

Article

Examining How Urban Public Spaces and Virtual Spaces Affect Public Opinion in Beijing, China

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Abstract: Urban public spaces significantly influence public perceptions and experiences. This study, conducted in Beijing, China, employs structural equation modeling (SEM) and Friedman testing to analyze key criteria—safety, attractiveness, facilities, activities, and social environment—that impact perceptions of both virtual and physical public spaces. The findings reveal that attractiveness is the most influential criterion, significantly shaping public opinion. Facilities and activities follow, highlighting the necessity for well-equipped amenities and engaging social activities. The social environment also plays a crucial role, emphasizing the need for spaces that foster social interactions. Safety, while important, is less influential compared to the other criteria. These results underscore the importance of aesthetic considerations, well-equipped amenities, and vibrant social environments in urban design. This study provides actionable insights for urban designers and planners, advocating for a balanced approach that prioritizes these criteria to enhance the quality of life in urban areas. By focusing on these aspects, urban planners can create more effective and satisfying public spaces that meet the diverse needs of the community, ensuring that both physical and virtual spaces contribute positively to urban living.

Keywords: Friedman testing; public perceptions; SEM analysis; urban environments; virtual reality



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1. Introduction

Urban public spaces have historically played a pivotal role in the formation and development of cities. The organization of ancient and medieval cities around public spaces underscores their importance in meeting the needs and requirements of inhabitants [1]. Furthermore, the visual aesthetics of urban public spaces can elicit emotional and psychological responses among users, influencing their happiness and life satisfaction [2,3]. Indeed, urban spaces significantly shape people's lifestyles [4,5] and can impact their mental and psychological well-being [5]. Urban planning is an iterative process involving continuous cycles of prediction, planning, and management of urban developments and changes [6]. In the planning and design of urban public spaces, incorporating stakeholders' opinions can enhance the precision of design and implementation [7]. Public participation is a key element for successful urban planning and should be institutionalized as a standard practice [8]. Given the diverse range of users and residents, including both professionals and the general public, participatory planning processes are of paramount importance [9]. Recognizing the significance of public opinion in urban space planning and design, governmental sectors have sought to anticipate evolving public sentiments to effectively manage social and spatial transformations [10].

Despite the profound impact of urban public spaces on emotional well-being and perceptions, there is a lack of comprehensive investigations into the specific characteristics that influence these spaces [11]. Various criteria and methodologies have been proposed

to evaluate the effects of urban spaces on public perceptions, encompassing psychological, architectural, environmental, and social factors [1,12,13]. For instance, some studies have employed advanced visualization techniques, such as virtual reality (VR) and city information modelling (CIM), to simulate and analyze different urban scenarios. In a previous study [13], sub-criteria related to users' experiences included immersion, ease of use, usefulness, physical comfort, mental comfort, and personal preferences.

From a technical point of view, one of the procedures enabling urban designers to investigate urban public spaces' impacts on people's perceptions is the consideration of several viable and parallel scenarios. Various visualization techniques can be used to simulate and create these scenarios [14–17]. Since traditional urban planning tools cannot demonstrate the dynamic interconnection between urban spaces' features precisely, VR technology has been used instead [18,19]. VR technology can render a city's components and features, thoroughly allowing for urban planners to examine various scenarios [20]. Virtual technologies like city information modelling (CIM) and urban digital twins (UDTs) can help urban designers and planners simulate and analyze different scenarios to make the best decisions in the urban planning process [13,21]. In a recent study, Ref. [6] used automated 3D gaze-tracking to evaluate public perceptions on two scenarios related to a dynamic vision in urban settings. Ref. [13] also utilized an innovative version of CIM to quantitatively and qualitatively evaluate non-expert users' experiences about a real-life urban community design in the Netherlands. As noted in the study [13], virtual CIM can contribute to optimized community designs and strong decision-making outcomes.

Despite the theoretical explorations of urban planning, empirical studies focusing on people's perceptions of these spaces remain limited [11]. This study employs structural equation modeling (SEM) with PLS3 and the Friedman method to evaluate people's perceptions and emotions concerning the visual appearance of both urban and virtual public spaces. To the best of the authors' knowledge, this is the first study to measure the influence of public spaces on residents' perceptions and opinions using SEM-PLS3 and the Friedman method. This study aims to achieve two primary objectives: (1) to evaluate the impact of virtual and urban public spaces on people's opinions and (2) to assess and rank the main influences using the SEM-PLS3 method. This paper draws on a comprehensive literature review to identify the key emotions that people may experience in public spaces, which shape their opinions about these spaces. Virtual spaces were evaluated using specialized technological equipment and a mobile-based 360-degree virtual reality platform. The impacts of both virtual and physical public spaces were assessed through a questionnaire administered to participants, with the data analyzed using statistical procedures. The findings of this study can assist designers and planners in enhancing the quality of their designs and avoiding potential pitfalls. It is important to note that this study focuses on the case area of Beijing, China.

Empirical studies focusing on people's perceptions of public open spaces further highlight the importance of these elements in urban planning. Anastasiou and Manika (2020) [22] explore the determinants and residential satisfaction from urban open spaces, emphasizing the crucial role of aesthetics and functionality in shaping public perceptions. Reyes-Riveros et al. (2021) [23] link public urban green spaces to human well-being, underscoring the psychological and emotional benefits of well-designed public spaces [23]. Paköz et al. (2022) [24] discuss the changing perceptions and usage of public spaces in the post-pandemic city, highlighting the dynamic nature of public space usage and its implications for urban design.

The potential contribution of this research lies in its practical application for urban planners and designers. By identifying and analyzing the key criteria that influence public perceptions of urban and virtual public spaces, this study provides actionable insights that can inform the design and planning processes. This research aims to bridge the gap between theoretical explorations and empirical studies by employing structural equation modeling (SEM) and Friedman testing to evaluate people's perceptions and emotions concerning the visual appearance of both urban and virtual public spaces. The findings

can help urban designers and planners create more effective and satisfying public spaces, ultimately enhancing the quality of life in urban areas.

Beijing was selected as the case study for several reasons. As one of the world's most populous cities, Beijing faces unique challenges related to urbanization, including high population density, rapid urban development, and a blend of traditional and modern urban landscapes. These characteristics make Beijing an optimal choice for analyzing public perceptions of urban and virtual public spaces. The city's diverse socioeconomic and cultural context provides a rich environment for examining how different urban design elements impact public opinion.

Research Questions:

What are the key criteria that influence public perceptions of urban and virtual public spaces in Beijing, China?

How do these criteria impact the formation of public opinion regarding these spaces?

Can the identified criteria be applied universally, or are they specific to the socioeconomic and cultural context of Beijing?

By addressing these research questions, this study aims to provide valuable insights that can guide urban planning and design practices, contributing to the creation of more livable and sustainable urban environments.

2. Methodology

In this part, we first introduce the scope of this study and then the method of identification and modeling of the research is discussed.

2.1. Case Study

Beijing, located in northern China, is one of the world's most populous cities. The city is characterized by its mountainous terrain, which covers 62% of its area, with the remaining 38% consisting of low plains. Spanning an area of 1.64 million square kilometers, Beijing stands as a significant global city, particularly in the context of urbanization issues. The 20th century witnessed a rapid acceleration in urbanization, accompanied by a surge in construction projects [25]. These distinctive features have positioned China as a prime location for urban development initiatives. Consequently, this study seeks to explore the opinions of Beijing residents concerning both virtual and physical urban public spaces.

2.2. Data and Sampling

This section outlines data collection, analysis, and hypothesis testing. Given the research questions and objectives, this chapter is structured into two main subsections. The first subsection provides a brief description of the study area, followed by an overview of the descriptive statistics. This includes demographic variables of the study population, such as gender, age, marital status, and educational level, as well as descriptive statistics for the questionnaire items.

2.2.1. Sampling Procedure

This study employed a stratified random sampling technique to ensure a representative sample of the population. The sample size was determined using the Cochran formula at a 95% confidence level, resulting in a total of 120 participants. This sample size is considered adequate for structural equation modeling (SEM) analysis.

Table 1 summarizes the criteria and sub-criteria employed by various researchers to evaluate the influence of public spaces on people's perceptions, along with the methodologies used in their studies.

Table 1. Criteria and sub-criteria for evaluating public spaces' influences on people's perceptions.

Authors' Names	Date of Research	Criteria	Sub-Criteria	Procedures
[1]	2016	Psychological, architectural, and digital aspects	Care for comfort of usage, rest and relax zones, good communication for making objects clear to follow, meeting the needs of residents, improving people's quality of life, favorable social networking, good restoration process, emphasizing valuable elements	Review of metamorphosed spaces
[18]	2020	The role of urban underground infrastructures in urban planning decisions	Spatial and dynamic relationships between infrastructures' features above and below city streets	VR
[11]	2020	Environmental perception and affective appraisal	Architecture and public space design that is pleasant, exciting, relaxing, safe, interesting, active, and familiar	Panel evaluation of 360-degree videos of real environments and mobile-based virtual reality platform
[26]	2021	Sentiment classification	---	Artificial intelligence (AI)
[27]	2021	Nodes of belonging, narratives of space, expanding boundaries	People, activities, novelty, ability, implicit cultural understandings, structural constructs, specific stories, personal memories, direct visual reactions, spatially, temporally, socially	
[6]	2021	Land use, buildings' height, density, development ratio, green ratio, public services, urban design	---	Eye-gaze tracking and data processing
[5]	2022	Macro and micro factors of physical environment, natural factors, social factors	Mixed use, height, density, public transportation, attractiveness and aesthetic factors, active frontage, access to light, walkability, green space, quality of noise, air pollution, social relationships, crime, social security	PLS-SEM
[28]	2022	Creation of new structures, recreation of existing designs	---	BIM and augmented reality (AR)
[9]	2023	Public participation and consensus	Actors, methods, levels, approaches, and conflicts	Statistical analysis methods
[13]	2023	Social, spatial, and lifestyle component	Leisure activities, interpersonal relationships, outdoor gathering areas, connected buildings, friendly walking routes, natural landscape, workout equipment, gardening, plant-based community, individual healthy habit plan	CIM and UDT
[10]	2023	Public opinion prediction and its revolutionary trends	---	Improved multi-objective gray wolf optimizer

Participant Selection

Participants were selected from various districts of Beijing to capture a diverse range of opinions. The selection criteria included:

Age: participants aged 20 years and above.

Residency: participants who had lived in Beijing for at least five years.

Occupation: a mix of professionals in urban planning, public opinion experts, and general public members to ensure varied perspectives.

Education: participants with at least a high school diploma to ensure they could comprehend the questionnaire.

Data Collection Techniques

Data were collected using a structured questionnaire designed to capture participants' opinions on both virtual and physical urban public spaces. The questionnaire was developed based on an extensive literature review and validated through a pilot study involving 20 respondents. The questionnaire included both closed-ended and open-ended questions to gather quantitative and qualitative data.

Exclusion Criteria

Participants who did not meet the selection criteria or failed to complete the questionnaire were excluded from this study. Additionally, any responses that were inconsistent or showed signs of response bias were also excluded to ensure the reliability of the data.

2.2.2. Research Hypotheses

The main hypothesis of this study is that specific criteria significantly influence public perceptions of urban and virtual public spaces. The specific hypotheses tested are as follows:

H1. *Attractiveness significantly influences public perceptions of urban public spaces.*

H2. *Facilities significantly impact public perceptions of urban public spaces.*

H3. *Activities have a significant effect on public perceptions of urban public spaces.*

H4. *The social environment plays a crucial role in shaping public perceptions of urban public spaces.*

H5. *Safety, while important, is less influential than the other criteria in shaping public perceptions of urban public spaces.*

Data Analysis

The collected data were analyzed using structural equation modeling (SEM) implemented with PLS3 software. The SEM approach is used to examine whether the model adequately represents the theoretical constructs and relationships proposed by the underlying theory. The model's reliability was evaluated through the consistency of the measurement items, and fit indices were used to assess how well the model fits the observed data. The model was modified if fit indices indicated poor fit.

Questionnaire Questions (Indicators)

For clarity, here are the questions corresponding to the dimensions:

Safety (Questions Q1–Q6)

How do you rate the overall safety of public space?

Do you feel comfortable using this public space?

Is the public space well-lit and free from pollution?

Are there sufficient walkways and pedestrian paths?

Does public space improve your overall quality of life?

Are safety measures adequately enforced?
 Attractiveness (Questions Q7–Q10)
 How visually attractive is the public space?
 Are there sufficient natural landscapes such as gardens?
 Do you find the structural design of the public space appealing?
 How important is novelty in the design of this public space?
 Facilities (Questions Q11–Q13)
 Are there adequate workout facilities in the public space?
 Is there sufficient outdoor dining available?
 Are the walking routes well-designed and accessible?
 Activities (Questions Q14–Q15)
 Are there ample leisure activities available in the public space?
 Are there designated rest and relaxation zones?
 Social Environment (Questions Q16–Q18)
 Are there areas for outdoor gatherings and social interactions?
 How do you rate the interpersonal relationships fostered in this space?
 Is there a favorable social network present in this public space?

Based on the analysis of related studies and research history, the dimensions of the research questionnaires were determined. Table 2 was then localized in accordance with the specific conditions of the research and the consultations and approvals of experts within the studied city.

Table 2. Dimensions used in the research.

Dimension	Sub-Dimensions	Supporting Literature
Safety	Care for comfort, improve quality of life, ability, access to light, pollution, walkability	[5,11,18,24]
Attractiveness	Novelty, gardening, natural landscape, structural constructs	[5,6,23,29]
Facilities	Workout equipment, outdoor dining facilities, walking routes	[13,22]
Activities	Leisure activities, rest and relax zones	[22,23]
Social Environment	Outdoor gathering areas, interpersonal relationships, favorable social networking	[5,10,22,23]

2.3. Methods

This subsection focuses on inferential statistics, where each research hypothesis is tested and validated using structural equation modeling (SEM) with PLS3 software. It details the calculations and techniques employed in the analysis.

Step 1: Descriptive Statistics of Research Data

This section involves a two-stage process. In the first stage, an explanation of the demographic characteristics of the research population is provided. In the second stage, descriptive statistics are presented for the questions in the questionnaire. It should be noted that the statistical population of this research entirely comprises experts in the field of public opinion. Given that SEM was used to analyze the data, the required sample size was calculated based on the rules of this method. The sample size was selected as 120, proportional to the size of the statistical population and based on the Cochran Formula (1) at a confidence level of 5% [30].

$$n = \frac{\frac{z^2 pq}{d^2}}{1 + \frac{1}{N} \left(\frac{z^2 pq}{d^2} - 1 \right)} = \frac{\frac{1.96^2 * 0.5 * 0.5}{0.05^2}}{1 + \frac{1}{N} \left(\frac{1.96^2 * 0.5 * 0.5}{0.05^2} - 1 \right)} = 120 \quad (1)$$

Since the sample size is an integer and is rounded up to cover sampling error, the final random sample size, including the return coefficient, was calculated as 120. This number of questionnaires was distributed and used in the analyses.

Step 2: Descriptive Statistics of Research Variables

In this stage, the status of each variable in the research conceptual model is presented using descriptive statistics from the sample population.

Step 3: Structures and Symbols Used in the Research

To fit the research conceptual model and test the main hypotheses, the SEM method was used through SMART PLS3 software. Since each component of the model is represented by symbols in SMART PLS3, Table 3 introduces these symbols.

Table 3. Names of variables and symbols used in SMART PLS3.

Row	Structure (Variable)	Symbol Used
1	Safety	Sa
2	Attractiveness	At
3	Facilities	Fa
4	Activities	Ac
5	Social environment	So
6	Formation of public opinion	Pu

As can be seen in Table 3, this research has six variables and sub-variables, each introduced with a specific code.

There are three stages to the review of the research model:

The first stage involves examining the external model.

The second stage involves examining the internal model.

The third stage involves examining the overall research model.

Step 4: Assessment of the measurement model (external model)

Calculating factor loadings involves determining the correlation between the indicators of a structure and the structure itself. When the value of this parameter equals or exceeds 0.4 [31] it indicates that the variance shared between the structure and its indicators is greater than the measurement error variance of that structure, and the measurement model is considered valid. Some authors, however, have specified 0.5 as the criterion for factor loadings [32]. It is imperative that if factor loadings between structures and indicators are less than 0.4, they should be modified or removed from the research model [33].

Step 5: External model reliability

We evaluated the reliability of the measurement model using Cronbach's alpha coefficient and composite reliability (CR). The Cronbach's alpha coefficient ranges from 0 to 1, with an alpha coefficient above 0.7 considered reliable [34]. However, Refs. [35,36] introduced 0.6 as the threshold for the alpha coefficient for variables with few questions. Cronbach's alpha is generally calculated using Formula (2) [37]:

$$\alpha = \frac{k}{k-1} \left(1 - \frac{\sum_{i=1}^k S_i^2}{\sigma^2} \right) \text{ or } \alpha = \frac{k\bar{C}}{\bar{V} + (k-1)\bar{C}} \quad (2)$$

where

k: number of questions;

S_i^2 : variance of question i;

σ^2 : variance of the total questions;

$\bar{C}$: average covariance between questions;

$\bar{V}$: variance of the average questions.

Step 6: Validity of external model

The validity of the external model was assessed based on two criteria: convergent validity and divergent validity. The Fornell and Larcker method was used to examine divergent validity in this study [38].

Step 7: Evaluating the structural model (internal)

In the process of evaluating the model fit of measurement models, we must also evaluate the structural model of the research. It is important to note that structural models are not related to questions (manifest variables); instead, only the latent variables and their relationships are examined [39,40]. The first output of PLS algorithm analysis in Smart PLS3 software is path coefficients, which indicate the regression coefficients and the extent of the independent variables' impact on the dependent variable. According to the rule of thumb, a path coefficient value higher than 0.2 is meaningful and acceptable. However, to ensure this, the bootstrapping test is used, presenting the existing values in the form of t-values. The model fit is determined using t-values, which should be greater than 1.96 to be considered significant at a 95% level of confidence. Although t-values indicate the accuracy of relationships, they cannot measure the strength of those relationships between dimensions. It is significant if the t-value exceeds 2.58 at a 99% level of confidence [29,41].

Step 8: T-values (Z significance coefficients)

For the purpose of assessing the fit of the research structural model, several criteria are utilized, with the most fundamental being the significance of the Z-score coefficients. At a 95% confidence level, the coefficients must be greater than 1.96 to be considered statistically significant based on t-values. Although t-values indicate the accuracy of relationships, they do not provide information about the strength of relationships between dimensions. The path coefficient is significant at a 99% confidence level if the t-value exceeds 2.58 [42].

Step 9: Regression coefficients of paths

To investigate the significance between research indicators and their related structures, the regression coefficient or path coefficient is used.

Step 10: Coefficient of determining R²

In this research, the parameter values of R-squared (R²) belonging to the research model variables were calculated using SMART PLS3 software. A larger R² value for the internal structure components of a model indicates a better model fit. According to [43], R² values of 0.19, 0.33, and 0.67 represent weak, moderate, and strong model fit, respectively.

Step 11: Impact size criterion (f²)

The intensity of the relationship between the model dimensions is determined by this measure. A value of 0.02 indicates a small effect size, a value of 0.15 indicates a moderate effect size, and a value of 0.35 indicates a large effect size. The relationship used in Formula (3) [44] is explained below:

$$f^2 = \frac{R^2_y(x \text{ included}) - R^2_y(x \text{ excluded})}{1 - R^2_y(x \text{ included})} \quad (3)$$

The assumptions of the formula are as follows:

$f^2 (x \rightarrow y)$: the effect size of x on y;

$R^2_y (x \text{ included})$: the R² value of dimension y when dimension x is included in the model;

$R^2_y (x \text{ excluded})$: the R² value of dimension y when dimension x is excluded from the model.

Step 12: Criterion Q²

To determine the predictive power of a model, the Q² measure must be used. Accordingly, if the Q² value for an internal dimension is 0.02, 0.15, or 0.35, the external dimensions related to the internal dimension have weak, moderate, or strong predictive power, respectively [40].

Step 13: Hypothesis testing

In this study, the structural equation modeling method was used to test and confirm the proposed hypotheses.

Step 14: Friedman Test

After conducting some pre-tests and structural equation modeling for the research model, this section discusses the Friedman test, which indicates the importance of each research variable for the respondents.

3. Results

The demographic variables of the statistical population, such as gender, age, marital status, and education level, are described. In Table 4, each variable is presented in terms of frequency and percentage.

Table 4. Demographic characteristics of the sample population.

Dimensions		Frequency	Frequency Percentage
Gender	Male	82	68.3
	Female	38	31.7
Age	20–30 years old	26	21.7
	30–40 years old	61	50.8
	40–50 years old	27	22.5
	Over 50 years old	6	5.0
Marital status	Married	75	62.5
	Single	45	37.5
Education level	Diploma and associate degree	15	12.5
	Bachelor's degree	77	64.2
	Graduate degree	20	16.7
	Doctorate	8	6.7
Work experience	5 to 10 years	31	25.8
	6 to 11 years	42	35.0
	11 to 15 years	33	27.5
	Over 15 years	14	11.7
Total		120	100%

The mean, standard deviation, mode, minimum, and maximum values of each variable were calculated and are presented in Table 5. The majority of the statistical population is classified as standard in all dimensions of this research.

Table 5. Descriptive statistics of research variables.

Dimensions	Mean	Median	Mode	Standard Deviation	Minimum	Maximum
Safety	3.78	4.00	4.00	0.918	2.00	5.00
Attractiveness	4.18	4.00	4.00	0.796	2.00	5.00
Facilities	4.17	4.00	4.00	0.803	1.00	5.00
Activities	4.15	4.00	5.00	0.895	2.00	5.00
Social environment	4.01	4.00	4.00	0.850	2.00	5.00
Formation of public opinion	4.27	4.00	4.00	0.719	2.00	5.00

The factor loadings of the questionnaire questions are shown in Table 6. As can be seen from Table 6, the factor loadings of all research questions, except for questions 3, 7, and 17 (red), are greater than 0.5. Therefore, we removed the questions with factor loadings less than 0.5 from the model and ran the research model again. The results presented below are based on the modified research model.

Table 6. Factor loadings of research questionnaire questions (indicators).

Structure	Question Number	Factor Loading
Safety	Q1	0.821
	Q2	0.788
	Q3	0.353
	Q4	0.690
	Q5	0.819
	Q6	0.809
Attractiveness	Q7	0.130
	Q8	0.836
	Q9	0.759
	Q10	0.869
Facilities	Q11	0.896
	Q12	0.799
	Q13	0.824
Activities	Q14	0.867
	Q15	0.868
Social Environment	Q16	0.721
	Q17	0.281
	Q18	0.864

Based on Table 7, Cronbach's alpha coefficients and composite reliability are presented for each dimension of this research questionnaire. The Cronbach's alpha coefficients and composite reliability scores for each construct are greater than 0.7, indicating appropriate model reliability.

Table 7. An evaluation of Cronbach's alpha and composite reliability.

Row	Dimension	Cronbach's Alpha	CR	Rho_A
1	Activities	0.789	0.863	0.803
2	Attractiveness	0.811	0.875	0.828
3	Facilities	0.929	0.940	0.944
4	Safety	0.900	0.919	0.910
5	Social environment	0.866	0.833	0.821
6	Public opinion formation	0.837	0.841	0.854

According to Table 7, the values of Cronbach's alpha coefficient and composite reliability for the six dimensions are above 0.7, indicating an appropriate reliability of the model.

The values of the average variance extracted (AVE) for the research dimensions are shown in Table 8.

According to the data in Table 8, all AVE values of the research dimensions are greater than 0.5. Therefore, the convergent validity of the present research model is confirmed. The examination of divergent validity using the Fornell and Larcker method was performed with SMART PLS3 software, and the results are shown in Table 9 for all research dimensions.

Table 8. AVE values of research dimensions.

Row	Dimension	AVE
1	Activities	0.525
2	Attractiveness	0.700
3	Facilities	0.521
4	Safety	0.801
5	Social environment	0.582
6	Public opinion formation	0.711

Table 9. Divergent validity using the Fornell and Larcker method.

	Ac	At	Fa	Sa	So	Pu
Activities	0.724					
Attractiveness	0.317	0.836				
Facilities	0.534	0.202	0.721			
Safety	0.266	0.745	0.343	0.894		
Social environment	0.242	0.667	0.654	0.307	0.763	
Public opinion formation	0.404	0.556	0.202	0.527	0.557	0.843

As shown in Table 9, the squared convergent validity of each dimension is greater than its correlation value with the other dimensions. Accordingly, the Fornell and Larcker method was used to evaluate the divergent validity of the research model. The significant Z-score coefficients for the research model's paths are shown in Table 10 and Figure 1.

Table 10. Z scores of path coefficients (t-values).

Row	Path	t-Value
1	Safety → public opinion formation	21.764
2	Attractiveness → public opinion formation	16.466
3	Facilities ← public opinion formation	6.195
4	Activities ← public opinion formation	9.421
5	Social environment ← public opinion formation	13.460

The results of this investigation, as shown by SMART PLS3, are presented in Table 11 and Figure 2.

Table 11. Path regression coefficients (beta).

Row	Path	Regression Coefficient
1	Safety → formation of public opinion	0.558
2	Attractiveness → formation of public opinion	0.588
3	Facilities → formation of public opinion	0.316
4	Activities → formation of public opinion	0.409
5	Social Environment → formation of public opinion	0.503

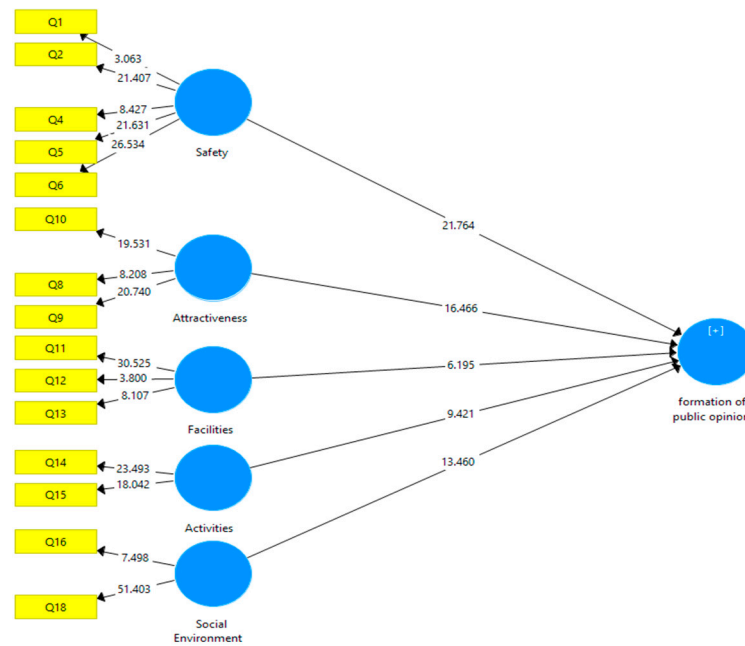


Figure 1. T-value amount in research structural model.

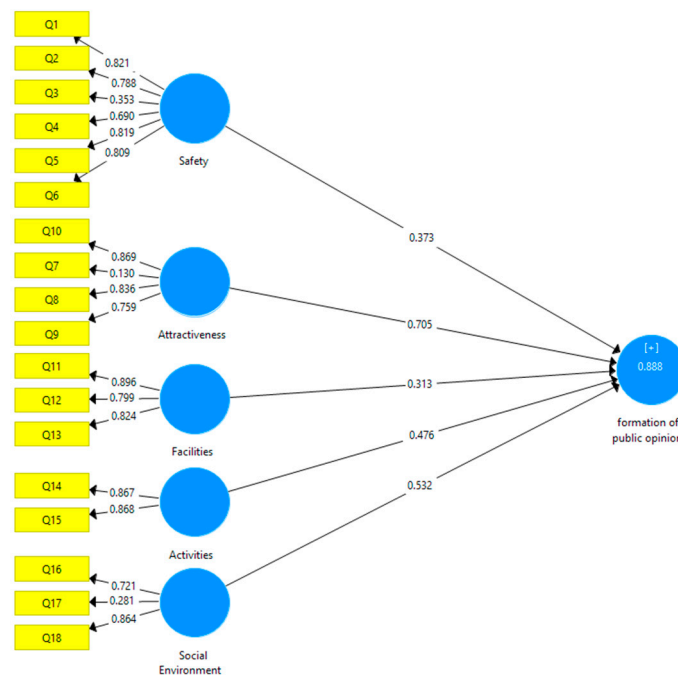


Figure 2. Regression coefficient amount in research structural model.

The findings of this study are summarized in Table 12, which presents the results of this research.

Table 12. R-squared (R^2) values of the research dimensions.

Row	Dimension	R-Squared (R^2) Values
1	Formation of public opinion	0.776

The findings presented in Table 11 indicate that the majority of the research dimensions exhibit R^2 values exceeding 0.67, signifying a robust model fit. Table 13 illustrates the effect size (f^2) values for the research variables.

Table 13. Effect size measure (f^2).

Row	Path	f^2
1	Safety → formation of public opinion	0.654
2	Attractiveness → formation of public opinion	0.237
3	Facilities → formation of public opinion	0.438
4	Activities → formation of public opinion	0.621
5	Social environment → formation of public opinion	0.570

According to the results in Table 13, the effect size measure of the above relationships is above the upper limit and is in good condition from the parameter (f^2) point of view. Therefore, the research model is approved.

The Q^2 values for the research variables are shown in Table 14.

Table 14. Q^2 values of the research dimensions.

Row	Dimension	Q^2 Values
1	Activities	0.253
2	Attractiveness	0.379
3	Facilities	0.352
4	Safety	0.310
5	Social environment	0.397
6	Formation of public opinion	0.378

According to the results in Table 14, the Q^2 values for the research variables are desirable, and the research model is approved from the (Q^2) point of view.

In this research, the main fit of the research model, the (SRMR), (rms Theta), and (NFI) indices were used since the structural equation modeling process was performed using (SRMR) software 3. The value of the (SRMR) index is 0.001, which is less than 0.05. The value of the (rms Theta) index is 0.051, which is less than 1.0, and finally, the value of the (NFI) index is 0.992, which is greater than 0.95. Therefore, the research model has the capability of good fit and generalization.

In this study, to test and confirm the proposed hypotheses, the structural equation modeling method was used. The statistical value (T-Value) and path coefficient (beta) for testing and confirming the proposed hypotheses are presented in Table 15.

Table 15. Results of testing the proposed hypothesis (T-Value) and path coefficient.

Hypothesis Title	Standard Error	(T-Value)	Path Coefficient	p -Value	Status
Safety → formation of public opinion	0.029	21.764	0.558	0.000	Accepted
Attractiveness → formation of public opinion	0.045	16.466	0.588	0.000	Accepted
Facilities → formation of public opinion	0.052	6.195	0.316	0.003	Accepted
Activities → formation of public opinion	0.119	9.421	0.409	0.000	Accepted
Social environment → formation of public opinion	0.069	13.460	0.503	0.000	Accepted

According to the data in Table 15, the T-values are greater than 1.96; therefore, all the proposed hypotheses are accepted, and the path coefficient values are in an appropriate state. In other words, for a unit change in the variables, the formation of public opinion variable will change by 55.8%, 58.8%, 31.6%, 40.9%, and 50.3%, respectively.

After conducting some pre-tests and structural equation modeling for the research model, this section discusses the Friedman test, which shows how important each of the

research variables was for the respondents. The higher the rank of the variables, the closer they are to the first rank, which means that variable was more important to the respondents. The results of this test are presented in Table 16.

Table 16. Results of the Friedman test.

Research Model Dimensions	Mean	Rank	Sig	Priority
Safety	3.78	4.81	0.000	5
Attractiveness	4.18	6.52		1
Facilities	4.17	6.02		2
Activities	4.15	5.75		3
Social environment	4.01	5.11		4

According to the results in Table 16, the “Attractiveness” variable with a rank of 6.52 took top priority, and the “Facilities” and “Activities” variables were second and third priority, respectively. Additionally, the “Safety” variable had the lowest rank and was the lowest priority among the respondents.

4. Discussion

The goals of the present study were, first, to evaluate and identify the main areas of urban and virtual public spaces’ influence on people’s minds, and second, to assess and categorize these main impacts using an SEM method and PLS3 software. Significant dimensions of public spaces’ effects on visitors’ perceptions were identified by comprehensively reviewing the related literature. These dimensions were then examined by testing the fit of the research model. During this stage, some indicators (questionnaire questions) were removed due to their unacceptable factor loadings. The reliability and validity of the proposed model were evaluated using Cronbach’s alpha coefficient and the Fornell and Larcker method. After this stage, the SEM method was comprehensively used to examine the overall fit of the research model. Finally, the validity of the hypotheses was assessed using the T-value and path coefficient (beta) from the SEM model, and these hypotheses were ranked through a Friedman test.

The dimensions identified in the present study were categorized into five general categories: safety, attractiveness, facilities, activities, and social environment. The safety category included care for the comfort of usage, improving people’s quality of life, ability, access to light, pollution, and walkability. Safety has been noted as one of the measurements influencing people’s perception of a public space [12,45]. As cited by [5], appropriate urban planning and feedback from users can improve the safety dimension of a public space. Safety in a public space has several aspects, including reducing natural hazards, protecting from possible crimes, and the liability of the main stakeholders [5,11,18,28]. The ability sub-criterion was removed from safety measurements since it did not satisfy the factor loading threshold. Other sub-criteria of the safety measurement were reliable (Table 6) and evaluated by the SEM method. Accordingly, the safety dimensions were of great significance (Figures 1 and 2; T-value: 21.764) and the hypothesis that safety could result in public opinion formation was confirmed (Table 14). Several research studies emphasize the significance of safety in forming public opinion [11,13,28]; however, the safety dimension was considered a non-significant criterion in the survey conducted in [11]. This may be because the research in [11] compared contemporary and traditional styles in public spaces, which are both safe and secure.

The attractiveness dimension included novelty, gardening, natural landscape, and structural constructs. The novelty sub-criterion was removed since its factor loading was not acceptable (Table 5). As [11] emphasized, contemporary public spaces have less visual attractiveness and familiarity for visitors compared to traditional ones. Therefore, novelty has less significance among other attractiveness sub-criteria. However, attrac-

tiveness dimension of public and virtual spaces can significantly affect public opinion formation [5,6,27,46]. This dimension can reduce visual fatigue during visits to urban and virtual public spaces [47]. The present research findings also support the importance of the attractiveness dimension. According to Table 15, attractiveness gained priority 1 among the 5 main criteria, and the hypothesis that attractiveness can influence people's perception of a public space is approved based on Table 15. The attractiveness of virtual and urban public spaces can be improved by increasing symmetrical features, adding ornamentation, and providing a natural appearance [11].

The facilities criterion involves three sub-criteria: workout equipment, outdoor dining facilities, and walking routes. Physical activities are part of urban public spaces' culture and should be considered one of the essential elements of public space planning [26]. Dining facilities can also have a positive effect on people's perception of an urban public space [13]. In this paper, the significance of providing appropriate urban facilities was emphasized by gaining the second rank in the priority hierarchy (Table 15). Consequently, it can be concluded that one of the positive effects of an urban public space is the quality and quantity of provided facilities.

The activities dimension consists of two sub-criteria: leisure activities, and rest and relax zones, and is related to people's preferences regarding their deeds in an urban public space. While some researchers have considered activities as a separate dimension of the urban space impact on people's perception [27], others have regarded activities as part of daily life routines [5]. Ref. [13] categorized leisure activities as a sub-criteria of the social component measurement, and rest and relaxation zones were considered to have positive impacts on people's perception by [26]. In the present study, this dimension gained third priority among the five dimensions, and the hypothesis of this factor's influence on public opinion formation was supported using a Friedman test (Table 15).

The social environment factor includes three sub-criteria: outdoor gathering areas, interpersonal relationships, and favorable social networking. Among these sub-criteria, interpersonal relationships did not achieve an acceptable factor loading, and was therefore removed from the research questions. However, the other two sub-criteria, with acceptable loading factors, have been mentioned in several research studies as effective elements on public opinion perception [5,10–13,26,27]. In the present study, the social environment ranked fourth among the five main criteria (Table 15), and the hypothesis that the social environment can influence public opinion formation was supported by the results of the Friedman test.

From the obtained results, it can be concluded that all of the proposed main criteria have a significant effect on public opinion formation regarding urban and virtual public spaces. Among the proposed dimensions, attractiveness gained the highest priority in the hierarchical ranking (Table 15). This result can motivate urban planners and designers to pay more attention to aesthetic issues. The next most significant criterion is facilities, suggesting that urban public spaces should be equipped with appropriate amenities such as workout equipment, outdoor dining places, and suitable walking routes. These apparently common facilities can positively affect people's perceptions of an urban public space. Moreover, designers should be aware of the significance of other dimensions, including activities, social environment, and safety. This is because all these aspects of designing and planning public environments gained acceptable values in the hypothesis testing, indicating that they can positively or negatively influence public opinion formation.

Below, this study provides valuable insights into how different criteria influence public perceptions of urban and virtual public spaces in Beijing, China, based on the aforementioned criteria.

4.1. Attractiveness

This study reveals that attractiveness is the most influential criterion, underscoring the importance of aesthetic appeal in urban public spaces. Attractive environments are more likely to be perceived positively, enhancing overall satisfaction and well-being of

users. For urban planners, this finding highlights the need to prioritize visual elements such as landscaping, architectural design, and integration of natural features. Beautifully designed spaces not only contribute to the aesthetic value of a city but also promote mental health and reduce stress among residents [48]. This result can motivate urban planners and designers to pay more attention to aesthetic issues, ensuring that public spaces are visually engaging and pleasing.

4.2. Facilities

Well-equipped amenities significantly impact public perceptions. The availability of facilities such as workout equipment, outdoor dining options, and well-designed walking routes contributes to the functionality and usability of public spaces. This finding suggests that urban planners should ensure public spaces are equipped with diverse and accessible amenities to cater to various user groups [22]. Providing such facilities can enhance the convenience and attractiveness of public spaces, making them more inviting and enjoyable. This dimension gained the second rank in the priority hierarchy, indicating its significance in shaping public opinion.

4.3. Activities

Engaging social activities are crucial for vibrant public spaces. Public spaces offering a range of leisure activities and rest zones are perceived more positively. This indicates that urban planners should design spaces encouraging social interactions and community engagement. Activities such as outdoor events, recreational sports, and cultural performances can transform public spaces into lively environments that foster social cohesion and community spirit [23]. This dimension ranked third, suggesting that activities play a significant role in influencing public opinion formation.

4.4. Social Environment

A vibrant social environment that fosters interactions is essential for building strong communities. Public spaces facilitating social networking and interpersonal relationships are highly valued. This finding highlights the importance of designing spaces that encourage socialization and community-building activities. Urban planners should create areas within public spaces conducive to gatherings, discussions, and social interactions, enhancing the social fabric of urban communities [24]. In the present study, the social environment ranked fourth among the main criteria, indicating its role in shaping public perceptions.

4.5. Safety

Safety, while important, is less influential compared to the other criteria. However, it remains a foundational aspect of sustainable urban design. Safe public spaces ensure all residents, including vulnerable populations, feel secure and comfortable. This finding suggests that while safety measures should be in place, urban planners should balance safety with other aspects such as attractiveness and functionality to create well-rounded public spaces [48]. The hypothesis that safety could result in public opinion formation was confirmed, emphasizing its importance despite being less influential.

4.6. Implications for Urban Planning

The findings of this study have several practical implications for urban planners and designers. First, the emphasis on attractiveness and facilities suggests that aesthetic appeal and functionality should be prioritized in the design of public spaces. Second, the importance of activities and social environment highlights the need for spaces encouraging social interactions and community engagement. Finally, while safety is crucial, it should not overshadow other aspects that contribute to the overall user experience.

4.7. Limitations and Future Research

This study is limited to Beijing, China, and the findings may not be generalizable to other cultural or geographical contexts. Future research should extend this study to other cities and regions to validate the findings. Additionally, the reliance on self-reported data may introduce bias, and future studies should consider using a combination of qualitative and quantitative methods to capture a more comprehensive understanding of public perceptions. Furthermore, some indicators (questionnaire questions) were removed due to their unacceptable factor loadings, which may affect the comprehensiveness of the results.

In conclusion, this study underscores the multifaceted nature of public space perceptions and provides actionable insights for urban planners. By focusing on attractiveness, facilities, activities, social environment, and safety, planners can create public spaces that enhance the quality of life, promote social equity, and contribute to the overall sustainability of urban areas. The findings advocate for a balanced approach in urban planning, ensuring that public spaces are not only safe but also aesthetically pleasing, functional, and conducive to social interactions.

5. Conclusions

Urban and virtual public spaces significantly influence people's perceptions and are pivotal for urban planners and designers. To design effective urban public spaces, it is crucial for designers to gather reliable feedback from users and residents, minimizing the risk of failure and enhancing the likelihood of meeting people's satisfaction. Various research approaches can be employed to collect people's opinions. In this study, two methods were utilized: presenting a virtual reality scheme of a public space and distributing questionnaires to gather insights from people's past experiences and opinions. The questionnaire's questions, including criteria and sub-criteria, were derived from an extensive literature review. The structural equation modeling–partial least squares 3 (SEM-PLS3) method was employed to analyze the respondents' answers using statistical procedures. As a primary objective, this study aimed to identify and categorize key indicators that influence people's perceptions of public spaces. Furthermore, the relationships between the proposed criteria and the formation of public opinion were evaluated using statistical tests like the Friedman test. The findings highlighted the importance of several main criteria—safety, attractiveness, facilities, activities, and social environment—in shaping people's opinions about public spaces. Notably, attractiveness emerged as the most significant factor with a mean weight of 4.18, underscoring the critical role of aesthetic considerations in public space design. The facilities criterion, encompassing workout equipment, outdoor dining facilities, and walking routes, ranked second, reflecting people's desire for diverse amenities in public spaces. The criteria of activities, social environment, and safety followed in third, fourth, and fifth positions, respectively. These insights can guide urban designers in prioritizing the most valued aspects when designing public spaces.

This study reveals that attractiveness is the most influential criterion in shaping public opinion about urban public spaces, followed by well-equipped amenities (facilities), engaging social activities, and a vibrant social environment that fosters interactions. Safety, while important, is the least influential criterion compared to the others. The study is limited to Beijing, China, and the findings may not be generalizable to other cultural or geographical contexts. The reliance on self-reported data from questionnaires may introduce bias, and this study focuses on a limited set of criteria, potentially overlooking other influential factors. Future research should extend study to other cities and cultural contexts to enhance generalizability, explore additional variables such as economic impact and environmental factors, investigate the long-term effects of these criteria on public opinion and urban planning outcomes, and utilize more diverse data collection methods, such as interviews and observational studies, to complement self-reported data.

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