CAADRIA 2024

Exploring visual factors influencing women's perceived insecurity in metro stations and adjacent built environments

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1. Introduction

1.1 Background

RANK	106 — 50 — 1	VAR. '21/'20	PROVINCE	TOTAL COMPLAINTS	REPORTS 100 THOUSAND INHABITANTS.
1		-	Milan	159613	4,866.33
2		+2 ▲	Bologna	47,192	4,636.64
3		-	Rimini	15,642	4,603.35
4		+3 ▲	Lawn	11,426	4,426.07
5		-3 ▼	Florence	42,957	4,277.32
6		-1 ▼	Turin	95,335	4,232.64
7		-1 ▼	Rome	179851	4,150.46
8		-	Imperia	8,461	3,955.24
9		-	Livorno	12,947	3,882.05
10		+2 ▲	Genoa	31,742	3,797.67

Data resources: Department of Public Security of the Ministry of the Interior

Previous studies have given Milan a unique name: ***'Italian Gotham City'*** , because Milan has the highest crime index in Italy

Why we only focus on Women?

Inclusive city

Building inclusive city is a very important part of United Nations Sustainable Development Goals.

1. Introduction

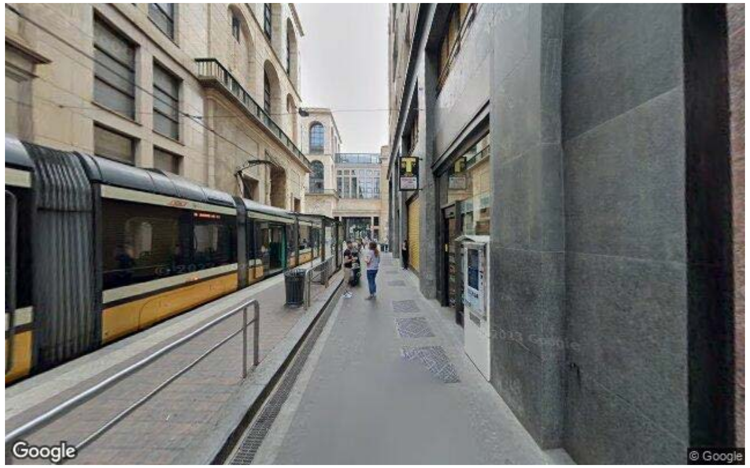
1.2 Background

Previous research has confirmed that women, who looks ‘vulnerable’, are more likely to feel insecurity. Since subway is a very important type of transportation, studying the safety of women when using subway is valuable

1. Introduction

1.3 Study object: Visual factors in Milan’s metro stations and buffer areas

Interior of metro stations



Surrounding buffer areas

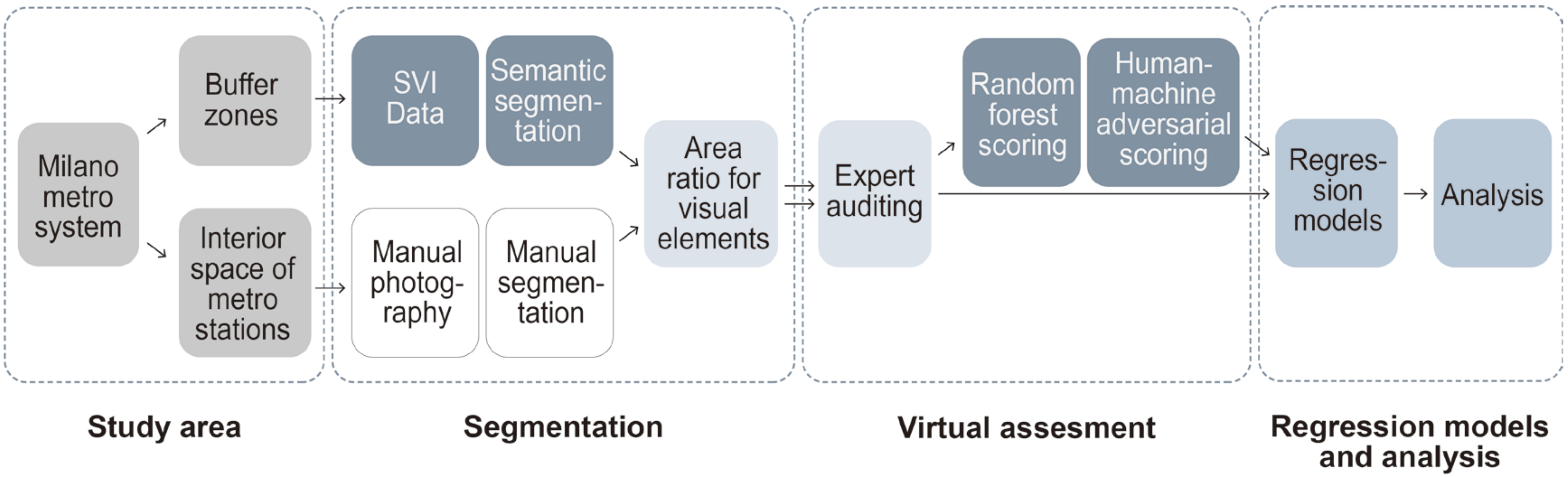
In order to represent the entire commuting experience, our study includes both the ***interior of metro stations*** and the ***surrounding buffer areas***.

Research gap

- Interiors and buffers have ***different built environments***, so they must contain different influencing factors. However, previous studies rarely make this distinction.
- Even if ***Street View Imagery*** is widely used for urban space, it ***lacks coverage of the interior spaces***, presenting challenges for using image datasets in metro stations.
- Our study aims to bridge gaps by manually taking pictures of the interiors, and then we analyze interiors and buffers ***separately.***

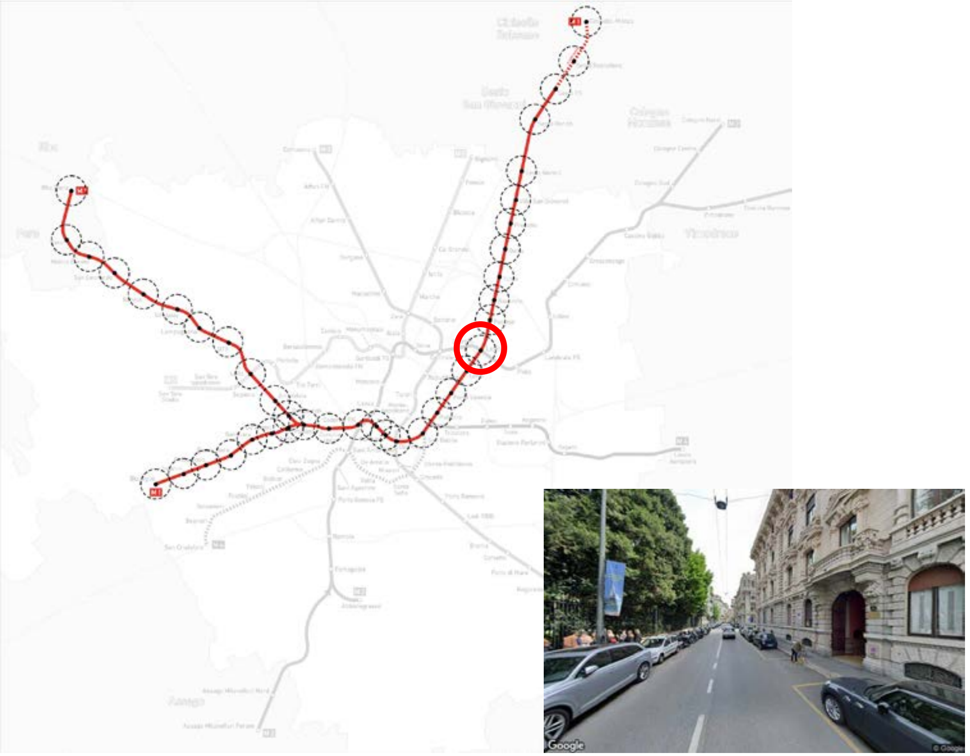
2. Methodology

2.1 Research framework

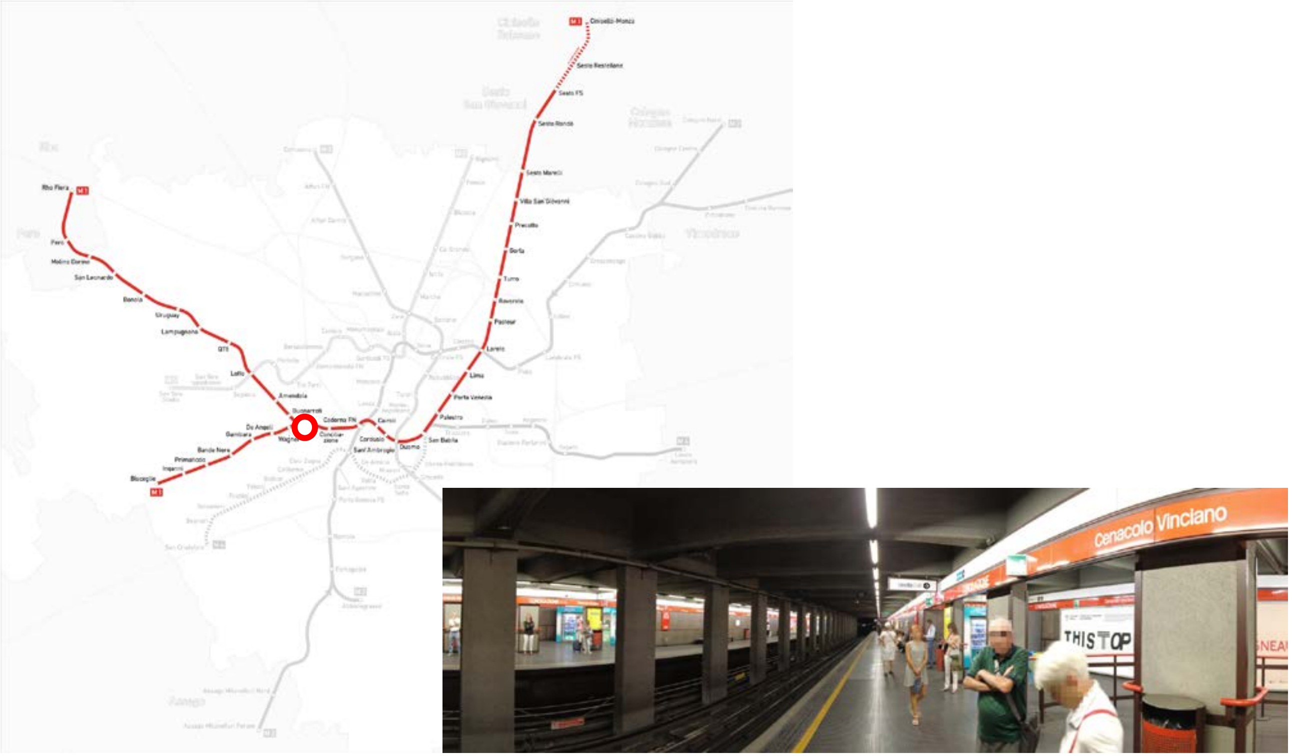


2. Methodology

2.2 Study area



Surrounding buffer areas



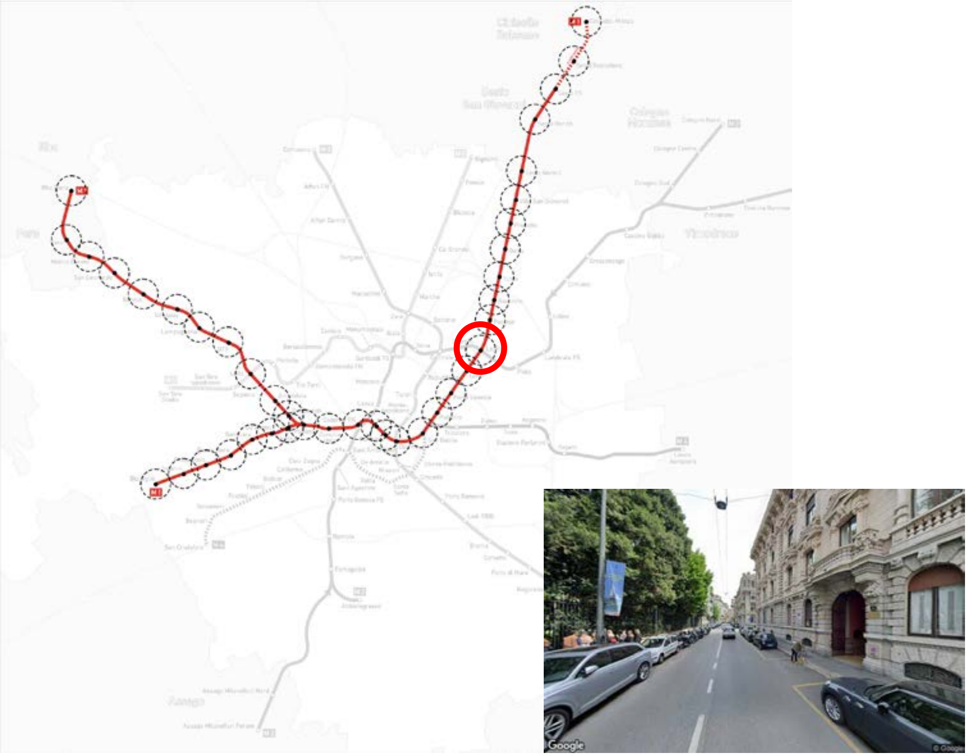
Interior of metro stations

A whole metro line in Milan——***Line 1***, the red line, and buffer areas are defined as walkable areas of 400 metres centred on each metro station.

Line 1 is selected due to its early construction, and it connect Milan's core area.

2. Methodology

2.3 Data resources (buffer areas)



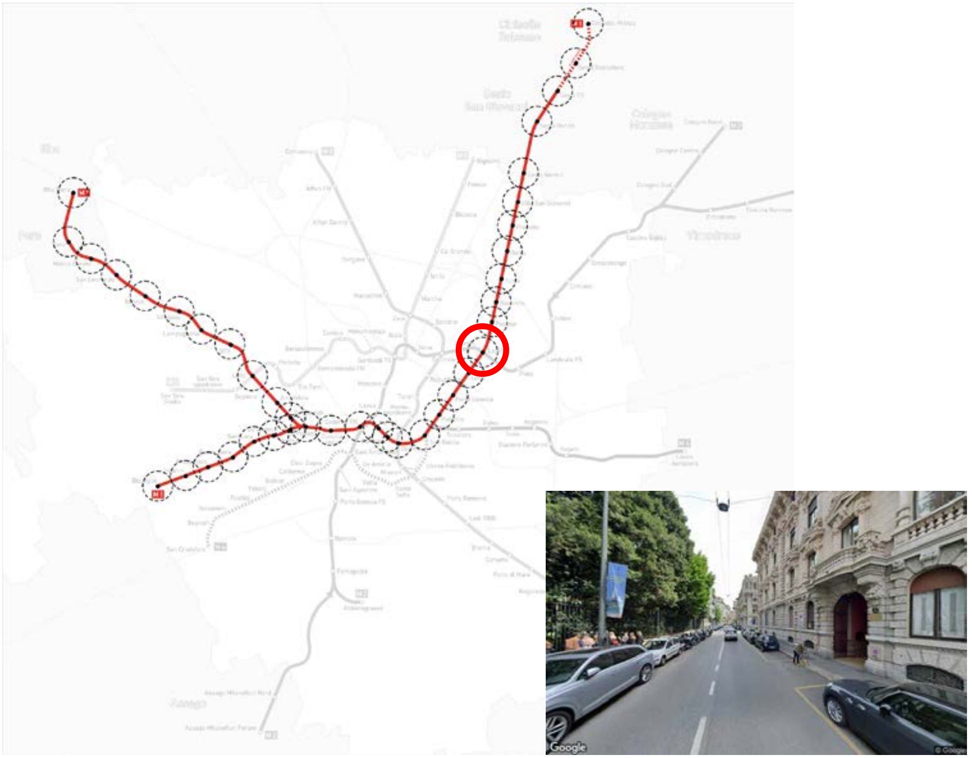
Principal component analysis of built environment in the buffer area

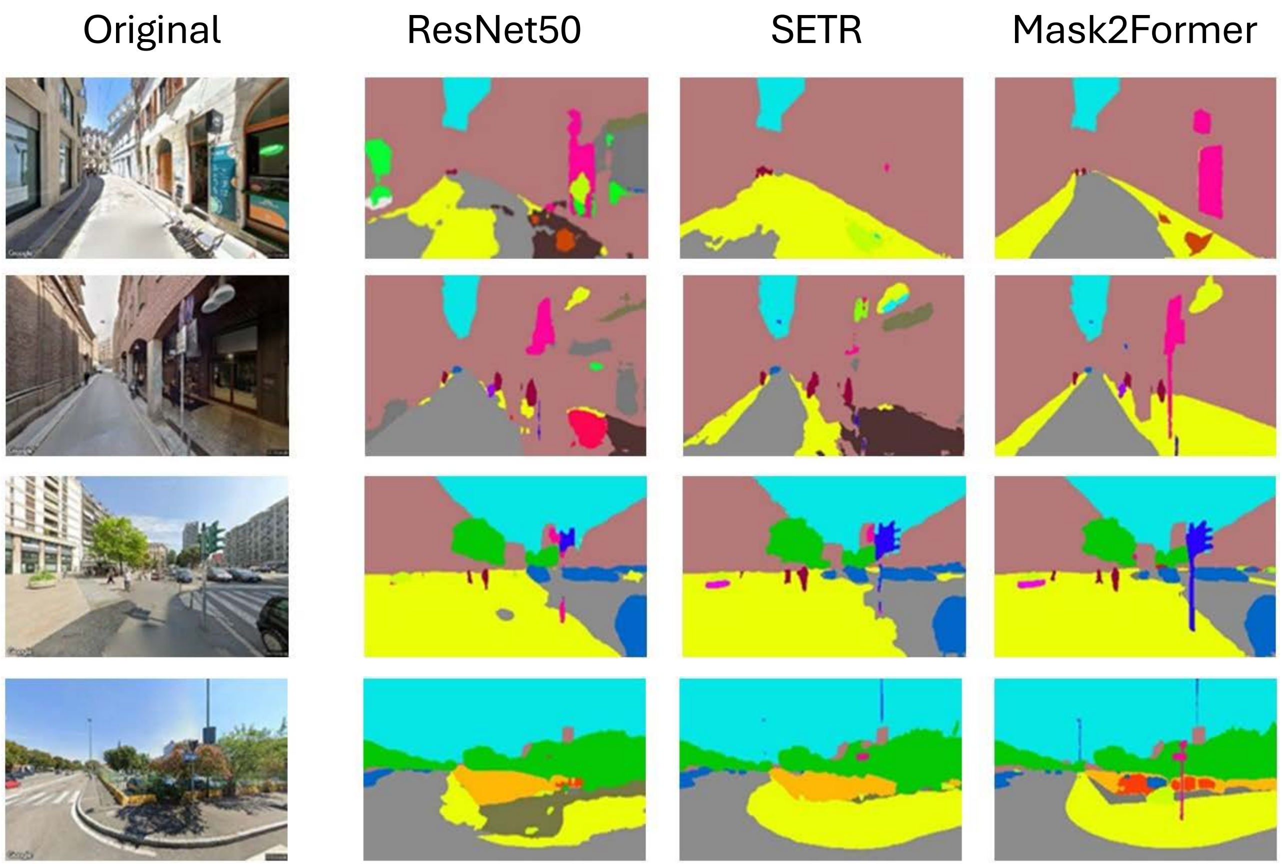
Classification	Factors	ADE20K Dataset
Visual Accessibility	Light	Streetlight
	Enclosure	Building
		Wall
		Fence
Vitality	Vegetation	Plant
		Tree
	Living	Person
		Animal
	Infrastructure	Traffic Light
		Traffic Signboard
	Commerce	Shop Sign
Surveillance	Person	Person
		Car
	Monitor	Surveillance Camera
	Window	Window
	Commerce	Shop Sign
Spatial Dimension	Road Width	Road
	Sidewalk Width	Sidewalk
	Unpaved Area	Earth
	Height Variation	Steps

For buffer areas, image resource is ***Google Street View***. Then, based on prior studies, we select these elements as influencing factors and classify them into four directions: Visual Accessibility, Vitality, Surveillance, and Spatial Dimension.

2. Methodology

2.3 Data resources (buffer areas)

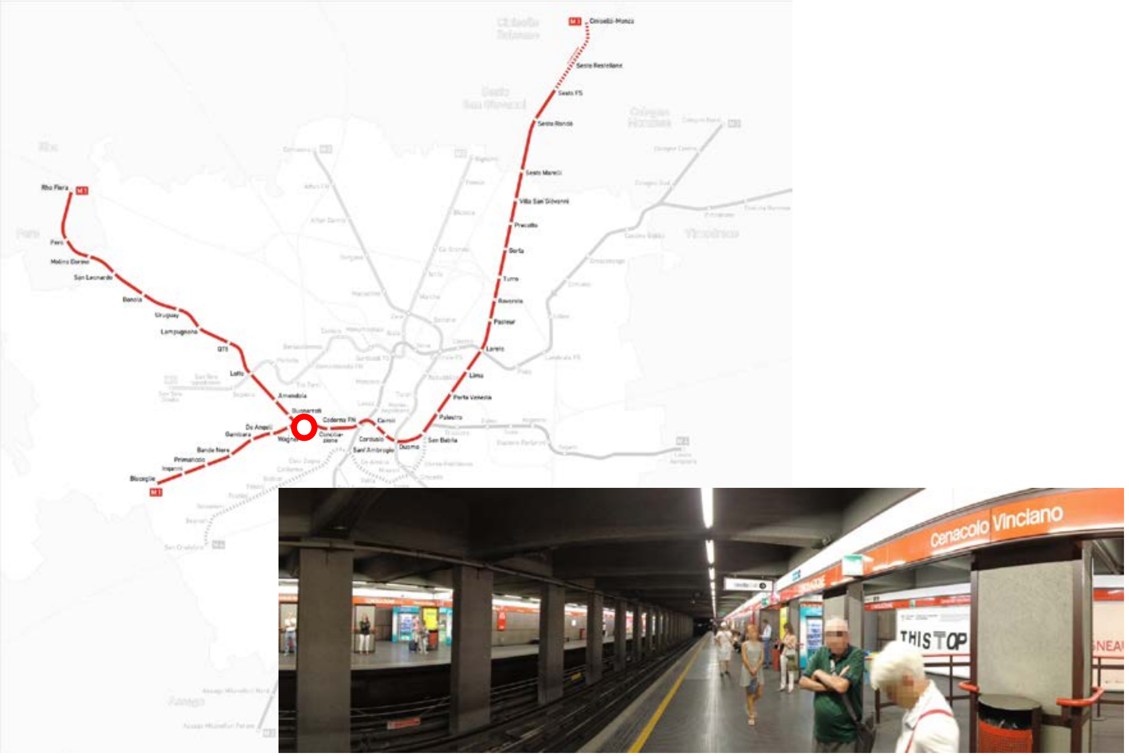




Comparison of three pre-trained neural network models, ***Mask2Former*** has the highest level of accuracy. Then, Mask2Former is used to semantically segment and calculate the area ratio of each element.

2. Methodology

2.4 Data resources (interior areas)



Principal component analysis of built environment in metro station

Classification	Factors	Manual segmentation
Visual Accessibility	Light	Artificial Light Natural Light
	Platform Width	Platform
	Access Width	Access
	Window	Visual Window
Surveillance	Passengers	People
	Storefronts	Store / Vending Machine
	Monitor	Surveillance Camera
	Security	Security Booth
	Window	Visual Window
Disorder	Infrastructure	Damaged Infrastructure
	Broken	Broken Infrastructure / Pavement
	Litter	Litter

We use the DJI Pocket 2 camera to capture ***180-degree photographs of various key areas***, including exit access points, ticket gates, platforms, and interchange passages—all of which are critical locations in commuter cores. Then we choose the influencing factors based on previous research and the current state of metro stations. All factors are divided into three groups: Visual Accessibility, Surveillance, and Disorder.

2. Methodology

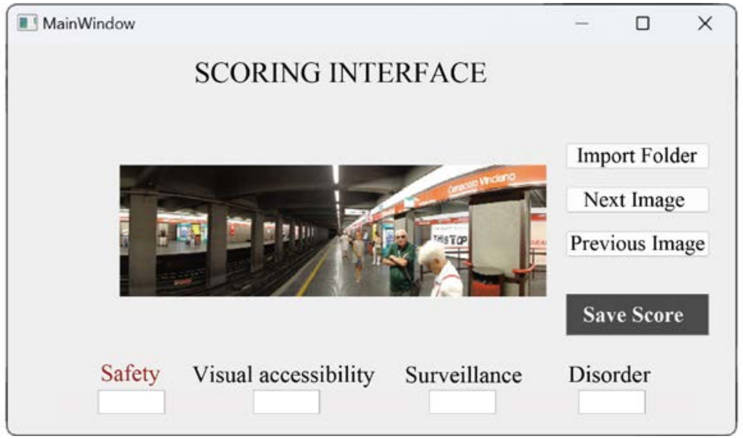
2.4 Data resources (interior areas)

Original | Manually Segmentation | Semantic Segmentation

Because the metro stations have ***unique environment***, we concern the accuracy of semantic segmentation, so we manually segment each element images and compare it with semantic segmentation. ***Manual segmentation has higher accuracy***. Since we only have 272 photos, we manually segment and compute the area ratio for each element.

2. Methodology

2.5 Data analysis



BUFFER AREAS

- Volunteers score 1,000 images, then we design a ***random forest model***.

  (The model is trained using the scores of the initial images, considering the proportion of different objects in each image)

- To improve model accuracy, we use a ***human-machine adversarial auditing approach***.

  (The process ends when the model's scores closely match the volunteer's score. Next, we randomly select 100 images for double-checking)

- Subsequently, scores for all images are ***automatically assessed.***

INTERNAL AREAS

- Due to the limited number of images, using machine learning is difficult. So, we use volunteer auditing for all images.

3. Results & Discussion

3.1 Buffer areas

- ***<u>MODEL FOR SAFETY</u>*** allows us to analysis the impact of different elements on safety scores. Model indicates that greater sidewalk and road width increase safety perception.
- ***<u>MODELS FOR OTHER PERCEPTIONS</u>*** shows the positive and negative factors across different dimensions. The spatial dimension model indicates that the existence of earth is a negative factor.

Model Summary (Safety)

R	R^2	Adj.R^2	D-W	P
0.873	0.761	0.757	1.638	0.001

Parameter Estimate (Safety)

Idx	Factors	Coefficients		VIF
	Constant	14.866		
Q_1	Streetlight	1909.002	0.289	1.099
Q_2	Building	13.601	0.174	2.458
Q_3	Wall	-83.251	-0.202	1.277
Q_4	Fence	17.812	0.045	1.417
Q_5	Plant	96.531	0.199	1.181
Q_6	Tree	67.063	0.483	1.629
Q_7	Person	197.821	0.042	1.036
Q_8	Animal	-122.470	-0.033	1.639
Q_9	Traffic Light	539.542	0.058	1.018
Q_{10}	Traffic Signboard	343.804	0.148	1.051
Q_{11}	Shop Sign	387.424	0.177	1.022
Q_{12}	Car	96.852	0.472	2.245
Q_{13}	Surveillance Camera	6856.104	0.159	1.639
Q_{14}	Window	81.256	0.231	1.333
Q_{15}	Road	58.732	0.458	3.777
Q_{16}	Sidewalk	119.781	0.535	2.283
Q_{17}	Earth	-36.982	-0.133	1.833
Q_{18}	Steps	-29.373	-0.038	1.059

$$P = \beta_0 + \beta_1 Q_1 + \beta_2 Q_2 + \cdots + \beta_{18} Q_{18}$$

<u>MODEL FOR SAFETY</u>

Model Summary (Visual Accessibility)

R	R^2	Adj.R^2	D-W	P
0.904	0.817	0.817	1.546	0.001

Parameter Estimate (Visual Accessibility)

Idx	Factors	Coefficients		VIF
	Constant	74.860		
Q_1	Streetlight	242.268	0.068	1.024
Q_2	Building	-37.630	-0.841	1.065
Q_3	Wall	-88.936	-0.410	1.008
Q_4	Fence	-38.450	-0.125	1.035

$$P = \beta_0 + \beta_1 Q_1 + \beta_2 Q_2 + \cdots + \beta_4 Q_4$$

Model Summary (Vitality)

R	R^2	Adj.R^2	D-W	P
0.918	0.842	0.842	1.686	0.001

Parameter Estimate (Vitality)

Idx	Factors	Coefficients		VIF
	Constant	48.008		
Q_1	Plant	26.576	0.119	1.018
Q_2	Tree	43.349	0.714	1.028
Q_3	Person	25.756	0.035	1.017
Q_4	Animal	374.276	0.226	1.006
Q_5	Traffic Light	136.657	0.032	1.003
Q_6	Traffic Signboard	541.943	0.404	1.269
Q_7	Shop Sign	180.245	0.174	1.27

$$P = \beta_0 + \beta_1 Q_1 + \beta_2 Q_2 + \cdots + \beta_7 Q_7$$

Model Summary (Surveillance)

R	R^2	Adj.R^2	D-W	P
0.796	0.634	0.634	1.590	0.001

Parameter Estimate (Surveillance)

Idx	Factors	Coefficients		VIF
	Constant	41.680		
Q_1	Person	286.352	0.489	1.017
Q_2	Car	50.695	0.634	1.067
Q_3	Surveillance Camera	-541.451	-0.070	1.185
Q_4	Window	18.513	0.186	1.057
Q_5	Shop Sign	253.450	0.308	1.191

$$P = \beta_0 + \beta_1 Q_1 + \beta_2 Q_2 + \cdots + \beta_5 Q_5$$

Model Summary (Spatial Dimension)

R	R^2	Adj.R^2	D-W	P
0.838	0.779	0.779	1.600	0.001

Parameter Estimate (Spatial Dimension)

Idx	Factors	Coefficients		VIF
	Constant	41.027		
Q_1	Road	40.508	0.759	1.257
Q_2	Sidewalk	51.734	0.493	1.131
Q_3	Earth	-31.845	-0.317	1.157
Q_4	Steps	11.832	0.035	1.007

$$P = \beta_0 + \beta_1 Q_1 + \beta_2 Q_2 + \cdots + \beta_4 Q_4$$

<u>MODELS FOR OTHER PERCEPTIONS</u>

3. Results & Discussion

3.2 Interior areas

Model Summary

R	R^2	Adj.R^2	D-W	P
0.839	0.703	0.688	1.572	0.001

Parameter Estimate

Idx	Factors	Coefficients		VIF
	Constant	63.179		
Q_1	Artificial Light	84.500	0.116	1.376
Q_2	Natural Light	139.564	0.164	1.111
Q_3	Platform	49.082	0.427	3.107
Q_4	Access	8.366	0.134	3.919
Q_5	People	127.239	0.526	1.057
Q_6	Store/Vending Machine	10.729	0.065	1.099
Q_7	Surveillance Camera	318.019	0.088	1.149
Q_8	Security Booth	102.408	0.231	1.212
Q_9	Visual Window	240.792	0.193	1.057
Q_{10}	Broken Infrastructure / Pavement	-304.951	-0.265	1.019
Q_{11}	Scattered Litter	-5145.838	-0.315	1.028

$$P = \beta_0 + \beta_1 Q_1 + \beta_2 Q_2 + \cdots + \beta_{11} Q_{11}$$

MODEL FOR SAFETY

- ***MODEL FOR SAFETY*** allows us to analysis the impact of different elements on safety scores. Model indicates that more broken infrastructure/pavement and scattered litter decrease safety.
- ***MODELS FOR OTHER PERCEPTIONS*** shows the positive and negative factors across different dimensions. The spatial dimension model indicates that the security booth is a positive factor.

Model Summary (Visual Accessibility)

R	R^2	Adj.R^2	D-W	P
0.787	0.619	0.610	1.855	0.001

Parameter Estimate (Visual Accessibility)

Idx	Factors	Coefficients		VIF
	Constant	55.163		
Q_1	Artificial Light	156.371	0.179	1.350
Q_2	Natural Light	136.446	0.134	1.097
Q_3	Platform	131.311	0.953	2.990
Q_4	Access	83.983	1.120	3.707
Q_5	Visual Window	214.026	0.143	1.054

$$P = \beta_0 + \beta_1 Q_1 + \beta_2 Q_2 + \cdots + \beta_5 Q_5$$

Model Summary (Surveillance)

R	R^2	Adj.R^2	D-W	P
0.864	0.747	0.741	1.917	0.001

Parameter Estimate (Surveillance)

Idx	Factors	Coefficients		VIF
	Constant	53.506		
Q_1	People	322.099	0.800	1.021
Q_2	Store/Vending Machine	64.942	0.237	1.020
Q_3	Surveillance Camera	567.729	0.095	1.055
Q_4	Security Booth	203.300	0.275	1.039
Q_5	Visual Window	277.298	0.133	1.019

$$P = \beta_0 + \beta_1 Q_1 + \beta_2 Q_2 + \cdots + \beta_5 Q_5$$

Model Summary (Disorder)

R	R^2	Adj.R^2	D-W	P
0.778	0.605	0.602	1.848	0.001

Parameter Estimate (Disorder)

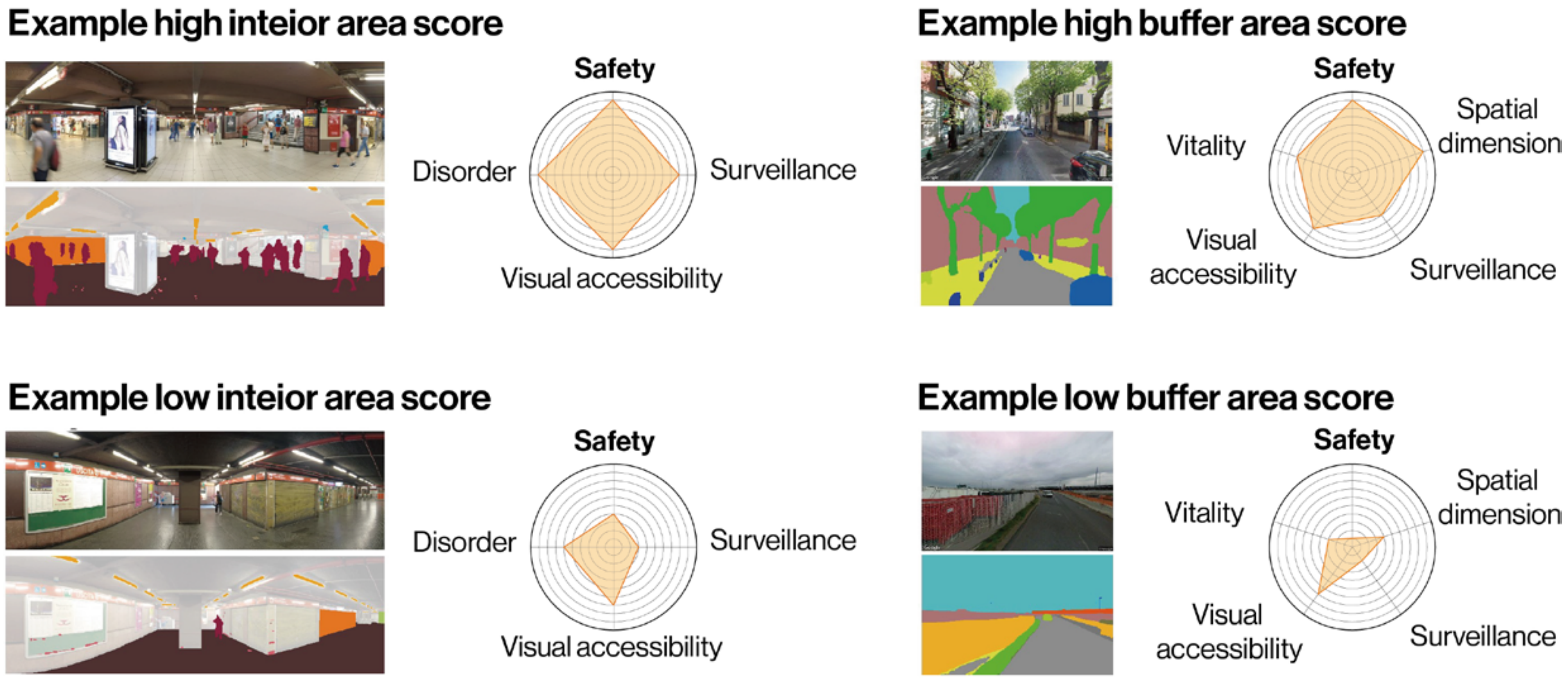
Idx	Factors	Coefficients		VIF
	Constant	81.552		
Q_1	Broken Infrastructure / Pavement	-889.605	-0.585	1.005
Q_2	Scattered Litter	-11015.182	-0.511	1.000

$$P = \beta_0 + \beta_1 Q_1 + \beta_2 Q_2$$

MODELS FOR OTHER PERCEPTIONS

3. Results & Discussion

3.3 Multidimensionally evaluation



Multidimensionally evaluation could be used to assess all metro stations and buffer areas in Milan. This approach could help us to propose specific strategies for future development.