Geospatial Modeling of Electric Vehicles Supply Equipment (EVSE) in California

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Research Algorithm

Geo-temporal Distribution of Charging Opportunity

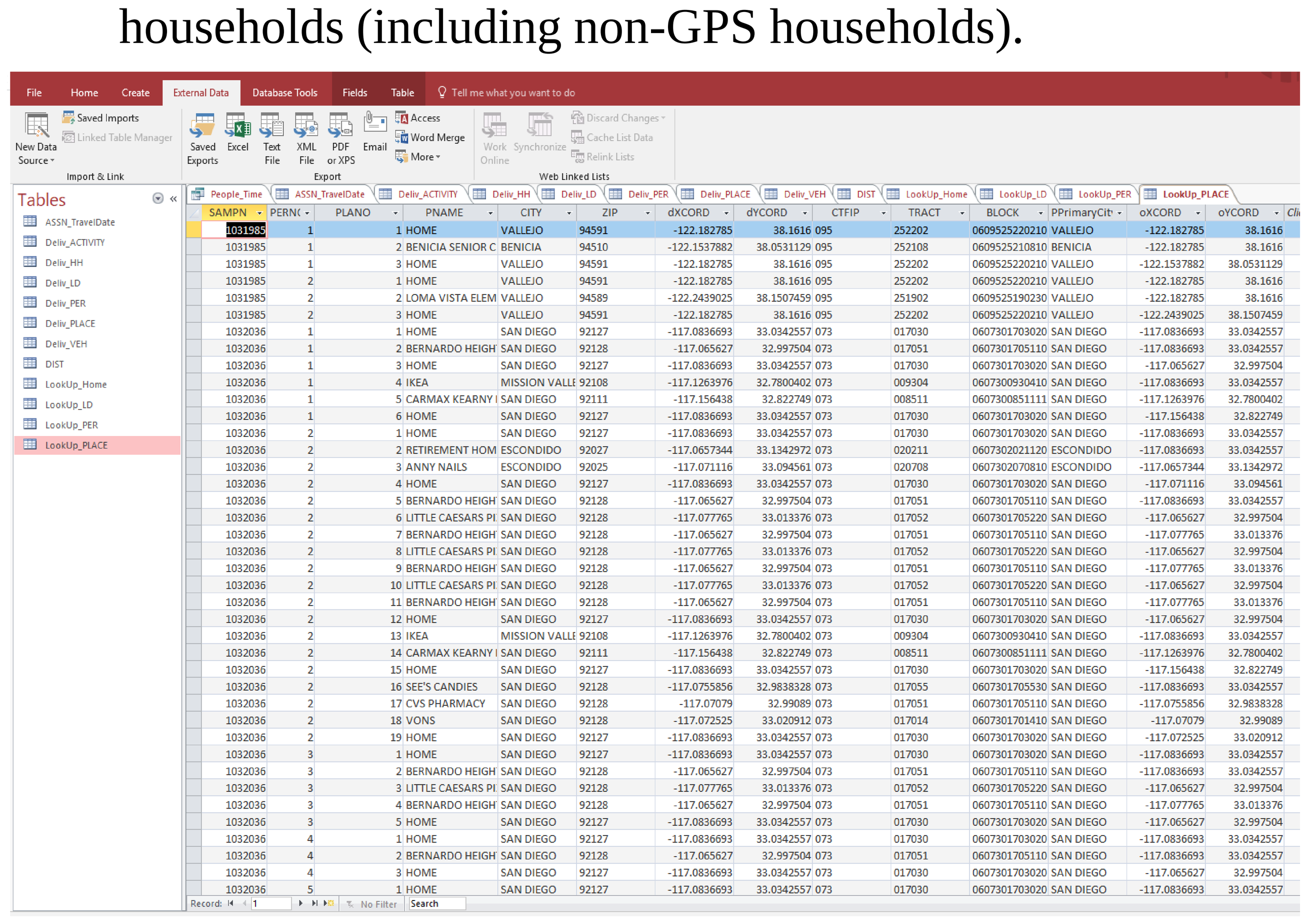
- We design a matrix of Charging Opportunity (CO) for any possible location as ***People · Dwelling time;***
- Understand the mobility of people, which is the initial demand no matter their travel pattern;
- Can be easily transferred to *Vehicle · Dwelling time* with different vehicle occupation rates under different scenarios with shared mobility or/and autonomous vehicle.

Optimized Geospatial EVSE system

- Mixed integer optimization model;
- Consider the temporal and geospatial disparity of electricity, as well as infrastructure;
- Minimize system cost = charging cost + infrastructure cost;
- Optimal locations for EVSE, and charging strategies.

Datasets

- *CHTS 2012 DATABASE:*
- ✓ 42,431 completed households: 36,714 non-GPS households and 5,717 GPS households;
- ✓ Of the GPS households 3,855 were wearable GPS, 422 used in-vehicle GPS only, and 1,440 used in-vehicle GPS plus OBD;
- ✓ Travel dairy datasets offer spatial and temporal information on the mobility of every person in the households (including non-GPS households).



- *California Air Resources Board Clean Vehicle Rebate Project, Rebate Statistics:*
- ✓ Records the location of the EV owners;
- ✓ Aggregate the records into zip code level;
- ✓ Adjust the CHTS weights by multiplying the EV ownership rates.

Results

- ***Geo-temporal Distribution of Charging Opportunity***

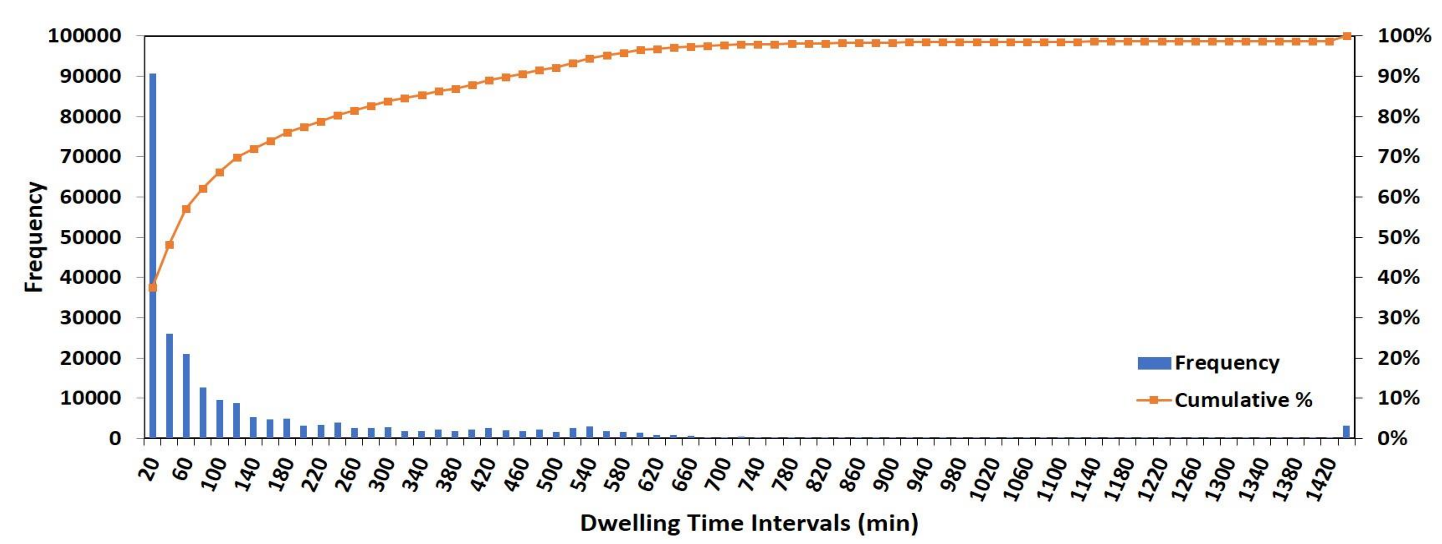


Fig. 1 Statistical Distribution of Non-home Dwelling Time

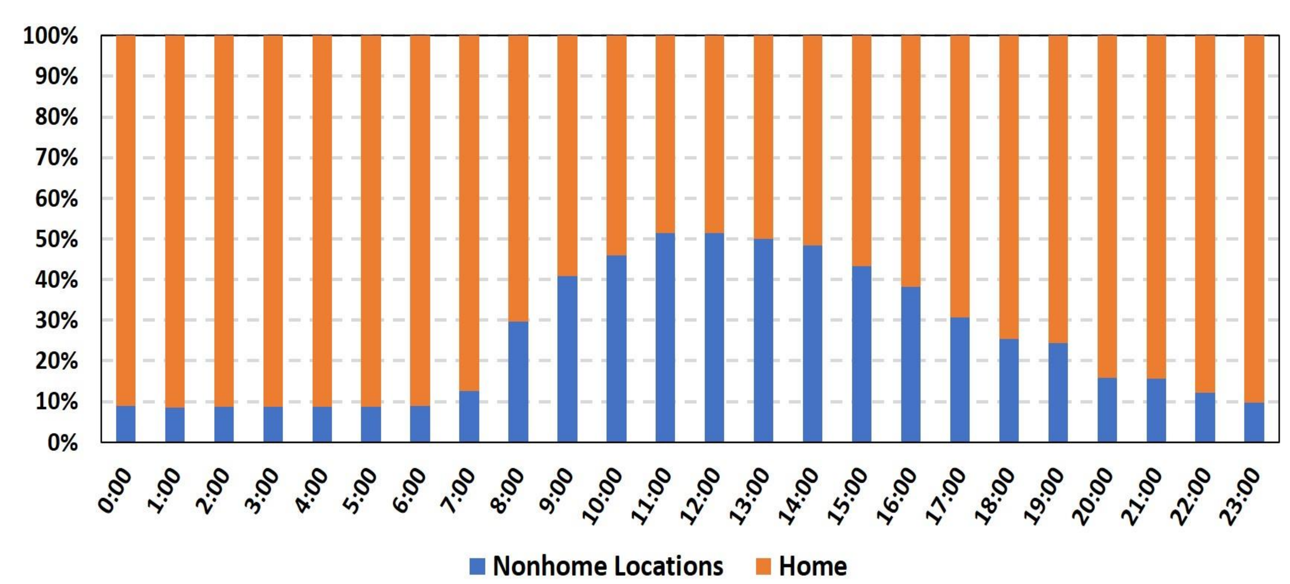


Fig. 3 Temporal Charging Opportunities

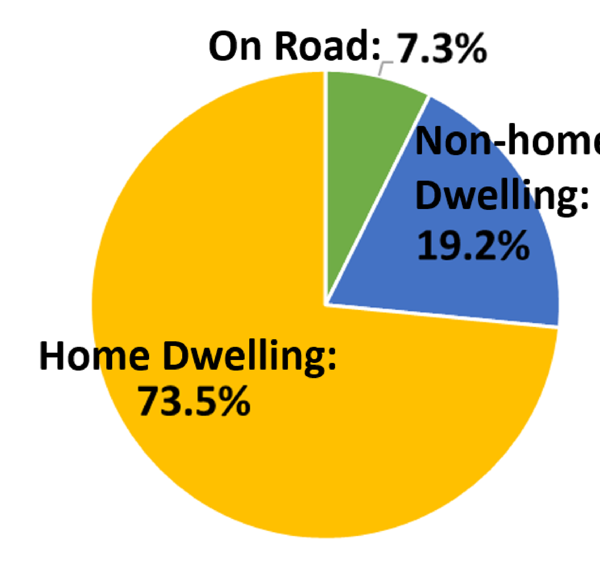


Fig. 2 Time Distribution of Daily People's Mobility

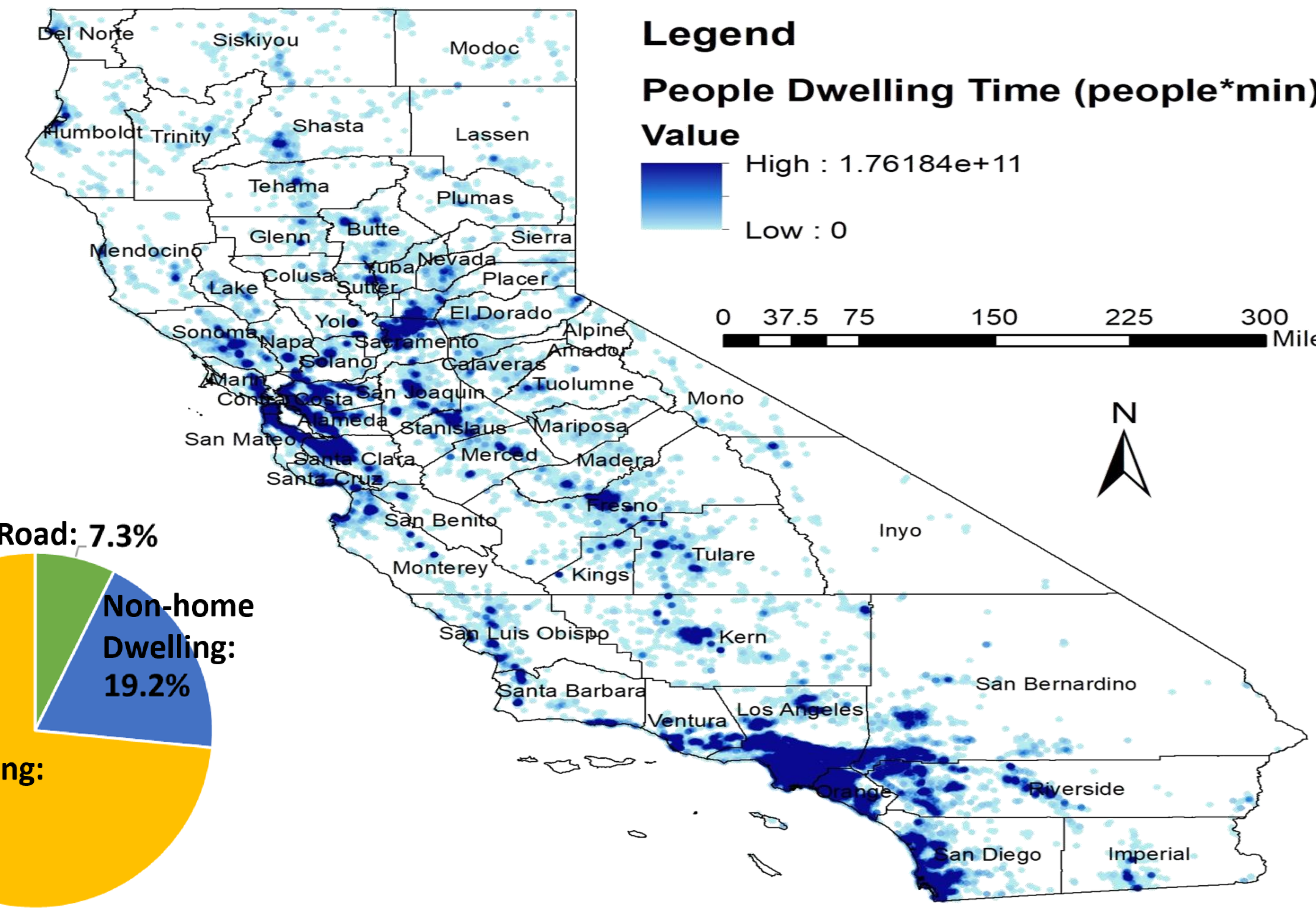


Fig. 4 Charging Opportunity Heat Map in California

- ***Optimized Geospatial EVSE system***

Sets

r regions /r1,r2,r3/

t time periods /t1*t24/

l charging levels /l1,l2,l3/

i individuals /i1,i2,i3/;

Parameters

VMT(i) individual daily travel distance in miles;

energyDem(i) individual daily energy demand in kWh;

powerCharge(l) power of three charging levels in kW

dwellingTime(t,i,r) individual dwelling time at different regions in hours

chargingPrice(r,l) in dollars of kWh

infraCost(r,l) in dollars

variables

chargingTime(i,t,r,l): charging time of individual i at region r in time period t with level l charger;

numCharger(r,l): number of charger at level l built at region r, integer

Objective

Min ChargingCost =
$\sum_i \sum_t \sum_r \sum_l$ chargingPrice(t,r,l)$*$chargingTime (i,t,r,l)$*$ chargerPower(l)
\+ $\sum_l \sum_r$ infraCost(r,l)$*$numCharger(r,l);

Constraints

$\sum_t \sum_r \sum_l$ chargingTime(i,t,r,l)$*$ chargerPower(l) - energyDem(i) $\geq$ 0;

chargingTime(i,t,r,l) ≤ 1;

$\sum_l$ chargingTime(i,t,r,l)- dwellingTime(t,i,r) ≤ 0;

$\sum_i ChargingTime(i,t,r,l)$ - numCharger(r.l) ≤ 0;

```
----    131 VARIABLE chargingTime.L

INDEX 1 = i1

                 l1

t9 .r2        0.319
t10.r2        1.000
t11.r2        1.000
t12.r2        1.000

INDEX 1 = i2

                 l1

t4 .r3        0.454
t10.r1        1.000
t11.r1        1.000
t12.r1        1.000
t13.r1        1.000

INDEX 1 = i3

                 l1

t3 .r2        1.000
t4 .r2        1.000
t9 .r1        1.000
t10.r1        1.000
t11.r1        1.000
t12.r1        1.000
t14.r3        1.000
t15.r3        0.416
```

L1 Charging Requirment	r1	r2	r3
t1	0	0	0
t2	0	0	0
t3	0	1	0
t4	0	1	0.454
t5	0	0	0
t6	0	0	0
t7	0	0	0
t8	0	0	0
t9	1	0.319	0
t10	2	1	0
t11	2	1	0
t12	2	1	0
t13	1	0	0
t14	0	0	1
t15	0	0	0.416
t16	0	0	0
t17	0	0	0
t18	0	0	0
t19	0	0	0
t20	0	0	0
t21	0	0	0
t22	0	0	0
t23	0	0	0
t24	0	0	0

Discussion

- Potential for Fast Charging at Non-home Locations: around 40% of the dwelling time intervals at non-home locations are within 20 mins, showing a big potential for fast charging facilities being used at non-home locations, including working, shopping and other public places;
- Home charging should still be the dominant charging pattern: at the state average level, people spend 73% of the time at home;
- Potential for demand management by optimally scheduling charging activities into charging opportunities.

Future Study

- Expand the current demo optimization model to the comprehensive model for CA with over 100 thousands individuals and over 1750 zip code levels:
  1. Computational limit
  2. Real-time price at zip code levels
  3. More constraints: limited budget/ battery size
- Integrating grid operation / renewable benefits into the optimization model – more comprehensive.
- Consider the constraints of electric grid, or the benefits to renewables integration into the EV charging system design.
- Conduct scenario analysis, investigating the impacts of new mobilities, such as shared mobility and vehicle automation, to charging opportunity distribution.

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