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Exploring the accessibility of public electric vehicle chargers in England, the UK

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Workshop Oxford Electric vehicles, urban development and energy infrastructure: comparative perspectives from the UK and South Korea
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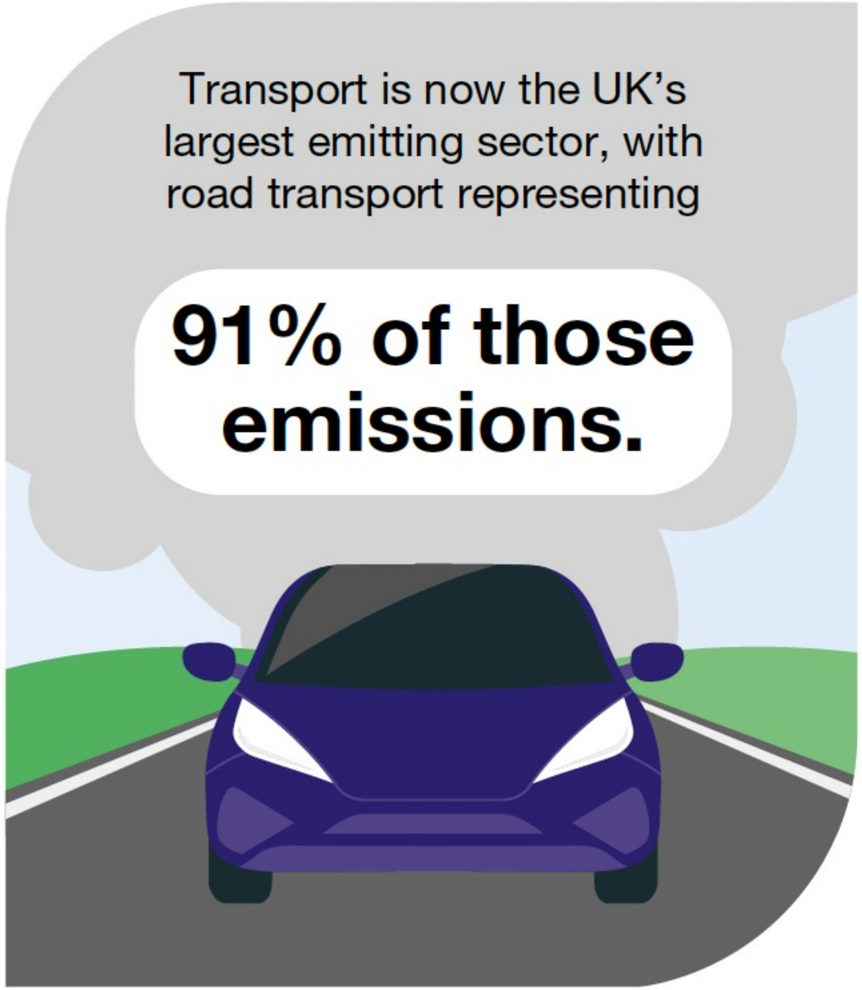
Contexts



- The UK Government has committed to net zero emissions by 2050.
- The transition to zero emission cars and vans is leading the way to decarbonise UK's transport (HM, 2021).
- End the sale of new petrol and diesel cars and vans from 2030; from 2035, all new cars and vans must be zero emission at the tailpipe.
- By 2030, there will be at least around 300,000 public charging points in the UK. (HM, 2022).
- Public charging options can reduce range anxiety and encourage adoption of EVs (Neaimeh et al., 2017; Lee et al.,2020; Globisch et al., 2019).

Q: What is the status quo of EV charging services and where should we build more public charging points?

Accessibility

- **The potential or possibility of various opportunities for interaction** (Hansen, 1959).
- **The (economic) benefits that people derive from access to the spatially distributed activities** (Handy and Niemeier, 1997, De Jong et al., 2007).
- **The number of opportunities that can be reached within a given travel time threshold** (Bhat et al., 2000; El-Geneidy et al., 2016).
- **The activities in which an individual can participate at a given time** (Neutens et al., 2010)**.**
- **The (observed or simulated) performance or service level of public transport infrastructure** (TfL, 2015).

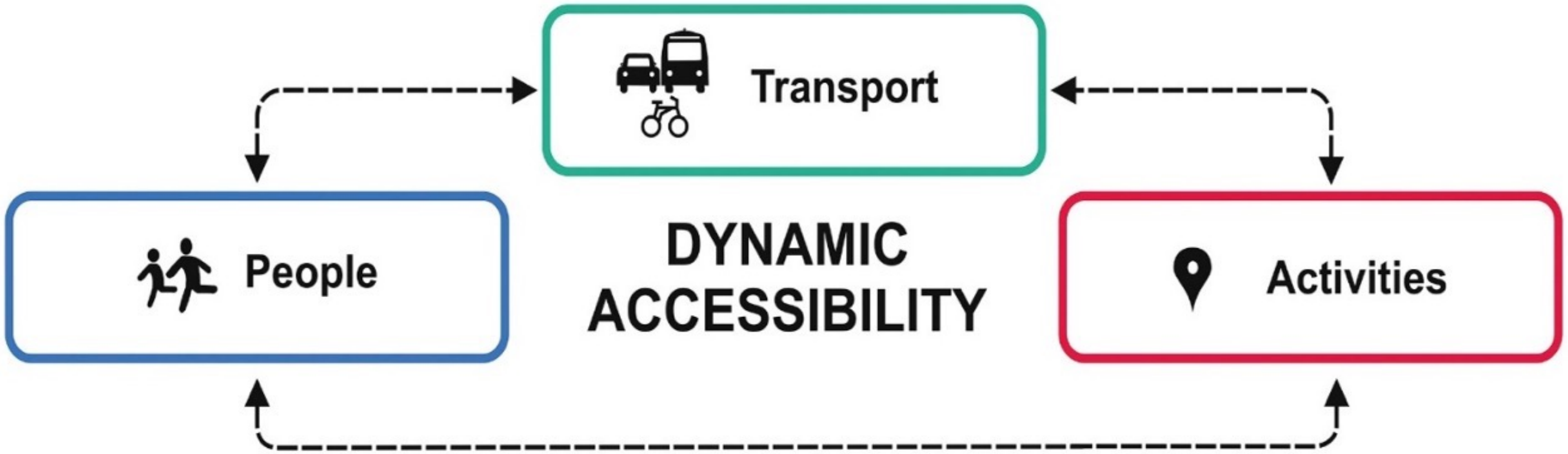
- **Accessibility:** The potential or possibility of various opportunities for interaction.

e.g., How many places you can get access to in a given amount of time.

- **Mobility:** The potential or capability for movement.

e.g., How far your can reach in a given amount of time.

Accessibility



$$A = \int (People, Transport, Activity)$$

Abstracted from Jarv et al., 2018 [https://www.sciencedirect.com/science/article/pii/S014362281731144X]

Accessibility

$$A = \int (People, Transport, Activity)$$

People **Transport** **Activity**

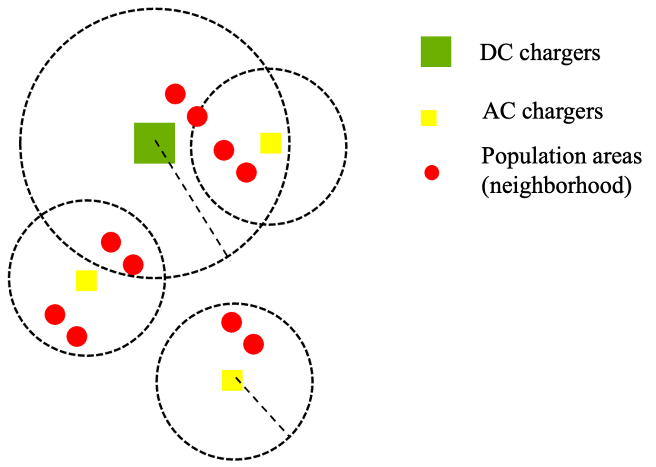
- job transit accessibility;
- the low-income group metro job accessibility;
- public transport food accessibility;
- evening metro accessibility;
- Low-income driving accessibility to EV charging services

EV Charging Accessibility & Equity

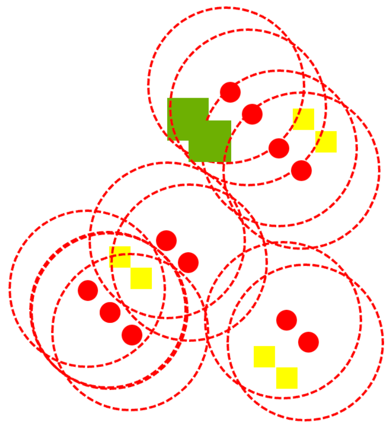
Authours	Year	Area	Data	Methods	Findings
Falchetta and Noussan	2021	Europe	Open Charge Map	populated weighted travel time to access to chargers	there is a stark inequality both across and within country accessibility to EV charging stations.
Pemberton et al.	2021	the UK	Open Charge Map; street network	spatial descriptive analysis	identified spatial unevenness and limited interconnectivity of rapid charging provision in road network, especially in rural areas in the UK.
Li et al.	2022	top ten Chinese Cities by EVCS capacity	"Charging Bar" (www.bjev520.com)	Opportunity-based accessibility & Global and Local Moran's I	reveal significant inequitable distribution but with different regional characteristics.
Park et al.	2021	a section of Seoul, South Korea	the Korea Environment Corporation (2020)	Gaussian two-step floating catchment area (G2SFCA)	spatial accessibility measurement can be summarized into a few temporal clusters
Hsu and Fingerman	2021	Carlifornia, US	Alternative Fuels Data Centre, Census data	probability of public EV charger access	This study found significant public charger access disparities based on the racial and ethnic majority, and the median household income of the CBGs
Roy and Law	2022	Orange County, South California	the Orange County, California energy commission, Department of Energy, US census Bureau	combines machine learning along with quantitative spatial analysis	The EV charging inequity index (EVCI) demonstrated areas with low vehicle ownership, high population density, high percentage of minority population, high percentage of people living below poverty levels, with less access to education, low median household income were categorized as high inequity areas.
Carlton and Sultana	2022	Chicaco, US.	he Alter- native Fuel Data Center (AFDC).	DBSCAN clustering	there is a strong relationship between mixed land use and chargers.

- Most of these studies have focused on individual cities and little is known about the differences between cities.
- Lack of UK knowledge.

Methods



Step 1: demand-population ratio



Step 2: aggregate demand-population ratio

1) Accessibility measurement: Gaussian 2-step Floating Catchment Areas (G2FCA)

Step 1: For each charger location *j*, search all MSOA (neighbourhood) locations *k* that are within a distance threshold d_0 from location j, and compute the charger's capacity-to-population ratio R_j, within the catchment areas, discounted by distance decay function $f(d_{kj})$. C_k is all MSOAs that can charger *j* could provide charging services. Considering the varying charging capacity between AC and DC chargers, this study assumes that a DC charger can serve 48 electric vehicles and an AC charger can serve four electric vehicles.

$$R_j = \frac{S_j\, f(S_j)}{\sum_{k\in\{d_{kj} \le d_0\}} C_k\, f(d_{kj})} \quad (1)$$

$$f(S_j) = \begin{cases} 4, & S_j \in AC \\ 48, & S_j \in DC \end{cases} \quad (2)$$

Step 2: For each MSOA population location *i*, search all charger locations *j* that are within the catchment areas of population location location *i*, and aggregate the charger's capacity-to-population ratios (derived from step1), R_j, discounted by distance decay function $f(d_{ij})$.

$$A_i^F = \sum\nolimits_{j\in\{d_{ij} \le d_0\}} R_j\, f(d_{ij}) \quad (3)$$

Methods

2) The vertical equity measurement

Horizontal equity means that the transport services' distribution of impacts between individuals and groups are equal and are provided regardless of their need or ability.

Vertical equity with regard to income and social class means that the distribution of transport services varies by groups and individuals in terms of social class and income (Litman, 2007)

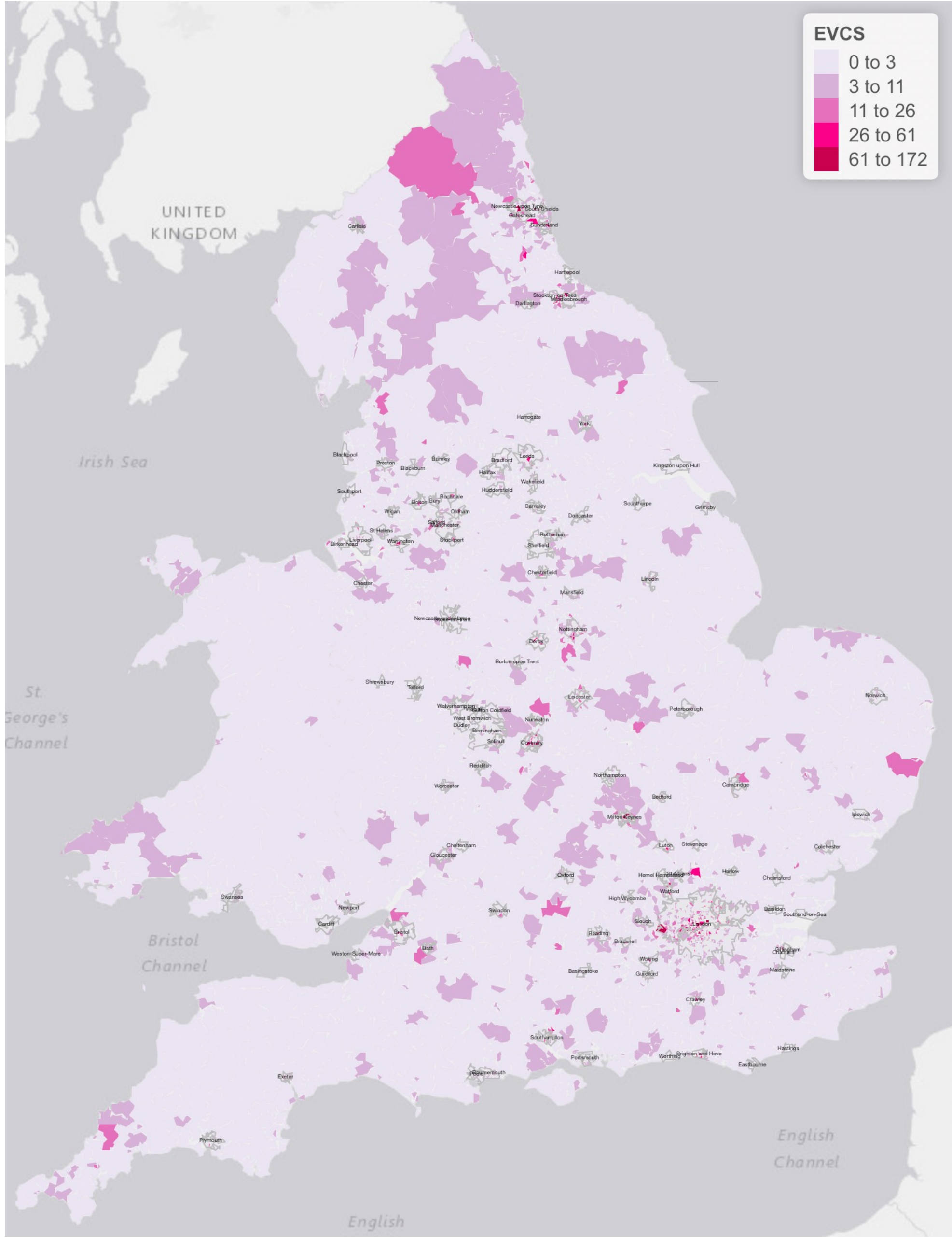
In line with Cheng and his colleagues' (2019) approach, a vertical equity indicator (Adli and Donovan, 2018), is calculated based on the **Spearman's rank correlation coefficient** between the rankings of accessibility to chargers and vulnerable index. As such, the vertical equity (VE, defined in *Eq. 3*) **measures if those boroughs with the lowest income group also have the highest accessibility to EV chargers** (Deboosere and El-Geneidy, 2018). That is to say, the low-income groups living in boroughs with low vertical equity are likely to have limited access to chargers and thus need more attention and priority for further interventions.

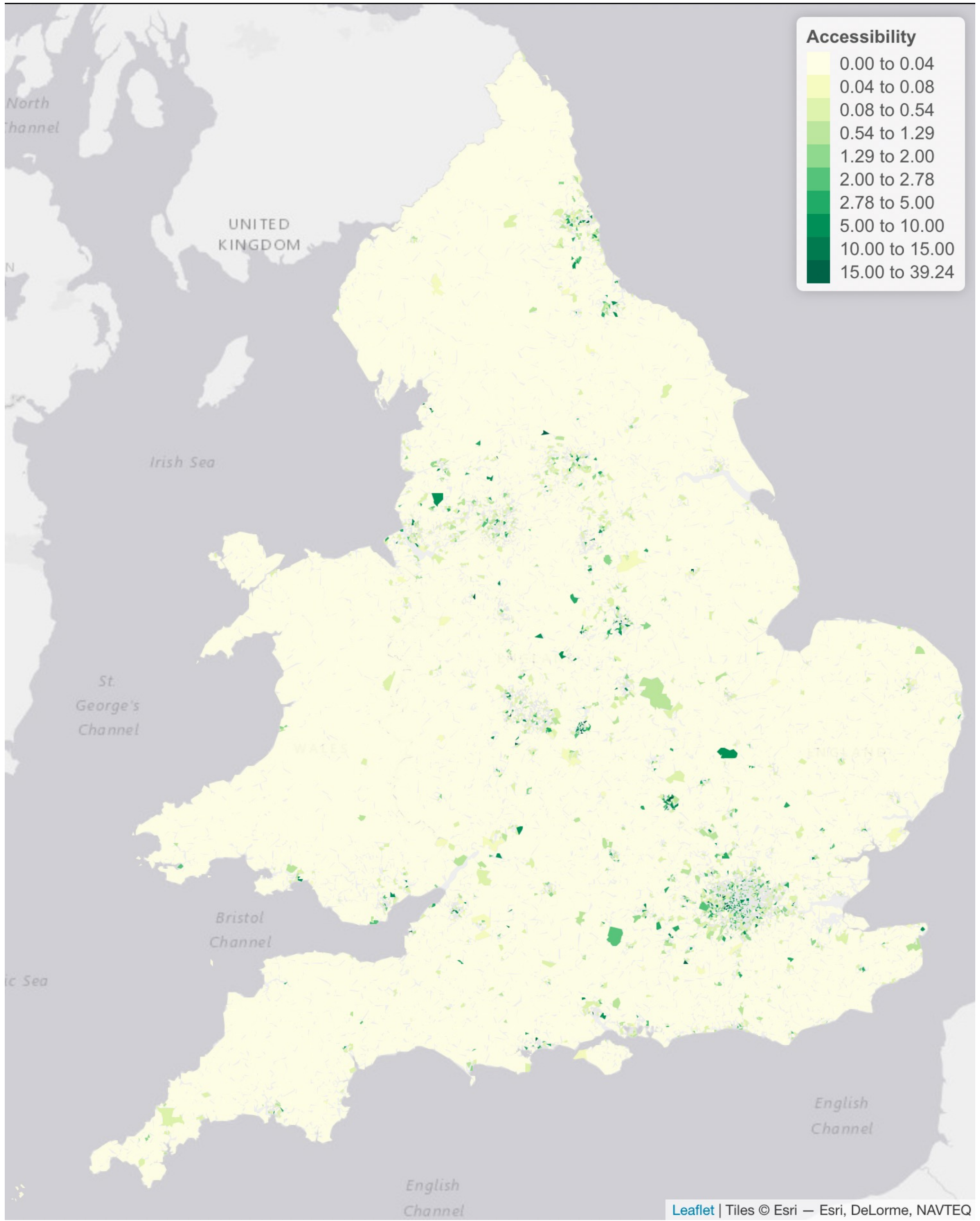
$$VE^B = \frac{cov\,(R_{Acc},\ R_{Income})}{\sigma_{R_{Acc}}\sigma_{R_{Income}}} \qquad (4)$$

where VE^B indicates the vertical equity indicator at borough level. cov indicates the covariance between the ranked accessibility R_{Acc} and the ranked vulnerable index, the income R_{Income}. The ranking order is in decreasing order, i.e., the R_{Income} is 1 if the LSOA has the lowest income within its borough. R_{Acc} is 1 if the LSOA has the highest degree of accessibility within its borough.

VE= 0  VE= 1

Results: 0) a big picture of EVCS in England, the UK





Results: 1) Taking London as an example

Accessibility measurements (msoa)

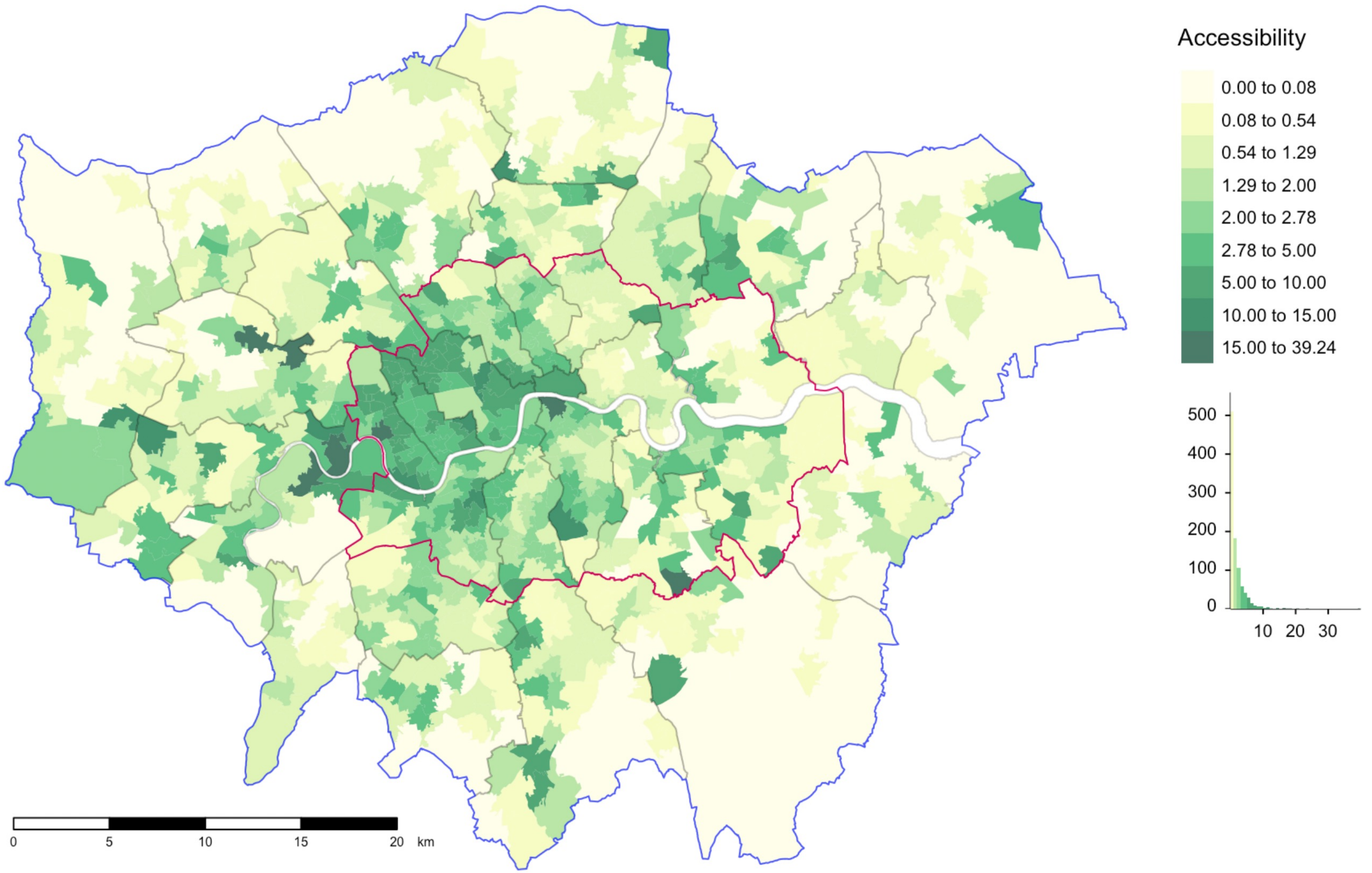


Fig 1. Accessibility to EV chargers at London MOSA levels

There are significant discrepancies in the accessibility of electric vehicle charging stations between and within boroughs.

- Inner London > Outer London
- Central West London area has a high level of accessibility to EV chargers.
- Particular areas with high degree (United Kingdom: 95% of motorways and A-roads should be within 20 miles of a charger)
- Significant difference among different boroughs

Results: 1) Taking London as an example

Accessibility measurements (borough)

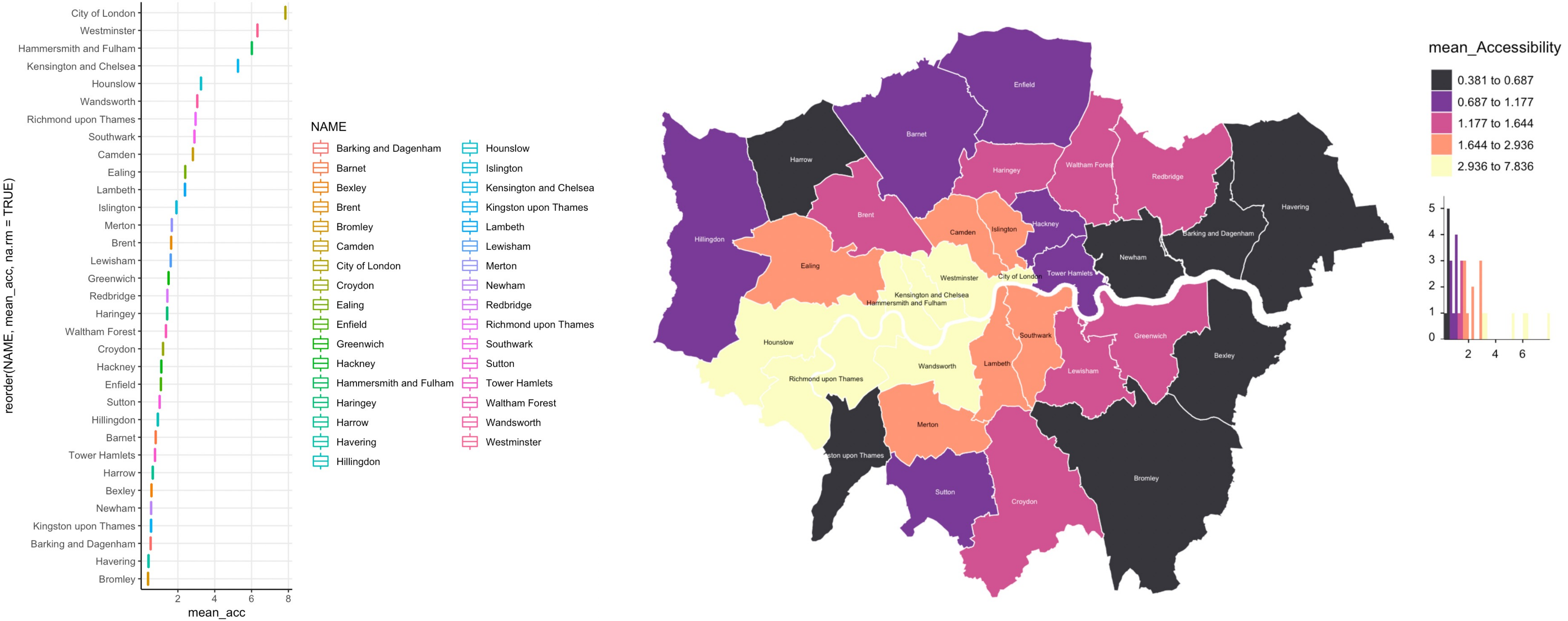


Fig. 2. Mean value of Accessibility at London borough levels

Results: 1) Taking London as an example

Vertical equity measurements

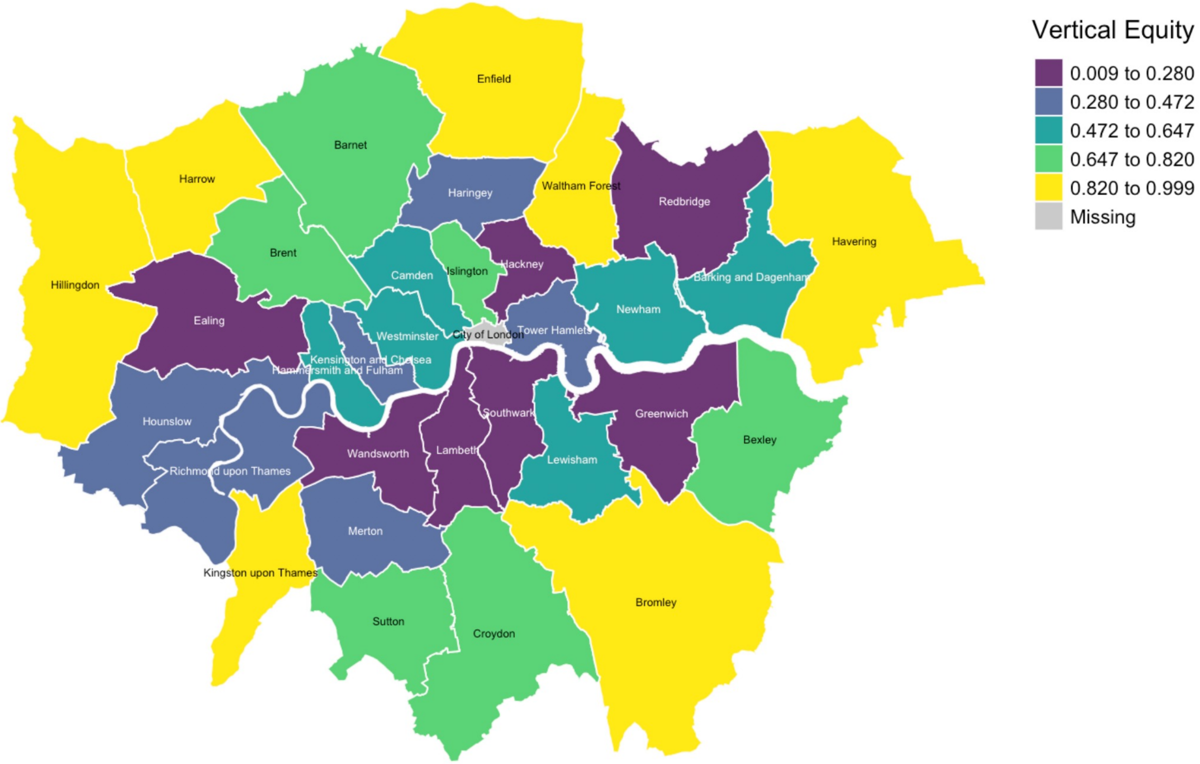
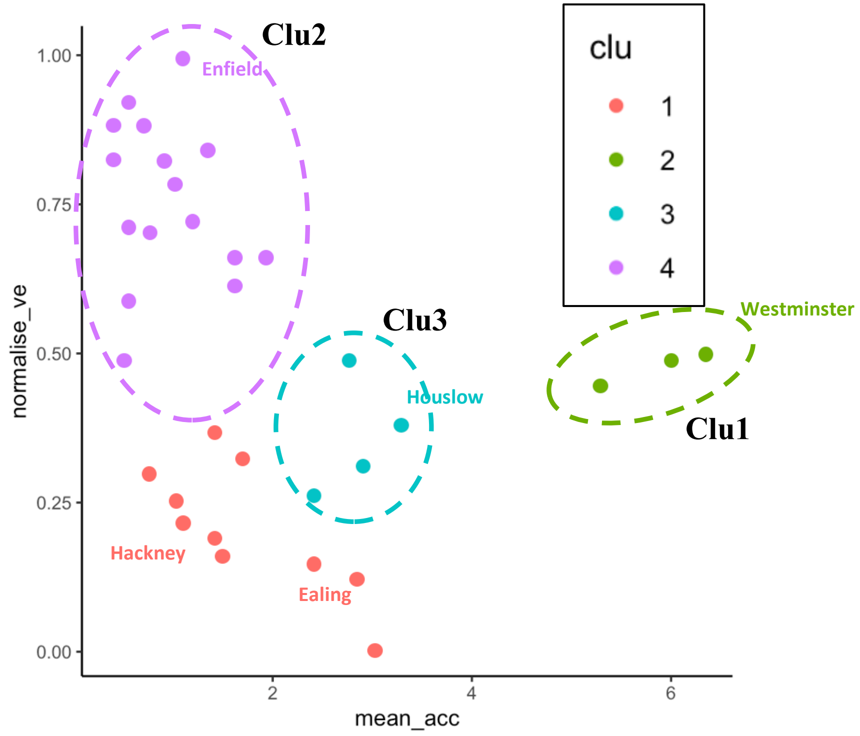
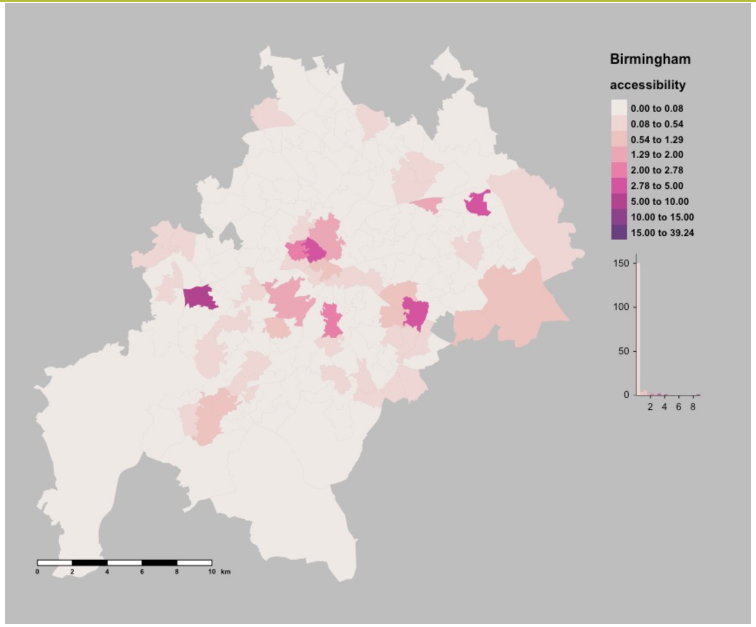


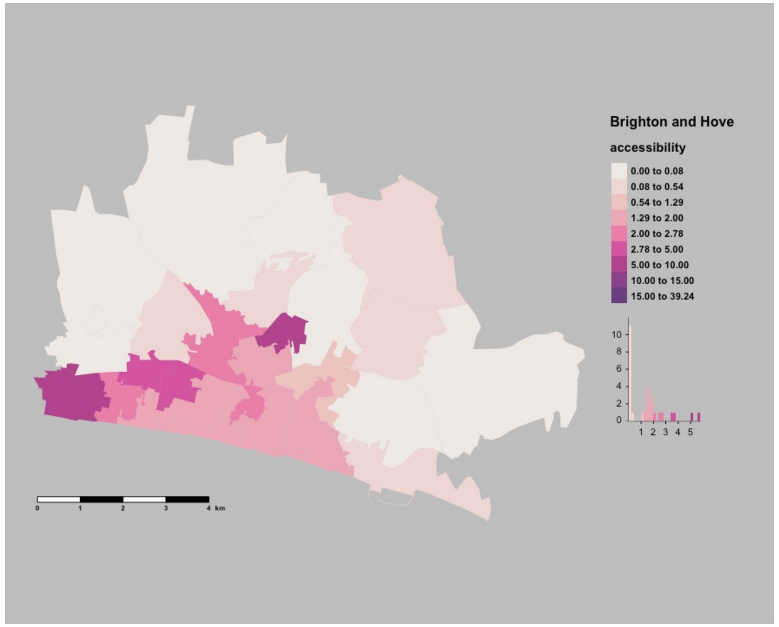
Fig. 3. Vertical equity at borough levels

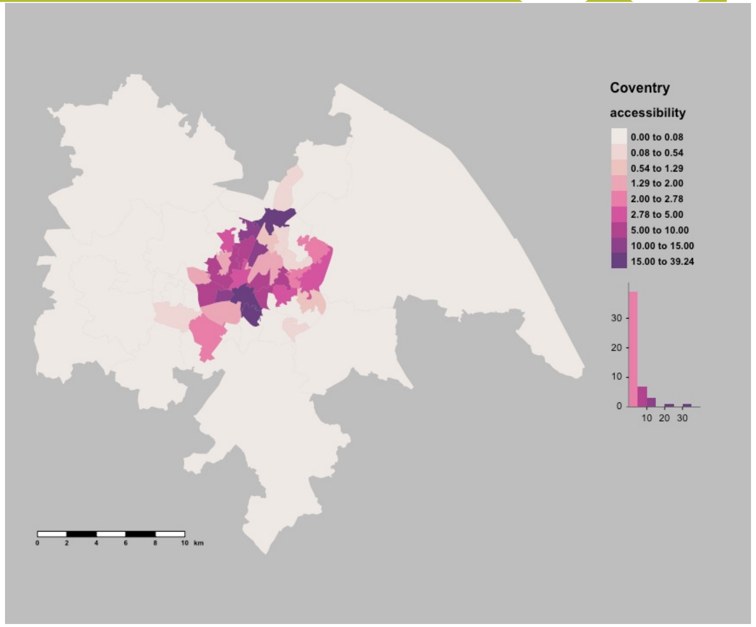


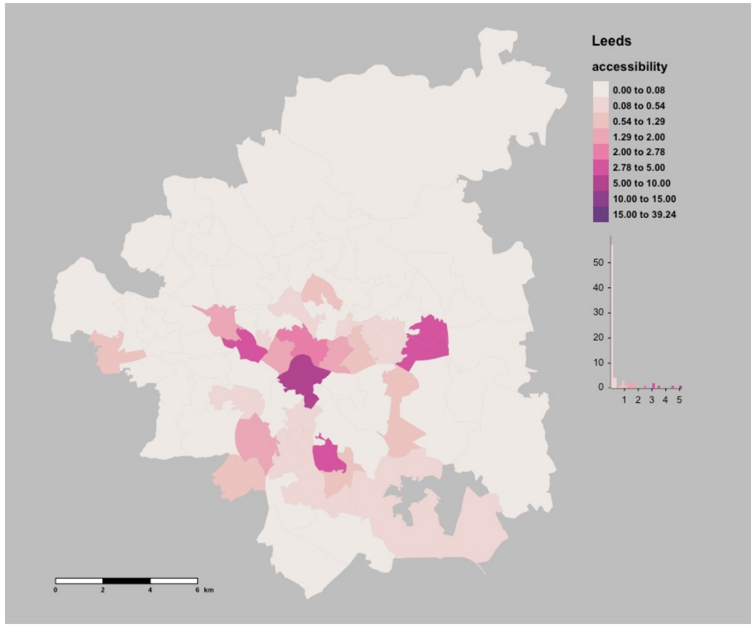
Cluster 1 (3)	high Acc & relative high VE	Westminster, Kensington	perform well both in terms of accessibility and vertical equity
Cluster 2 (15)	low Acc * high VE	Enfield, Sutton	VE seems to be insignificant, focus on installing more chargers
Cluster 3 (4)	medium Acc & medium VE	Houslow, Richmond	Compared to Clutster1, the acc can be improved
Cluster 4 (10)	low Acc * Low VE	Hackney, Ealing	Significant disparities between different income groups, introduce inclusive policies

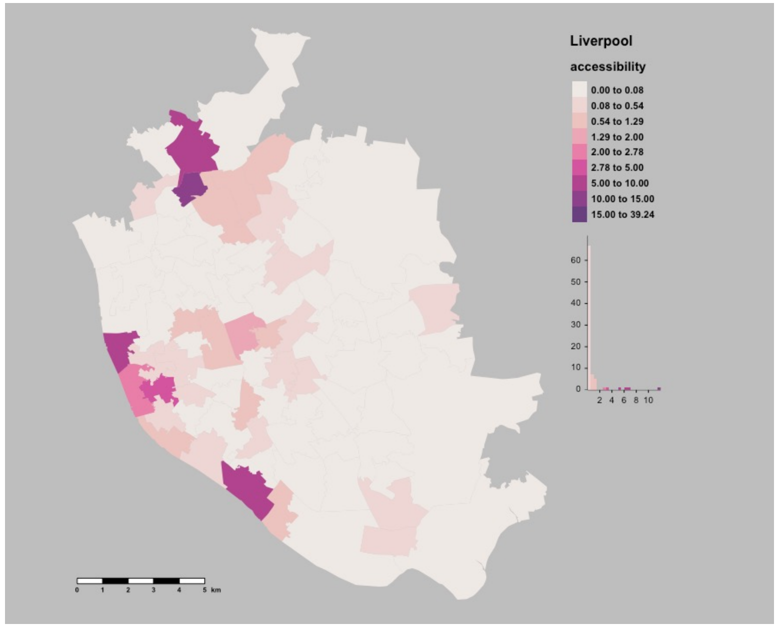
Results: 2) 12 England cities

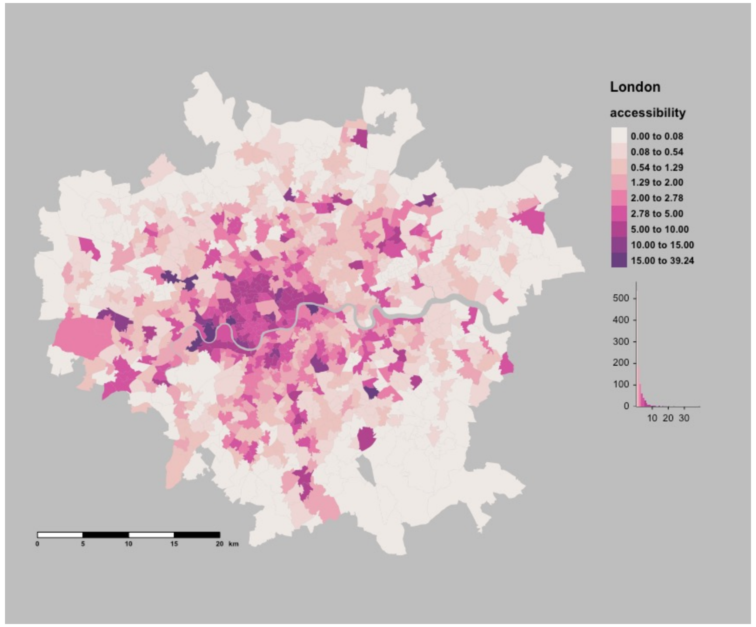




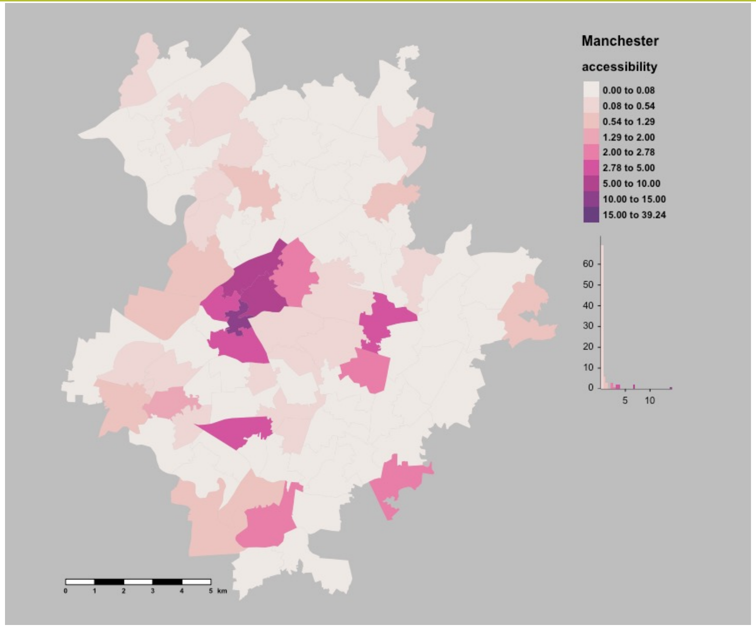


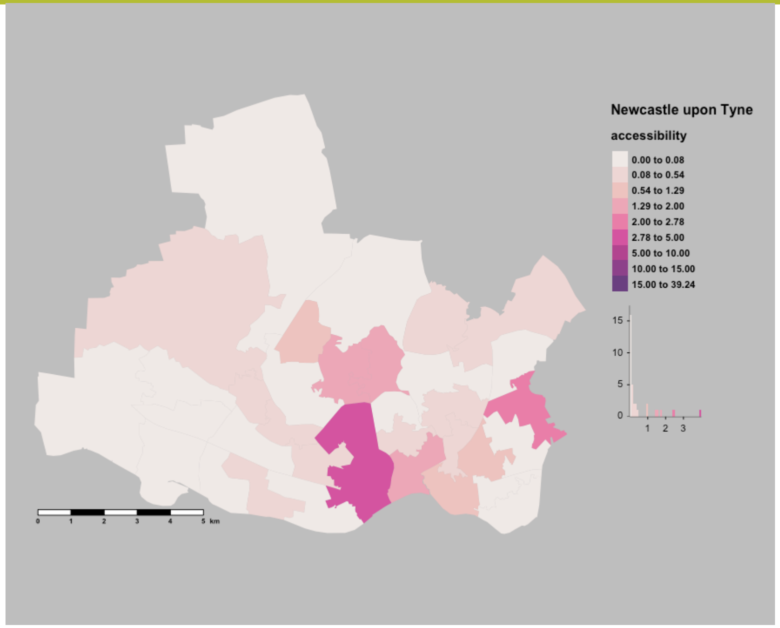


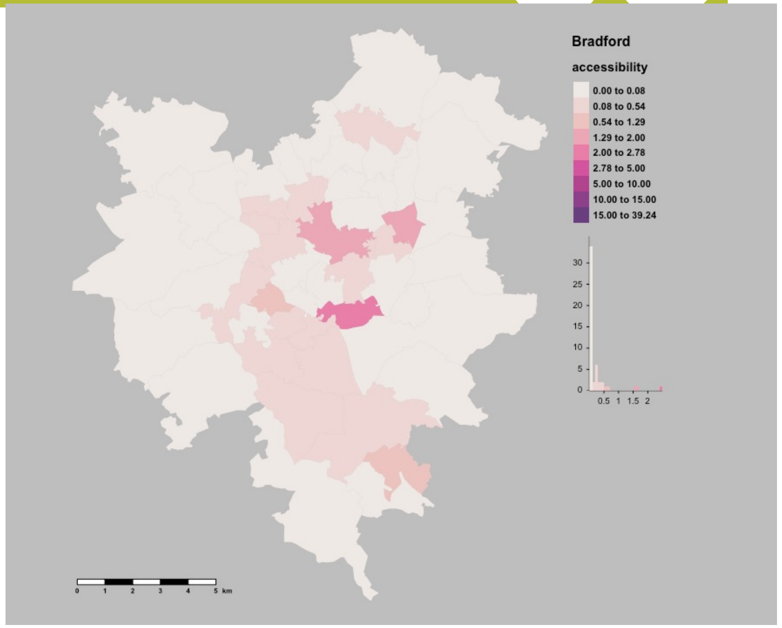


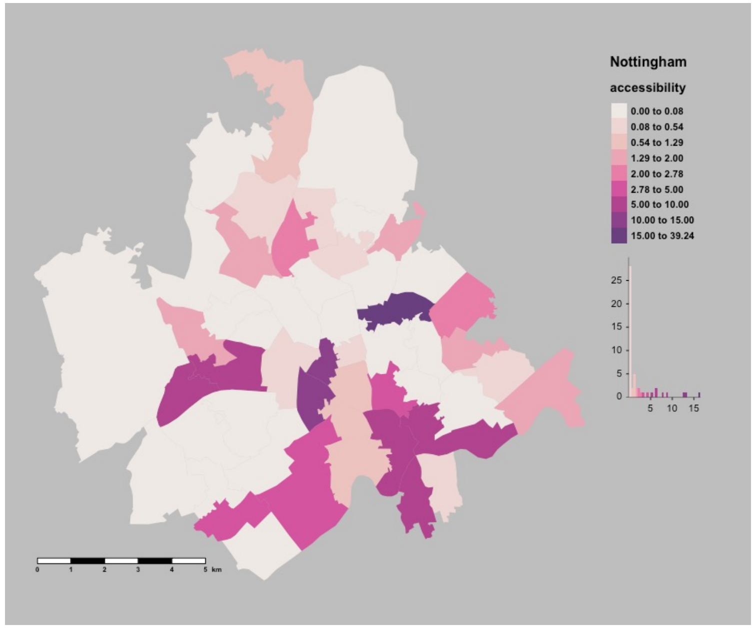


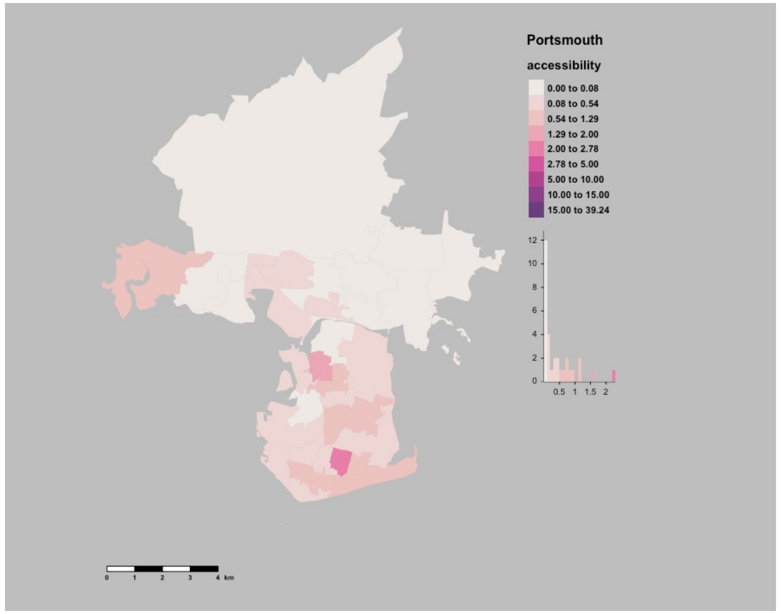
Results: 2) 12 England cities

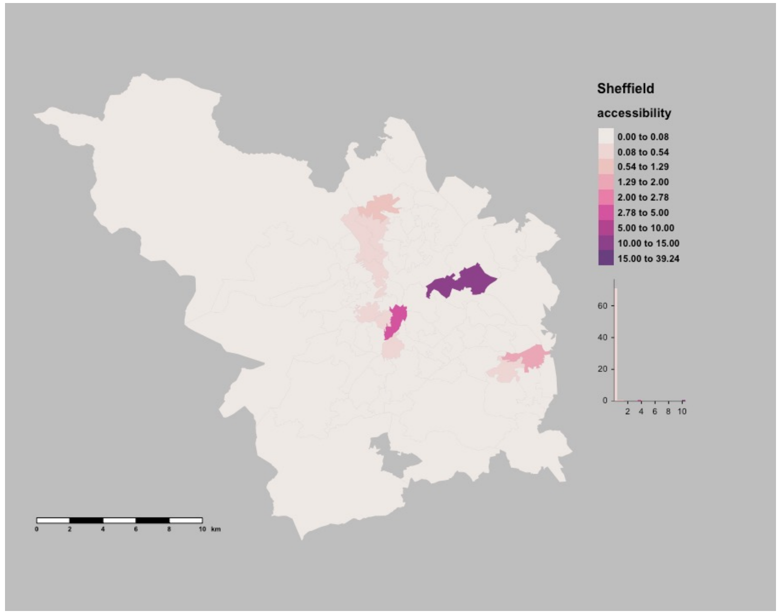












Results: 2) 12 England cities

Table 1. Some key facts of EV charging services

City	acc	ve	gini	ratio
Birmingham	0.256	0.593	0.888	16.710
Bradford	0.207	0.889	0.812	13.670
Brighton and Hove	1.454	0.000	0.540	258.000
Coventry	5.428	0.780	0.804	9.570
Leeds	0.484	0.832	0.829	9.910
Liverpool	0.590	0.506	0.874	15.750
London	1.767	0.243	0.646	25.370
Manchester	0.699	0.601	0.854	14.070
Newcastle upon Tyne	0.477	0.477	0.762	16.830
Nottingham	2.072	0.549	0.757	4.640
Portsmouth	0.432	0.412	0.615	36.500
Sheffield	0.228	0.999	0.961	4.250

1) Acc: electric car friendly cities: e.g., Coventry, Nottingham

2) VE: Sheffield, Bradford, Leeds

3) gini: not evenly spatial distributed

4) Ratio (slow/fast): Brighton, Portsmouth

Recap & Ongoing work

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1) Provide the first-hand data on the public EV charging services accessibility in England, UK

2) Identify several areas that requires a great attention in further EV charging infrastructure development

3) There are stark spatial discrepancies of EV accessibility, either within or between England cities.

4) Provide an example comparing the performance of EV charging developments in different cities.

Next step:

5) EV Accessibility, different types of Chargers

Any insights, comments?