Community Charging Hubs in Multi-Unit Dwellings: Electric Vehicle Charging Management and Technoeconomic Assessment

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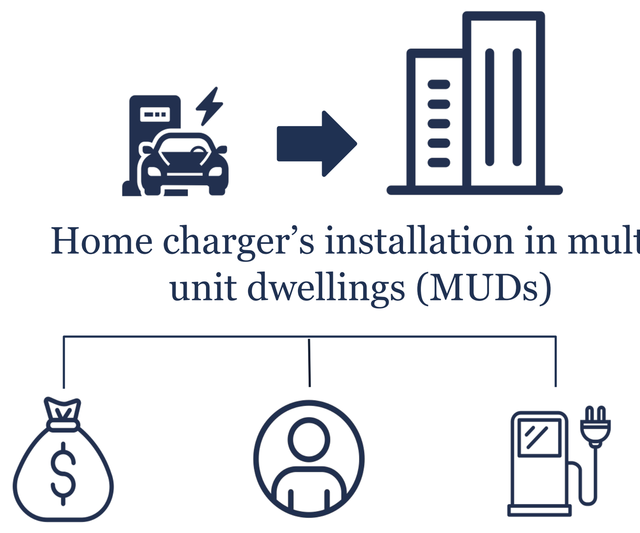
INTRODUCTION

Community charging hubs are essential for residents of multi-unit dwellings (MUDs) due to sparse home charging infrastructure and parking spots

- Less than 50% of household vehicles have access to dedicated parking (Traut et al., 2013).
- Limited access to reliable charging infrastructure could hinder electric vehicle (EV) ownership and use (Mersky et al., 2016).

35.32%	73.55%	Based on the 2019 American Housing Survey
Garages in MUDs	Garages in single family homes	

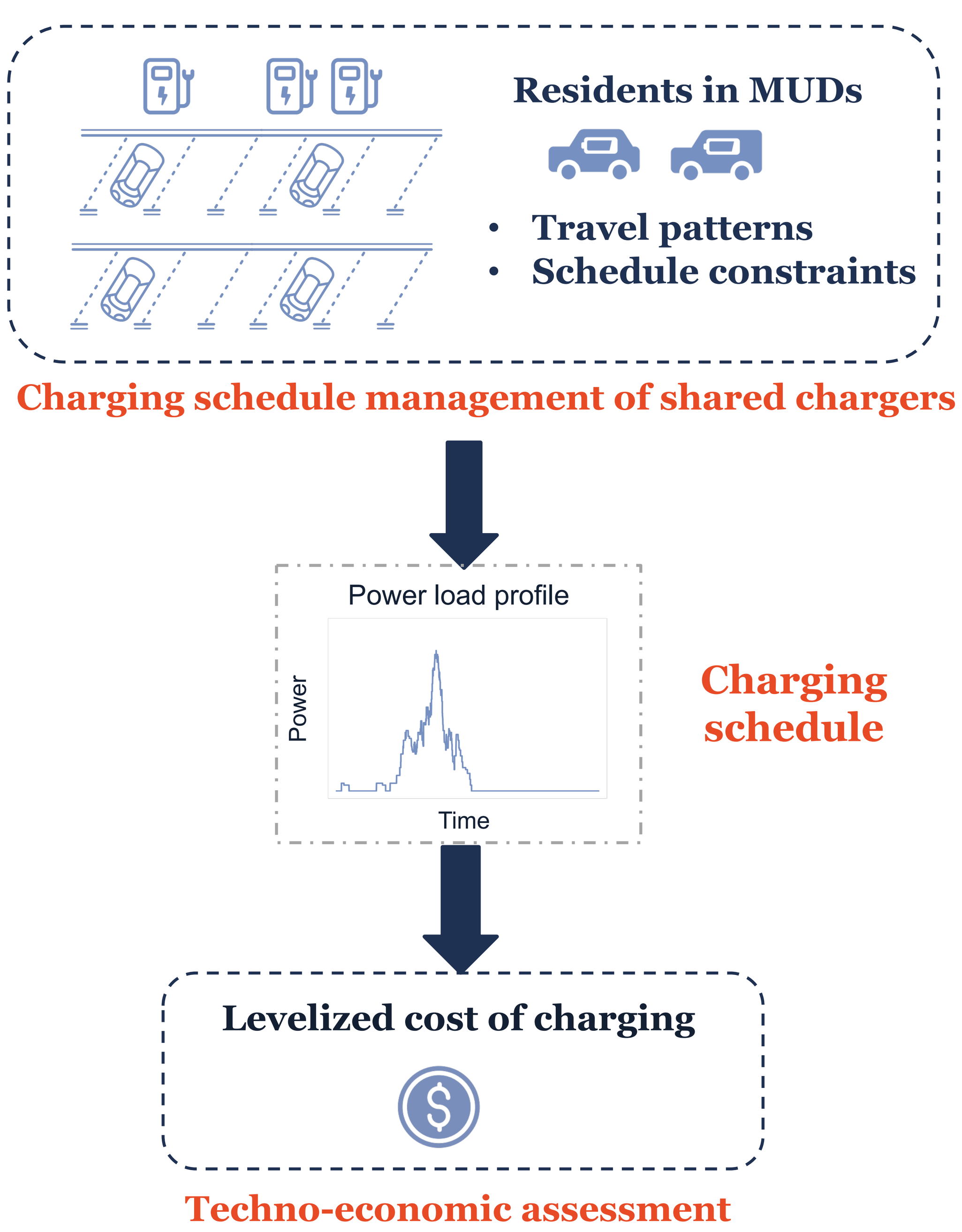
There are **barriers** to home charger installation and access (Ge et al., 2021), especially for residents of MUDs.



Democratizing access to shared chargers for MUD residents is a prerequisite for equitable EV adoption and use and a fair transition to decarbonized transportation.

RESEARCH HIGHLIGHTS

- Our research framework evaluates the viability of community charging hubs for MUDs, proposes algorithms for **centrally shared chargers' management and charging session scheduling**, and conducts the MUD community charging hub's **techno-economic assessment.**



- We uncover **tradeoffs** between the charging hub's performance and its levelized cost of charging. As additional charging stations are installed, the **total charging hub's waiting time** is often reduced, but **the levelized cost of charging** rises. Installing **DCFC stations** costs more than adding level-2 chargers but reduces waiting time more drastically.
- **Pareto optimal charger configurations** based on the levelized cost of charging and the system's performance are created.
- The **cost and performance metrics** of the small, medium, and large charging hubs and their **load profiles** are presented.

METHOD

Charging schedule management

We modified the Job Shop Scheduling Problem (JSP) for EV charging scheduling in MUDs. The objectives of charging scheduling in MUDs include:

- Minimizing the **makespan** → Efficient operation of the charging hub with **compact schedule**
- Minimizing the **total waiting time** → MUD residents' **satisfaction with the performance of the system**

The charging scheduling model cannot be efficiently solved with commercial solvers. Instead, we propose a heuristic method, depicted in Fig. 1.

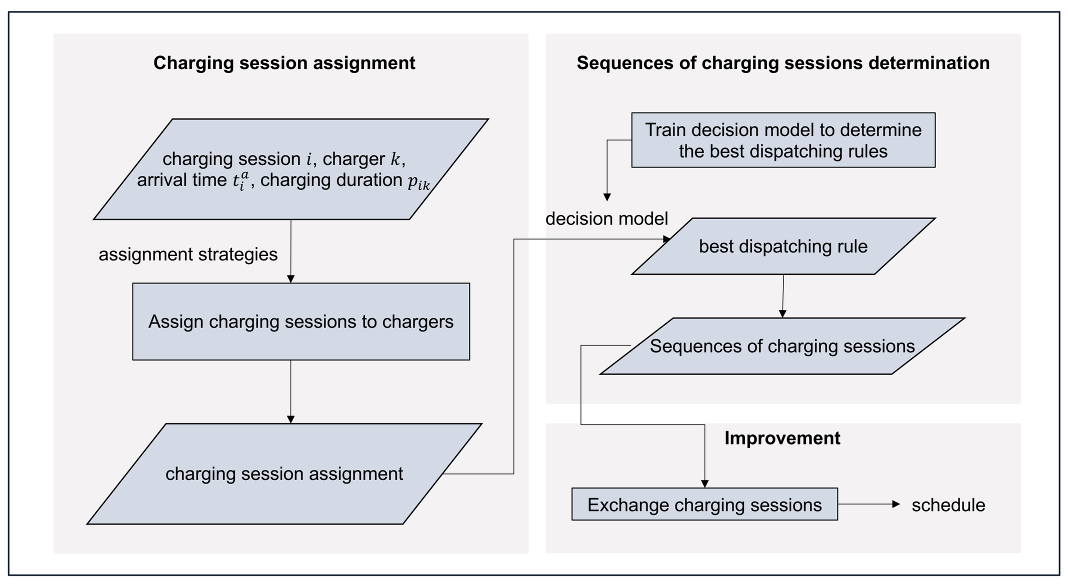


Figure 1. A schema of the proposed heuristic method to solve the charging scheduling model

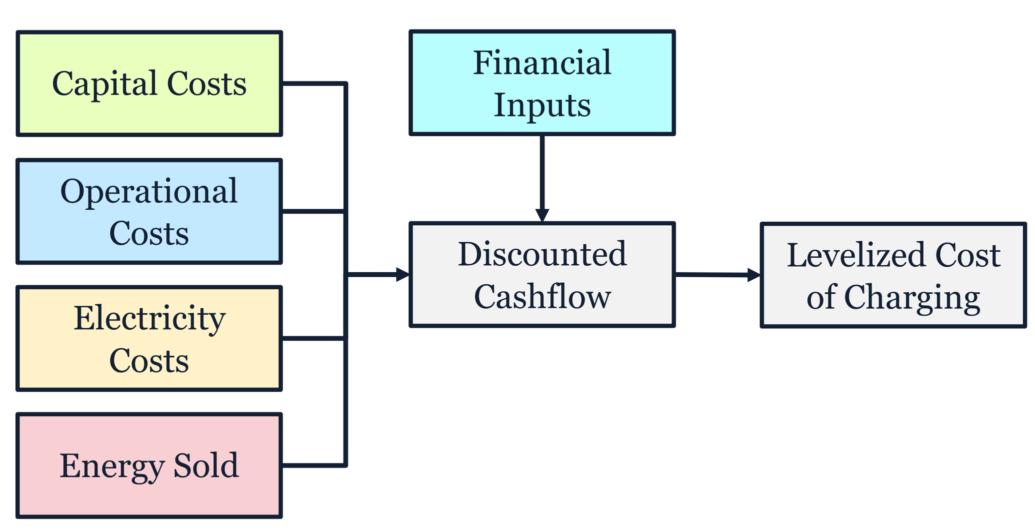
Techno-economic assessment

Discounted cashflow rate of return analysis

- Solve for **levelized cost of charging** with fixed Internal Rate of Return and analysis period

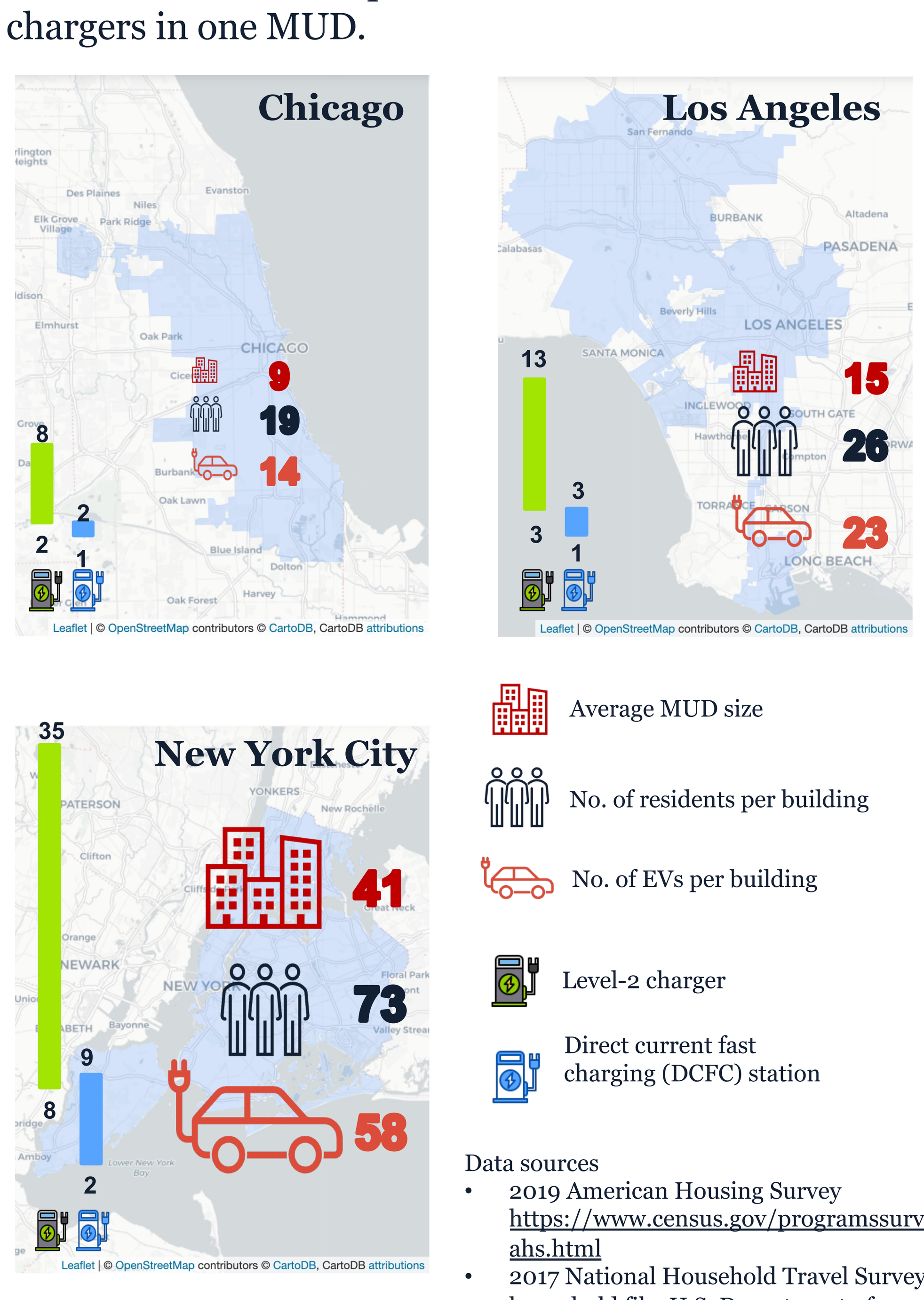
Three MUDs charging station **ownership/business models**

- **Residential** (e.g., homeowners association)
- **Utility** (e.g., local electric utility)
- **Private Company** (e.g., public charging infrastructure investor)



NUMERICAL EXPERIMENTS

We apply our modified JSP charge scheduling model and techno-economic assessment in **Chicago IL**, **New York City NY**, and **Los Angeles CA** for numerous **charger compositions**. We create a scenario for each metropolis, where EV drivers compete for a limited number of chargers in one MUD.



Data sources

- 2019 American Housing Survey https://www.census.gov/programssurveys/ahs.html
- 2017 National Household Travel Survey, household file, U.S. Department of Transportation

RESULTS

Coupled charging hub performance and levelized cost of charging

We demonstrate the hub's **trade-offs** between total waiting time and the levelized cost of charging in Fig.2.

- When additional level-2 chargers are enabled, the total waiting time is reduced, but the levelized cost of charging increases.
- The levelized cost of charging is shown to vary substantially by the number of chargers, hub location, and ownership model.

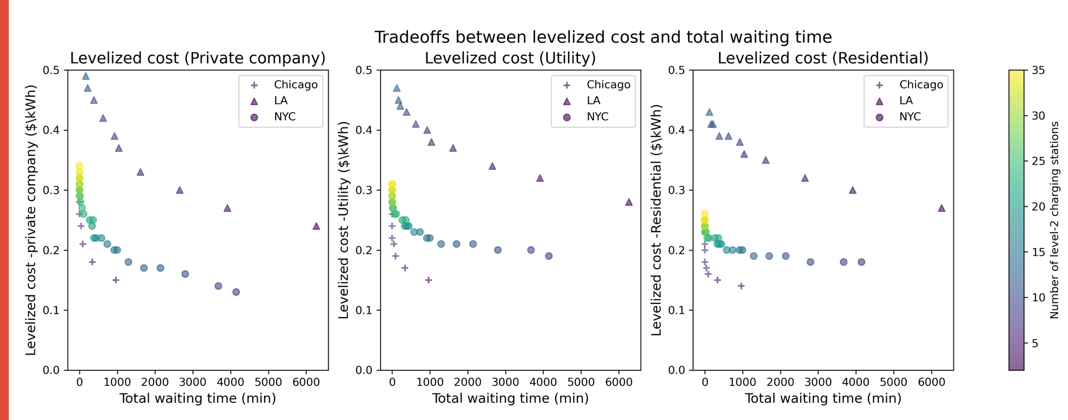


Figure 2. Trade-offs between levelized cost of charging and total waiting time, when only level-2 charging stations are installed in the MUD charging hub

Pareto frontier considering performance and levelized cost of charging for a mix of level-2 and DCFC stations in MUD charging hubs

Combining the results enables the investor and owner to understand the implications of their MUD charging hub's parameters on the system's performance (total hub's waiting time) and the levelized cost of charging.

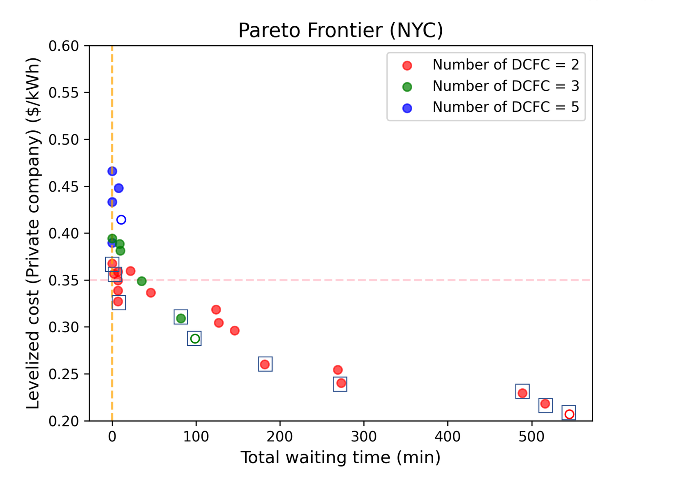


Figure 3. Pareto frontier of chargers' power mix in New York metro area considering the trade-offs between performance and cost of charging.

Charging hubs sizing and their power profiles

For each metropolitan area, we define a **small, medium,** and **large** charging hub configuration that meets the same charging demand volume and provide insights on **the cost and the performance metrics** in Table 1. The average 48-hour **power profiles** are presented for various charging station configurations in Fig.4.

Table 1. Cost and performance metrics for level-2 chargers in charging hubs

Study area	Charging hub size	Number of level-2 chargers	Total waiting time (min)	Levelized cost of charging ($/kWh)		
				Private company	Utility	Residential
Chicago	Small	2	1853	0.15	0.15	0.14
	Medium	5	46	0.24	0.21	0.17
	Large	8	0	0.3	0.26	0.21
New York City	Small	8	4147	0.13	0.19	0.18
	Medium	21	271	0.25	0.25	0.22
	Large	35	0	0.34	0.31	0.26
Los Angeles	Small	3	6270	0.24	0.28	0.27
	Medium	8	927	0.39	0.40	0.38
	Large	13	123	0.51	0.47	0.43

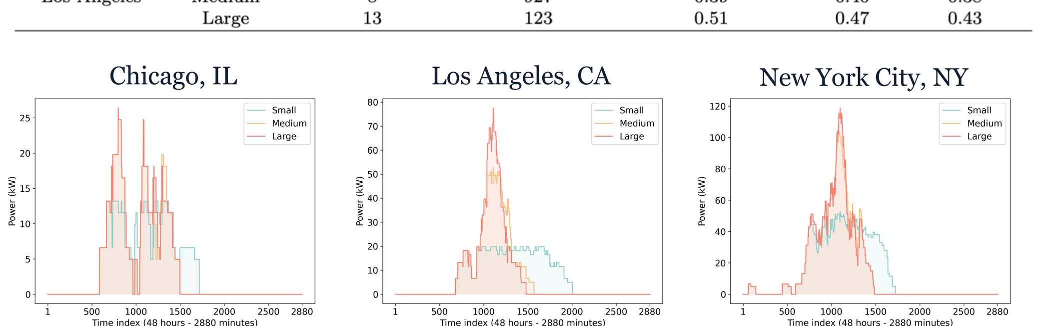


Figure 4. Average 48-hour load profiles of small, medium and large charging hubs.

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