A Unified Equity Metric for Data-Driven Decision Making: A Tract-Level Case Study for Electric Vehicle (EV) Policy Recommendations

Zhi "Owen" Li, Ph.D.; Janille Smith-Colin, Ph.D., P.E.; Jianhui Wang, Ph.D.

Department of Civil & Environmental Engineering, Southern Methodist University, Dallas, TX, U.S.

Department of Electrical and Computer Engineering, Southern Methodist University, Dallas, TX, U.S.

SMU Lyle School of Engineering

Smith-Colin Equity Policy & Jianhui Wang Energy Research Group

George W. Bush Institute

INTRODUCTION

OBJECTIVE

- To propose a unified equity index for Census tract level typology analysis
- To make policy recommendations for improving equitable EV infrastructure planning
- To provide a foundation for future data driven simulations of EV scenarios

WHY UNIFIED EQUITY METRIC

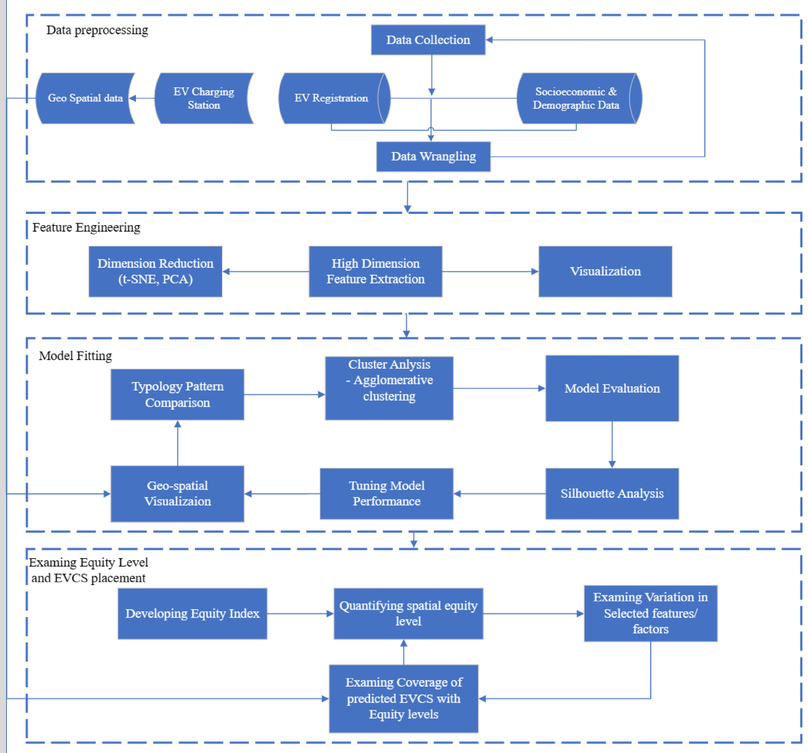
- Enabling Data-Driven Simulations
  - Ever-increasing availability of data and data-driven techniques.
- Subjectivity (Domain knowledge) vs Objectivity (Data-driven)
  - Domain knowledge is crucial but could be influenced by individual biases and interpretations.
- Enhancing Communication and Coordination
  - Policymakers, stakeholders, and experts from diverse fields can provide data (get involved).

UNIFIED EQUITY METRIC

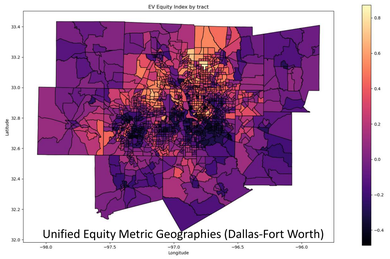
$$\text{EVCS Equity Index (EVCSEI)} = \tanh\left[\alpha \times \text{EVCS\_index} - \text{TCAI}(var_1, var_2, \ldots var_k)\right]$$

- EVCS_index is a function of the number of EV charging stations (EVCS);
- Tract Composite Attribute Indicator (TCAI), is designed to represent a given tract's composite attribute which considers attributes (var_1,var_2, ...var_k) of the tract and converts to one value;
- The *tanh* function is used to map the input to a bounded range between -1 and 1;
- The α is a scaling factor that can be adjusted to control the sensitivity of the equation.

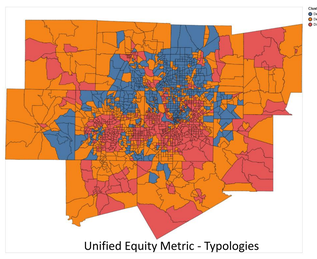
WORKFLOW



UNIFIED EQUITY METRIC & CLUSTER ANALYSIS



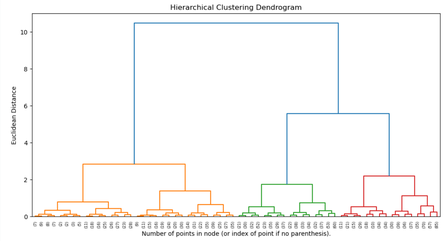
Unified Equity Metric Geographies (Dallas-Fort Worth)



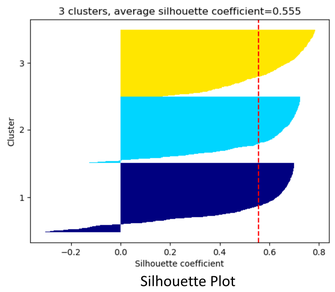
Unified Equity Metric - Typologies

- Proposed equity metric aligns well "visually with USDOT Justice 40 geographies
  - Most advantaged areas - Dallas uptown, Frisco, Keller
  - Most disadvantaged areas - South-eastern Dallas, South-Eastern Fort Worth
- Unified Equity Metric typologies named - Developed, Developing, and Disadvantaged (3D's).

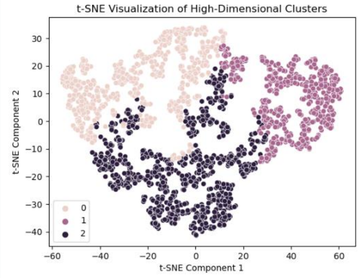
MODEL EVALUATION



Dendrogram Plot



Silhouette Plot



t-SNE Visualization

1. Dendrogram visually represents the hierarchical relationships between data points by illustrating their clustering and similarity in a tree-like structure.
   - It indicates the good number of clusters is three.
2. Silhouette plot provides a graphical representation of the quality and separation of clusters in a dataset
   - The best silhouette score is 0.555 for 3 clusters.
3. t-SNE visualization transforms high-dimensional data into a simpler two-dimensional representation, where similar data points are placed closer together
   - It shows three well separated typologies

EV ADOPTION RATES & EVCS ACCESSIBILITY

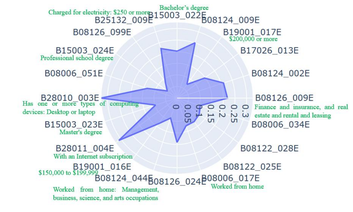
EV adoption rates and EVCS Accessibility for each typology

Typology	Count	EVCS count			Population			EV count			Accessibility	
		mean	std	sum	mean	std	sum	mean	sum	EV Adoption rate	Population Per EVCS	EV count Per EVCS
Developed	583	0.744	2.08	434	4527	1803	2639414	21.4	12454	0.47%	6081	13.6
Developing	528	0.718	2.07	379	4389	2021	2317389	64.0	33807	1.46%	6114	89.2
Disadvantaged	593	0.489	1.85	290	4362	1445	2586537	6.7	3944	0.15%	8919	11.2

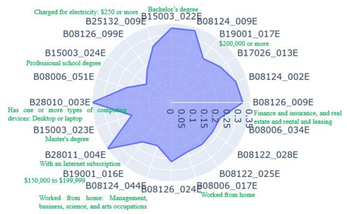
- **Developing** communities – have the highest EV adoption rates but lower accessibility to EVCS.
- **Disadvantaged** communities - despite having sufficient accessibility to EVCS, exhibit the lowest EV adoption rates.
- **Developed/advantaged** communities - characterized by advantaged socioeconomic demographics, show adequate accessibility to EVCS; however, exhibit low EV adoption rates.

TYPOLOGY ANALYSIS

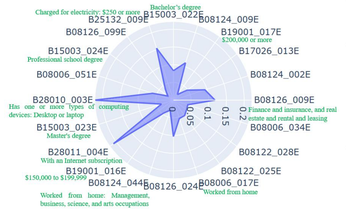
Radar plots for each typology



Developing



Developed



Disadvantaged

- **Developing typology -** displays a more diverse mix of occupations, educational levels, and income brackets
- **Disadvantaged typology -** exhibits variation in socio-demographic characteristics, including lower educational attainment, lower internet and computing resources. The workforce tends to engage in blue-collar and lower-income occupations.
- **Developed/advantaged typology -** highly advantaged socio-demographic characteristics. Educational attainment is notably high, with the largest population holding bachelor's degrees. The workforce tends to engage in white-collar occupations.

POLICY RECOMMENDATIONS

- **Developing typology -** requires additional EV infrastructure to accommodate growing EV ownership.
- **Disadvantaged typology –** EV registration should be prioritized by policymakers and EV usage encouraged.
- **Developed/advantaged typology -** shows adequate accessibility to EVCS but relatively low EV adoption rates, potentially influenced by factors such as remote work trends and range concerns.

CONTRIBUTIONS & FUTURE WORK

- Research develops data-driven, objective Unified Equity Metric for EV planning.
- Proposed Unified Equity Metric produces 3 distinct EV typologies.
- Proposed Equity Metric typologies leverage tract-level features and are aligned well with USDOT Justice 40 disadvantaged tracts (ground truth) for the Dallas-Fort Worth area.
- EVCS and EV planning supported by typology-based (i.e., developing, disadvantaged, developed/advantaged) policy recommendations.
- Research provides comparison of the EV adoption rates and EVCS accessibility at Census tract level.
- Unified Equity metric can narrow miscommunication and coordination gaps, and support decision making across diverse stakeholder groups.
- Future work will integrate the Unified Equity Metric into data-driven simulations such as Agent Based Modeling and Reinforcement Learning.

FURTHER INFORMATION

- Scan the second QR code to get in touch with me.
- For more information, please reach out via the emails below:
  - Zhi "Owen" Li: oli@smu.edu
  - Janille Smith-Colin: jsmithcolin@smu.edu
  - Jianhui Wang: Jianhui@smu.edu

Zhi "Owen" Li Google Scholar

Zhi "Owen" Li LinkedIn page