Frontiers of Architectural Research

Visual factors and perceived insecurity in metro stations: a comparative study of Milan and Beijing

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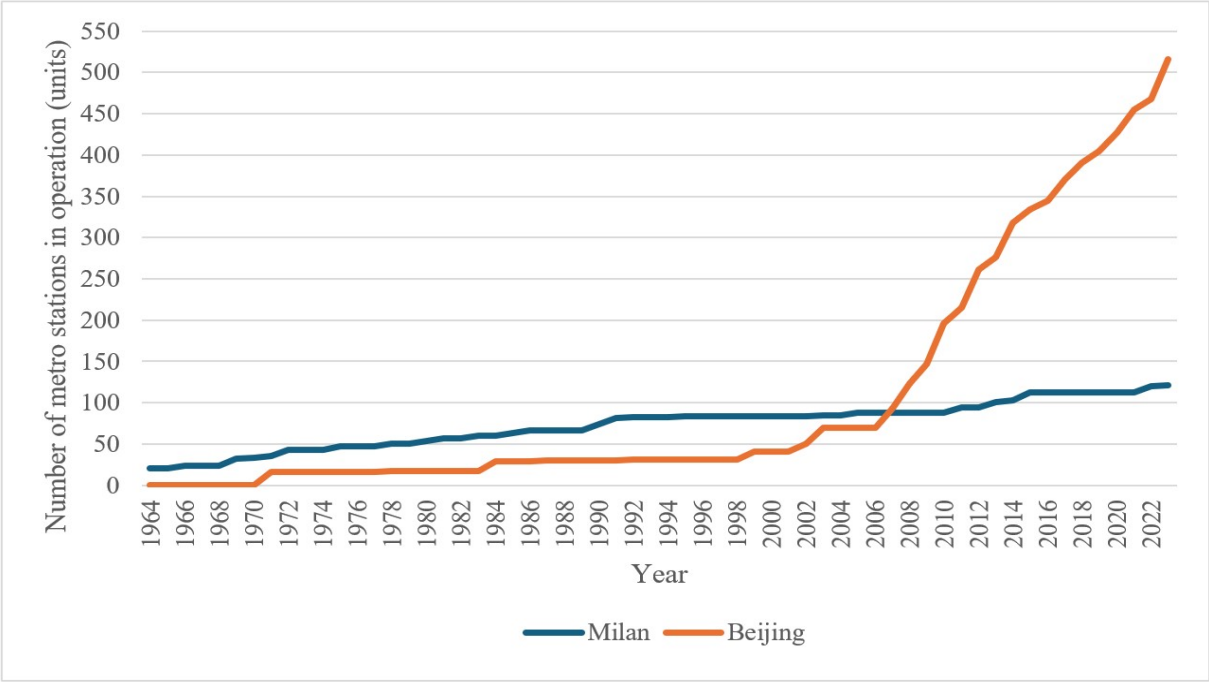
1. Introduction

Old station in Milan

New station in Milan

Metro stations, as essential public spaces, not only serve as vital transportation hubs but also form part of the broader urban environment that shapes public experiences and perceptions. An important concern for passengers in these environments is ***safety***, particularly in underground spaces where the design and organization of the physical surroundings play a crucial role. ***Despite various modern renovations in older metro stations, newer stations are generally perceived as safer. Why?***

1. Introduction



A major challenge is ***defining "old" and "new"*** metro stations, as urban development patterns vary between cities and countries. To address this issue, the study focuses on two cities, ***Beijing and Milan***, which represent contrasting models of urban development. The historical trends of the construction of the metro systems in Milan and Beijing reflects these differences in urban development patterns

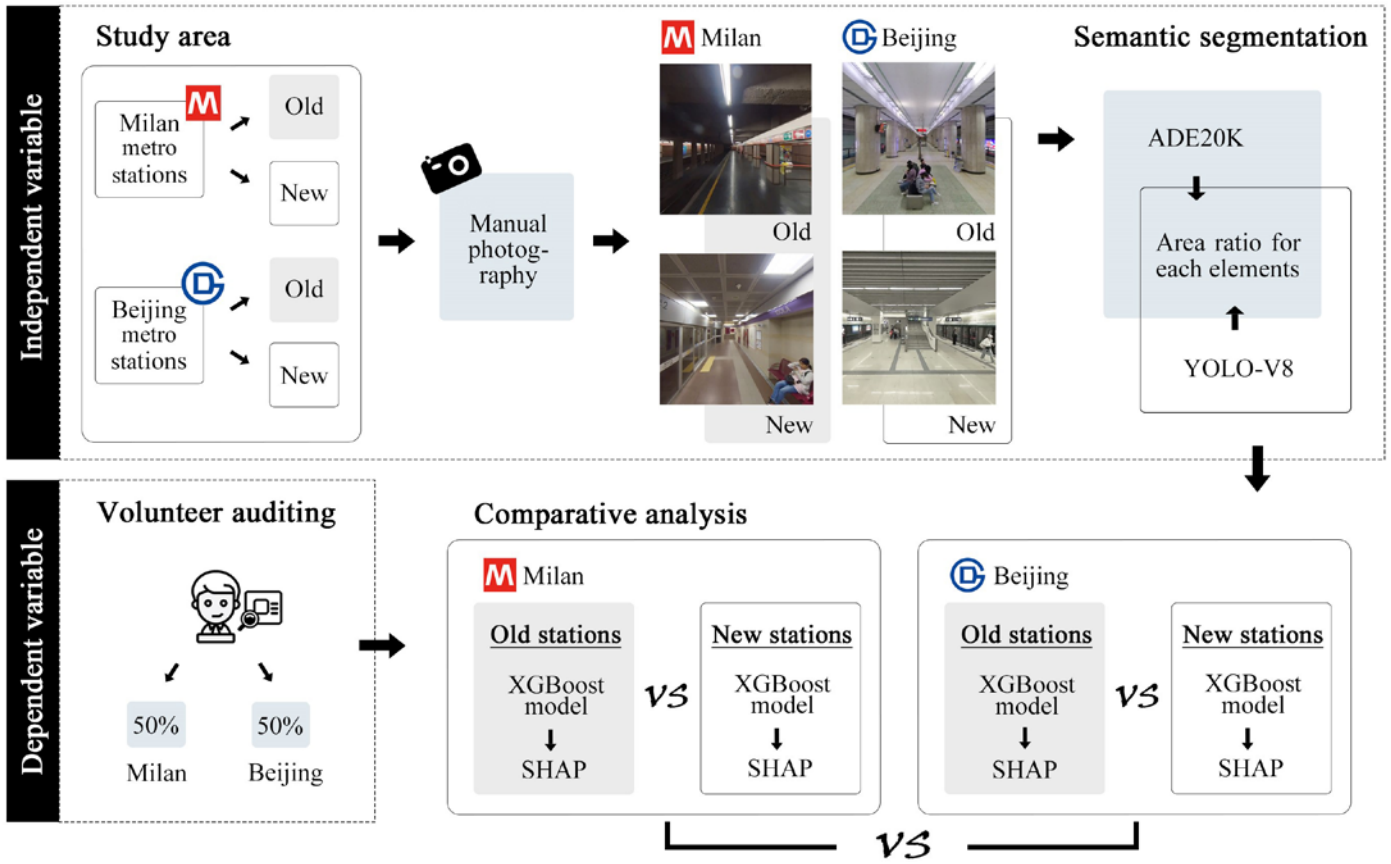
Research gap

- Most existing image datasets ***lack coverage of underground spaces***, and due to the unique environmental features of metro stations, widely used semantic segmentation datasets are unsuitable for accurately segmenting ***some distinct characteristics of underground areas***.

- Previous studies on safety perception in public transport have mainly concentrated on entire areas or specific areas within a city. These studies assessed all stations using a uniform standard, without considering that ***old and new stations vary significantly*** in terms of equipment, lighting, and spatial conditions, all of which directly influence passengers' sense of safety.

2. Methodology

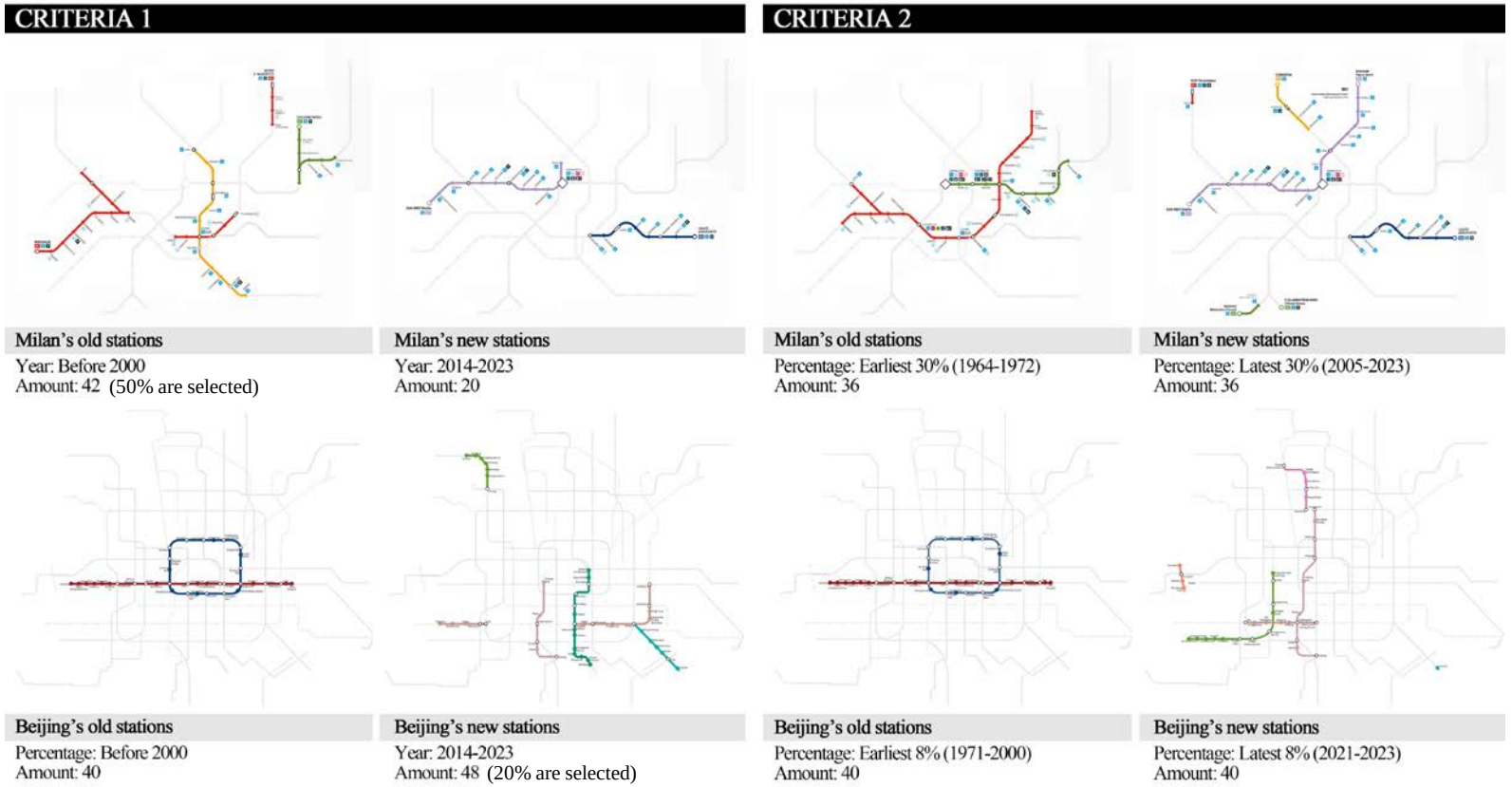
2.1 Research framework



- Our research proposes a novel methodology, offering a new approach for future studies on the built environment ***in underground public space.***
- We employ a ***360-degree*** mobile capture method and train a ***YOLOv8*** model, to accurately segment and analyze the unique features of underground metro stations.
- we employ the ***XGBoost*** model to more accurately capture these complex relationships and use the ***SHAP*** package to explain the contribution of each feature to safety perception.

2. Methodology

2.2 Criteria to define new and old metro stations in Milan and Beijing



Due to the distinct development models of the two cities, our study employs ***two distinct criteria***. This approach ensure that we consider both the historical evolution and the pace of development in shaping the safety perceptions of metro users in these two cities.

2. Methodology

2.3 Data collection

360° panorama photographs

Perspective photographs

We employ Insta360 X3 to manually capture ***360-degree*** photographs of selected metro stations. Then we transform them into four ***90-degree*** perspective photographs

Semantic segmentation

- ADE20K

  (Firstly, we use ADE20K for semantic segemantation)

- YOLOv8s-Seg

  (Secondly, for the features that show low accuracy or cannot be segmented with ADE20K, the YOLOv8s-Seg network are employed to perform segmentation)

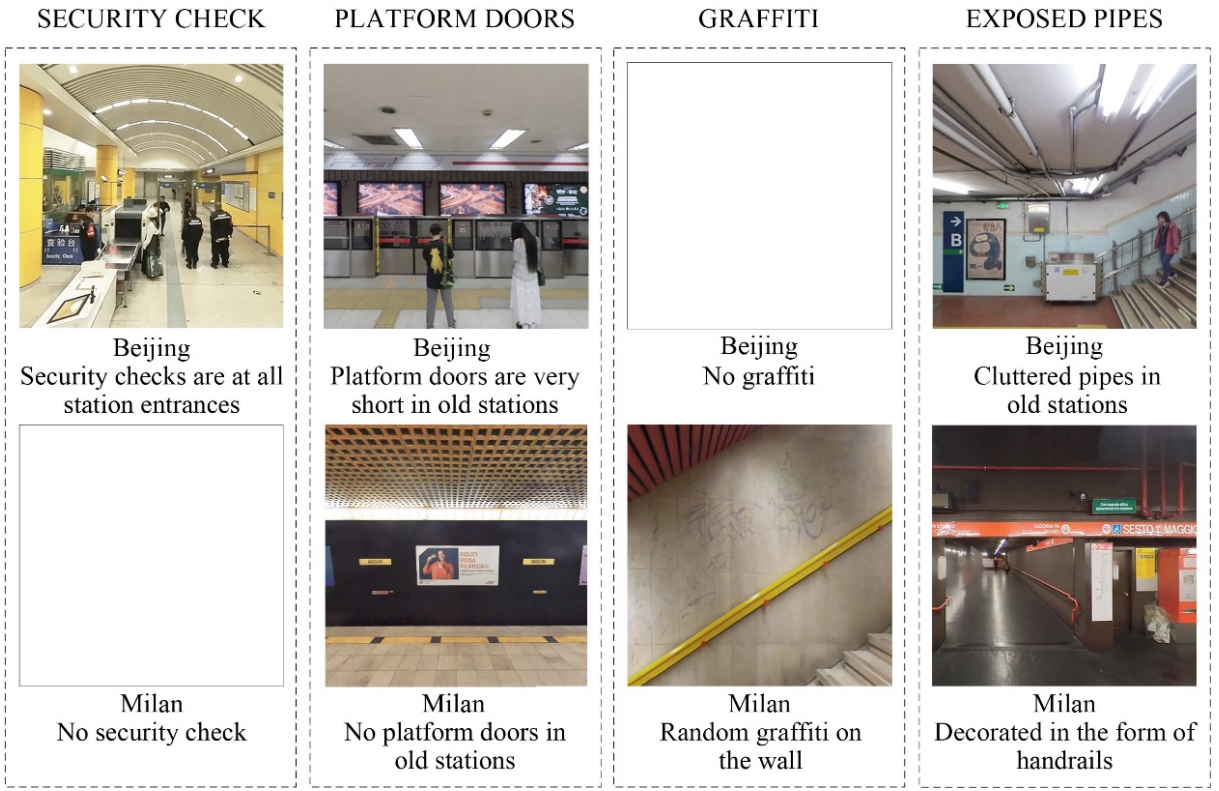
- Manual mode

  (Thirdly, for features with limited photos, YOLO training is not feasible, so we manually annotate them using Labelme)

2. Methodology

2.4 Influencing factors

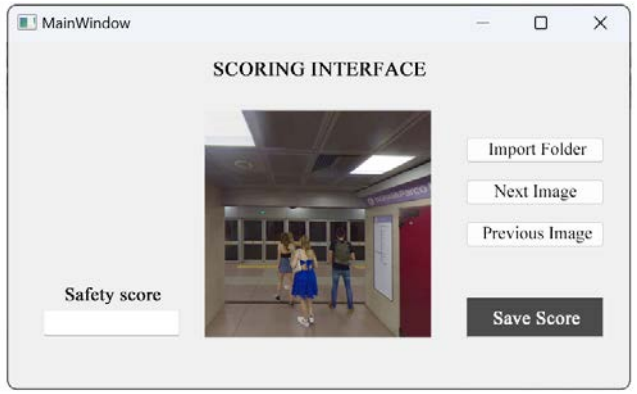
Classification	Factors	Segmentation	Sources
Visual accessibility	Light	Artificial light	(Coppola and Silvestri, 2021; Sadeghi and Jangjoo, 2022; Stjernborg, 2024)
	Enclosure	Floor	
		Wall	
		Column	
	Equipment	Platform doors	
		Stairs	
		Railing	
Surveillance	Passengers	People	(Ceccato and Paz, 2017; Coppola and Silvestri, 2021; Cui et al., 2023b; Paydar et al., 2017b; Sakip and Abdullah, 2012; Stjernborg, 2024)
	Monitor	Surveillance camera	
	Security	Security booth	
		Security check	
	Window	Visual window	
Vitality	Passengers	People	(Ceccato and Paz, 2017; Cui et al., 2023b; Paydar et al., 2017b; Stjernborg, 2024)
	Storefronts	Store / Vending machine	
	Signboards	Billboards / Signage	
	Graffiti	Graffiti	
Disorder	Broken	Broken pavement	(Ceccato and Paz, 2017; Park and Garcia, 2020; Paydar et al., 2017b)
		Broken ceilings	
		Broken walls	
	Litter	Scattered litter	
	Equipment	Exposed pipes	
	Graffiti	Graffiti	



The built environments in Milan's and Beijing's metro stations is different, our study extract and analyze factors from these two cities separately.

2. Methodology

2.5 Auditing



Volunteer auditing interfaces

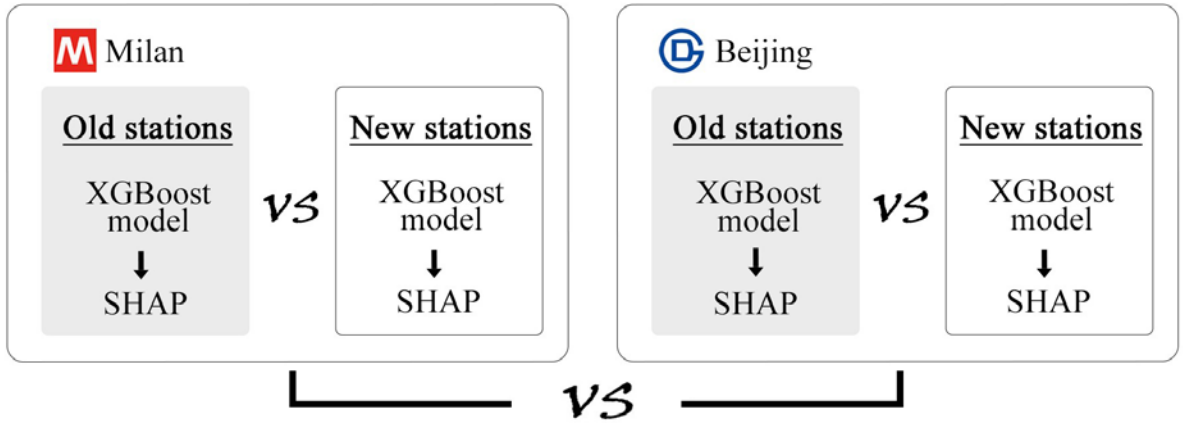
Descriptive statistics for the volunteers

Variables	Proportion/Mean (SD)
Residence (%)	
Milan	50
Beijing	50
Gender (%)	
Male	42.50
Female	57.50
Age	25.31 (4.79)
Education (%)	
High school or below	12.5
College and above	87.5

Our study develops a ***Graphical User Interface*** for volunteer auditing, enabling volunteers to assign scores that assess security perception. To ensure uniformity, all volunteers receive an operational manual outlining the criteria and score intervals. The intervals are defined as follows: below 40 denotes very insecurity, 40-60 signifies insecurity, 60-80 indicates security, and above 80 represents very security.

2. Methodology

2.6 Modeling



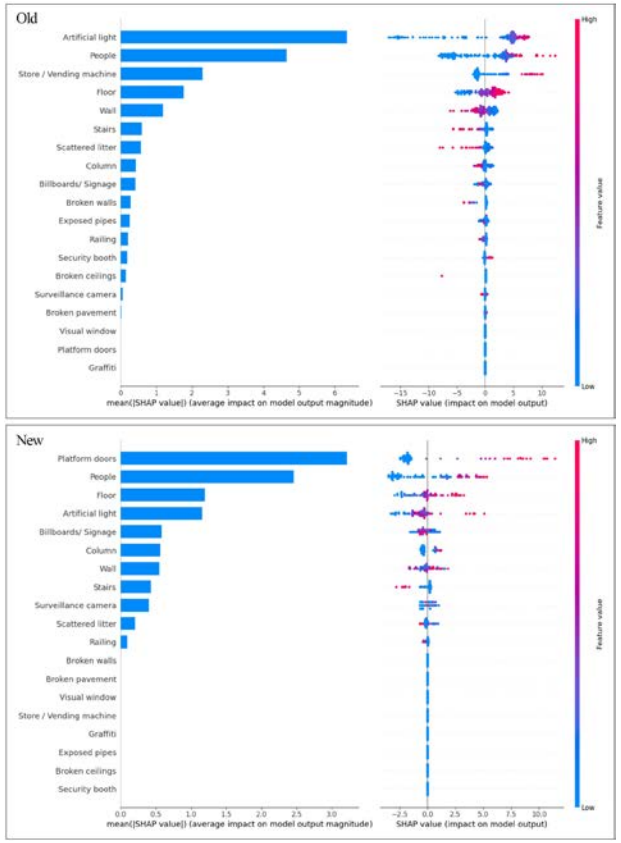
Model performances

Hyper-parameters		Criteria 1				Criteria 2			
		Milan		Beijing		Milan		Beijing	
		old	new	old	new	old	new	old	new
R-squared	Training set	0.95	0.92	0.88	0.93	0.93	0.96	0.88	0.97
	Test set	0.73	0.71	0.69	0.70	0.77	0.77	0.69	0.76
MAE	Training set	2.35	1.69	2.95	1.95	2.82	1.35	2.95	1.16
	Test set	5.24	3.39	4.82	4.10	5.13	4.04	4.82	3.31
RMSE	Training set	3.08	2.14	3.89	2.64	3.59	1.78	3.89	1.57
	Test set	7.00	4.06	6.30	5.46	6.71	5.15	6.30	4.61
MAPE	Training set	5.97	2.81	5.45	3.28	6.64	2.36	5.45	1.83
	Test set	12.26	5.59	9.63	6.83	11.83	7.80	9.63	5.33

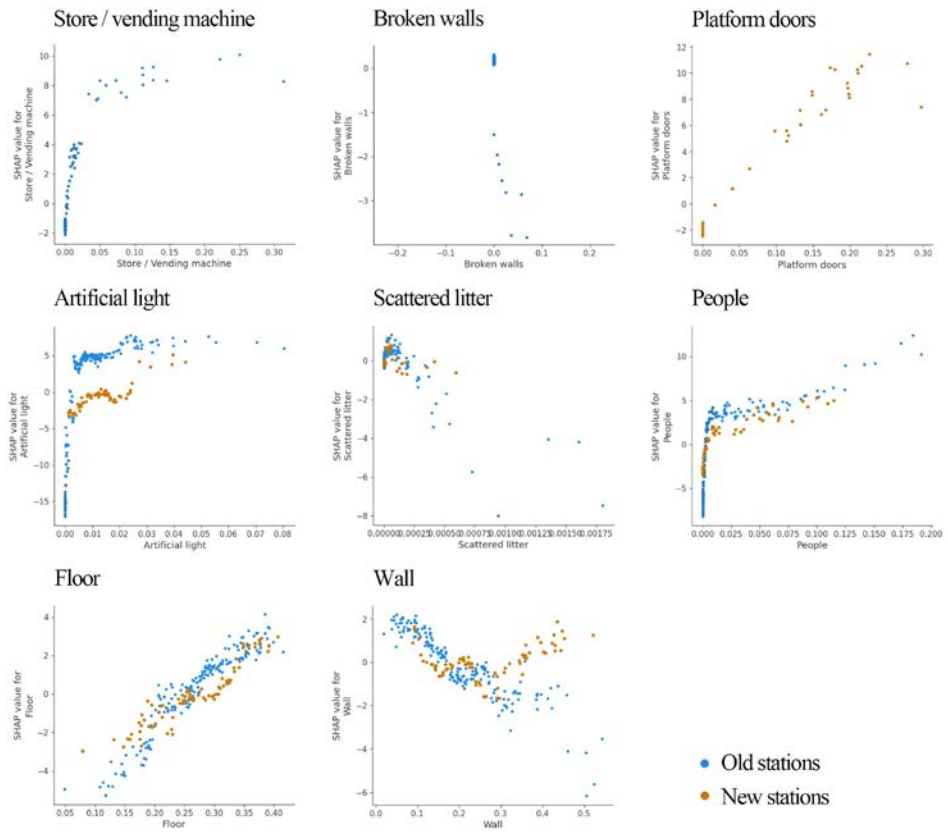
- We define the area ratio of different factors as the ***independent variable*** and the volunteer auditing scores as the ***dependent variable***
- using the ***XGBoost*** method to build regression models and ***SHAP*** for interpretation.
- Our research compares old and new metro stations in ***Milan and Beijing***, developing four distinct models for each criteria

3. Results and discussion

3.1 Results in Milan (Criteria 1)



Comparison of relative importance of factors in old and new metro stations (Criteria 1)

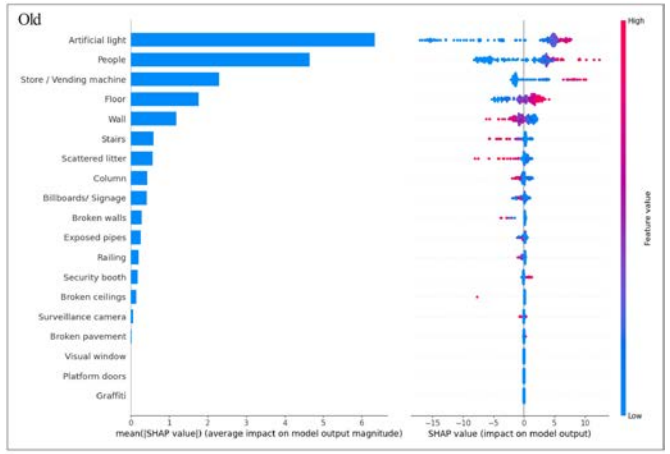


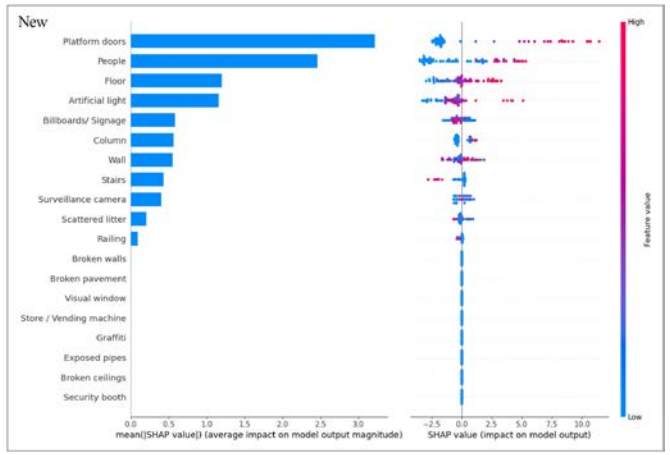
Comparison of local effects of variables on people's safety perception in old and new metro stations (Criteria 1)

- Visual accessibility: ***Artificial light*** plays a crucial role, particularly in old stations. Both old and new stations show a high correlation between ***floor area*** and safety, but ***walls*** are more significant in old stations.
- Surveillance: ***People*** are significant in both old and new stations
- Vitality: ***Stores and vending machines***, are positive impact in old stations. **Platform doors,** have more substantial impact on safety perception in new stations.
- Disorder: ***Scattered litter and broken walls*** have negative impact in old stations.

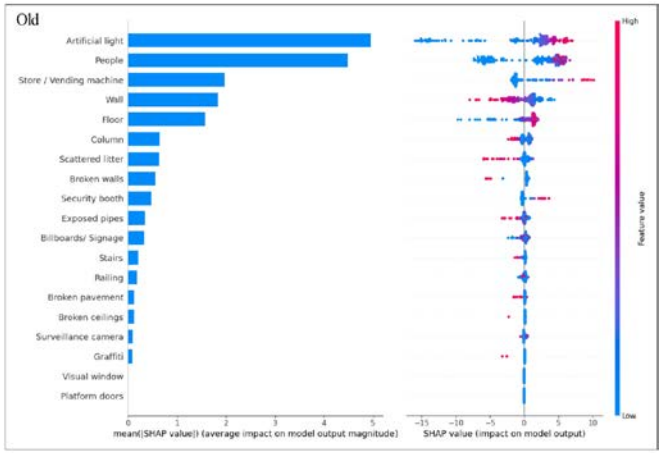
3. Results and discussion

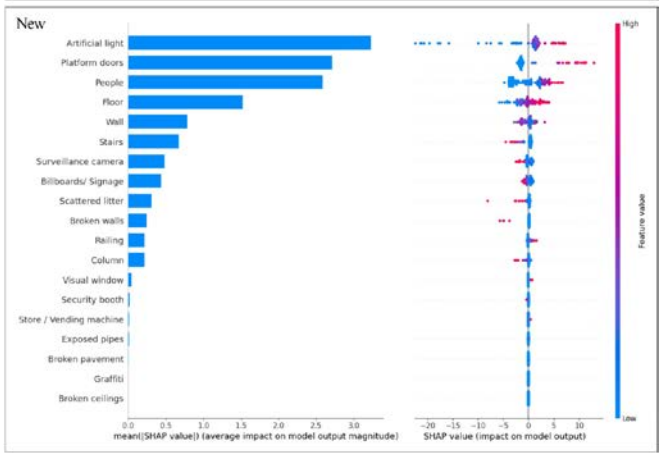
3.2 Results in Milan (Criteria 1 VS Criteria 2)



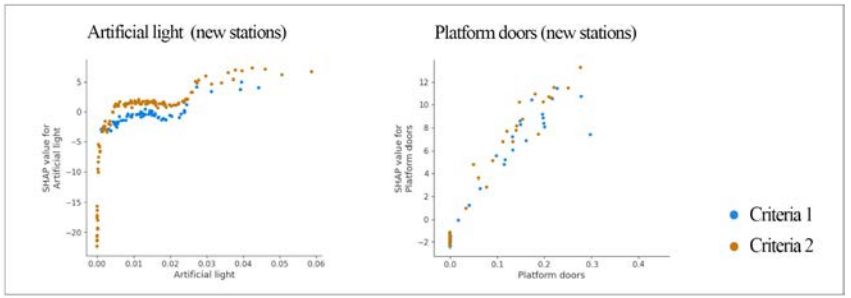


Criteria 1





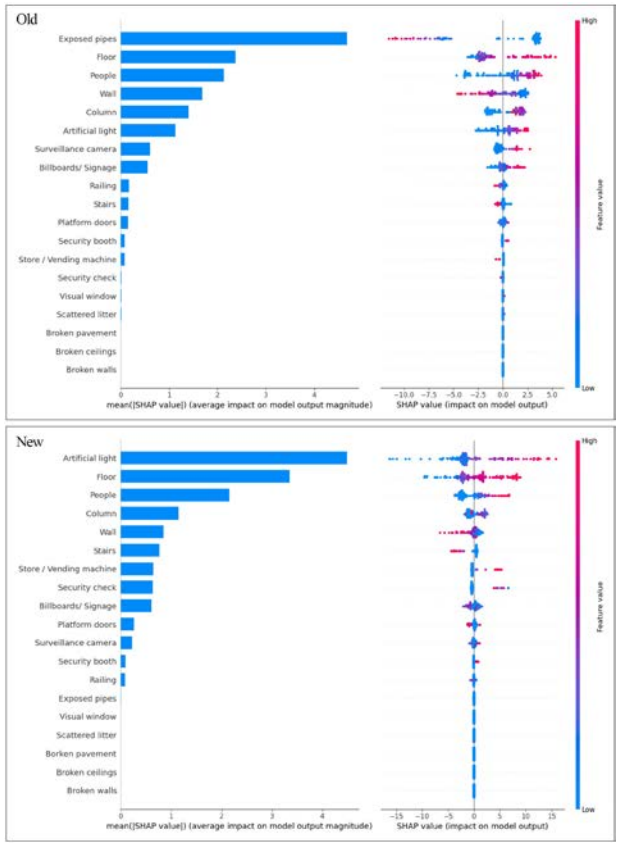
Criteria 2



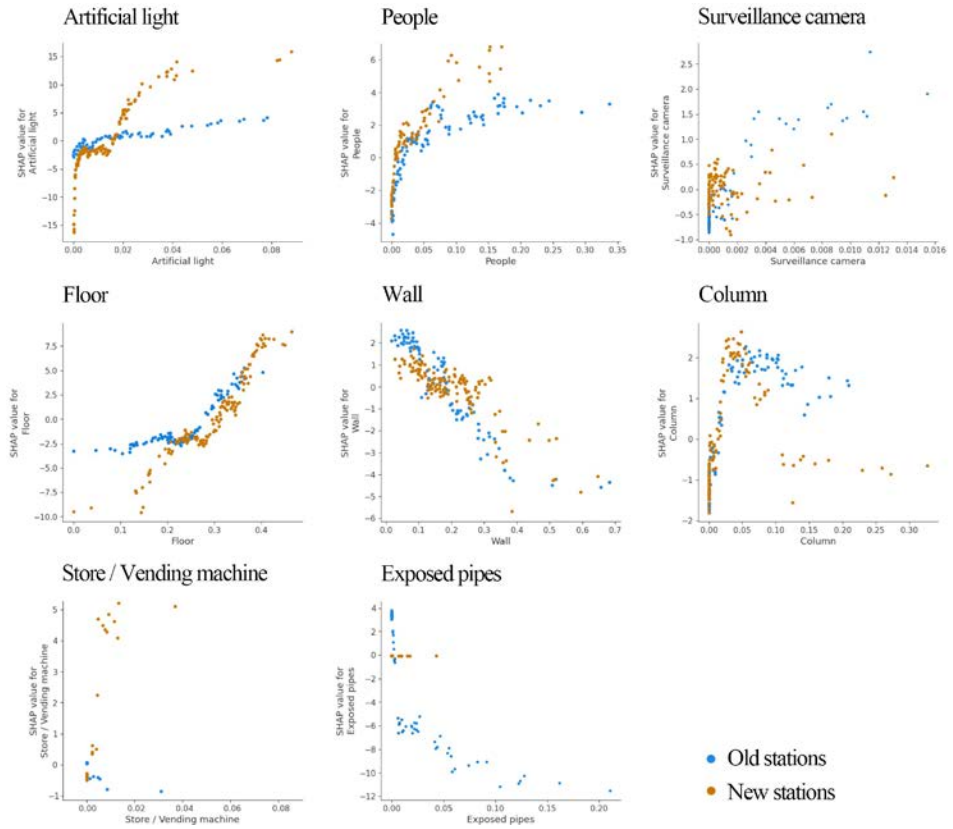
- In new stations under Criteria 1, ***platform doors*** are the most influential factor affecting safety perception. However, in Criteria 2, ***artificial lighting*** is the dominant factor.

3. Results and discussion

3.3 Results in Beijing (Criteria 1)



Comparison of relative importance of factors in old and new metro stations (Criteria 1)

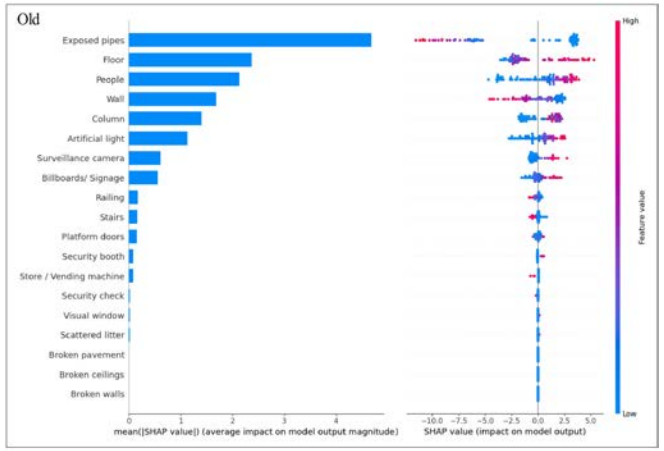


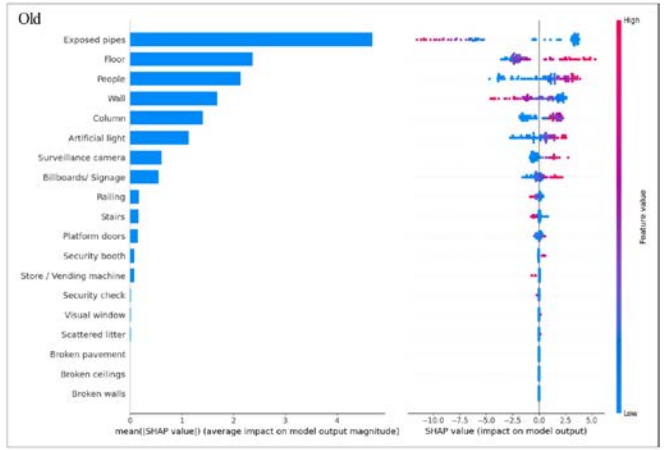
Comparison of local effects of variables on people's safety perception in old and new metro stations (Criteria 1)

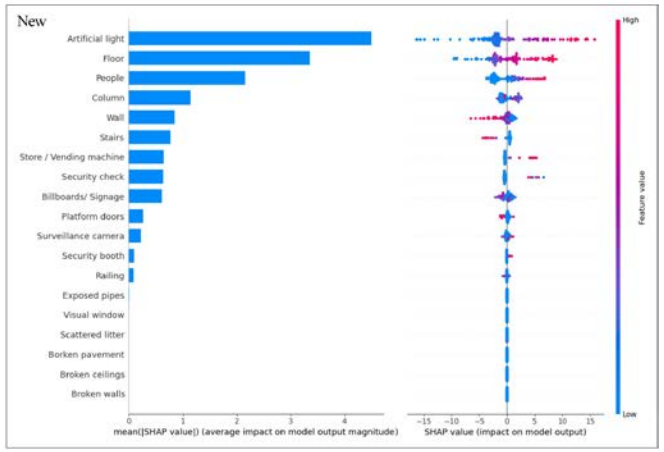
- Visual accessibility: ***Artificial light*** plays a more significant role in new stations. Elements such as ***floors, walls, and columns*** demonstrate various association with safety in both old and new stations.
- Surveillance: ***People*** are significant in both old and new stations. However, ***surveillance cameras*** are more positive in old stations.
- Vitality: ***Stores and vending machines*** is positive in new stations but slightly negative impact in old stations.
- Disorder: In old stations, ***exposed pipes*** are the most dominant explanatory variable.

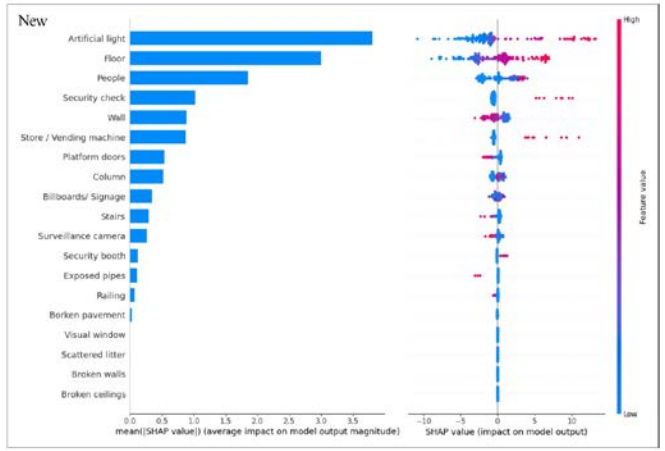
3. Results and discussion

3.4 Results in Beijing (Criteria 1 VS Criteria 2)



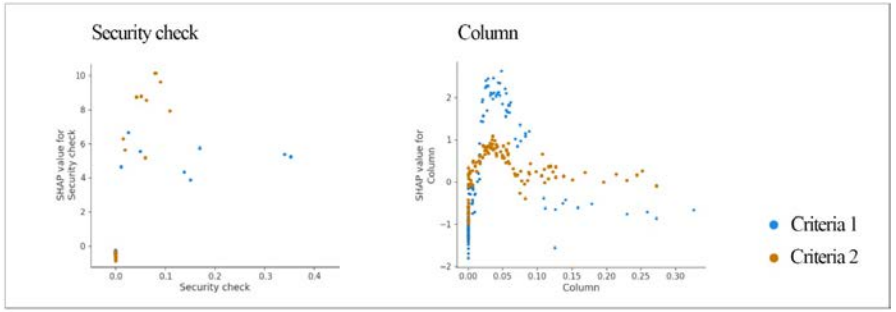






Criteria 1

Criteria 2



- The comparative analysis highlight the significant role of ***security check and column***.

3. Results and discussion

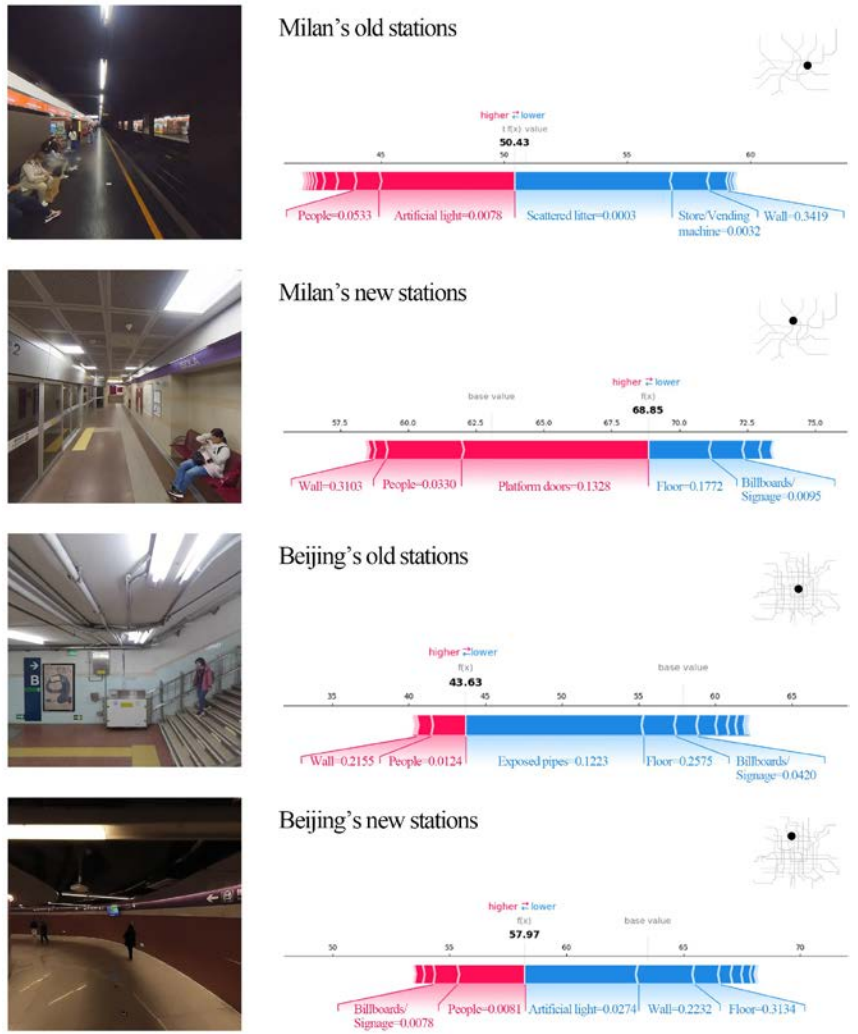
3.5 Milan VS Beijing

- Visual accessibility: Milan's oldest metro stations have ***poorer lighting*** due to aging infrastructure. However, despite being more modern, some areas in Beijing's new stations still suffer from poor lighting. Additionally, in both cities, ***floors*** is positively associated with safety perception, while ***walls*** show the opposite association.

- Surveillance: The presence of ***people*** consistently correlates with safety perception in both Milan and Beijing, regardless of the station's age. However, ***surveillance cameras*** play a more prominent role in Beijing.

- Vitality: ***Platform doors*** are present in both old and new metro stations in Beijing, they have little influence. In contrast, in Milan, platform doors only exist in new stations, where they have a strongly positive effect on safety. Additionally, ***stores and vending machines*** are common in old stations and are positively associated with safety in Milan, while in Beijing, they are limited in amount and negatively impact safety in old stations.

- Disorder: elements are all negatively associated with safety perception in both cities, particularly in older stations. In Milan, a combination of ***broken walls, ceilings, pavement, and litter*** plays a role, whereas in Beijing, ***exposed pipes*** are the dominant factor.



Localized safety perception analysis of typical spaces from old and new stations in both cities