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Electric Vehicle Charging Network Optimization Considering Regional Resource Dependencies

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Introduction

- Optimal EV charging allocation is critical for electrification but often ignores **spillover effects** between regions.
- **Better allocation methods** are needed to optimize station placement, charger types, and costs while considering spillover effects and meeting real-world constraints.

Key Contribution

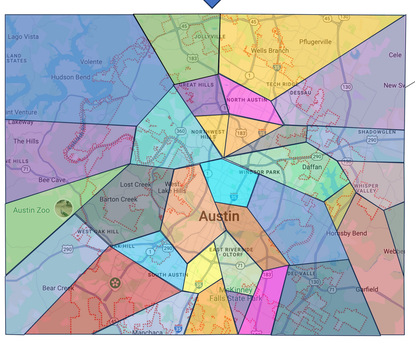
Developed a novel **bipartite network framework for EV charging optimization** that: 1) introduces Voronoi-K-means clustering to better capture demand spillover effects; 2) adopts choice modeling philosophy via a bipartite network (linking drivers to stations); 3) optimizes charger placement, type, and number while minimizing costs.

Research Framework

Step 1: Charging Demand Partition

- (Lats, Longs) of existing **EV charging stations** & charging recording
- (Lats, Longs) of **POIs** (e.g., café, school, etc.)
- (Lats, Longs) of **traffic monitoring** cameras & traffic flow recording

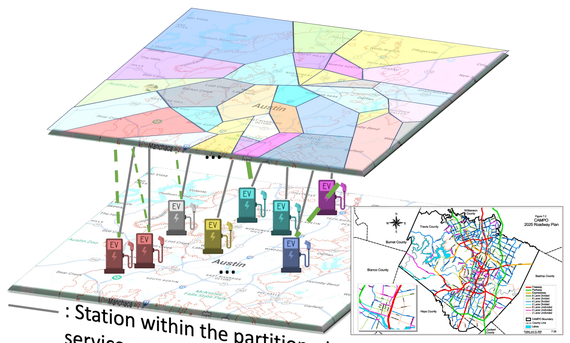
Partition method (Voronoi-weighted K-means clustering)



Partitioned service zone

*Each partitioned service zone has similar charging demand

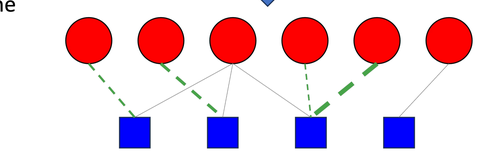
Step 2: Network Representation of Charging Demand-Resources Alignment



: Station within the partitioned service zone

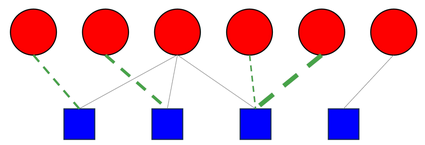
: Driving distance between a service zone without a charging station and its nearest station

Bipartite network modeling



:Partitioned service zone node
:EV charging station node
:Link with weigh (equal to driving distance)
:Link with 0 weigh

Step 3: EV Charging System Optimization



Optimization problem formulating

Optimizing design decisions:
- Existing stations that need to expand
- Location of new stations
- Charger types and quantities for expanded and new stations

Objective 1: Minimize total expenses

Objective 2: Minimize EV driver driving cost

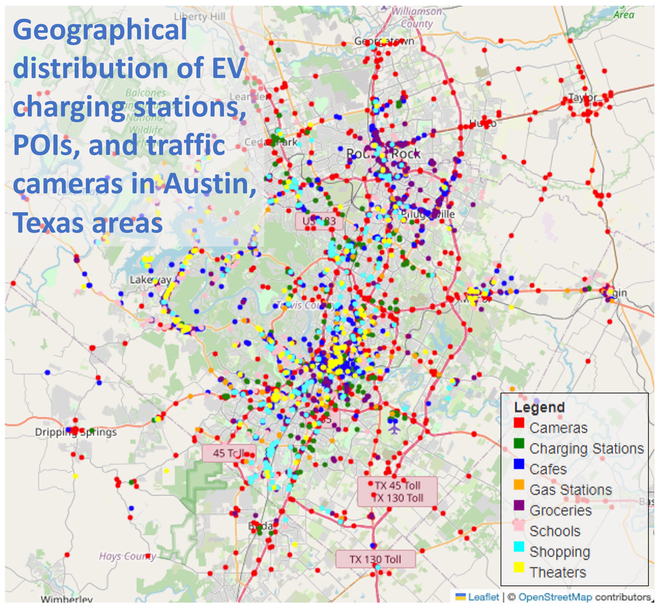
Objective 3: Maximize coverage efficiency of charging demand

S.T.
- Within budget constraint
- Charging power limitation of each station

Genetic Algorithm

Optimal design decisions

Case Study



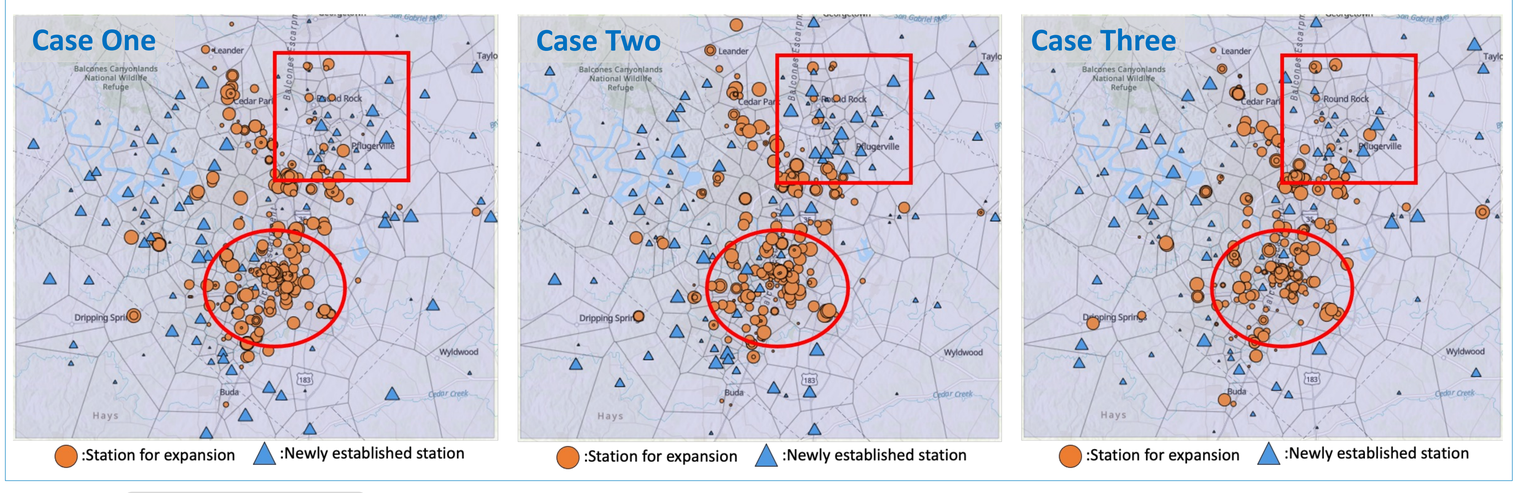
Scheme of test cases

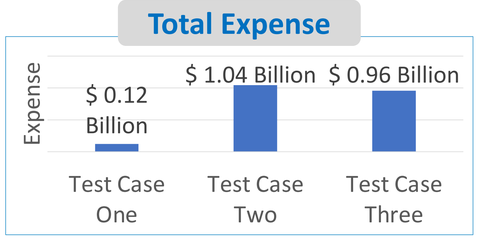
Test Case	Budget ($)	Charger Type
Case One	1 Billion	Level 2 (6.6 kW)
Case Two	1 Billion	DC 50 kW
Case Three	0.1 Billion	DC 50 kW

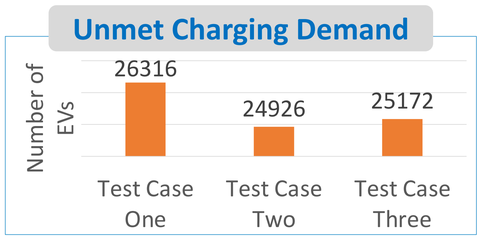
Results

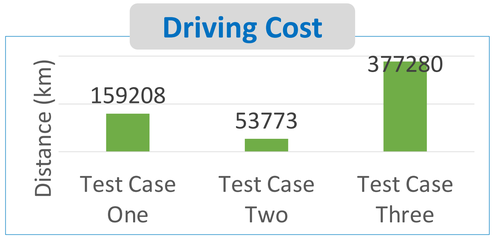
- **Case One:** Prioritized downtown expansions + even distribution; shows 88% unmet demand.
- **Case Two:** Clustered new stations in northern regions; shows optimal performance (96% demand met, 66% lower driving distance).
- **Case Three:** Focused on station expansions and shows higher driving costs due to sparse coverage.

Optimal EV charger placements









Future Work

- Incorporate **temporal factors** (e.g., charging speed) for demand prediction
- Consider **power grid**
- Conducting **sensitivity analysis** for different configurations (e.g., # of partitioned service zones)
- Explore **bipartite network model** to uncover its potential to guide EV charging planning
- Develop algorithms or computing strategies for **high-dimensional optimization problem**

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