

Charging Uncertainty: Real-Time Charging Data and Electric Vehicle Adoption

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Motivation: Why real-time data?

- ▶ Electric vehicle adoption crucial for meeting EPA greenhouse gas emissions standards and broader US climate goals.
- ▶ Prior literature finds charging infrastructure is key in drivers' vehicle choice (Springel 2021; Sommer and Vance 2021; Li et al 2017; Zhou and Li 2018, Xing, Leard, and Li 2021) and money spent on charging infrastructure has greater impact than money spent on vehicle subsidies (Cole et al 2023).
- ▶ But charging experiences are poor: Rempel et al 2022 (72.5% of Bay Area chargers functional), Asensio et al 2020 (almost half of public charging reviews are negative), Asensio & Liu 2024 (78% average reliability score nationwide).
- ▶ Real-time data has significant potential to save drivers time *and ease range anxiety*, especially on long trips far from home.

What is the current state of real-time data on highway DC fast chargers?

Motivation: Why real-time data?

- ▶ **Our definition of real-time data:** real-time information on charger status and price available alongside charger location and type *in a central app(s)*
- ▶ Precedent for requiring real-time data: mandated for all NEVI-funded chargers
- ▶ CPOs (charge point operators) may not want to share data:
concerns about business-stealing, revealing downtime or utilization, forgoing potential monetization

What would be the impact on EV adoption of requiring real-time data reporting at all public highway fast chargers?



1. Two novel data sources: scraped data from PlugShare.com and survey evidence
2. Current status of real-time data
3. Two-sided model of EV industry
 - ▶ Consumer vehicle choice, accounting for variability in charging experience
 - ▶ Charging station supply
4. Results: impact of real-time data on EV adoption, carbon emissions

Data on real-time data: PlugShare.com



The screenshot displays the PlugShare mobile application interface. At the top, the PlugShare logo is on the left, and 'PlugShare for Business' and 'EN' are on the right. A search bar at the top left contains 'CambridgeSide Mall'. Below the search bar is a photo of the charging station. The main information card for the station is dark blue and includes the text: 'TESLA ONLY', '8.6 CambridgeSide Mall', 'NACS (Tesla)', 'Supercharger 72 kW Shopping Center', and a green 'Check In' button with a checkmark. Below this card are icons for 'BOOKMARK', 'ADD PHOTO', 'DIRECTIONS', and 'REPORT'. A section titled 'You have never checked in here' contains a location pin icon and the address: 'CambridgeSide Mall, 100 CambridgeSide Pl, Cambridge, MA 02141, USA'. Below that is a phone number: '+1 877-798-3752'. The bottom section is titled 'Payment Required' and contains the text: 'If you scan your parking ticket as soon as you plug in you can get the first 30 minutes of parking free. Parking is \$3.00 to \$30.00, depending on duration. \$3.00 for up to 1 hour. \$3.00 for 3 hours with restaurant validation.' The right side of the screen shows a map with a pop-up window for the selected station, displaying the rating '8.6 CambridgeSide Mall', the address 'CambridgeSide Mall, 100 CambridgeSide Pl, Cambridge, MA 02141, USA', and '8 chargers Plug Types: NACS (Tesla)'. The map also shows various other points of interest like 'Blaze Pizza', 'Lechmere Canal Park', 'Foot Locker', 'Bath & Body Works', 'T.J. Maxx', 'Apple CambridgeSide', 'BlueTech Healthcare', 'Saleria', 'Mangolia Home Theater', 'The Cheesecake Factory', and 'Kimpton Marlowe Hotel'.

Data on real-time data: PlugShare.com

No Real-Time Data

Plugs (2 Kinds)		More Details
	CHAdeMO 2 Plugs 50 kW Shell Recharge 2 Stations	
	CCS1 2 Plugs 50 kW Shell Recharge 2 Stations	

Real-Time Data

Plugs (2 Kinds)		More Details
	CCS1 4 Plugs 100 - 350 kW EVgo 4 Stations 2 Available 1 In Use 1 Unavailable	
	CHAdeMO 4 Plugs 100 kW EVgo 4 Stations 2 Available 1 In Use 1 Unavailable	

Data collection: regular scraping of details of public DC fast chargers ($\geq 50\text{kW}$) within two miles of exits on 6 interstates covering 40 states (I-5, I-10, I-75, I-80, I-90, I-95) between March and August 2024

Data on driver beliefs: Survey evidence

Real-time data accelerating EV transition relies on drivers' beliefs about station reliability, conditional on having real-time data or not

- ▶ Surveyed 908 prospective car buyers and 813 current EV drivers
- ▶ Asked to assess probability of successfully charging at:
 1. Charger with real-time data reporting at least one plug working and available
 2. Charger with real-time data reporting at least one plug working but none available
 3. Charger without real-time data
- ▶ Will present key results where relevant to our model – see paper for more details!

Real-time data reporting is limited.

Real-time data reporting on August 18, 2024:

	I-5	I-10	I-75	I-80	I-90	I-95	Total
Total Stations	350	187	150	214	189	336	1,426
% w/RT Data	45.4%	31.6%	33.5%	30.0%	23.3%	28.6%	33.2%
Non-Tesla Stations	248	116	91	133	111	188	887
% w/RT Data	64.1%	50.9%	49.5%	53.4%	39.6%	51.1%	53.4%
Non-Tesla/EA	197	82	70	89	81	150	669
% w/RT Data	80.7%	72.0%	64.3%	79.8%	54.3%	64.0%	70.9%

Excluding Tesla and EA improves real-time data reporting, at the cost of 53% of stations.

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Real-time data reporting varies substantially.

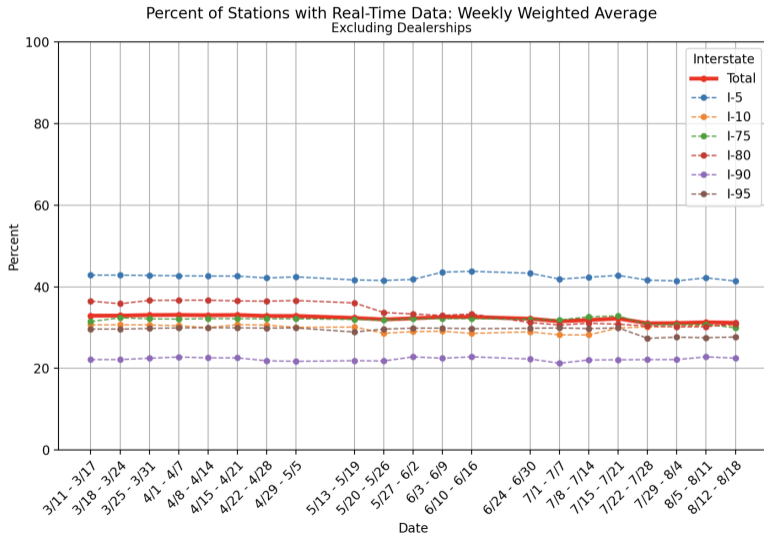
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Real-time data reporting varies substantially.



Reporting of real-time data is stagnant.



Model: EV Demand

Adapt model from Cole et al (2023), modifying utility function so that number of DC fast chargers is a random variable

- ▶ Consumers choose to purchase an EV or ICE within a vehicle class (cars or light trucks) to maximize expected utility
- ▶ Utility from an ICE:

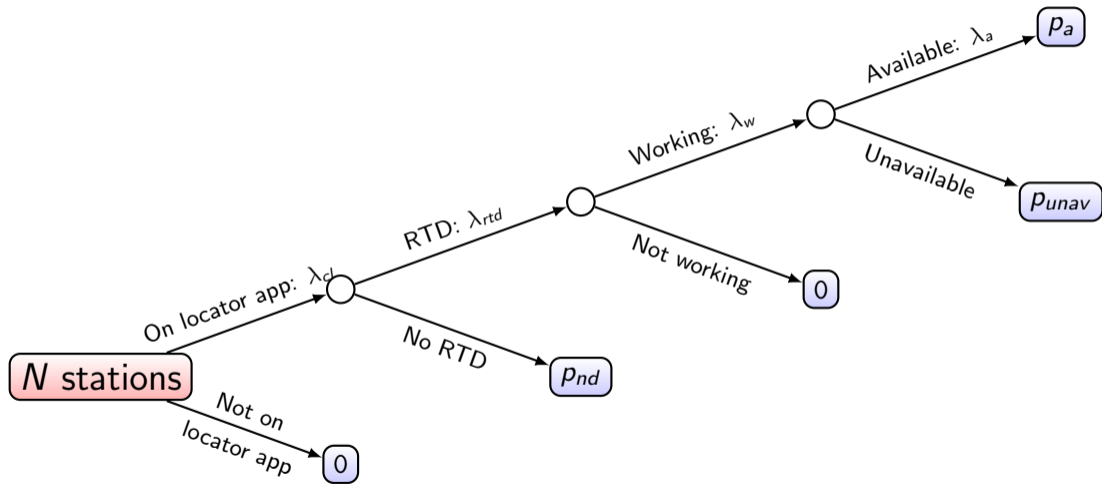
$$U_{ijt,ICE} = P_{ICE,t}^{\beta_P} e^{\psi_{ICE,t}} e^{\varepsilon_{ICE,ijt}}$$

- ▶ Utility from an EV:

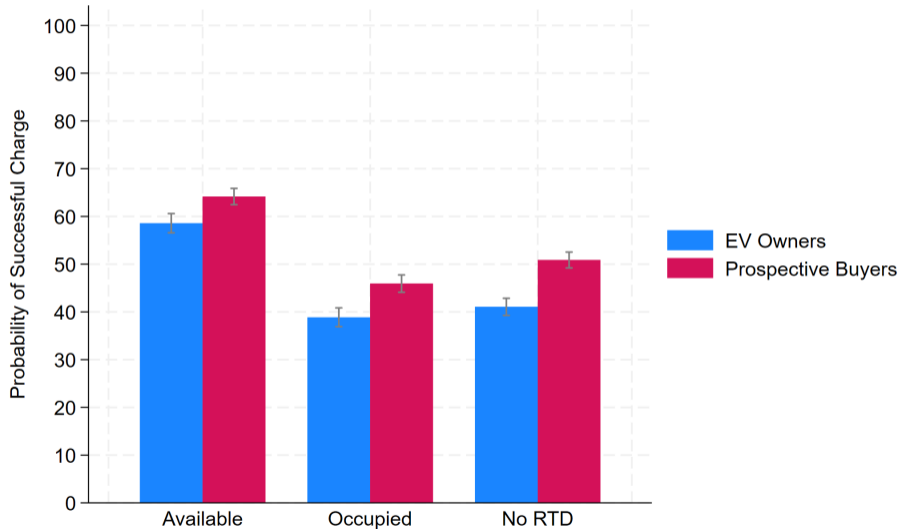
$$U_{ijt} = E[P_{EV,t}^{\beta_P} (\mu_t N_{t,l3})^{\beta_{l3}} (N_{t,l2}/Q_{t-1})^{\beta_{l2}} e^{\psi_{jt,EV}} e^{\varepsilon_{ijt,EV}}]$$

where μ_t is a Bernoulli random variable representing perceived charger reliability

Parameterizing μ_t : probability of successful charge across charger types



Parameterizing p_a , p_{unav} , and p_{nd} from survey data



Model: Charging Station Supply

Representative charging firm: profit is expected profit across chargers with and without real-time data

Key assumptions:

- ▶ Out-of-service stations and stations not appearing on a charging locator deliver no profit
- ▶ Stations without real-time data work with the same probability as stations with real-time data
- ▶ Profits from working stations with real-time data are the same as profits from working stations without real-time data

Yields profit function:

$$\pi_t = \lambda_{cl} \lambda_w (\exp(\kappa) / (N_t))^{1/\gamma} Q_t$$

Model: Charging Station Supply

Representative charging firm builds stations until they are indifferent between building today or in the next period:

$$\pi_{t,13}(N_t, Q_t) = C_t - \frac{1}{1+r} C_{t+1}$$

Yielding our charging station supply function:

$$\ln(N_t) = \kappa + \gamma \ln(\lambda_c \lambda_w) + \gamma \ln(Q_t) - \gamma \ln(\tilde{C}_t)$$

4 key simulation scenarios:

- ▶ **Baseline:** EV penetration under current policy (IRA & IIJA) with no change in real-time data availability; calibrated to 48% of 2030 new car sales
- ▶ **Scenario 1:** Real-time data reporting (λ_{rtd}) increases to 100% by 2029
- ▶ **Scenario 2:** Scenario 1 + uptime for DCFCs (λ_w) increases to reach 95% in 2029
- ▶ **Scenario 3:** Scenario 2 + driver confidence in real-time data (p_{rtd}) increases to 100% in 2029

Run Monte Carlo simulations of each scenario, drawing parameters from distributions of scraped PlugShare data and survey data

Impact of RTD scenarios on EV share of new vehicle sales

	Baseline	All stations provide RTD		and 95% uptime		and full driver confidence in RTD	
			ppts over baseline		ppts over baseline		ppts over baseline
2025	11.4%	11.5%	0.10	11.5%	0.15	11.8%	0.46
2026	21.0%	21.3%	0.32	21.2%	0.20	22.3%	1.37
2027	29.2%	29.7%	0.55	29.8%	0.64	32.1%	2.96
2028	36.6%	37.3%	0.76	37.8%	1.18	41.3%	4.76
2029	43.0%	44.0%	0.94	44.7%	1.67	49.4%	6.36
2030	48.0%	48.9%	0.94	49.7%	1.73	54.4%	6.36

Impact of RTD scenarios on EV fleet size

	Baseline	All stations provide RTD	% over baseline	and 95% uptime	% over baseline	and full driver confidence in RTD	% over baseline
2025	4.61	4.63	0.39%	4.63	0.54%	4.69	1.71%
2026	7.77	7.84	0.91%	7.83	0.74%	8.08	3.93%
2027	12.05	12.21	1.30%	12.21	1.34%	12.84	6.49%
2028	17.22	17.49	1.58%	17.57	2.02%	18.75	8.85%
2029	23.04	23.45	1.78%	23.64	2.61%	25.51	10.73%
2030	29.20	29.73	1.83%	30.04	2.89%	32.53	11.43%

Impact of RTD scenarios on carbon emissions from LDVs

	All stations provide RTD	and 95% uptime	and full driver confidence in RTD
2025	-0.1	-0.2	-0.6
2026	-0.3	-0.2	-1.5
2027	-0.7	-0.8	-3.9
2028	-1.2	-1.7	-7.5
2029	-1.7	-2.7	-11.4
2030	-2.4	-4.0	-16.0

Note: assumptions on power sector emissions from Stock & Stuart (2021)

Conclusion

- ▶ Real-time data reporting is poor, doing little to alleviate bad charging experiences.
- ▶ Survey respondents do not fully trust real-time data, but it provides a marked improvement over stations without real-time data.
- ▶ Real-time data reporting *alone* has little effect on EV adoption, but can have a significant impact when accompanied by increased driver trust in data:
 - ▶ 11.4% increase in the size of the light-duty EV fleet in 2030
 - ▶ 6.4 percentage point increase in EV sales share in 2030 from 48.0% to 54.4%
- ▶ Can lead to considerable reductions in carbon emissions from LDVs
 - ▶ Accomplishes additional 20% of IRA/IIJA reductions from LDVs (as predicted in Cole et al 2023) at virtually no fiscal cost – vs. \$451 billion

Thank you!
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