenance expenses, additional capital cost (such as land and parking space acquisition), and incentive credits (to lower equipment or installation costs) *(32, 33)*. Studies have shown that coordinated charging can change the plug-in EV charging load and reduce the number of charging points by encouraging customers to charge their EVs during off-peak hours, resulting in corresponding investment cost savings *(34)*. In order to increase charger utilization and reduce unnecessary idle time at charging stations, many connection patterns between chargers and parking bays are proposed to automatically switch cables for the next EV waiting to be charged, e.g., SOMC *(34)*, MCMP *(25)*.

For both Level 2 and DC fast chargers, equipment cost varies greatly with power rating. Generally, Level 2 home chargers are less expensive than nonresidential chargers since they are wall-mounted in weatherproof locations like garage. Commercial Level 2 chargers and DC fast chargers for public access are usually installed on a pedestal and exposed to the elements, adding cost to the chargers. The Rocky Mountain Institute paper *(33)* reported the range of Level 2 and DC fast charger costs in Table 4. According to Future Energy, a public dual-port Level 2 EVSE unit costs around $5,500 and can charge two vehicles simultaneously. Moreover, optional protective bollards, which cost approximately $400 each, and parking blocks, priced at around $600 each, may also be desired by commercial enterprises *(35)*.

Table 4. Range of Level 2 and DC Fast Charger Costs *(Source: 33)*

Charger Type	Location	Power Rate	Cost Range
Level 2 Charger	Residential	2.9 kW-7.7 kW	$380 - $689
	Commercial	7.7 kW-16.8 kW	$2,500 - $4,900
DC Fast Charger	Public	50 kW	$20,000 - $35,800
		150 kW	$75,600 - $100,000
		350 kW	$128,000 - $150,000

In 2019, the ICCT working paper *(36)* provided equipment cost by charging level and number of chargers per pedestal. Costs are summarized in Table 5.

Table 5. Hardware Cost by Charging Type and Number of Chargers Per Pedestal *(Source: 36)*

Charging Level	Type	Chargers Per Pedestal	Per Charger Cost
Level 2	Non-networked	1	$1,182
Level 2	Non-networked	2	$938
Level 2	Networked	1	$3,127
Level 2	Networked	2	$2,793
DCFC	Networked 50 kW	1	$28,401
DCFC	Networked 150 kW	1	$75,000
DCFC	Networked 350 kW	1	$140,000

Besides the cost estimation presented in the above table for single-port DC fast chargers, *(37)* also estimated the cost of dual-port 50 kW DCFC, revealing a cost range of $25,000 to $35,000 per charger. To estimate the cost of Level 2 and DCFC charging stations under various charging time, *(38)* presented cost estimates for commercial Level 2 and DC fast chargers in Table 6.

Table 6. Cost Estimation of Charger under Different Charge Time *(Source: 38)*

Charge Time	Charger Type	Amperage	Voltage	Power (kW)	Estimated Charger Cost
4-8 hours	Level 2	48 A	200-240 V	9.6 to 11.5 kW	$700 – $2,000
2-5 hours	Level 2	80	200-240	16 to 19.2	$1,800 – $4,000
1-2 hours	DCFC	100	480	48	$30,000 – $40,000
30-60 min	DCFC	200	480	96	$55,000 – $65,000
15-30 min	DCFC	250	480	120	$65,000 – $75,000

Unlike equipment costs, which are relatively static and depend on the level of charger, installation costs fluctuate over time and can be subject to market conditions. Local labor rates significantly impact DCFC installation costs, increasing up to $350 per dollar increase in the labor rate. Additionally, longer physical distance between power source to DCFC leads to higher cost for materials, labor, and hardscape, with approximately $200 per foot *(39)*. The cost of installation also varies greatly by location, with an estimated range of $600 to $12,700 for Level 2 and $4,000 to $51,000 for DCFC *(32)*. Take Blink dual-port DCFC as an example, the median installation cost for such pedestal was $22,626 *(40)*. *(36)* also provided installation cost for EVSE by charging types and number of chargers per site, as shown in Table 7.

Table 7. Installation Costs Per Charger by Type and Number of Chargers Per Site *(Source: 36)*

Charger Type	# Chargers Per Site	Per Charger Cost
Level 2*	1	$2,836
	2	$3,020
	3 to 5	$3,090
	>6	$2,305
DCFC (50 kW)	1	$45,506
	2	$36,235
	3 to 5	$26,964
	>6	$17,692
DCFC (150 kW)	1	$47,781
	2	$38,047
	3 to 5	$28,312
	>6	$18,577
DCFC (350 kW)	1	$65,984
	2	$52,541
	3 to 5	$39,097
	>6	$25,654

* Public and workplace Level 2 chargers outside of California state.

In general, more EVSE units installed at once usually lower the average cost per unit, especially in commercial installations *(39)*.

CONCLUSIONS

In conclusion, the electrification of transportation requires the development of charging infrastructure to support the widespread adoption of EVs. The City of Austin serves as a case study, highlighting the need for both public and private support to develop EVSE. Co-locating private EVCS with/alongside public EVCS can maximize utilization and achieve cost-sharing while offering convenience for EV drivers. The *public* charging stations here are primarily Level 2 and DCFC, with approximately 462 Level 2 charging stations (with 1+ cords per station) and 37 DCFC charging stations serving the Austin area. Together, the 462 Level 2 stations can charge approximately 979 EVs simultaneously. Each Level 2 charging port serves roughly 17 EVs and 413 households across the City of Austin. DCFC stations are much more expensive to deploy, and Tesla Superchargers dominate the City of Austin's options, with Tesla's 8 supercharging stations making up 94 of the city's 123 Level 3 charging ports. Areas with high demand but limited access to charging stations, particularly near existing parking lots, gas stations, intersections, and highways, are identified in this report as potential sites for new EVCS. Three promising locations are identified and considered co-locating with public EVCS. Besides co-location with existing EVCS, CS operators may also consider upgrade existing charging power to meet the growing demand for EV charging in the city of Austin.

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