Research Paper

Research on Healthy Street Identification and Evaluation Based on Social Media Data and Street View Imagery

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Abstract

Improving urban health is a significant challenge of the 21st century and a common good that concerns all people. Streets are important public spaces for public walking, and walking helps maintain physical and mental health and prevent infectious diseases. Therefore, it is necessary to identify and evaluate healthy streets that promote active public walking. The current construction of healthy streets lacks technical means and feedback platforms for public participation, while public active walking willingness and behavior information on social media can fill this gap. This study proposes a healthy street evaluation method based on social media data and street view images, which is used to evaluate the walking environment from the public perspective. This paper retrieves social media "Xianghongshu" posts related to "Citywalk", uses natural language processing to extract street samples, uses semantic segmentation and deep learning to process street view image data, and uses SPSS and LightGBM models to explore the predictive ability and correlation of healthy street elements and spatial perception with social media attention. The results show that the correlation between various spatial elements and social media attention is weak or insignificant, while spatial perception "safety" and "wealthy" have a significant positive correlation with social attention. Some spatial elements have a correlation with spatial perception, such as "lighting" and "greening" are positively correlated with "beautiful". In terms of social media attention prediction ability, the importance of spatial elements is lower than spatial perception. This may mean that in the dissemination and interaction of social media content, spatial perception features are more important than spatial elements. Therefore, when urban planners evaluate streets from the perspective of public participation, they can first clarify the design objectives from the perspective of improving spatial perception, and then focus on the spatial elements related to such perception.

Keywords

Health Street, Citywalk, Deep learning, Social Media, SVI, Public Engagement

1. Introduction

Health is supposed to be integrated into all policies so as the development of urban area should be centred on people's health, declaring by the World Health Organization inspired by Ottawa Charter for Health Promotion. Urban built environment affects health, so how to reduce health risks and enhance health potential through urban design has become a hot topic. Optimising the walking environment and building healthy streets are good to reduce the risk of non-communicable diseases caused by unhealthy lifestyles such as sedentary behaviour and reduced physical activity (Rosenberg, P. et al., 2016).

Public participation is a method that can be used to evaluate and optimise street design. The American-Canadian theorist Jane Jacobs was the first to advocate for public participation in the construction of safe and vibrant urban streets in the 20th century. Her approach to understanding urban space and her perspective have been revisited and have inspired urban development for different contexts and needs (Hirt & Zahm, 2012). For example, many social organisations promote community environmental improvement by organising urban walking events (e.g. Jane's Walk) and conducting bottom-up neighbourhood environmental and built environment assessments (Gómez-Varo, I. et al., 2022). Existing design research has shown the improvement of urban pedestrian environment can promote community participation (Hassen, N. and Kaufman, P., 2016), such as improving sidewalks, increasing connectivity, and optimising lighting and street furniture (Rogers, S.H. et al., 2013). Street design optimisation and promoting public participation are mutually reinforcing.

In today's Chinese social media, urban walking activities represented by "Citywalk" have become a way of exploring the built environment of the streets. At the end of 2023, Xiaohongshu and Chinese Academy of Social Sciences jointly released the "2023 Annual Life Trend Observation Report." "Citywalk" was selected as one of the top ten lifestyle keywords, and related topics were viewed more than 2.1 billion times. Citywalk is an active physical activity that integrates walking into leisure and entertainment, which can promote health. The preference for Citywalk in social media can to some extent reflect people's willingness and spatial tendency to engage in active walking activities. For a long time, due to the high cost of communication and limited public participation channels, the public voice for improving the health of the built environment has been weak. Current healthy street assessments rely heavily on traditional methods such as questionnaires and scoring assessments. The application of big data is still in its infancy, and fewer attention has focused on the potential contribution of social media to optimise the walking environment and healthy street assessments. Therefore, studying social media data related to "Citywalk" topics can supplement the long-standing lack of public participation in street design and the insufficient basis for healthy street assessments. It can also provide a good sample for summarising the characteristics of healthy street spatial elements, which is of positive significance for the construction of refined healthy cities.

2. Conceptual framework

2.1. Literature review

The impact of streets on public health has become a consensus. Healthy streets shift the focus from cars to people by limiting health risks, promoting healthy behaviours and enriching health resources, so as to meet people's needs for physical and mental health development. The streets walkability is crucial factor that promotes physical activity in the built environment . Integrating physical activity into daily life leads to better health (Sallis, J.F. et al., 2012). As one of the most important evaluation criteria to characterize healthy streets, walkability measurement is helpful to identify and evaluate healthy streets. Related research (Jensen, W.A. et al., 2014) has identified the difference between audited walkability as an objective standard for assessing the walking environment and perceived walkability as a subjective standard for assessing the walking experience, and advocates combining the two to better identify and assess the quality of streets. Objective evaluations are often based on surveys and assessments by professionals and institutions, such as surveys on land use diversity, number of street intersections, traffic flow, public transport connectivity, linearity of walking routes, width of pavements, lighting, number of residents or commuters and vegetation coverage, to assess whether a street is convenient, accessible, has a sense of community, is comfortable and safe(Baobeid, A. et al., 2021； Cerin, E. et al., 2006; Frank, L.D. et al., 2005). Subjective evaluation focuses more on the experience and feelings of pedestrians and residents. It assesses the convenience, safety, walkability, thermal comfort, aesthetic attributes and infrastructure quality of the street through surveys, group discussions, interviews, etc (Cerin, E. et al., 2006; Ewing, R. et al., 2009; Kim, S. et al., 2014; Baobeid, A. et al., 2021). Some scholars combine objective and subjective evaluations, using psychological greenery, visual congestion, outdoor enclosure and visual walkways indicators to form a framework for walkability that combines the feature extraction techniques of objective evaluation and the perception of subjective evaluation (Zhou, H. et al., 2019). The combination of subjective and objective evaluations can more comprehensively and accurately identify and assess the pedestrian environment on the street, providing a basis for subsequent healthy street construction.

2.2. SVI in Healthy Streets Assessment

Compared to other data, street view images are closer to the perspective of a person's perceptual experience of a space and have unique advantages in healthy street assessment. Taking green space exposure metrics as an example, open, standardised, geo-referenced, wide-coverage streetscape views can provide new exposure measures for epidemiological studies, and the measured exposure measures are less correlated with traditional methods such as NDVI, and are better able to exclude interferences such as community-based socio-economic factors in health studies (Larkin, A. and Hystad, P., 2019). For street users, daily exposure to greenery is more important than greenness metrics, with visual levels of street greenery (rather than HDVI) being positively correlated with cycling probability (Lu, Y. et al., 2019)， and more strongly associated with propensity to choose practical walking activities.

Developments in deep learning and computer vision have provided significant support for understanding street scene images, with large-scale models and large-scale image datasets facilitating the execution of tasks such as scene classification, target detection, and semantic analysis (Zhang, F. et al., 2024). With the help of datasets trained on a large number of labelled images, such as Place 2 and ADE20K, the spatial elements of street view images are segmented, extracted, classified, and become the basis for quantitative analysis. Previous studies on health related to environment relies on field surveys and questionnaire interviews to collect information about the physical environment (Gullón, P. et al., 2015), which is quite time-consuming and the evaluation is susceptible to subjective factors. Street view images, which are captured in abundant quantities over short periods of time, are also more advantageous in identifying health-related visual elements such as greenery, pavements, food advertising lights, etc (Chen, J. et al., 2023).

Machine learning algorithms provide an effective and high-performing approach for information extraction in complex street environments（Zhou, H. et al., 2019). Numerous studies have showed how to audit and assess the impact of the built environment through street view imagery. Some studies have demonstrated how street view imagery act in assessing the impact on public health. For example, street view imagery assessments have identified ways to improve the walking experience and safety (Wu, Y.T. et al., 2014; Wang, R. et al., 2019) to promote physical health, identify unhealthy food and drink advertising to warn of poor dietary environments (Boyland, E.J . et al., 2016), and the natural environment can also be identified to guide psychological recovery (Quinn, J.W. et al., 2019; Hyam, R., 2017), improve mental health such as depression (Wu, Y.T. et al., 2014).

2.3. Social Media Data for Healthy Streets Assessment

People's perceptions of streets are critical to assessing their health. Traditional survey methods for spatial assessment rely on long-term fieldwork and limited survey samples, such as Kevin Lynch's cognitive maps, Jane Jacobs' observation records, and William White's behavioural observations. In recent years, with the help of social media and online platforms, a large amount of individual spatial preference and perception information has been collected, and the sample size and credibility of spatial assessments have greatly increased. (1) Social media data can reflect health behaviours. Lu et al. (2021) observed an association between the use of urban nature parks and the severity of epidemics during Covid-19 and noted that large, inexpensive urban green spaces can strengthen the resilience of communities in coping with crises and epidemics. (2) Social media data can foretell health risks. Peng C. (2020) used machine learning techniques to build models that can assess and analyse HPV vaccination issues and individual depression and anorexia through social media data. (3) Social media data can optimise health resources. Zhang R. (2020) used social media data and facial expression reading as technical support to explore the mechanism of blue space on public physical and mental health, and put forward a proposal to enhance the accessibility and openness of the space to promote the public's physical activity and positive emotions. Social media is a good source of data for the Healthy Streets Assessment because it can reshape the power structure in urban planning, engaging citizens, professionals, and third parties in communication and collaboration (Lin, Y., 2023). Based on this, this paper hopes to explore the correlation between social media data and healthy spatial elements and spatial perception.

3. Healthy Streets Assessment

3.1. Research framework

This paper constructs a conceptual framework to identify and evaluate healthy spatial elements in street view images that promote walking by reflecting walking intentions using data from social media-related topics and simulating walking experiences using street view image data. The information provided by this study can help inform design decisions for healthy streets.

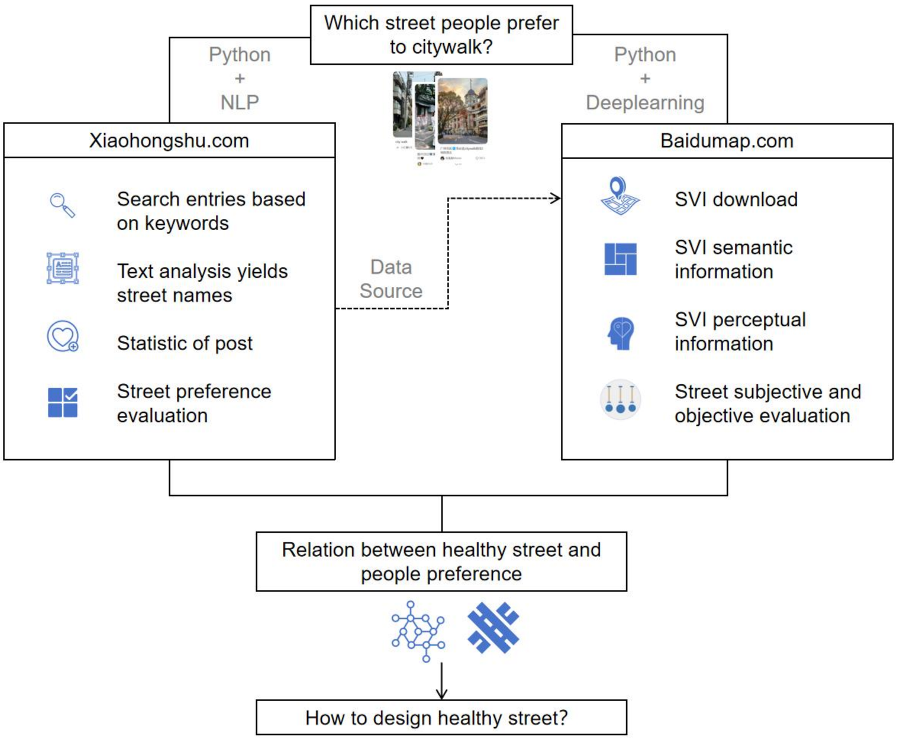


Figure 1. Conceptual framework. Source: Author.

3.2. Assessment system

The aim of this paper is to construct a system for identifying and evaluating healthy street elements based on SVI images. As there are many dimensions and indicators to characterise healthy streets, the research is based on a literature review and divides the street space into three types of space: architectural interface, motorized space and non-motorized space, and screens 12 spatial elements as quantitative indicators. Among them, the architectural interface focuses on the spatial enclosure of the street, the motorised space focuses on the degree of motorisation and the friendliness to slow traffic, and the non-motorised space focuses on whether it is suitable for walking, cycling and staying.

Building a healthy street element recognition and evaluation system based on street view imagery is the purpose of this study. Because there are many dimensions and indicators to characterize healthy streets, based on literature review, the street space is divided into three categories: architectural interface, motorized space and non-motorized space. 12 spatial elements are screened as quantitative indicators of audited walkability and their positive and negative impacts on health are discriminated (Table 1) .Among them, the architectural interface is concerned with the spatial enclosure of the street, the motorized space is concerned with the degree of motorization and the friendliness of walking, while the non-motorized space is concerned with whether it is suitable for walking, cycling and staying. Spatial elements in street view images can be identified by semantic segmentation, and corresponding parameters can be formed by calculating the percentage of elements in the image, which provides a basis for subsequent analysis (Table 2). At the same time, in order to better identify and evaluate the quality of streets, the man-machine confrontation scoring framework proposed by Yao Yao et al to describe perceived walkability is adopted in this study, and 6 parameters on street spatial perception are formed: "beautiful", "safety", "depressing", "wealthy", "lively", "boring".

Classification	Street elements	Health effect	Content
Architectural Interface	Building	+	Buildings, walls, fences, etc. can form visual enclosures (Wang, R. et al., 2019), which have a positive health impact on special groups with reduced walking ability, such as the elderly and children (Vanwolleghem, G. et al.,
	Wall	+	
	Fence	+	
	Sky	-	Higher visual enclosure (i.e. lower sky ratio) makes pedestrians feel safer and more comfortable, thus increasing the likelihood of walking (Ewing, R. & Handy, S., 2009). In addition, due to the street thermal effect, the proportion of the sky in the SVI is moderately negatively correlated with pedestrian flow and the walking index (Yin, L. & Wang, Z., 2016).
Motorised Space	Road	-	Motor vehicle speed is negatively correlated with road safety (Lee H et al., 2019)
	Motor vehicle	-	Obstacles in the street, such as parked cars and billboards, are a source of traffic congestion and reduce the willingness of pedestrians to walk (Lee, He, & Sohn, 2017).
	Crossing facilities	+	Pedestrians are willing to spend more time using signalised crossings and less time using footbridges and underpasses, especially women and older people (Anciaes, P.R. & Jones, P., 2018).
	Traffic signs	+	Traffic signs increase the orderliness of the environment, reduce cognitive load, and alleviate negative emotions caused by the environment (Yin, L. & Wang, Z., 2016).
Non-motorised Space	Lighting	+	Street lighting improves the visibility of spaces and increases the psychological safety of pedestrians (Li W., 2016)
	Street furniture	+	The length of street furniture is positively correlated with the social behaviour of pedestrians and negatively correlated with commercial activity (Xu, L. & Kang, Q., 2014).
	Sidewalk	+	The ratio of road area to sidewalk area in the pedestrian's field of vision affects the pedestrian's feelings and behaviour (Zhou, H. et al., 2019).
	Greening	+	The quality and quantity of street greenery are positively correlated with leisure physical activity, and the higher the street greenery rate, the healthier the street (Lu, Y., 2019).

Table 1. The health effects of spatial elements in SVI. Source: Author.

Classification	Definition	Elements	Symbols	Content	Data type
Architectural Interface	Architectural interface enclosure	Building	B_n	The proportion of the pixel area of walls, fences and buildings to the total pixel area	percentage
		Wall fence	I_n		
		Sky	K_n	The proportion of the pixel area of the sky in the SVI	percentage
Motorised Space	The degree of motorisation and the degree of friendliness to pedestrians in motorised spaces	Road	R_n	The proportion of the pixel area of the road in the SVI	percentage
		Motor vehicle	V_n	The proportion of the area of the pixels of the motor vehicle in the SVI	percentage
		Crossing facilities	C_n	Presence or absence of pedestrian crossings, overpasses and other facilities for crossing the street in SVI	Boolean (0 or 1)
		Traffic signs	P_n	Presence or absence of traffic signs in SVI	Boolean (0 or 1)
Non-motorised Space	The degree to which non-motorised spaces are suitable for walking, cycling and staying	Lighting	L_n	The proportion of the pixel area of the lighting facilities in the SVI	percentage
		Street furniture	F_n	The proportion of the pixel area of the street furniture in	percentage
		Sidewalk	D_n	The proportion of the pixel area of the sidewalk in the SVI	percentage
		Greening	T_n	The proportion of the pixel area of the greening in the SVI	percentage

Table 2. Measurement of spatial elements in SVI. Source: Author.

3.3. Data source and processing

The study selected Xiaohongshu, a Chinese platform with 300 million monthly active users, as the data source. On January 25, 2024, the author retrieved a total of 1,918 posts related to the theme of street walking by searching for keywords such as "Citywalk", "Jane’s Walk", "city observation". The data of the related posts includes basic information of the posts (title, post link, text, post cover, publication time, IP address, location information, keywords), post influence (number of shares, likes, and comments), author information (gender, author's age, author's occupation), and author influence (number of followers, fans, and likes and collections). Since posters often publish their posts a few days after their outings, the obtained "IP address" and "location information" do not accurately reflect the specific locations and streets mentioned in the text. Therefore, this study prioritized natural language processing for text recognition, determining the locations described in the posts by analyzing the 'title' and 'text'. As the "post cover" photos are taken from various angles and do not adequately reflect the street scenery, Baidu Maps' street view was chosen as a supplement. Based on the street names, panoramic images of all sample streets were obtained using Python and the Baidu API. The study employs the algorithm inplace-ABN (Bulò, Porzi, and Kontschieder 2018) and the pre-trained dataset Label mapping in the Mapillary Vistas dataset (Neuhold et al. 2017) for semantic segmentation of the data. After data cleansing, natural language processing, and summary statistics, a total of 894 streets were obtained as research samples.

Number	Elements	Type	Remark
1	Building	Construction	independent variable
2	Wall	Construction	independent variable
3	Fence	Construction	independent variable
4	Sky	Sky	independent variable
5	Road	Flat	independent variable
6	Motor vehicle	Vehicle	independent variable
7	Crossing facilities	Construction	independent variable
8	Traffic signs	Object	independent variable
9	Lighting	Object	independent variable
10	Street furniture	Object	independent variable
11	Sidewalk	Flat	independent variable
12	Greening	Object	independent variable

Table 3. Segmentation items in this research dataset. Source: Author.

4. Results and discussions

4.1. Topic trend

From the perspective of time distribution, the topic of "Citywalk" began to attract attention from April 2021, and the topic popularity continued to rise from 2023 and reached the peak of discussion in August 2024, after which the topic popularity declined (Figure 2).

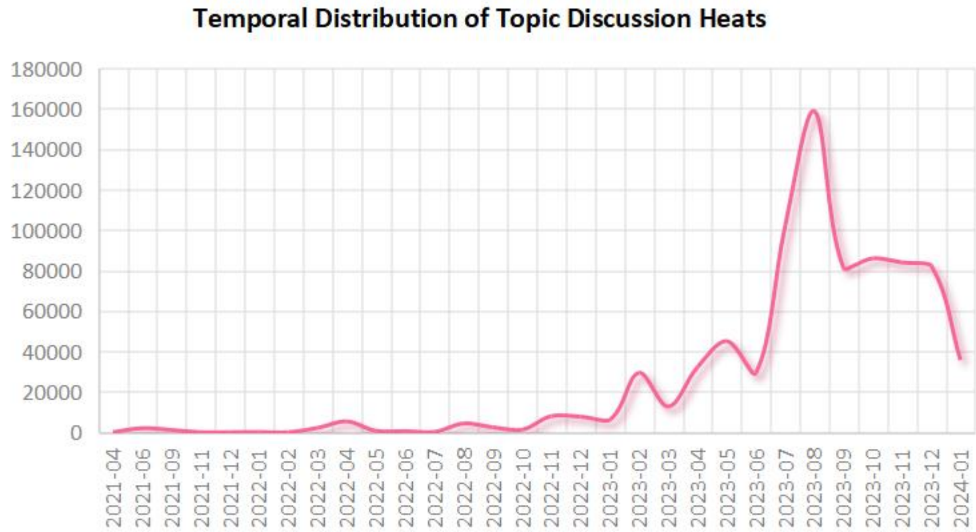
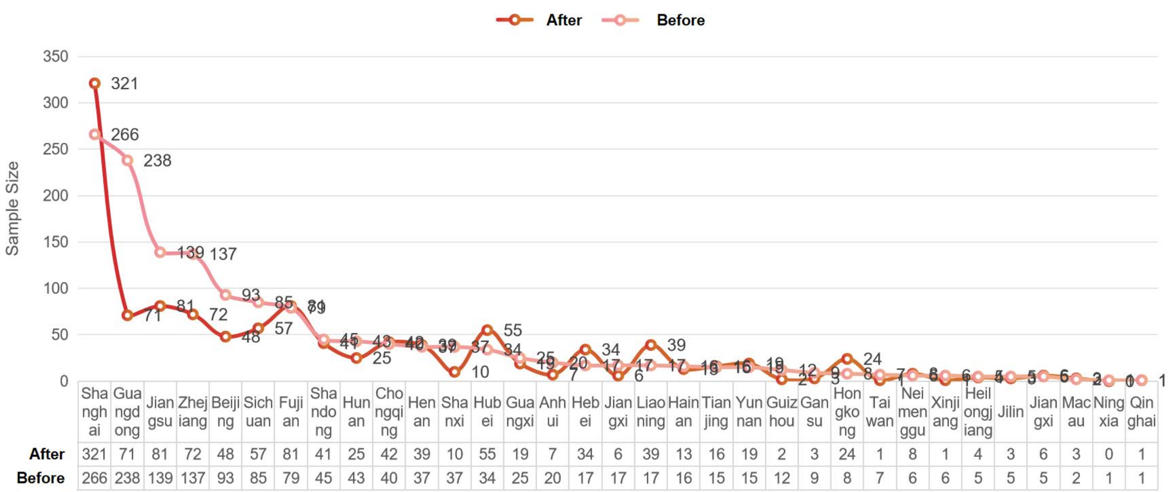


Figure 2.Time heat of the topic. Source: Author.

Natural language processing (NLP) has improved the accuracy of the description of the social information source region (IP) (Figure 3), and Shanghai is the city with the highest output of relevant social content. Regions such as Jiangsu, Zhejiang and Shanghai saw the most posts, while eastern and central China saw higher interest in the topic.



	Shanghai	Guangdong	Jiangsu	Zhejiang	Beijing	Sichuan	Fujian	Shandong	Hunan	Chongqing	Henan
After	321	71	81	72	48	57	81	41	25	42	39
Before	266	238	139	137	93	85	79	45	43	40	37

	Shanxi	Hubei	Guangxi	Anhui	Hebei	Jiangxi	Liaoning	Hainan	Tianjing	Yunnan	Guizhou
After	10	55	19	7	34	6	39	13	16	19	2
Before	37	34	25	20	17	17	17	16	15	15	12

	Gansu	Hongkong	Taiwan	Neimenggu	Xinjiang	Heilongjiang	Jilin	Jiangxi	Macau	Ningxia	Qinghai
After	3	24	1	8	1	4	3	6	3	0	1
Before	9	8	7	6	6	5	5	5	2	1	1

Figure 3. Provinces distribution using natural language processing. Source: Author.

From the perspective of regional differences, there are differences in the interaction amount of content published in different regions at different time points. Posts from Shanghai, Zhejiang, Guangdong and other places have a higher volume of interaction since May 2023, indicating that these cities have a higher social focus on the walkability of urban streets (Figure 4). In terms of gender differences, Shanghai, Henan and Zhejiang provinces had higher interaction volume for male content posts, while most other regions had lower interaction volume. The regions with the highest interaction volume of women's content are Shanghai, Jiangsu, Hubei, Zhejiang, Guangdong and Beijing. The overall trend shows that women post more interactive content than men, especially in Shanghai, Zhejiang and Guangdong (Figure 5).

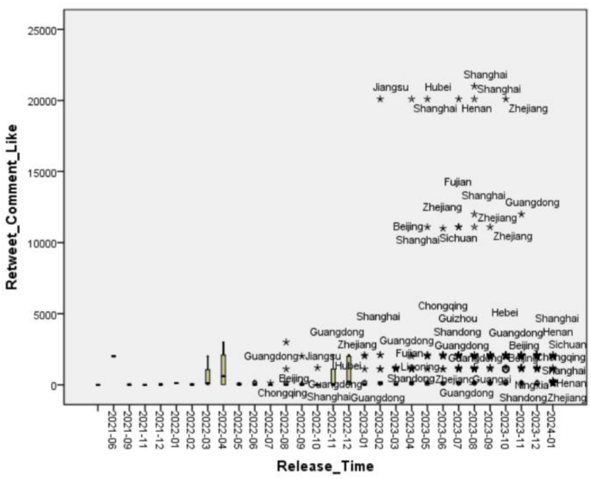


Figure 4. Discussions in different places at different times. Source: Author.

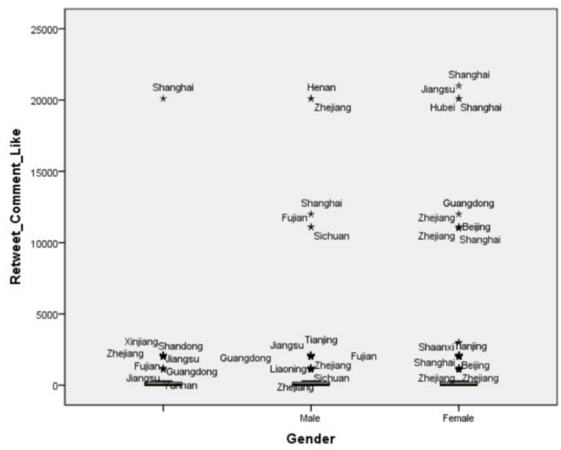


Figure 5. Discussion of different genders in different regions. Source: Author.

4.2. Correlation analysis

The study leveraged SPSS version 22 to perform one-tailed Pearson correlation tests on a spectrum of feature values, and subsequently employed Python to generate the correlation matrix heatmap (**Figure 6**). The findings reveal that while correlations between various spatial elements and social attention are generally weak or non-significant, perceptions of "safety" and "wealthy" are notably correlated with social attention at a significant level ($p<0.01$). Furthermore, among the spatial elements, the correlation coefficient between buildings and the sky is 0.215 ($p<0.01$), between roads and traffic signs is 0.233 ($p<0.05$), and between sidewalks and greening is 0.325 ($p<0.01$), all of which point to significant positive correlations. This implies that these pairs of elements act as common influencers in street scenes, collectively impacting environmental quality. Additionally, there exists a correlation between spatial elements and spatil perception; for instance, the correlation coefficient between lighting and the perception of beauty is 0.139 ($p<0.05$), indicating a significant positive correlation. This suggests that adequate lighting may enhance the aesthetic appeal of the environment. In a similar vein, the correlation coefficient between greening and the perception of beauty is 0.325 ($p<0.01$), which suggests that the extent of greenery significantly influences the environment's aesthetic appeal positively.

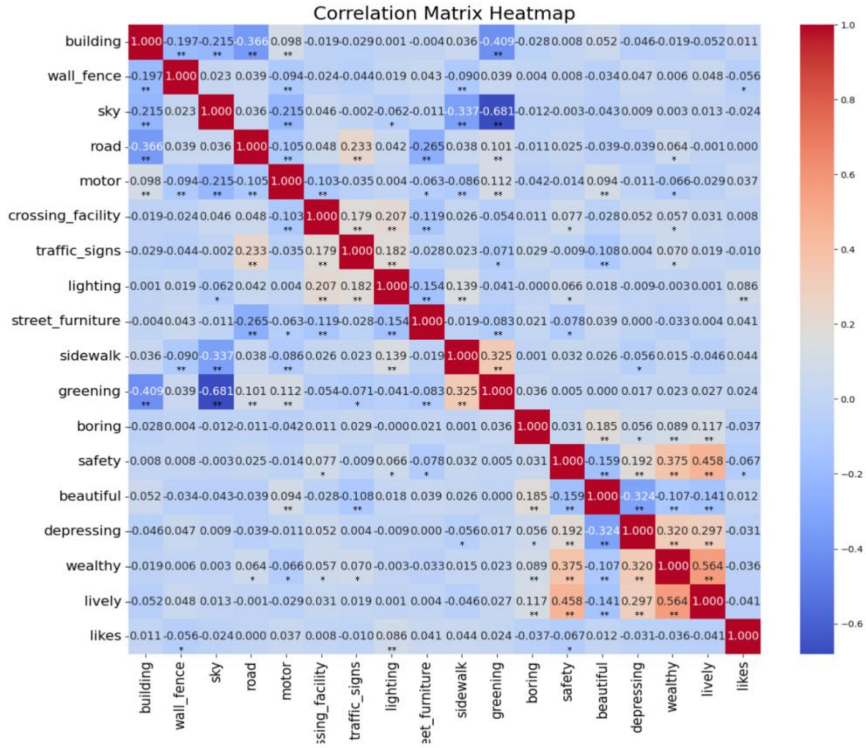


Figure 6. Correlation matrix heat map. Source: Author.

4.3. Weight analysis

To explore the predictive power of various spatial elements and spatial perceptions on social attention, the study employed the LightGBM model to learn from the data. The SHAP values, which elucidate the outcomes of the LightGBM model, are depicted in the following figure (Figure 7). Arranging the spatial perceptions that positively influence social media content attention according to their feature importance, they are, in order: a high "beautiful" value, a low "oppressive" value, a high "active" value, a high "wealthy" value, a high "safety" value, and a low "boring" value. In contrast, the feature importance of spatial elements is lower than that of spatial perceptions. The spatial elements that positively influence social media content attention are, in order: a high "street furniture" value, a low "road" value, a low "motor vehicle" value, a high "lighting" value, a high "greening" value, and a high "crosswalk facilities" value, while "traffic signs," "sky," "fences," and "buildings" have little impact on the predictive results. This is in line with the previous judgments on the health impacts of various spatial elements and also indicates that some elements has no influence on the predictive outcomes of health street attention based on the street view and social media. This may imply that in the dissemination and interaction of social media content, spatial perception features are more important than spatial element features. This finding challenges the inherent cognition of urban planners, who tend to believe that simply increasing or decreasing a single spatial element can enhance the walkability of streets, neglecting the fact that assessments of streets should first focus on spatial perceptions.

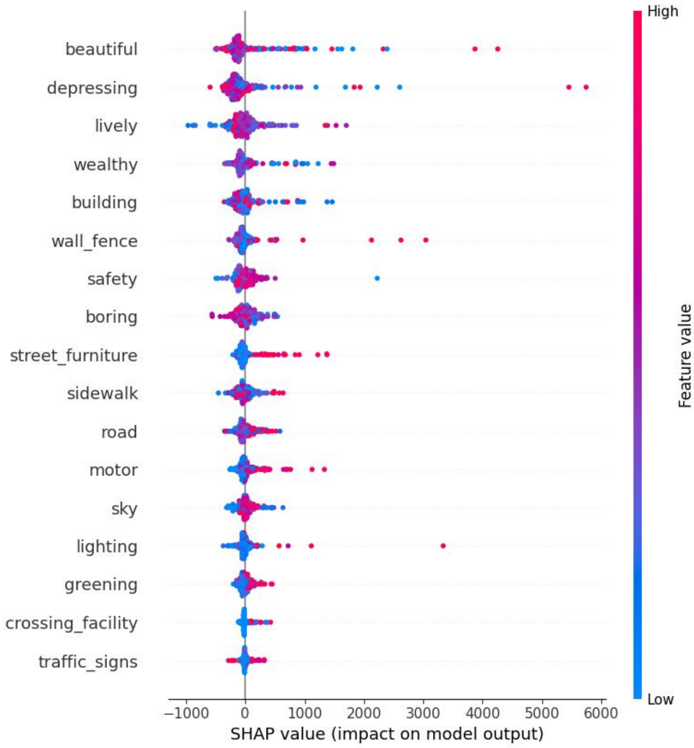


Figure 7. SHAP values of various elements. Source: Author.

4.4. Academic innovation

From the perspective of data sources, the study utilized Xiaohongshu, one of the most popular Chinese social media platforms among young people, as its data source. Compared to other social media platforms, posts on Xiaohongshu regarding urban space topics typically feature more detailed textual descriptions and a higher level of interactive influence, with address information also being more readily available. In terms of information processing methods, the study employed natural language processing based on textual descriptions to extract location information from the text, thereby enhancing the accuracy of the sample street information. Methodologically speaking, the study explored the correlation between social media content attention and spatial elements as well as spatial perceptions, proposing a strategy that prioritizes spatial perceptions over the improvement of spatial elements in the assessment of healthy streets.

4.5. Existent insufficiency

Although street view imagery shows great potential for assessing healthy streets, there are problems with the temporal and spatial coverage of the data (Larkin, A. and Hystad, P., 2019). It is challenging to randomly selecting a street view from a human perspective to represent the average level, as there are differences in the years and seasons when different streets are photographed. For elements with seasonal distribution differences, such as greenery, it is difficult to eliminate this part of the error. At the same time, for elements with spatial distribution differences, such as crossing facilities, streetlights, and street furniture, the reliability of street view images may be reduced. There is controversy over the positive or negative health effects of individual spatial element indicators. For example, in different climatic regions, pedestrians' sensitivity to the proportion of sky area varies, and even within the subtropical region, preferences differ across seasons. As a result, the final model fitting shows that such elements have no predictive power. Looking at the coverage of the study population, the main users of the social media platform Xiaohongshu are young people aged 18-34, with a user ratio of about 30% male and 70% female, thus our results have certain limitations. The time span of our data collection is from April 2021 to January 2024, with a limited sample size, and the model fit and related trends await further refinement with an increase in sample size.

5. Conclusions

Our research findings indicate that integrating spatial elements and perceptions from street view images with social media data constitutes an effective method for street assessment. Social media data offers subjective evaluations of popular streets, while objective parameters relies on street view imagery. By comparing subjective and objective data, we can analyze the correlation between the two, providing a reference for the weighting and revision of indicators in a healthy street assessment system, and facilitating the implementation of design practices. This study aids governments and relevant designers in quickly grasping the dynamics of internet data while saving labor and material costs, and in reviewing and guiding the construction of healthy cities in a context-specific and gradual manner.

Funding/Support: This study was supported by the Project on Theories and Methods of Green Construction for Large-scale Projects in Subtropical Meso-scale Cities (Grant No. 2022KA01), which is a self-directed research topic of the National Key Laboratory of Subtropical Architecture and Urban Science, South China University of Technology.

6. References

Anciaes, P.R. and Jones, P. (2018) ‘Estimating preferences for different types of pedestrian crossing facilities’, *Transportation research part F: traffic psychology and behaviour*, *52*, pp.222-237.

Baobeid, A., Koç, M. and Al-Ghamdi, S.G. (2021) ‘Walkability and its relationships with health, sustainability, and livability: elements of physical environment and evaluation frameworks’, *Frontiers in Built Environment*, *7*, p.721218.

Boyland, E.J., Nolan, S., Kelly, B., Tudur-Smith, C., Jones, A., Halford, J.C. and Robinson, E. (2016) ‘ Advertising as a cue to consume: a systematic review and meta-analysis of the effects of acute exposure to unhealthy food and nonalcoholic beverage advertising on intake in children and adults’, *The American journal of clinical nutrition*, *103*(2), pp.519-533.

Bulo, S.R., Porzi, L. and Kontschieder, P. (2018) ‘In-place activated batchnorm for memory-optimized training of dnns’, In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 5639-5647).

Cerin, E., Saelens, B.E., Sallis, J.F. and Frank, L.D. (2006) ‘Neighborhood Environment Walkability Scale: validity and development of a short form’, *Medicine and science in sports and exercise*, *38*(9), p.1682.

Ewing, R. and Handy, S. (2009) ‘Measuring the unmeasurable: Urban design qualities related to walkability’, *Journal of Urban design*, *14*(1), pp.65-84.

Chen, J., Chen, L., Li, Y., Zhang, W. and Long, Y. (2023) ‘Measuring physical disorder in urban street spaces: a large-scale analysis using street view images and deep learning’, *Annals of the American Association of Geographers*, *113*(2), pp.469-487.

Frank, L.D., Schmid, T.L., Sallis, J.F., Chapman, J. and Saelens, B.E. (2005) 'Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ', *American journal of preventive medicine*, *28*(2), pp.117-125.

Gómez-Varo, I., Delclos-Alio, X. and Miralles-Guasch, C. (2022) 'Jane Jacobs reloaded: A contemporary operationalization of urban vitality in a district in Barcelona', *Cities*, *123*, p.103565.

Gullón, P., Badland, H.M., Alfayate, S., Bilal, U., Escobar, F., Cebrecos, A., Diez, J. and Franco, M. (2015) 'Assessing walking and cycling environments in the streets of Madrid: comparing on-field and virtual audits', *Journal of urban health*, *92*, pp.923-939.

Hassen, N. and Kaufman, P. (2016) 'Examining the role of urban street design in enhancing community engagement: A literature review', *Health & place*, *41*, pp.119-132.

Hirt, S. and Zahm, D. eds. (2012) *The urban wisdom of Jane Jacobs*. Routledge.

Hyam, R. (2017) 'Automated image sampling and classification can be used to explore perceived naturalness of urban spaces', *PLoS One*, *12*(1), p.e0169357.

Jensen, W.A., Brown, B.B., Smith, K.R., Brewer, S.C., Amburgey, J.W. and McIff, B. (2017) 'Active transportation on a complete street: Perceived and audited walkability correlates', *International journal of environmental research and public health*, *14*(9), p.1014.

Kim, S., Park, S. and Lee, J.S. (2014) 'Meso-or micro-scale? Environmental factors influencing pedestrian satisfaction', *Transportation Research Part D: Transport and Environment*, *30*, pp.10-20.

Larkin, A. and Hystad, P. (2019) 'Evaluating street view exposure measures of visible green space for health research', *Journal of exposure science & environmental epidemiology*, *29*(4), pp.447-456.

Lee, H. and Kim, S.N. (2019) 'Shared space and pedestrian safety: Empirical evidence from pedestrian priority street projects in Seoul, Korea', *Sustainability*, *11*(17), p.4645.

Lee, J., He, S.Y. and Sohn, D.W. (2017) 'Potential of converting short car trips to active trips: The role of the built environment in tour-based travel', *Journal of Transport & Health*, *7*, pp.134-148.

Li, W. (2016) '*Research on urban street landscape based on daily safety (psychological safety and behavioral safety)*', Shenyang Agricultural University.

Lin, Y. (2023) 'How can social media reshape power relations in urban planning?: Discover how social media transforms power relations in urban planning as Dr. Yanliu Lin examines its impact on government-society relation and collaborative practices in the Chinese context', *The Project Repository Journal*, *17*, pp.64-67.

Lu, Y. (2019) 'Using Google Street View to investigate the association between street greenery and physical activity', *Landscape and Urban Planning*, *191*, p.103435.

Lu, Y., Yang, Y., Sun, G. and Gou, Z. (2019) 'Associations between overhead-view and eye-level urban greenness and cycling behaviors', *Cities*, *88*, pp.10-18.

Lu, Y., Zhao, J., Wu, X. and Lo, S.M. (2021) 'Escaping to nature during a pandemic: A natural experiment in Asian cities during the COVID-19 pandemic with big social media data', *Science of the total environment*, *777*, p.146092.

Neuhold, G., Ollmann, T., Rota Bulo, S. and Kontschieder, P. (2017) 'The mapillary vistas dataset for semantic understanding of street scenes', In *Proceedings of the IEEE international conference on computer vision* (pp. 4990-4999).

Peng C. (2020) '*Research on health problem analysis method based on social media data*', Tianjin University.

Quinn, J.W., Mooney, S.J., Sheehan, D.M., Teitler, J.O., Neckerman, K.M., Kaufman, T.K., Lovasi, G.S., Bader, M.D. and Rundle, A.G. (2016) 'Neighborhood physical disorder in new york city', *Journal of maps*, *12*(1), pp.53-60.

Rogers, S.H., Gardner, K.H. and Carlson, C.H. (2013) 'Social capital and walkability as social aspects of sustainability', *Sustainability*, *5*(8), pp.3473-3483.

Rosenberg, P., Kano, M., Ludford, I., Prasad, A. and Thomson, H. (2016) '*Global report on urban health: equitable, healthier cities for sustainable development*', World Health Organization.

Sallis, J.F., Floyd, M.F., Rodríguez, D.A. and Saelens, B.E. (2012) 'Role of built environments in physical activity, obesity, and cardiovascular disease', *Circulation*, *125*(5), pp.729-737.

Vanwolleghem, G., Van Dyck, D., Ducheyne, F., De Bourdeaudhuij, I. and Cardon, G. (2014) 'Assessing the environmental characteristics of cycling routes to school: a study on the reliability and validity of a Google Street View-based audit', *International Journal of Health Geographics*, *13*, pp.1-9.

Wang, R., Lu, Y., Zhang, J., Liu, P., Yao, Y. and Liu, Y. (2019) 'The relationship between visual enclosure for neighbourhood street walkability and elders' mental health in China: Using street view images', *Journal of Transport & Health*, *13*, pp.90-102.

Wu, Y.T., Nash, P., Barnes, L.E., Minett, T., Matthews, F.E., Jones, A. and Brayne, C. (2014) 'Assessing environmental features related to mental health: a reliability study of visual streetscape images', *BMC Public Health*, *14*, pp.1-10.

Xu, L. and Kang, Q. (2014) 'The impact of spatial and interface characteristics of commercial streets on pedestrian staying activities: A case study of Nanjing West Road in Shanghai', *Urban Planning Forum*, (03), pp. 104–111.

Yin, L. and Wang, Z. (2016) 'Measuring visual enclosure for street walkability: Using machine learning algorithms and Google Street View imagery', *Applied geography*, *76*, pp.147-153.

Zhang R. (2020) '*Urban blue spatial characteristics affecting public health under social media data*', Harbin Institute of Technology.

Zhang, F., Salazar-Miranda, A., Duarte, F., Vale, L., Hack, G., Chen, M., Liu, Y., Batty, M. and Ratti, C. (2024) 'Urban Visual Intelligence: Studying Cities with Artificial Intelligence and Street-Level Imagery', *Annals of the American Association of Geographers*, *114*(5), pp.876-897.

Zhou, H., He, S., Cai, Y., Wang, M. and Su, S. (2019) 'Social inequalities in neighborhood visual walkability: Using street view imagery and deep learning technologies to facilitate healthy city planning', *Sustainable cities and society*, *50*, p.101605.