Evolution of Historical Urban Landscape With Computer Vision and Machine Learning

A Case Study of Berlin

May 27

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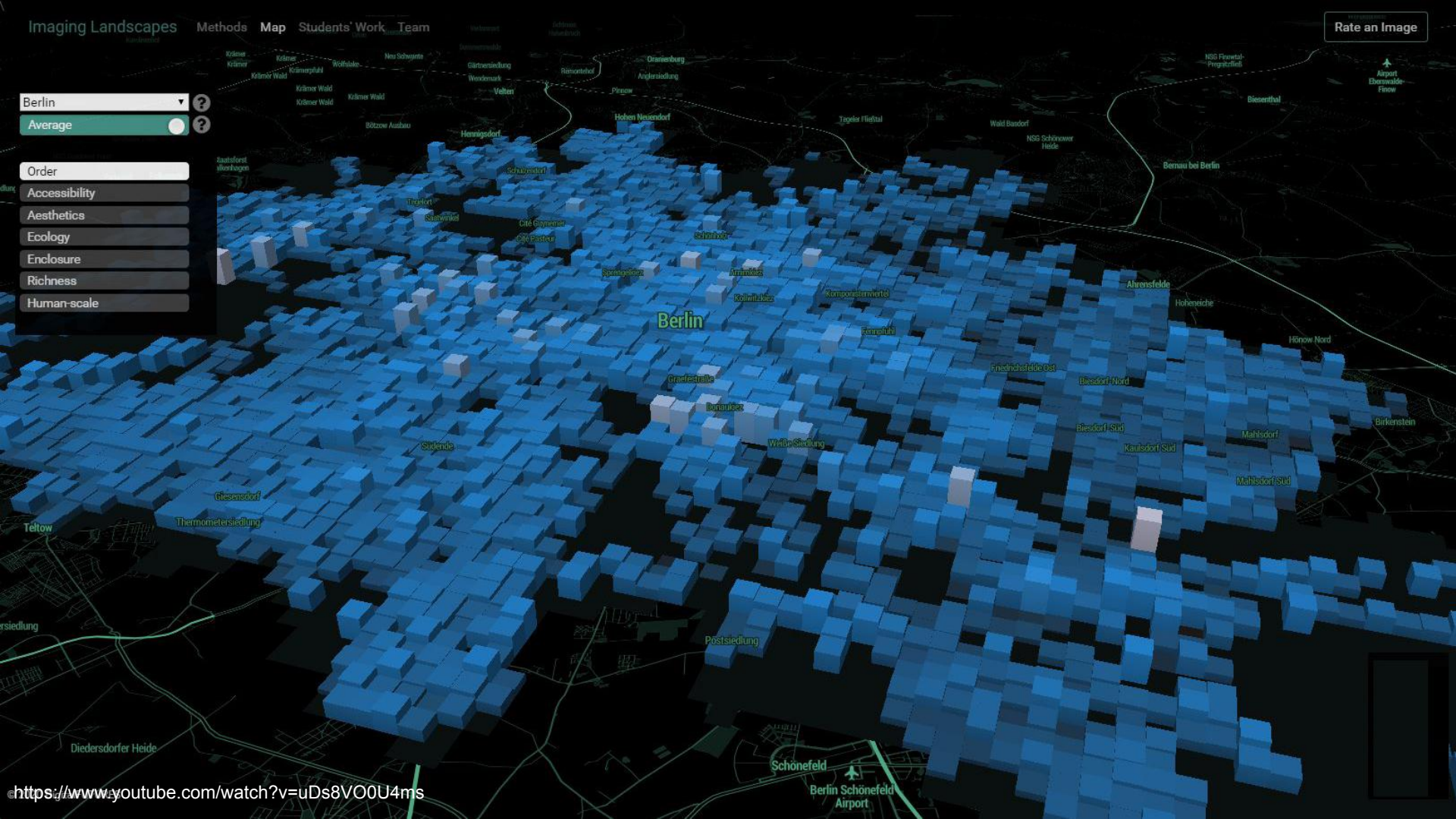
Content

1. Introduction
2. Methodology
3. Analysis and Discussion
4. Conclusion

1. Introduction

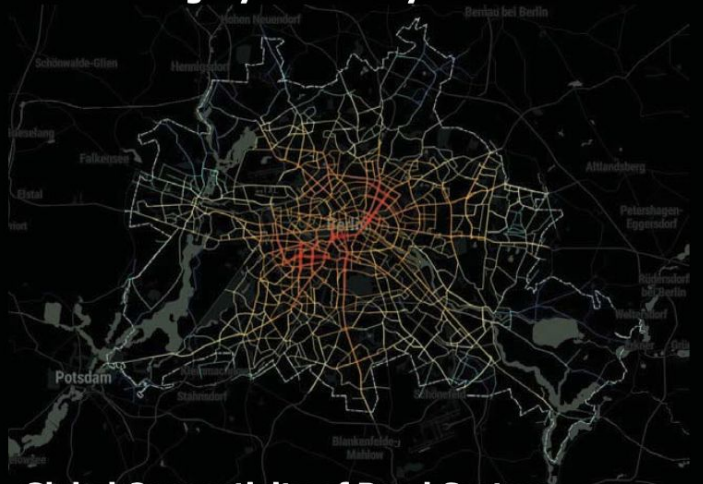


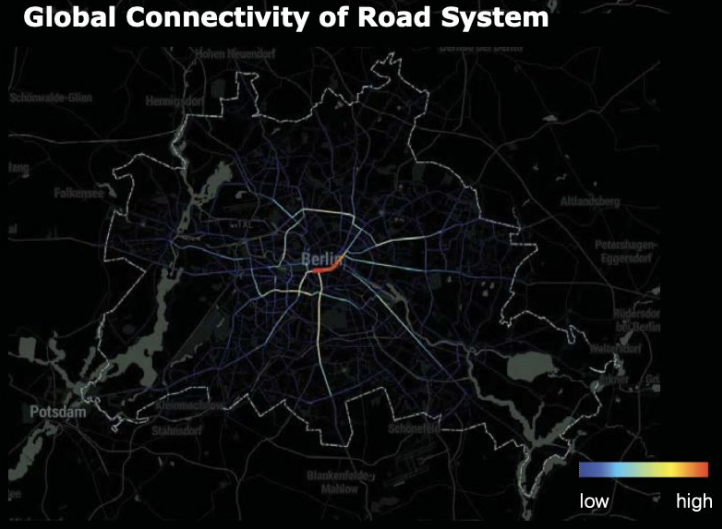
https://www.youtube.com/watch?v=uDs8VO0U4ms

Berlin

A capital was divided and governed by Capitalist and Socialist ideologies historically.

After reunification, we can still tell its polycentric structure and low connectivity with spatial syntax analysis.





Research Objects

1. Test of how these digital technologies can be used to quantify physical features and perceptual qualities;

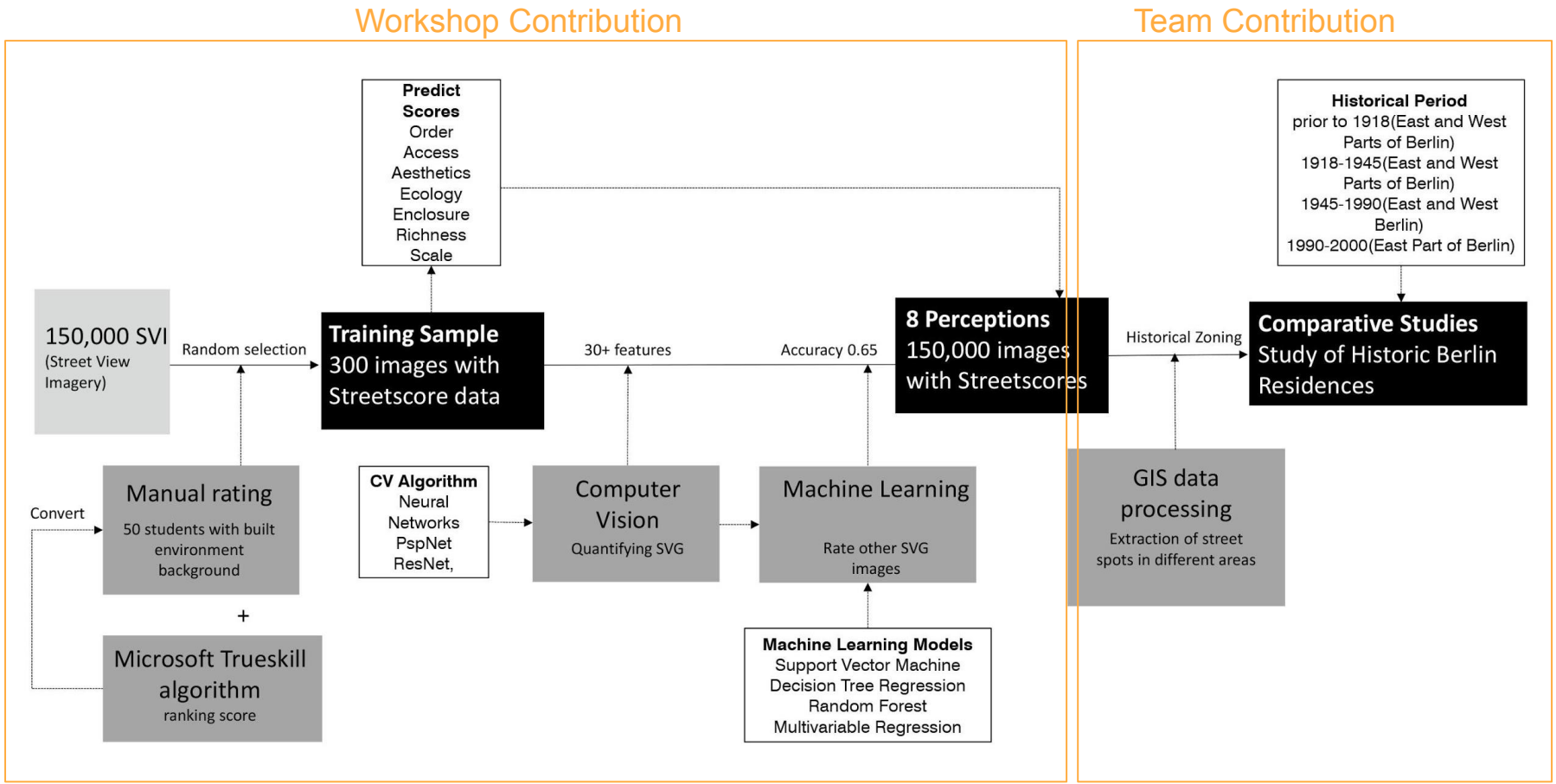
2. Quantify the differences in human perceptions of the built environment under the impact of major historical events;

3. Reveal the correlations between perceptual qualities and historical contexts in perspective of Berlin's planning policy.

2. Methodology

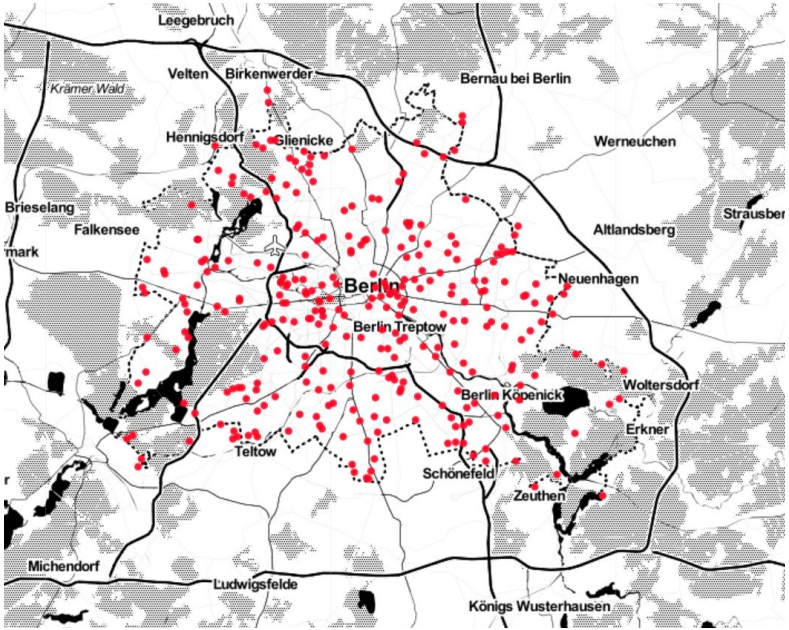
Data & Method

0 | Overall Framework & Workflow



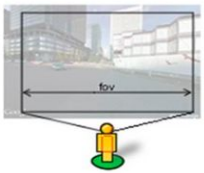
1 | Street View Image Sampling

a. Randomly sample 300 street view image points across Berlin as the training data



b. Download street view images with consistent angles and requirements from Google Static Image API

Point of view is located in the middle of the road and parrelled to the road direction, control by a list of variables including ['fov','pitch','heading']



2 | Street View Perception Data Acquisition

Q1. Typology

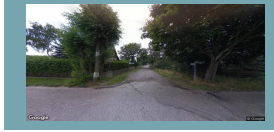
Residential

Office

Commercial

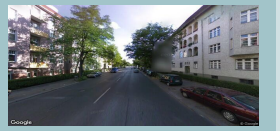
Suburban

Rural



Q2. Order

High



Low

Q3. Access

High

Low

Q4. Beauty

High

Low

Q5. Ecology

High

Low

Q8. Scale

High

Low

Q6. Enclosure

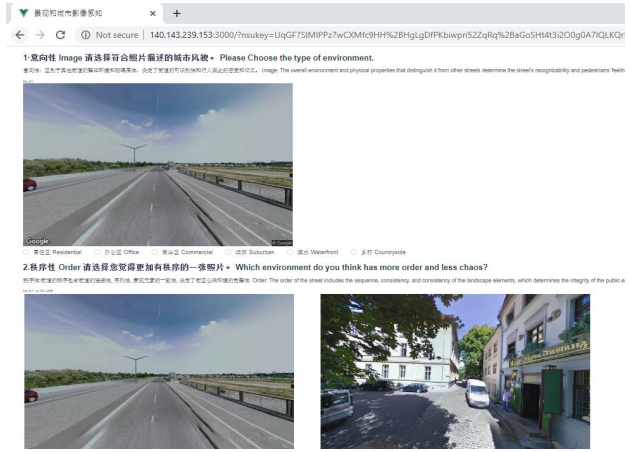
High

Low

Q7. Richness

High

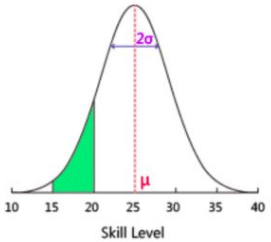
Low



2 | Street View Perception Data Acquisition

hese preferences are then translated to scores with **Microsoft TrueSkill Algorithm**.

if x wins y:
updates:
y=y-pts x=x+pts



$$\mu_x \leftarrow \mu_x + \frac{\sigma_x^2}{c} \cdot f\left(\frac{(\mu_x - \mu_y)}{c}, \frac{\varepsilon}{c}\right) \quad [1]$$

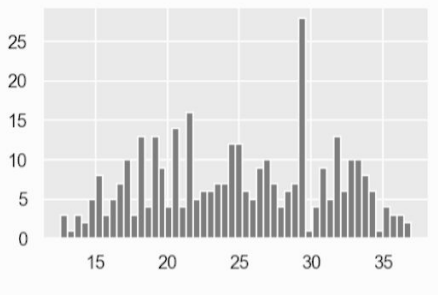
$$\mu_y \leftarrow \mu_y - \frac{\sigma_y^2}{c} \cdot f\left(\frac{(\mu_x - \mu_y)}{c}, \frac{\varepsilon}{c}\right) \quad [2]$$

$$\sigma_x^2 \leftarrow \sigma_x^2 \cdot \left[1 - \frac{\sigma_x^2}{c} \cdot g\left(\frac{(\mu_x - \mu_y)}{c}, \frac{\varepsilon}{c}\right)\right] \quad [3]$$

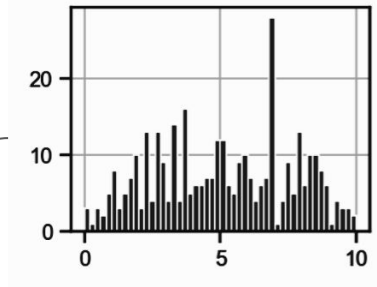
$$\sigma_y^2 \leftarrow \sigma_y^2 \cdot \left[1 - \frac{\sigma_y^2}{c} \cdot g\left(\frac{(\mu_x - \mu_y)}{c}, \frac{\varepsilon}{c}\right)\right] \quad [4]$$

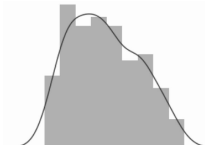
$$c^2 = 2\beta^2 + \sigma_x^2 + \sigma_y^2 \quad [5]$$

Normalize the ranking scores



normalized from [0-40] to [0-10]



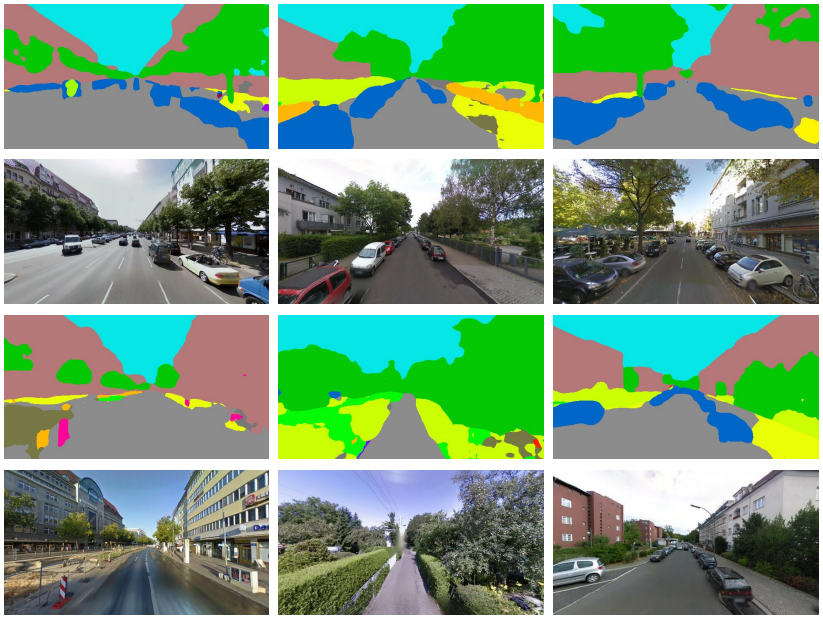


logorithm transformation

3 | Street Feature Extraction

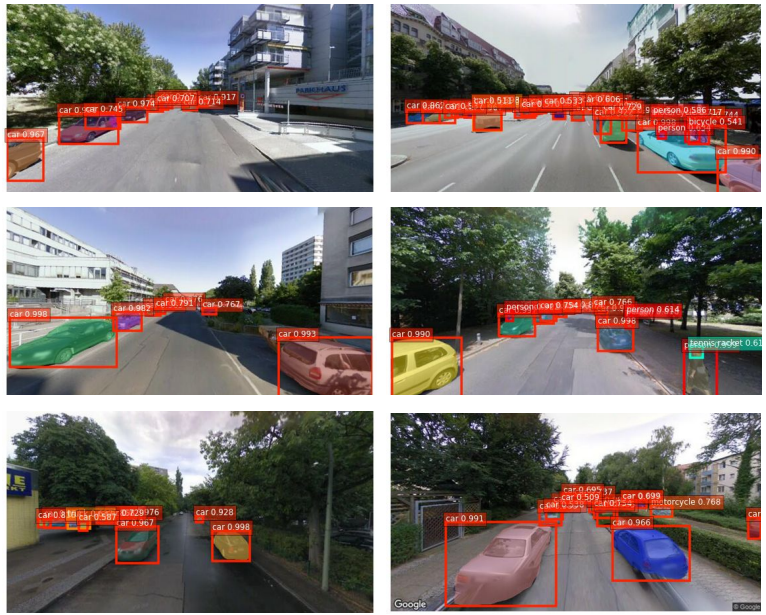
Semantic Segmentation

(with pre-trained PSPNET model, 85% accuracy on cityscapes)



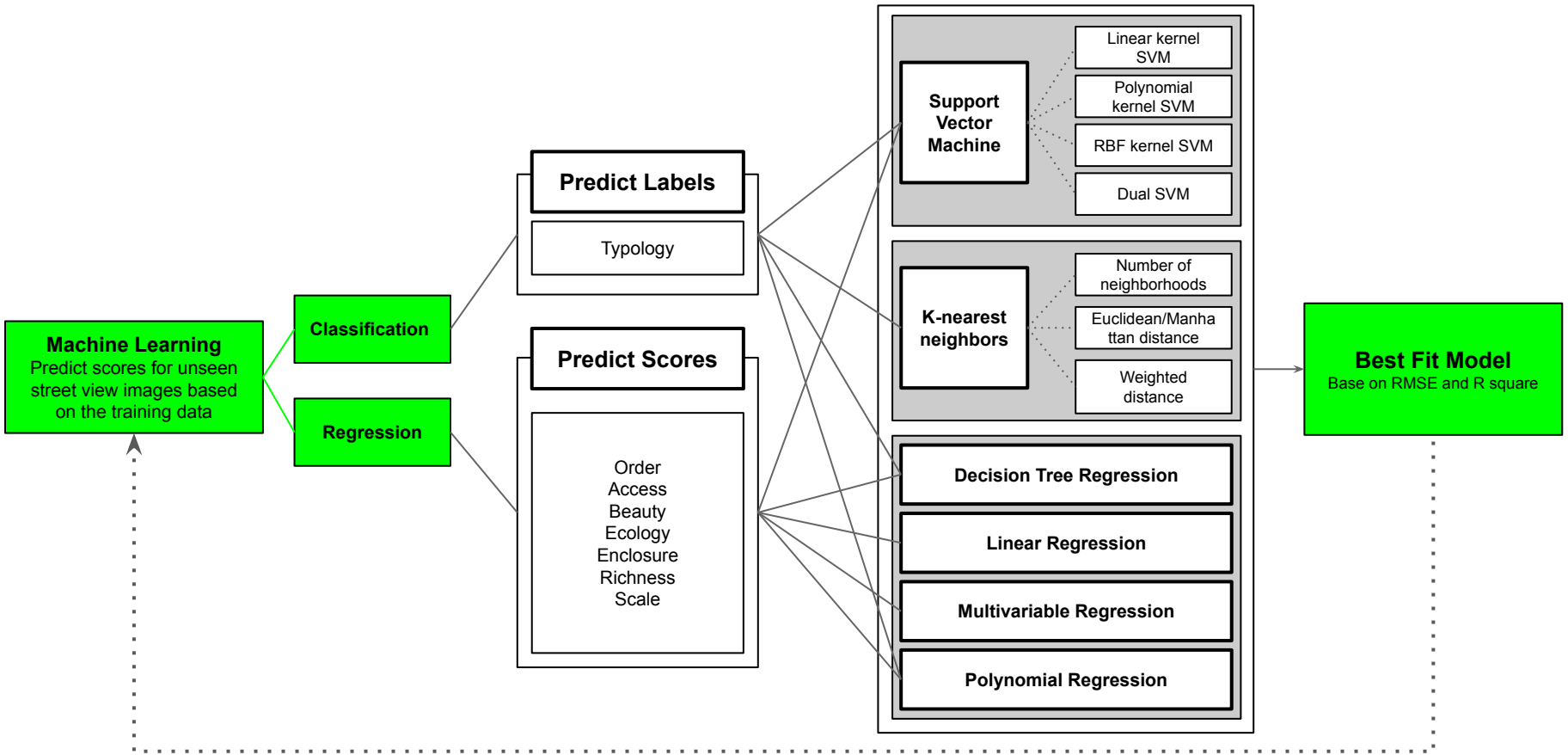
Instance Segmentation

(Mask R-CNN)



4 | Model Training

Machine Learning with Classification and Regression Algorithms



4 | Model Training

Model Selection

Model Selection

ML Models	Q1_Type	Q2_Order	Q3_Access	Q4_Aesth	Q5_Eco	Q6_Enclo	Q7_Rich	Q8_Scale
KNN	0.47	0.36	0.40	0.38	0.48	0.44	0.49	0.41
Random Forest	0.60	0.48	0.55	0.54	0.56	0.59	0.59	0.51
Decision Tree	0.59	0.49	0.50	0.54	0.52	0.56	0.53	0.49
Gaussian Process	0.58	0.44	0.51	0.52	0.55	0.53	0.58	0.45
GradientBoosting Regression	0.58	0.46	0.52	0.49	0.52	0.57	0.54	0.48
ADA	0.56	0.47	0.51	0.49	0.53	0.54	0.53	0.48

Imaging Landscapes
Methods
Map
Students Work
Team
Rate an Image
Berlin
Samples
Subway Station
Population
Population Density
Ahrensfelde
Hoheneiche
Schönholz
Cité Guynemer
Jungfernheide
Cité Pasteur
Tegel Airport
Leopoldkiez
Amimkiez
Komponistenviertel
Sprengelkiez
Kollwitzkiez
Fennpfuhl
Spandauer Vorstadt
Berlin
Friedrichsfelde Ost
Berlin Olympic Stadium
Graefestraße
Donaukiez
Tempelhofer Feld
Schillerpromenade
Weiße Siedlung
Hundeauslaufgebiet Grunewald
Grunewald
Wuhlheide
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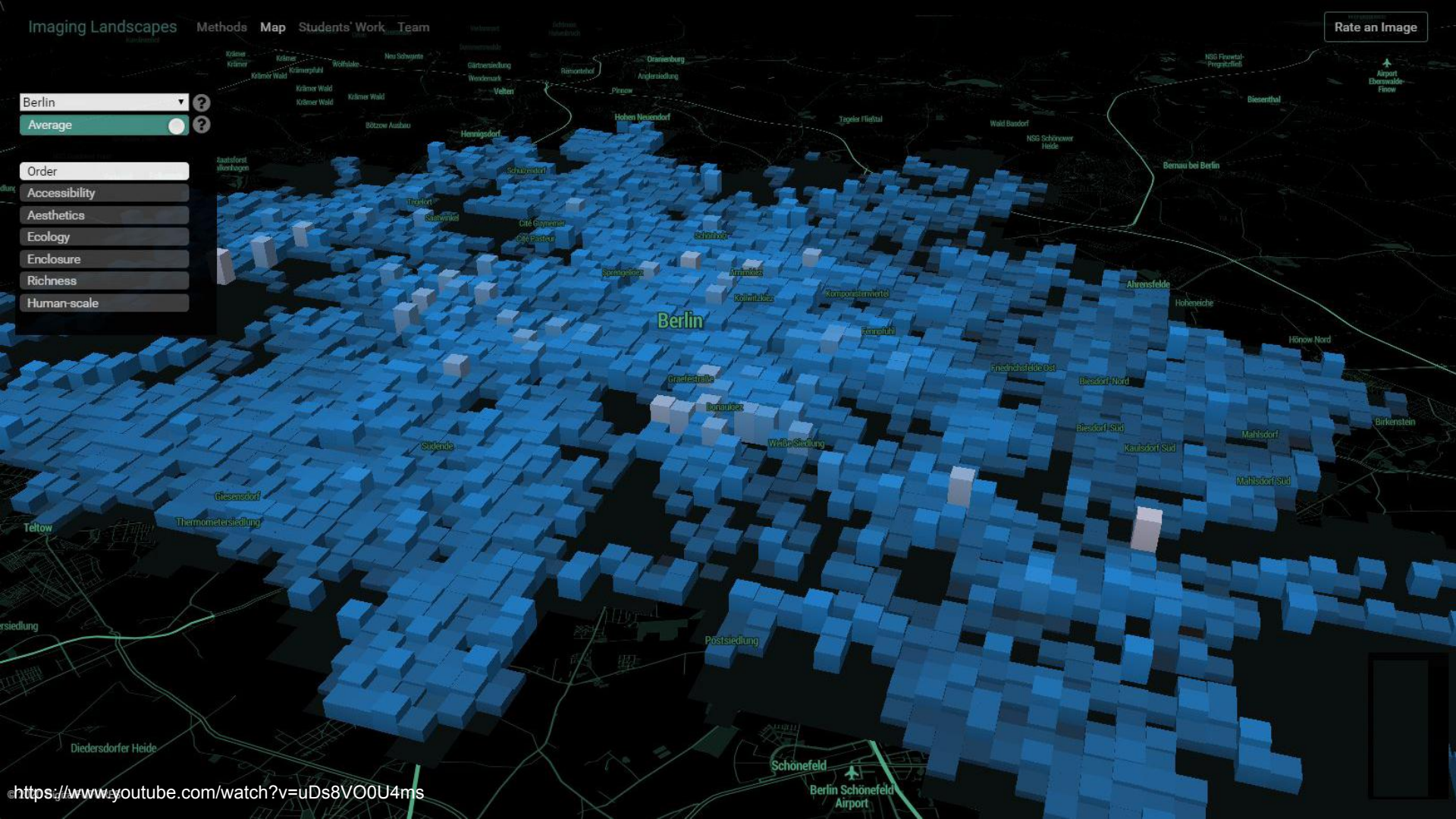

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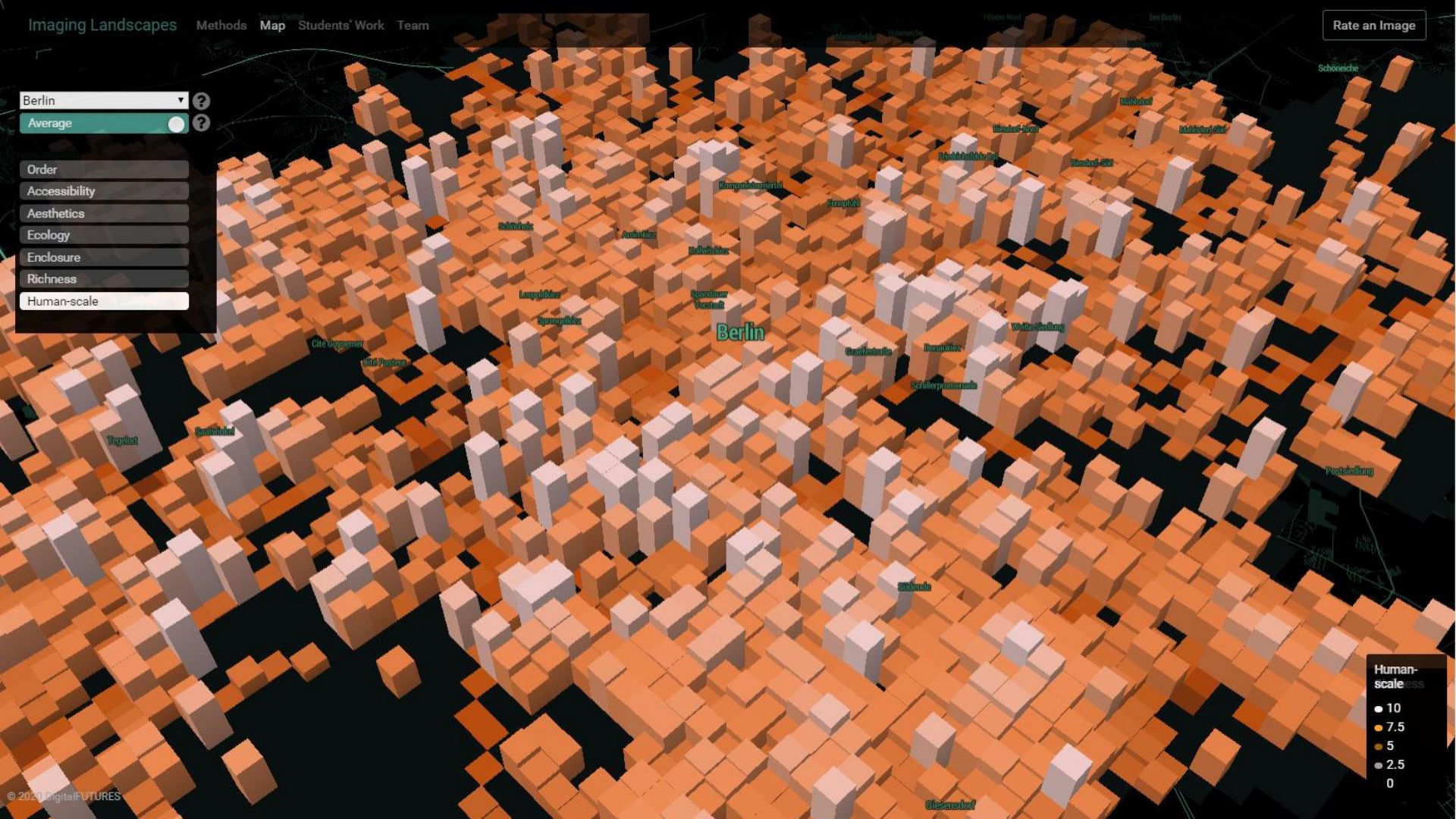
Imaging Landscapes
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Students' Work
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Rate an Image
Berlin
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Order
Accessibility
Aesthetics
Ecology
Enclosure
Richness
Human-scale
Berlin
Human-scale
10
7.5
5
2.5
0
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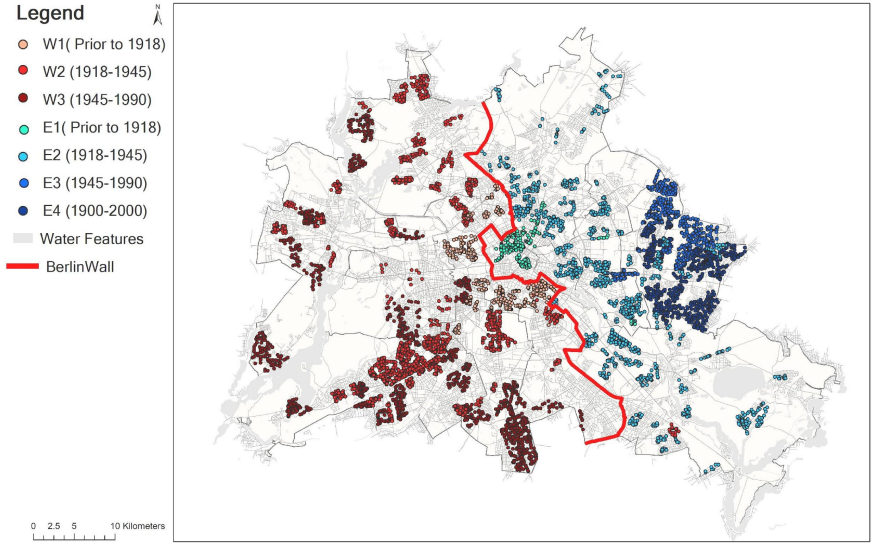
5 | Historic Residential District Zoning

We selected the streetscape data that is closest to chronological age in GIS and divided them into E1-4 and W1-3 sections.

German Empire (1871)
WWI (1914-1918)
Weimar Republic (1918)
Nazi Germany (1945)
WWII (1939-1945).
Divided Berlin (1945-1989)



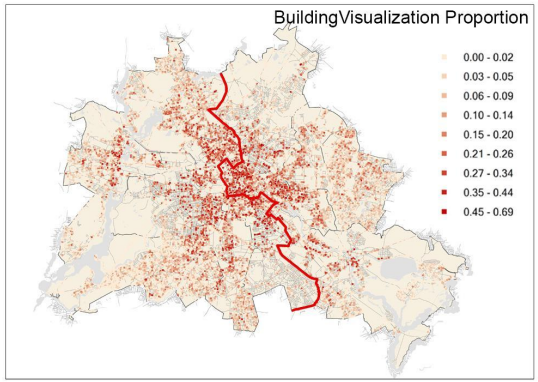
3. Analysis and Discussion

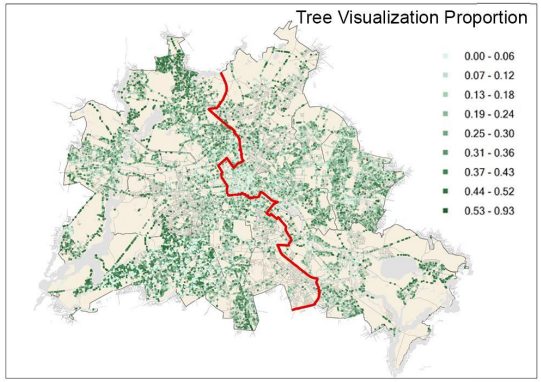
Perception Data Visualization
Analysis of Perceptual Qualities
Historical Context and Planning Policies

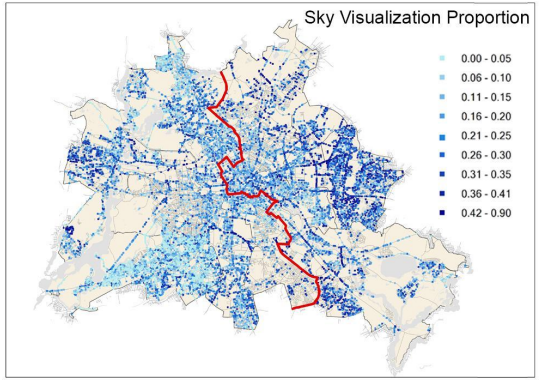
1 | Street View Perception Data Visualization

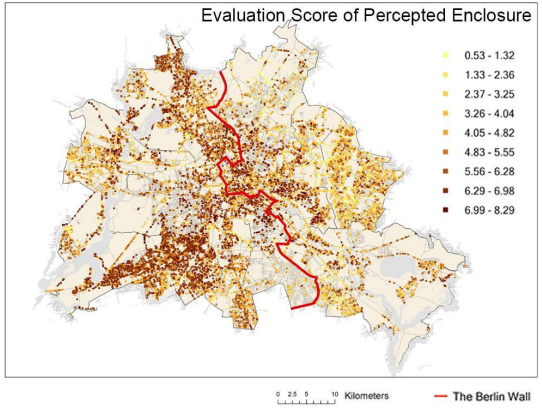
4 key streetscape features: **sky, tree, building, and road** take significant fractions in a SVI image

- **High building** visibility in the center of Berlin
- **High tree** visibility in the north and south outskirts (Frohnau and Lichtenrade)
- **High sky** visibility in the east and west outskirts (Hellersdorf and Neu-staaken)
- **Enclosure** is **positively** correlated to **building** visibility and **tree** visibility, but **negatively** correlated to **sky** visibility.







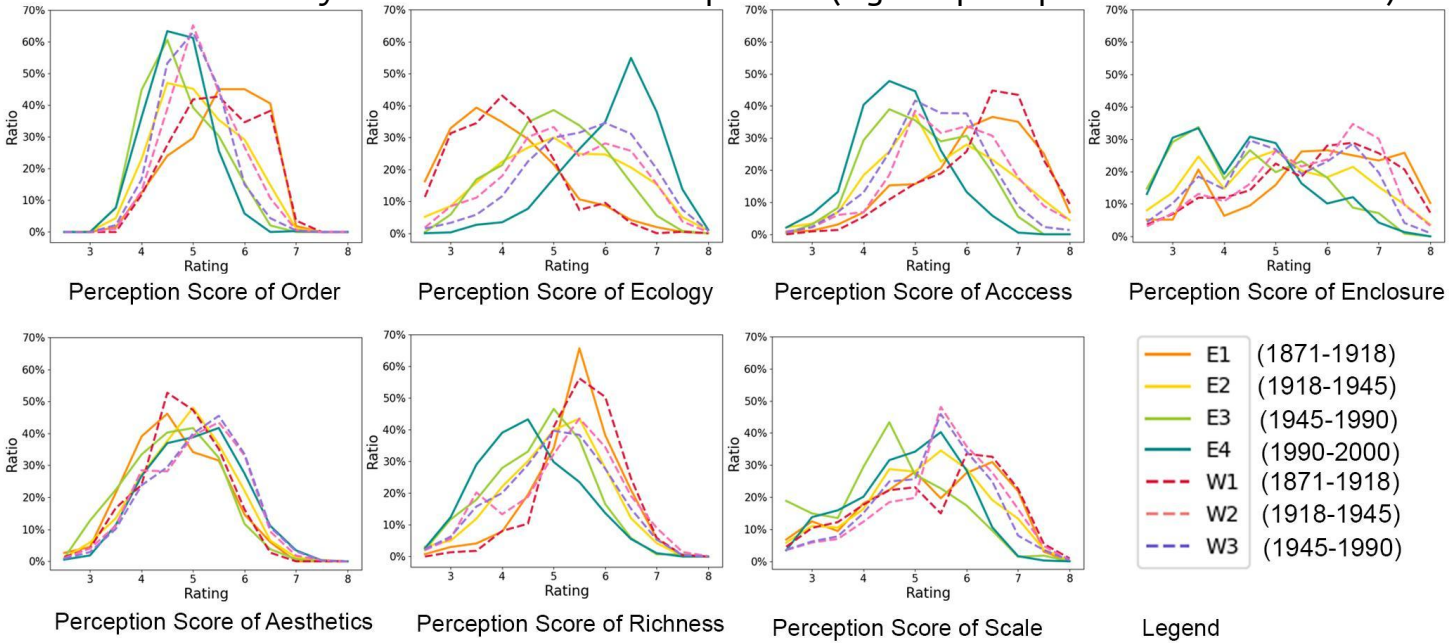


2 | Analysis of Perceptual Qualities in Different Historical Districts

- Data are moderately skewed at certain periods. (e.g. In the Perception Score of Ecology, the E1 and W1 periods have a right-skew distribution while the W3 and E4 periods have a left-skew distribution.)

- The datasets are close to a normal distribution. (e.g. the Perceptual Score of Aesthetics)

- The data are evenly distributed with no clear pattern. (e.g. the perceptual score of Enclosure)



2 | Analysis of Perceptual Qualities in Different Historical Districts

The **median score** from each period and region is selected to represent its score in the middle.

- E1 and W1 share high score in access and order but low evaluation in perception score of ecology and aesthetics.
- E2 and W2 show generally good performance in each perceptual score.
- W3 has low evaluation of order though, better performance in the evaluation of scale and enclosure compared to E3.
- E4 inherits low evaluation of order and enclosure from E3 district, but better performance of ecology and aesthetics.

Comparison of Perception Median Score							
Perception / Time	Order	Ecology	Access	Enclosure	Aesthetic	Richness	Scale
East1 (1871-1918)	5.61	3.92	6.32	5.87	4.64	5.49	5.32
East2 (1918-1945)	5.03	5.11	5.38	4.84	4.90	5.11	5.23
East3 (1945-1990)	4.62	5.02	5.04	3.74	4.65	4.82	4.46
East4 (1990-2000)	4.70	6.31	4.62	3.74	5.00	4.41	5.02
West1 (1871-1918)	5.46	4.02	6.51	5.89	4.76	5.59	5.59
West2 (1918-1945)	5.08	5.22	5.69	5.72	5.11	5.34	5.58
West3 (1945-1990)	4.95	5.68	5.38	5.06	5.17	5.11	5.44

3 | Associate Perceptual Qualities to Historical Context and Planning Policies

Hobrecht Plan (1862)

Define public and private spaces
High parcel density
Low score in Ecology and Aesthetics
High score in Access and Order

The Weimar Republic

Building reform movement
High quality of housing standard
“Berlin Modernism Housing Estates”
Good in each perceptual score

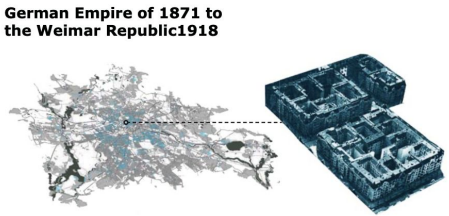
West Berlin & East Berlin

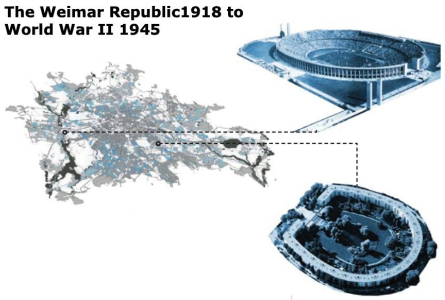
Soviet urban planning (‘Plattenbau’)
Low score in Scale, Enclosure, & Aesthetics
High score in Ecology

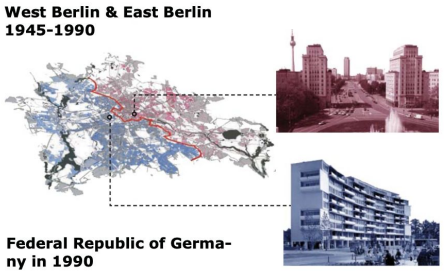
Interbau 1957 (Hansa District)
“City of Tomorrow”
Urbanity-through-density
High score in Ecology, Scale, Richness & Aesthetics

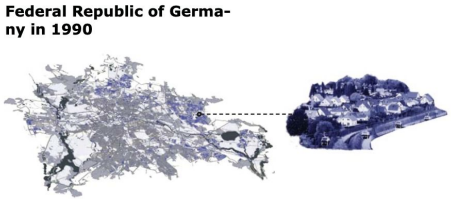
German Reunification

Visually change Plattenbau facades
Reconstruct the central city
Single-family houses and smaller apartments
Low score in order and enclosure
Better performance in ecology and aesthetic









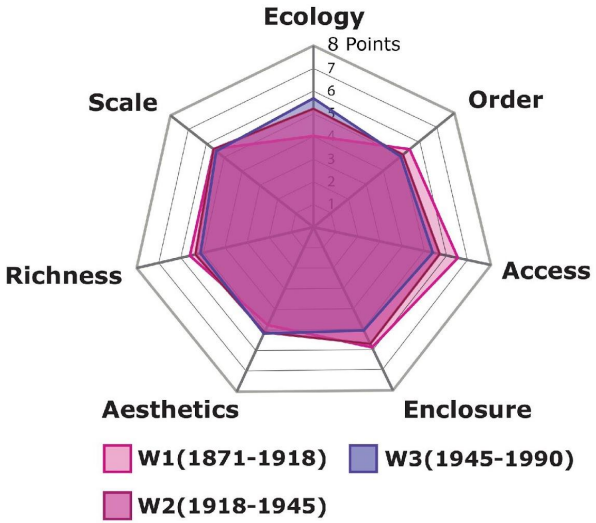
4. Conclusion

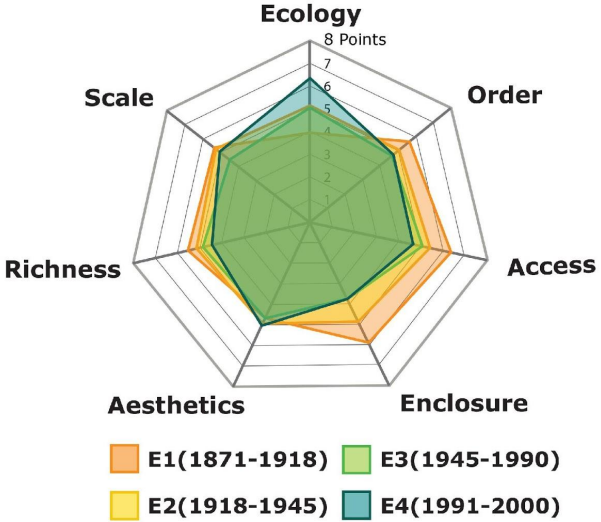
1 | Finding

- The increase of ecology and enclosure represents housing policies and design codes have improved overcrowding densities, created more open spaces, and developed a better ecological environment since the post-war period.

- The west part of Berlin showed consistent results with the east part at the same period until Berlin was divided in 1945. The housing estates built in E3 represents low evaluation of enclosure, aesthetics, richness and scale.

- Though the government attempted to integrate the urban landscape of East Berlin to West Berlin after the reunification, people's perceptions can still tell the difference of the urban features which respond to their construction characters and historical contexts.





Thank you!

Q & A