Predicting Property Prices Using Latent Constructs of Multimodal Accessibility and Neighborhood Quality

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Why Does It Matter

- Property prices guide **household decisions** and shape **long-term infrastructure investment**.
- Rapid **urban growth** pushes **land values up**, which in turn reshapes where jobs, services, and transportation are built.
- Analyzing the spatial price patterns helps us ensure that **growth benefits everyone**, not just a few.

Impact on different groups: Rising prices benefit homeowners and investors while increasing cost burdens, and displacement risk for marginalized communities.

Prices, Access, and Quality

- **Multimodal access** and **neighborhood quality** are major drivers of property prices.
- This relationship is a key input for **urban planning and infrastructure investment**.

Pedestrian and transit-oriented 16th Street (left) and car-centric commercial corridor of 17th Street (right) in Denver

Background and Research Gap

Transit and neighborhood attributes influence property values; effects vary by urban form, and local context.

Key findings

- Transit premium, varies by mode & context. (Mathur and Ferrell 2013; Zhong and Li 2016)
- Walkable, mixed-use neighborhoods boost prices. (Duncan 2011; Bowes and Ihlanfeldt 2001)

Research gap

- Most studies rely on simple distance or single-mode metrics.
- Most previous studies focus on prediction, lacking interpretable Machine Learning (ML) that informs planners.

This Study

Builds comprehensible metrics for multimodal accessibility and neighborhood quality and apply an interpretable model to predict and explain price variation.

Data (Denver Metro, 2020)

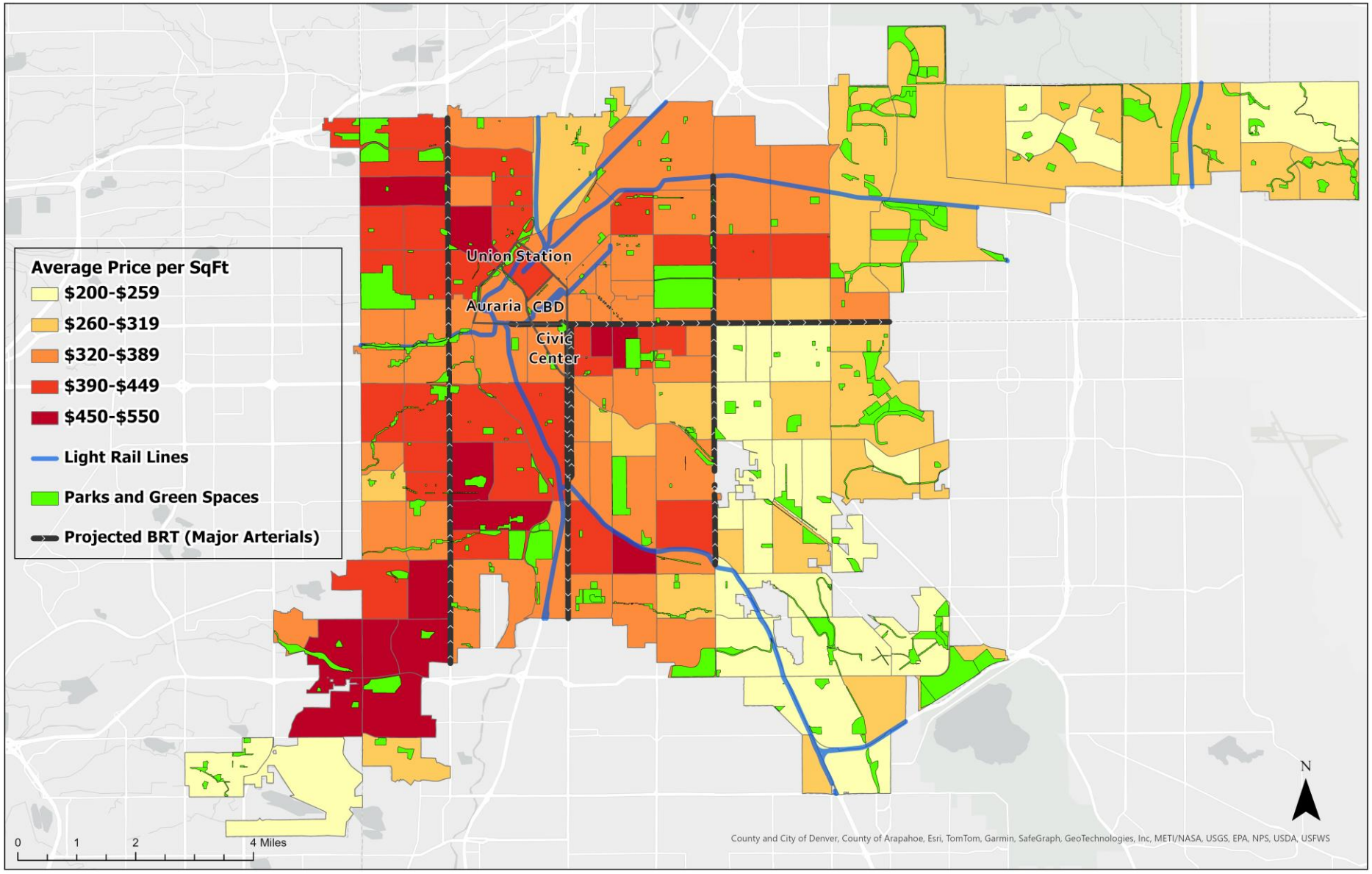
300,000 **residential parcels** with **market values** and attributes (*City Assessor's Office*)

Sociodemographic variables from American Community Survey (ACS), U.S. Environmental Protection Agency (EPA), and Denver Regional Council of Governments (DRCOG)

Transit metrics from Regional Transportation District (RTD)

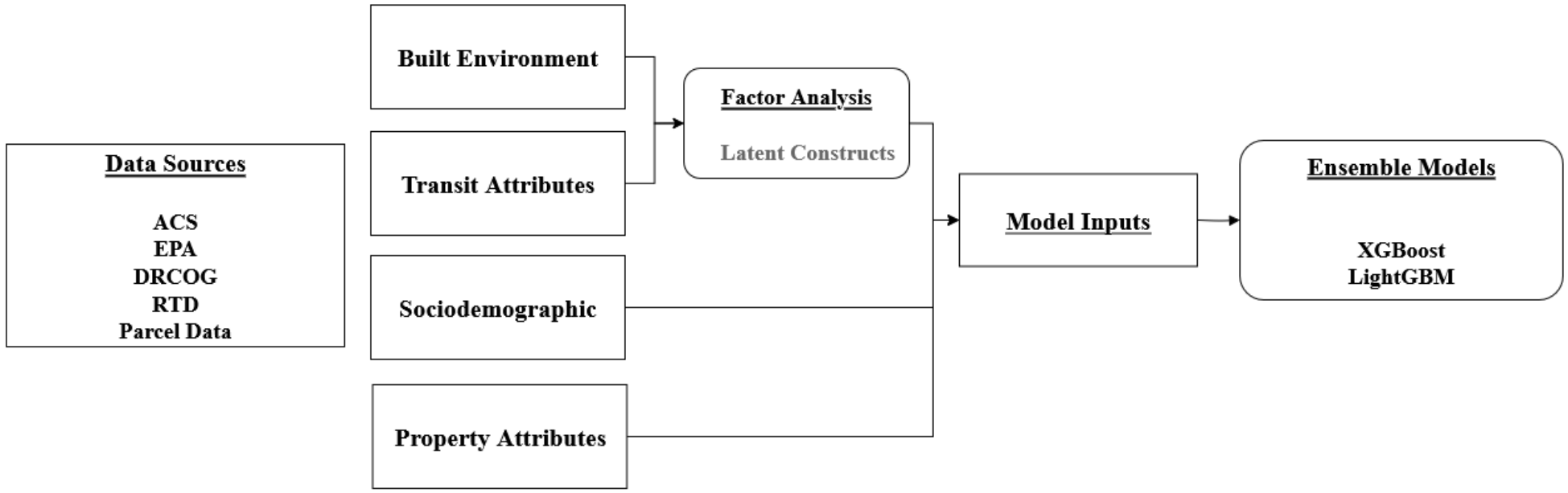
Built environment: sidewalks, tree canopy, bike facility, school distances (DRCOG).

Average price per square foot of residential properties in Denver Metro



Methods

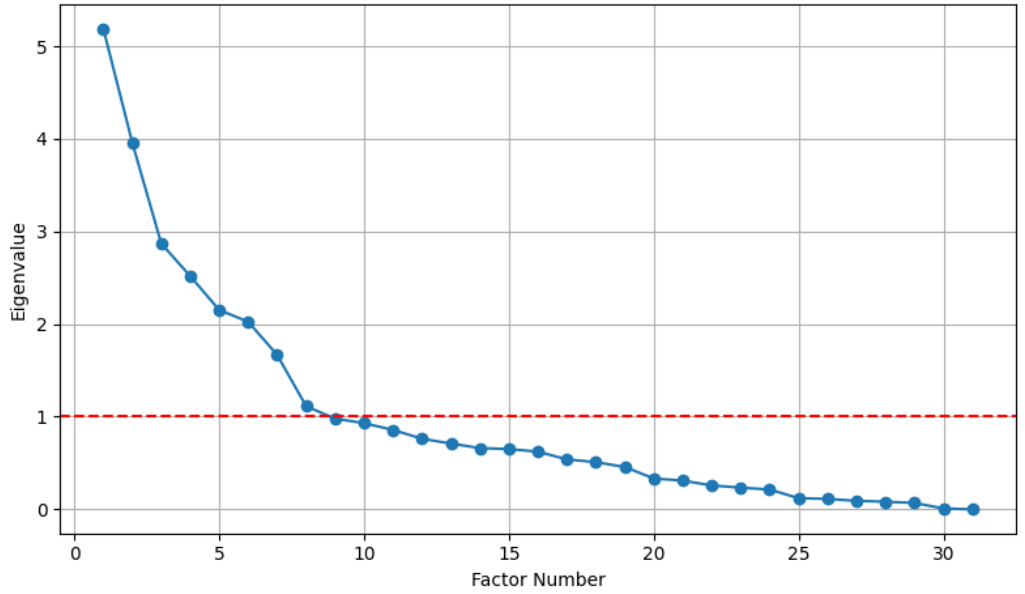
- Latent constructs derived via exploratory Factor Analysis (EFA) to address multicollinearity.
- Predictive modeling using ensemble methods (XGBoost and LightGBM) for improved accuracy.
- Feature-level interpretability through SHAP values, showing variable importance and effects.



Overview of the study methodology

Explanatory Factor Analysis

- **Testing for Data Suitability**: Bartlett's test significant, supporting factor analysis.
- **Factor Extraction**: 8 factors identified (eigenvalues > 1); Scree plot suggested 6 factors.
- **Predictive Modeling**: 4 factors selected for performance, meaningful insights on multimodal accessibility and neighborhood quality, balancing accuracy and interpretability.



Scree plot of eigenvalues by factor

Explanatory Factor Analysis

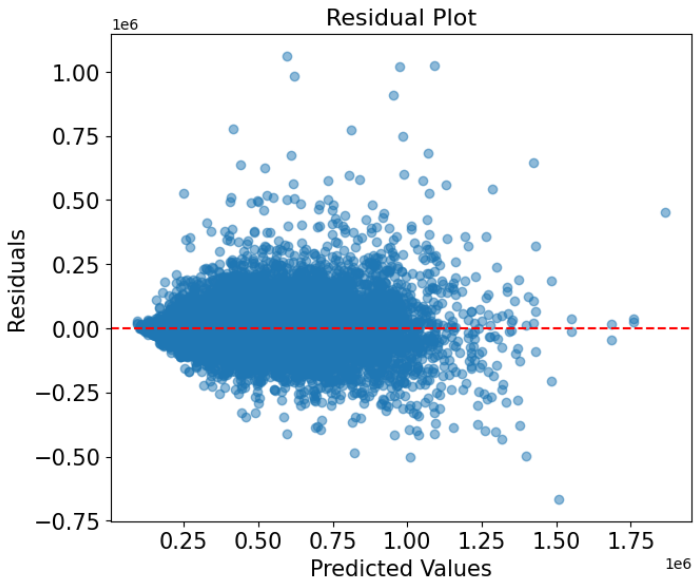
Neighborhood Quality
Park Area Pct
Sidewalk Length
ADA Sidewalk Length
Elementary School Distance
High School Distance
Employment Cluster Distance
Tree Canopy Area
Rail Lines 1 Mile

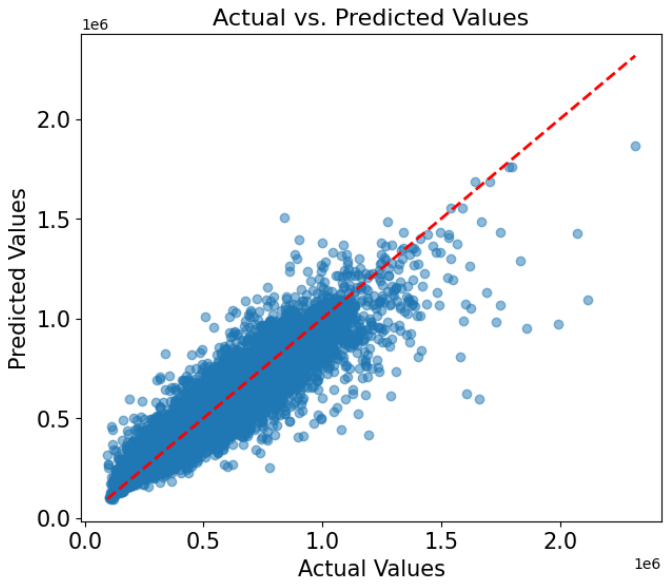
Transit Infrastructure Proximity
Rail Lines 1 Mile
Bus Stops
Distance from the population-weighted centroid to nearest transit stop
Proportion of CBG employment within ½ & ¼ mile of fixed-guideway transit stop
Gross service employment density
Gross retail employment density

Pedestrian-Weighted Network Density
Total road network density
Network density (facility miles of pedestrian-oriented links per sq mile)
Pedestrian-oriented intersection density

Mixed Land Use
Employment and Household entropy
Trip productions and attractions equilibrium index
Deviation of CBG ratio of jobs/pop from the regional average
Household Workers per Job Equilibrium Index

Findings



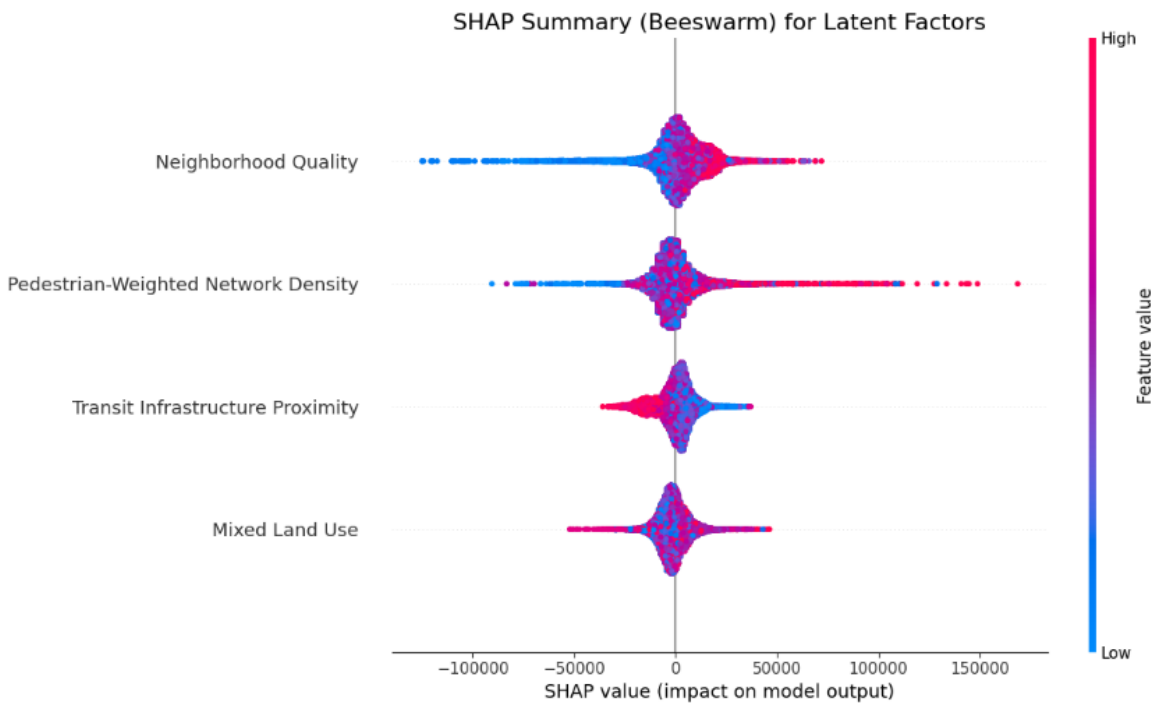


Residual and prediction plots for the best-performing model (XGBoost)

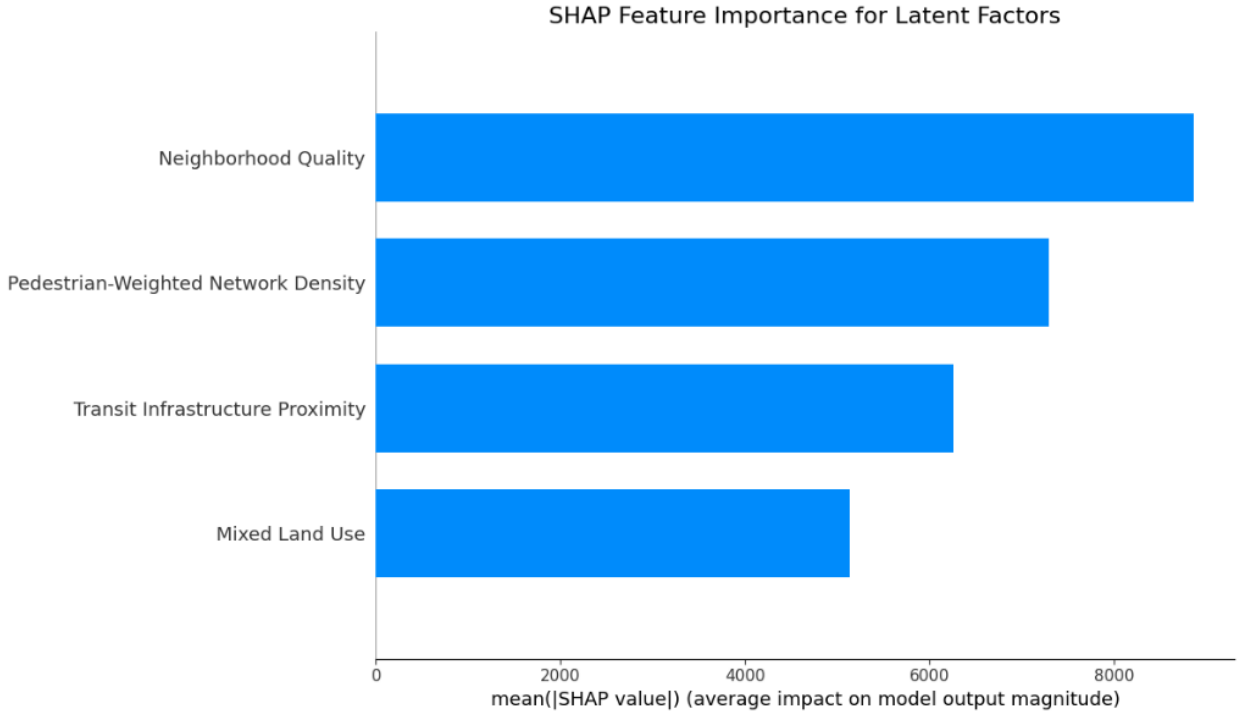
Model	Train		Test	
	R^2	RMSE	R^2	RMSE
XGBoost	0.9	55419	0.87	63920
LightGBM	0.85	68324	0.84	69849

SHAP findings

SHAP values show each feature's impact on predictions.



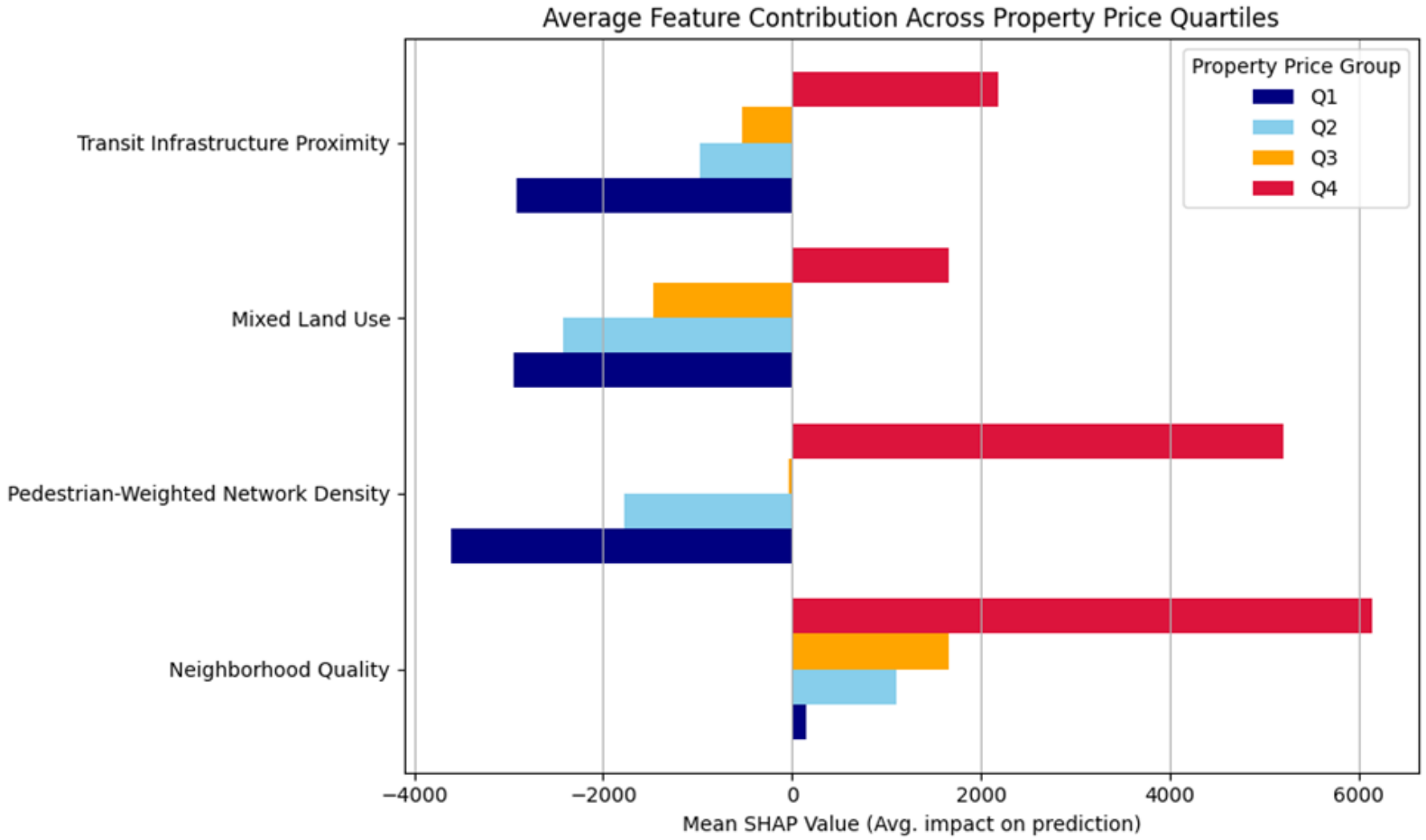
SHAP beeswarm plot



Relative importance of the latent factors

Subgroup analyses

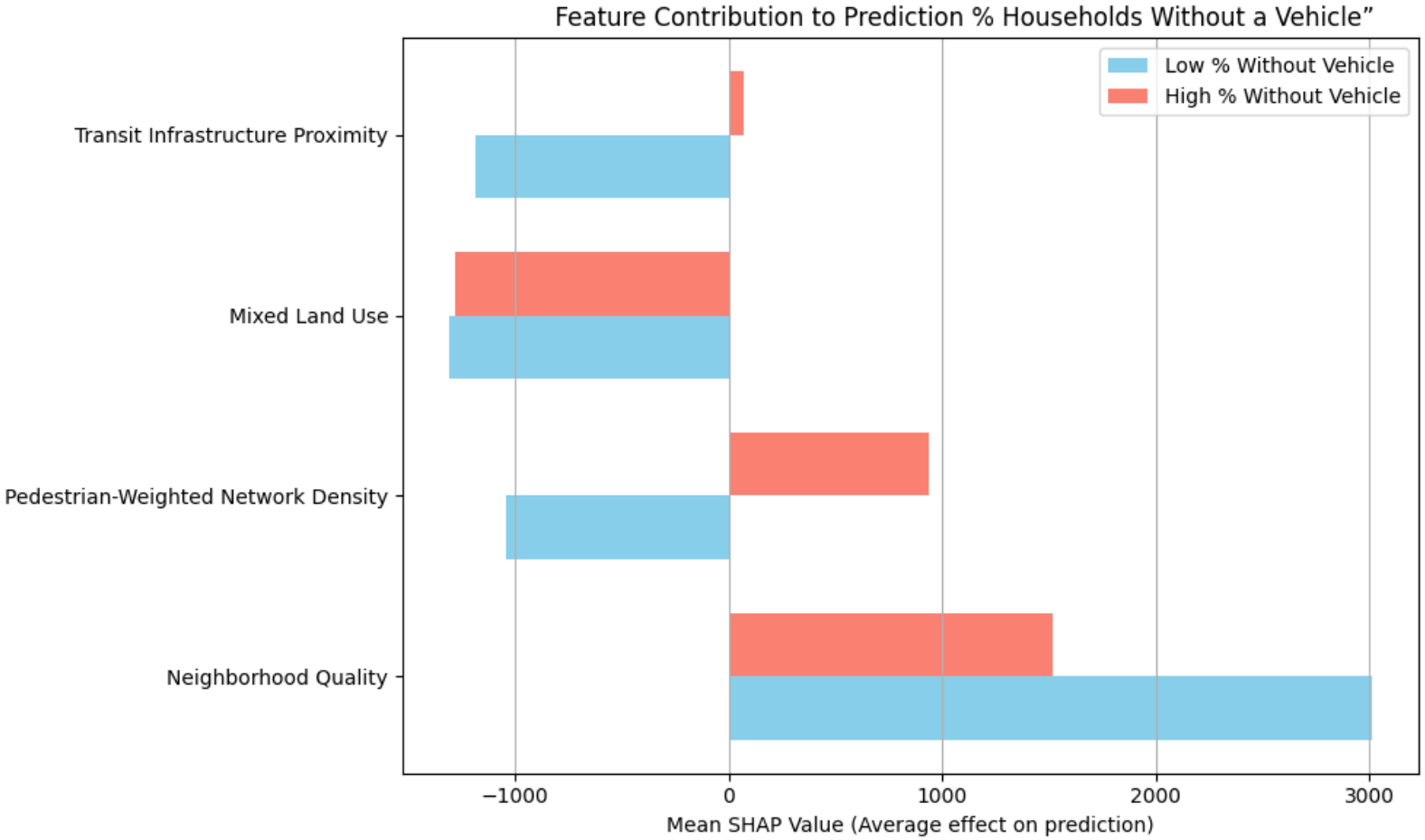
1. **Price quartiles**: high-priced areas show strong positive effects of neighborhood quality and walkability.



Latent factors impacts across property price quartiles

Subgroup analyses

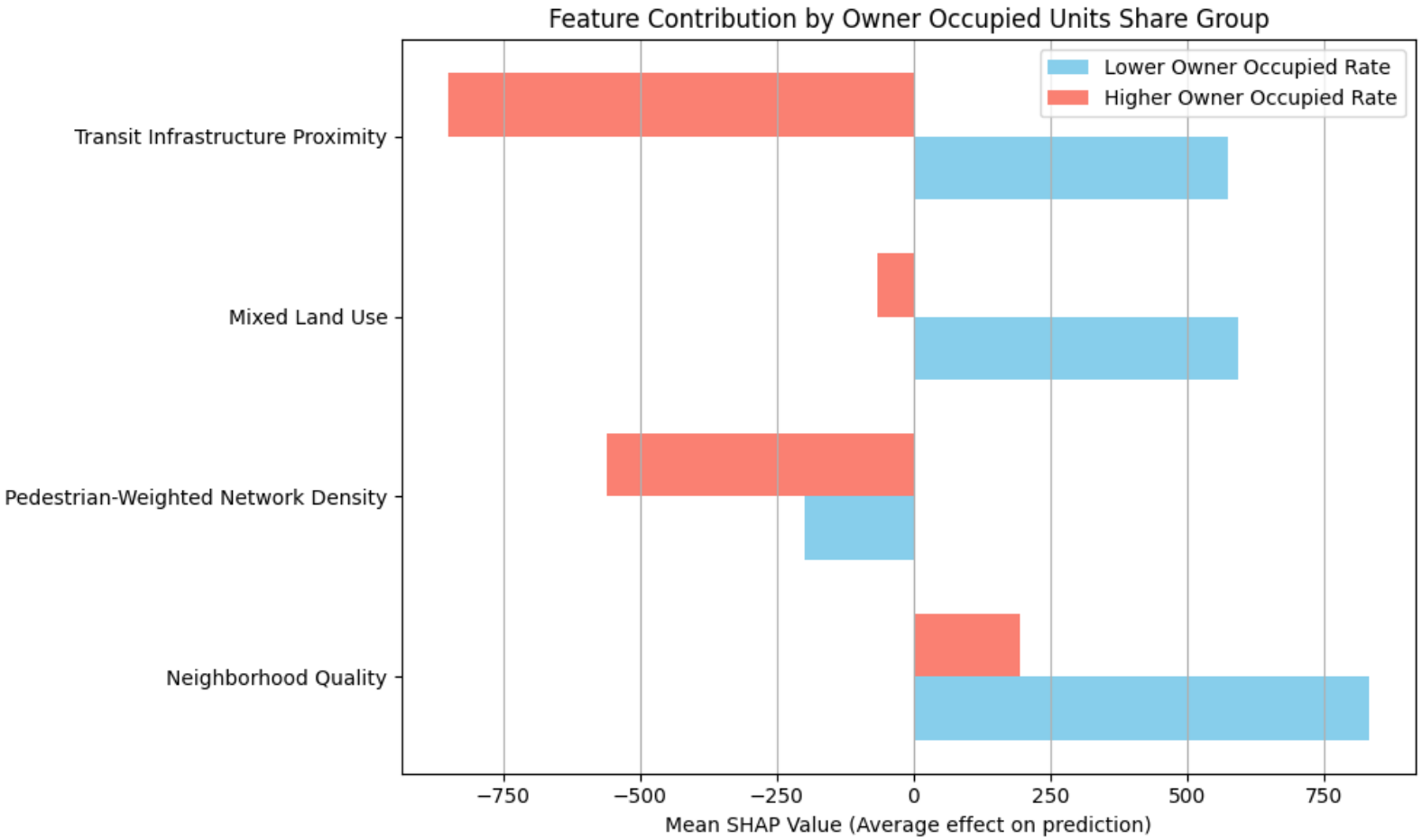
2. **<u>Vehicle Ownership</u>:** transit premiums in areas with more zero-vehicle households.



Latent factors impacts by vehicle ownership subgroup

Subgroup analyses

3. **Owner-occupation:** effects vary by local socioeconomic context.



Latent factors impacts by owner-occupied share subgroup

Policy implications

- Investments in neighborhood quality (sidewalks, green space) can increase property values broadly.
- The improvements can raise property values in ways that may displace long-term residents.

Context-sensitive strategies: prioritize walkability and quality improvements in high-value areas; target transit where vehicle ownership is low.

Conclusions & future work

- Built environment and accessibility variables could be highly correlated, complicating traditional modeling.
- Latent constructs capture multidimensional accessibility and neighborhood quality effectively.
- XGBoost with latent factors provides strong predictive performance for property prices.
- SHAP-based interpretability helps planners understand the key factors driving price variations.

Future: longitudinal analysis of transit investments, extend framework to other metros, incorporate school quality & safety metrics.

Thank you

Questions?

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