Influences of new high-rise buildings on visual preference evaluation of original urban landmarks: a case study in Shanghai, China

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ABSTRACT

Newly-built high-rise buildings exert an unneglectable influence on the original urban outer spatial form. The visual preference evaluation of this influence can be taken as a key reference factor for the evaluation of public acceptance in the course of urban modernization. This paper sets two representative buildings of Shanghai as the research objects: The Oriental Pearl Radio & TV Tower, serving as the original urban landmark, and Shanghai Tower, representing the newly-built high-rise building. Relative height ratio, relative mass ratio, and relative distance ratio of the two buildings at different viewpoints are set as the physical properties. Eight key observation sites were selected as the viewpoints where photos of the two buildings were taken. Then, photo stimulation experiments were conducted with participants and the results were analyzed. The analytical results indicate that newly-built high-rise buildings exert certain influence not only on the urban outer spatial form centering around original urban landmarks, but on the potential change of urban viewpoints as well. The value ranges of relevant physical properties are also influential to visual preference evaluation. Height ratio (0.75, 1.00 and 1.50, 1.71), mass ratio (0.75, 1.10), and distance ratio (0.60, 0.78), the visual preference evaluation would be scored comparatively higher.

1. Introduction

In terms of urban spatial form, urban landmarks are of great significance for the urban image and overall style. Urban landmarks are defined as “external orientation points which are usually highly recognizable physical objects in urban spatial forms” (Lynch 1960). From the perspective of cultural transmission, urban landmarks are an indispensable and integral channel for people to perceive urban spaces (Han and Zhao 2018). Meanwhile, urban landmarks are also important carriers of urban history and culture and display the unique characteristics of a certain city that are formed over time (Li 2012).

Many cities of developing countries are keen on building urban landmarks to demonstrate their images among world metropolitan groups (Yun 2019). China is no exception in this case. Since the reform and opening-up in 1978, more and more high-rise buildings have sprung up in Chinese cities with the rapid development of the Chinese economy. In the context of rapid urban development in China, the surroundings of many urban landmarks are changing all the time (Wang 2018). The newly-built high-rise buildings exert various influences on the city and its central district, especially on the original urban architectural heritage (Short 2007). The increasing number of buildings and higher structures exert an unneglectable impact on the original urban spatial form, especially the original urban landmarks.

1.1. Research background

The Oriental Pearl Radio & TV Tower (hereinafter referred to as “the Tower”), located in Lujiazui finance and business district, Pudong New District, Shanghai, China, has been one of the most iconic representations of urban landmarks of modern Shanghai since its completion over twenty years ago. Started in July 1991 and put into use in May 1995, the 468-meter-tall tower has become the symbol of Shanghai in the history of Chinese modern urban development for many years. The architectural image of the tower has been used to represent Shanghai in numerous books, postcards, television programs, and network platforms and has spread all over the world. For many people, the Tower is indisputably a key representative architecture of China’s urban modernization, thus being emulated by many cities in China in their attempts to establish their own modern urban images.

In 2016, twenty-one years after the construction of the Tower, another eye-catching super high-rise building – the Shanghai Tower (put into operation in January 2017) – was erected in the Lujiazui architectural complex in Pudong New District of Shanghai. At a distance of 750 m to the Tower, Shanghai Tower is a super high-rise building that is multifunctional for businesses, offices, a hotel, commerce, entertainment, and sightseeing. With a height of 632 m, Shanghai Tower ranks the No.1 highest building in China and
No.2 in the whole world – among all the buildings constructed up to 2018.

The appearance of Shanghai Tower noticeably changes the spatial form of Lujiazui architectural complex in Pudong New District. Some researchers maintained that one key function of an urban landmark lay in its aesthetic value and more and more super high-rise buildings would change the spatial form which was mainly composed of the original urban landmarks; at the same time, the public visual satisfaction would change accordingly (Browne 2006). Therefore, the primary question to be investigated in this research is whether the construction of Shanghai Tower would influence the public’s visual preference Evaluation of urban spatial form of the Lujiazui finance and business district in Pudong New District of Shanghai – which centers around the Tower.

1.2. Visual preference evaluation

As a well-known and widely used research method, visual preference evaluation is often used to evaluate the visual influence of different architectural factors in architectural and natural surroundings. Although no consensus has ever been reached about its definition or implementation, this method is widely used to evaluate visual preference (Hernández, García, and Ayuga 2004). According to Tang and Wang (2007) and the Landscape Institute (2013), visual preference is caused by human activities. Iverson (1985) put forward the concept of visual quality, which, according to Iverson, is the result of interplay between the vertical and horizontal angles of the image object. He further described the visual effect of the image object from the quantitative perspective. Jacobs (2011) observed that landscape studies could replace individual psychological or mental studies. In other words, the research focus was not placed upon individual minds but the common meaning and image.

Photo stimulation is an important research method to study visual preference evaluation. Although photo display has certain limitations (Daniel 2001; Palmer and Hoffman 2001; Steinitz 2001), it is the most widely used and the most effective method for aesthetic evaluation (Barrosoalba 2012; Daniel 2001). Photos have been widely used to substitute actual landscapes in the previous research. Stamps lii (1990) proved that there was a high positive correlation between the information obtained by common people from static colored photos and that from actual scenery. Dupont et al. (2017), Daniel and Vining (1983), Abello and Bernaldez (1986), Kaplan et al. (1989), Ribe (1994), Bulut and Yilmaz (2008), Pfüger et al. (2010), and Howley et al. (2012) all used photos to substitute actual landscapes in their visual preference studies. Other researchers also explored the influence of physical property change on landscape aesthetics and tried to establish the corresponding relationship between physical properties and landscape aesthetics (Real, Arce, and Sabucedo 2000; Buhoff et al. 1994).

1.3. High-rise buildings

There is no clear definition of high-rise buildings yet (Karimimimoshaver and Winkemann 2018). Nevertheless, it seems to be an inevitable trend of urban development to build more and more high-rise buildings.

As for the urban spatial form, high-rise buildings, remarkably higher than surrounding buildings (Catchpole 1987), are not only one type of urban morphology but also a carrier of ideology. It is believed that high-rise buildings play a key role in urban spatial and visual continuity (Tavernor 2007). They are used to create a special image (Veschambre 2018) – a highly recognizable image (Czyńska and Rubinowicz 2019). For the urban spatial form which is featured with high-rise buildings, visual quality is the most important characteristic which exerts a direct influence on the public preference for high-rise buildings (Bulut and Yilmaz 2009). Cohen (1999) maintained that high-rise buildings were crucial to urban space and to adjust the building height would be beneficial for urban landscape protection.

As for the urban skyline, one study conducted by Heath, Smith, and Lim (2000) indicated that a direct relationship between the complexity of skylines and visual preference existed. Iii, Nasar, and Hanyu (2005) found that the urban skyline was often adjusted by controlling the height, mass, roof, and color of buildings. Karimimimoshaver and Winkemann (2018) claimed that the influence of high-rise buildings on urban skyline can be assessed from the following three dimensions: aesthetic dimension, visibility dimension, and meaning dimension.

In terms of the height of high-rise buildings, Lin, Homma, and Iki (2018) argued that high-rise buildings could be harmonized with the surroundings by adjusting their height, but that would weaken the visual impact of high-rise buildings. Yabuki, Miyashita, and Fukuda (2011) used an AR method to study the fusion of different building heights and surrounding landscapes. Samavatekbaten, Gholami, and Karimimoshaver (2016) discovered that the height, roof, and color of high-rise buildings were the most important physical features. And the most influential factor for visual preference evaluation was the height of building. Therefore, the building height is set as one of the variables.

In terms of the mass of high-rise buildings, some researchers have been conducted to explore the influence of various physical properties of high-rise buildings (such as slenderness ratio and distance) on visual
preference (Lim and Heath 2011). Short (2007) put forward that existing urban landscapes would be noticeably influenced by new buildings. Dupont et al. (2017) conducted a study which indicated that the public’s visual contrast varied noticeably as the mass of landscape architectures changed. Therefore, it is necessary to take mass as one variable.

According to the previous research, distance is one key factor that influences visual aesthetics. Ashihara (1981) demonstrated the relationship between distance and architectural texture through a series of photos. Ladd (1987) studied how the ratio between the horizontal distance (between viewpoint and visual object) and the height of the visual object influenced the viewers’ mental and aesthetic experience. García, Hernández, and Ayuga (2006) stressed that observation distance was extremely vital for the texture of the visual object. Lin, Homma, and Iki (2018) divided the observation distance into three levels: long-range, mid-range, and close range. Zarghamia et al. (2019) studied the tension created by the height, width, and height–width ratio of high-rise buildings and exerted upon the observers at different distances.

As the above literature review indicates, height, mass, and distance are three important factors that influence the visual preference evaluation of high-rise buildings.

1.4. Research questions and aims

To investigate the influence of newly-built high-rise buildings on the outer spatial form of existing urban landmarks, this research improved the visual preference evaluation method which is usually based on a single viewpoint. The relative data of the two research objects were taken as the research foundation for visual preference evaluation. A series of photos that contained both the Tower and Shanghai Tower was taken at different viewing areas. These photos clearly demonstrated the changes in relative height, relative mass, relative distance, and relative distance between the viewpoint and the central point. Through photo stimulation, visual evaluation, image analysis, and statistical analysis, the visual preference law existing in the spatial form of new high-rise buildings and original urban landmarks was explored. On this basis, the potential influence of this visual preference law was also studied on the future change of urban viewing areas.

This research aimed to find a method to study the following questions: With newly-built high-rise buildings appearing in the certain areas of existing urban landmarks, will people evaluate the outer spatial form of buildings appearing in this area differently? If the answer is positive, in what way(s)? What factors are influential in this process? What possible change will this difference bring forth on the future urban development? This research method should possess certain calculability and reflect people’s subjective feelings.

2. Method

2.1. The location where the photos were taken

The research material of this study is mainly a series of photos of the Tower, Shanghai Tower, and their background architecture complex. These photos were taken at 8 viewpoints such as Chen Yi Square, Financial Plaza, the plaza of the Gutzlaff Signal Tower (as shown in Figure 1). All the 8 viewpoints are either located in the intersection of main roads or landmark squares, where the Tower, Shanghai Tower, and their background architecture complex can be seen clearly.

Figure 1. The 8 viewpoints.
As the famous sightseeing area where visitors and local residents can experience the new and old Shanghai cityscape, the 8 viewpoints have become the most popular places for international visitors to take photos. Therefore, the 8 viewpoints are highly representative.

2.2. Capturing photos

Photos of architectural groups in Lujiazui district were taken respectively in similar weather conditions at Central Shiliupu pier, North of Shiliupu Pier, the plaza of the Gutzlaff Signal Tower, Financial Plaza, Chen Yi Square, Shanghai People’s Heroes Memorial Tower, Rainbow Bridge, and Music Square. To ensure the comparability, these photos were taken with the same procedures. Given that cellphones have become the most widely used picture-taking tools for most tourists and local citizens, all the photos were taken with an iPhone X (12MP rear dual cameras, f/1.8 and f/2.4 apertures, and optical image stabilization) in panorama mode and processed with the same image processing software. In the end, 8 photos in total – one basic photo from each viewpoint – were selected.

2.3. The photos of urban spatial form before and after the construction of Shanghai tower

The 8 photos were processed to remove Shanghai Tower with Photoshop CS5 according to the different viewing angles at the 8 viewpoints. Consequently, 16 photos were obtained and shown in the following figures (Figures 2 and 3). The 16 photos obtained display the state of the Tower and its surrounding architectural groups before and after the construction of the Shanghai Tower at the 8 viewpoints.

2.4. The photophysical properties of the tower and Shanghai tower

The photophysical properties of the Tower and Shanghai Tower were divided into four categories in the experiment: relative height (denoted as H1 and H2), relative mass (denoted as W1 and W2), relative distance to the vertical center line (S), and relative distance between the vertical center line of the Tower and Shanghai Tower and the center line of the photo (denoted as L1 and L2).

2.4.1. The relative height of the tower and Shanghai tower

The 8 photos were input to AutoCad2014 for drawing distance analysis. The relative height of the Tower and Shanghai Tower was defined as follows: the relative height of the Tower in each photo was defined as H1 and that of Shanghai Tower as H2. Then, the ratio of relative height of the Tower and Shanghai Tower can be calculated with the following equation: \( a = H1/H2 \). The results are shown in Table 1.

2.4.2. The relative mass of the tower and Shanghai tower

For the convenience of calculation, the relative mass of the Tower and Shanghai Tower is calculated in the following way: first, to grid the photo and then count the number of squares that the Tower occupies (denoted as W1) and that of the Shanghai Tower (denoted as W2). In this case, a square is not fully filled, it would be counted as half a square (0.5 square). Then, the ratio of the relative mass of the Tower and Shanghai Tower can be calculated with the following equation: \( b = W1/W2 \). The results are shown in Table 2.

Figure 2. After the construction.

Figure 3. Before the construction.
2.4.3. The relative distance of the tower and Shanghai tower

To simplify the calculation, a vertical center line was set in the photo and the relative distance between the vertical center line of the Tower and the vertical center line of the photo (denoted as L1) and that between the vertical center line of the Shanghai Tower and the vertical center line of the photo (denoted as L2) were calculated. On this basis, the relative distance between the Tower and Shanghai Tower (denoted as S1) could be obtained with the following equation: S1 = L1 + L2. Then, the ratio of S1 and the overall width of the photo (denoted as D) could be calculated as follows: c = S1/D. Given that the positions of the two buildings in the photo may influence the viewers’ visual preference, the central point of the line between the two buildings was set and then the relative distance between the central point and the vertical center line of the photo (denoted as S2) was calculated with the following equation: S2 = | (L1+ L2)/2-L1|. Then, the ratio of S2 and D could be displayed as follows: d = S2/D. The relative distance between the vertical line of the Tower, that of Shanghai Tower, and that of the photo was calculated and shown in the following table (Table 3).

Table 1. The relative height of the tower and Shanghai tower (Two decimal places are kept).

| Viewpoint | Relative height of the Tower H1 | Relative height of Shanghai Tower H2 | Average ratio a |
|-----------|---------------------------------|-------------------------------------|----------------|
| A1        | 10.15                           | 7.04                                | 1.44           |
| A2        | 10.80                           | 6.32                                | 1.71           |
| A3        | 10.58                           | 9.71                                | 1.09           |
| A4        | 9.59                            | 10.51                               | 0.91           |
| A5        | 7.05                            | 10.98                               | 0.64           |
| A6        | 5.60                            | 11.34                               | 0.49           |
| B1        | 10.97                           | 7.25                                | 1.51           |
| B2        | 9.90                            | 8.69                                | 1.14           |

Table 2. The relative mass of the tower and Shanghai tower (Two decimal places are kept).

| Viewpoint | Relative mass of the Tower W1 | Relative mass of Shanghai Tower W2 | Average ratio b |
|-----------|--------------------------------|-----------------------------------|----------------|
| A1        | 26                             | 20                                | 1.30           |
| A2        | 19                             | 20.5                              | 0.93           |
| A3        | 20                             | 18                                | 1.10           |
| A4        | 15                             | 19.5                              | 0.77           |
| A5        | 9                              | 39.5                              | 0.23           |
| A6        | 9                              | 40                                | 0.25           |
| B1        | 25                             | 13.5                              | 1.85           |
| B2        | 11.5                           | 6.5                                | 1.77           |

2.5. Experiment participants’ visual preference survey

Eight photos taken at 8 different viewpoints (as shown in Figure 2) were grouped and numbered as A1, A2, A3, A4, A5, A6, B1, and B2. At the same time, this group of photos was processed with Photoshop CS6 to remove Shanghai Tower, thus creating another group of photos (as shown in Figure 3). The second group of photos were numbered as A1-1, A2-1, A3-1, A4-1, A5-1, A6-1, B1-1, and B2-1. Both groups of photos were printed in full color and then bound randomly in book form. The participants in the experiment would not obtain any clues for the physical properties that these 16 photos represented.

These photos – as the judging criteria of the photo-stimulation method to evaluate the landscapes – were shown to the participants in the 8 viewing areas along the west bank of the Huangpu River in Shanghai. The participants scored each photo according to their preference within the range of 1~5 (1 denoting the least preference and 5 denoting the most preference). They could change their scores as they wished before the end of the experiment. The first round of evaluation in the experiment was conducted on 18 April 2019, with a total of 120 participants. The scores of each photo were counted and the average scores were calculated. To ensure the reliability of the experiment, a second round of evaluation in the experiment was conducted on 27 April 2019, with a total of 110 new participants. Given that the average preference scores of the two rounds of experiments were similar (one-way analysis of variance: F = 0.439, p = 0.325), the questionnaires of the two rounds could be further analyzed together. Among the 230 questionnaires in the two rounds, 206 were valid, with the validity rate reaching up to 89.6%.

Then, the data collected were analyzed with SPSS 22.0, an analytical software which was widely used in similar studies (Nematchoua, Ricciardi, and Buratti 2018). The score of A1 was compared with that of A1-1; the score of A2 was compared with that of A2-2; and the rest was done in the same manner. A paired-sample T test was used to verify the influence of Shanghai Tower on participants’ visual preference evaluation of the Tower. On this basis, multi-linear regression analysis was conducted for in-depth study.

3. Results

The average score of each photo (denoted as S) is calculated and shown in Table 4, the highest score being 4.73 whereas the lowest being 2.01. The average
The score of all the photos is 3.27. The photos which are numbered as A2 and A2-1 are scored the highest, the average score being 4.73 and 4.52, respectively. The photos which are numbered as A6 and A5-1 are scored the lowest, the average score being 2.01 and 2.29, respectively.

In the experiment where photos are used to replace actual urban landscapes, the average score of the photo is taken as the data that reflects the participants’ visual preference evaluation.

### 3.1. The visual influence necessity of Shanghai tower on the tower

At first, a paired-sample method was used to prove that the construction of Shanghai Tower did exert an influence on the visual preference evaluation of the urban spatial form of Lujiazui district in Pudong New District. As is indicated by the calculation results, the average score of visual preference displays a noticeable difference before and after the removal of Shanghai Tower from the photos (t = 2.331, P = 0.048 < 0.05). Consequently, it can be concluded that the existence of Shanghai Tower does influence the visual preference evaluation of the Tower, thus justifying the necessity and feasibility of the experiment. The calculation results are shown in Table 5.

Multiple linear regression analysis was then conducted to further analyze the data collected. In the multiple linear regression model, relative height ratio, relative mass ratio, relative distance ratio, and ratio of relative distance to vertical central line (hereinafter referred to as ratio a, b, c, and d, respectively) are taken as independent variables and the average score of photos as a dependent variable. The results indicate that ratio a (p = 0.015), b (p = 0.033), and c (p = 0.047) have a significant influence on the average score of photos and the ratios and the average score are positively correlated; on the other hand, ratio d (p = 0.602) has no significant influence on the average score of photos. Therefore, when stepwise multiple linear regression analysis is conducted, ratio d is excluded. The calculation results are shown in Table 6.

Next, the possibility of interaction between the physical properties of photos was studied. Collinearity analysis of the independent variables was conducted with a multiple linear regression model. As is shown in Figure 4, the standardized residuals of this model are normally distributed; meanwhile, the tolerance of ratio a is 0.409, its VIF being 2.444, that of ratio b is 0.467 and its VIF = 2.141, and that of ratio c is 0.623 and its VIF = 1.605. According to Arriaza et al. (2004), John (2008), and Menard (2002), when VIF is over 10 or tolerance is smaller than 0.2, the model has collinearity. As is shown in Table 6, the VIFs of ratio a, b, and c are all smaller than 10 and their tolerance are all larger than 0.2. Besides, the residuals are distributed normally. In this case, it can be safely concluded that the model does not have collinearity.

### Table 5. The necessity and feasibility checking of the experiment.

| Pair       | Score before the removal of Shanghai Tower | Score after the removal of Shanghai Tower | t   | df | Sig. (2-tailed) | 95% Confidence Interval of the Difference |
|------------|--------------------------------------------|------------------------------------------|-----|----|----------------|-----------------------------------------|
| A1 view point | 3.01                                        | 3.24                                     | 0.34889 | 0.44907 | 0.14969 | 0.00371 0.69407 | 2.331 8 0.048 |
| A2 view point | 4.73                                        | 4.52                                     | 0.44907 | 0.14969 | 0.00371 | 0.69407 |
| A3 view point | 3.76                                        | 3.24                                     | 0.14969 | 0.00371 | 0.048 |
| A4 view point | 3.69                                        | 3.27                                     | 0.048 |
| A5 view point | 3.26                                        | 2.29                                     | 0.271 |
| A6 view point | 2.01                                        | 2.48                                     | 2.106 |
| B1 view point | 3.89                                        | 3.21                                     | 2.016 |
| B2 view point | 2.93                                        | 2.41                                     | 3.21 |

### Table 6. Multiple linear regression analysis.

| Model                  | Unstandardized coefficients | Standardized coefficients | Collinearity Statistics |
|------------------------|-----------------------------|---------------------------|-------------------------|
|                        | Std. Error | Beta | t    | Sig. | Tolerance | VIF |
| (Constant)             | 1.172     | 0.369 | 0.731 |
| Relative height ratio (a) | 0.526     | 0.482 | 2.678 | 0.015 | 0.409    | 2.444 |
| Relative mass ratio (b) | 0.572     | 0.394 | 2.265 | 0.033 | 0.467    | 2.141 |
| Relative distance ratio (c) | 0.644     | 0.271 | 2.106 | 0.047 | 0.623    | 1.605 |
| Ratio of relative distance to vertical central line (d) | 7.731     | –0.166 | –0.565 | 0.602 | 0.714    | 1.400 |

a. Dependent Variable: score

### Table 4. The comparison of the average score of visual preference at the same viewpoint before and after the removal of Shanghai tower.

| Viewpoint | Before the removal of Shanghai Tower | After the removal of Shanghai Tower |
|-----------|--------------------------------------|-------------------------------------|
| A1 view point | 3.01                                | 3.24                                |
| A2 view point | 4.73                                | 4.52                                |
| A3 view point | 3.76                                | 3.24                                |
| A4 view point | 3.69                                | 3.27                                |
| A5 view point | 3.26                                | 2.29                                |
| A6 view point | 2.01                                | 2.48                                |
| B1 view point | 3.89                                | 3.21                                |
| B2 view point | 2.93                                | 2.41                                |
3.2. Photo score and physical property

Through curvilinear regression analysis, the influence of ratio a, b, and c on the average score of photos was explored. In total, six models were tested and the one boasting the highest degree of fitting was selected according to the value of $R^2$ (as shown in Figure 5).

Figure 4. Collinearity judgment.

Figure 5. Curvilinear regression analysis.

(1) For ratio a, when its value is within the interval (0.75, 1.00), a good visual preference evaluation score can be obtained; when its value is within the interval (1.50, 1.71), an excellent score can be obtained; when within the intervals (0.64, 0.75) & (1.00, 1.50), a poor score is to be obtained.
(2) For ratio b, when its value is within the interval $(1.80, +\infty)$, a good visual preference evaluation score can be obtained; when its value is within the interval $(0.75, 1.10)$, an excellent score can be obtained; when within the intervals $(0.23, 0.75)$ & $(1.10, 1.80)$, a poor score is to be obtained.

(3) For ratio c, when its value is within the interval $(0.6, 0.78)$, a good visual preference evaluation score can be obtained; when within the interval $(0.2, 0.6)$, a poor score is to be obtained.

(4) Through comparing the individual variable points which differ from the overall trends, it can be seen that when ratio a is 1.71, ratio b 0.9, and ratio c 0.5, the visual preference evaluation is scored highest.

4. Discussions

The experiments indicate that the relative height ratio, relative mass ratio, relative distance ratio between the newly-built high-rise building and the existing urban landmarks do exert a significant influence on visual preference evaluation of the overall urban spatial form. Meanwhile, according to literature study, these factors are of high reference value for the study of urban spatial form evaluation. This paper not only aims to prove the practical significance of the existing literature, but more importantly, provides quantified reference ranges for urban spatial form design. To be specific, this paper aims to provide comparison parameters of key factors of newly-built high-rise buildings and existing urban landmarks at certain viewing areas.

4.1. The influence of Shanghai tower on visual preference

Through comparing the photo scores before and after the removal of Shanghai Tower, it can be observed that before the removal, the top four scores go to the photos taken at viewpoints A2, A3, A4, and B1; however, after the removal of Shanghai Tower, the photo scores corresponding to the above four viewpoints all decline, but to a different degree. As is shown in Figure 1, the above four viewpoints are the best locations to appreciate the architectural complex of Lujiazui financial district. In the photos taken at the four viewpoints, the Tower occupies the main part of the picture. The corresponding ratio a is $1.71/1.09/0.91/1.51$, and that of ratio b is $0.93/1.10/0.77/1.77$, respectively. Therefore, the photos taken at these viewpoints can demonstrate the Tower as the urban landmark under the skyline effectively; meanwhile, the newly built high-rise buildings – as long as the mass is relatively proper – will not cause the intervention of destructive factors for visual preference evaluation into urban spatial form. Instead, the newly built high-rise buildings can enrich urban spatial form and diversify the scenery with its focus being more prominent.

The four photos that were scored relatively low were taken at viewpoints A1, A5, A6, and B2, respectively. In the photos taken at viewpoint A5, A6, and B2, the Tower is set near the border of the picture and only takes up a relatively small proportion of the whole picture. Consequently, the visual effect is likely to be much lower than the public’s mental expectation on Shanghai urban spatial form, which justifies the relative poor evaluation. The photo taken at viewpoint A1 was rated low despite the good viewpoint, but this can be ignored as an experimental error.

4.2. The influence of physical property on visual preference

The experimental results of a photo’s physical property indicate that the visual preference evaluation would be scored relatively high when the relative height ratio is within the intervals $(0.75, 1.00)$ and $(1.50, 1.71)$, and the relative mass ratio is within the interval $(0.75, 1.10)$. As is proved, at certain viewpoints, if the design height and mass of new high-rise buildings can be within the above intervals, the public acceptance will be relatively higher. One interesting experimental phenomenon is that when the relative height ratio is within the interval $(1.50, 1.71)$, visual preference evaluation improves significantly. The experimental objects within this interval are viewpoints A2 and B1. In the photos taken at these two viewpoints, the relative height of Shanghai Tower is lower than the existing landmarks. Contrarily, in the photos taken at viewpoint A4 whose relative height ratio is within the interval $(0.75, 1.00)$, the relative height of Shanghai Tower is larger than that of the Tower, thus achieving an objective evaluation score.

Second, when the relative mass ratio is within the interval $(0.75, 1.10)$, the visual preference evaluation scores corresponding to viewpoints A2 and A3 are comparatively higher than other experimental objects. Observed from the viewpoints A2 and A3, Shanghai Tower is quite close to the Tower in terms of mass, but in the photos taken at the corresponding viewpoints, Shanghai Tower is partially blocked by its surrounding buildings and thus cannot display its full image to the viewers. Accordingly, Shanghai Tower tends to be the background of the Tower in the vision of the viewers, which highlights the focus of the whole photo and thus justifies the higher scores.

When the relative distance ratio is within the interval $(0.6, 0.78)$, the visual preference evaluation scores corresponding to viewpoints A2 and A4 display a noticeable rise. Some uncontrollable external factors such as light or composition might cause some data error to the experimental results, but will not influence the judgment over the overall change trend of data.
Therefore, this experiment proves that the height and mass of new high-rise buildings do influence the way urban residents and tourists evaluate the typical urban impressions on the existing urban landmarks. The over high-rise buildings, that is, the high-rise buildings which are higher than the average height of architecture surrounding the original urban landmarks, would influence the viewers’ visual preference evaluation of urban spatial form through the destructive intervention. By controlling the height and mass of new high-rise buildings within certain intervals in the process of planning and design, the public acceptance of urban spatial form after the intervention can be ensured. The illuminating conclusion drawn from the experiment of relative distance ratio can be taken as compensatory measures in the case that the height and mass control cannot be carried out effectively.

4.3. The visual impact evaluation of viewing areas

Among all the photos taken at the 8 viewpoints, those taken at A2 (Chen Yi Square), B1 (Rainbow Bridge in the riverside green space of North Bund), A3 (Financial Plaza), and A4 (Meteorological information plaza) were scored higher than the rest. The specific scores of the photos taken at these four viewpoints are as follows: A2 (4.73), B1 (3.89), A3 (3.76), and A4 (3.69). Chen Yi Square is located over against Nanjing East Road where tourists and traffic flow converge, thus being an important tourist attraction in the Bund. Since its construction over 30 years ago, countless photography shoots on the Bund have been arranged there. Meanwhile, the image of the Tower as the urban landmark of Shanghai has become deeply rooted in the public’s minds and emerged as the key symbol of Shanghai urban spatial form. In spite of the impact brought by the construction of Shanghai Tower, the photos taken at the above viewpoints can still highlight the dominant position of the Tower in urban spatial form of Shanghai. Being in line with the public’s mental expectation, it would be natural for these photos to be scored favorably.

Among all the photos taken at the 8 viewpoints, those taken at B2, A5, A1, and A6 were scored comparatively lower. The relative mass ratios of the photos taken at viewpoint A5 and A6 are 0.21 and 0.06, respectively. This clearly indicates that Shanghai Tower occupies a relatively excessive proportion of the whole photo. The comparatively low scores of the photos can be justified by the following two points. One, the relative mass of Shanghai Tower is too much to be reasonably proportionate, thus reducing the harmony and aesthetic value of the whole photo. Two, compared with the mass of the Tower, that of Shanghai Tower is too prominent in the photo, which goes against the public’s mental expectation and thus destroys the deeply rooted impression that the Tower takes the leading role in the urban spatial form of Shanghai. The above two points can explain why the photos did not get positive acknowledgement from the public. In the photo taken at B2, the mass of building groups on the left side is far out of proportion to that on the right side of the photo. In this case, the whole photo displays an imbalance in its composition, which fails to highlight the status of the Tower as the urban landmark and leads to a low score in the end. In terms of the photo taken at A1, its score belongs to the lower middle level. It can be ignored as an exceptional case of experimental error.

4.4. Limitations and future research

As is indicated by the experimental results, the group of photos that contain Shanghai Tower are scored at an average of 3.42. The top score, 4.73, is attributed to the photo taken as viewpoint A2, of which ratio a is 1.71, ratio b 0.9, and ratio c 0.5. According to the above discussion, both ratio a and ratio b are both within the intervals of a relatively good evaluation. Only the parameter of ratio c belongs to the extreme value. Therefore, it can be inferred that some out-of-lab factors exist that exert impact on ratio c, such as uncontrollable visual perception principles or constitutive elements of the overall picture.

The process of how human beings perceive certain urban spaces is complicated in that it is a process of different senses interweaving and overlaying with each other, such as senses of sight, hearing, smell, touch, and direction. Besides, it is also interwoven with the perception impression of scenes of the same kind (Xili and Siostrom 2015). This experiment did not cover all the statistic factors relevant to visual preference evaluation. Instead, the focus was only given to the influence of new high-rise buildings on visual preference evaluation of the existing urban landmarks. But this study can provide a valuable reference for urban planning and landscape design. In the following research, more factors can be analyzed comprehensively and thus more detailed reference data can be obtained.

5. Conclusion

The components of the main visual activities or urban landmarks can be taken as the most important part of city images in that they play a decisive role in urban visual images (Lynch 1960). The outer spatial form of urban landmarks is also closely related to skylines. As previous researches reveals, the physical factors such as building height, building volume, the distance between viewpoints and buildings exert substantial influence on the component of skylines (Stamps, Nasar, and Hanyu 2005; Gassner 2013). Urban skylines...
reflect the global characters of a city in cultural, social, and economic dimensions (Al-Kodmany and Ali 2013; Gassner 2009).

The conclusion drawn in this paper could help architects to further understand the reference factors that the mass public is concerned about when conducting visual preference evaluation of urban landmarks and their surrounding architectural complex. As can be drawn from the experiment, the height and mass control of newly built high-rise buildings as well as the relative distance ratio are highly important references for the visual preference evaluation of the Tower – the existing urban landmark of Shanghai. When relative height ratio is within the intervals (0.75, 1.00) and (1.50, 1.71), relative mass ratio is within the interval (0.75, 1.10), and relative distance ratio is within the interval (0.60, 0.78), the visual preference evaluation would be scored comparatively higher. In other words, at certain viewpoints, if the design height and mass of new high-rise buildings can be set within the above parameter intervals, the design can be accepted by the public more positively.

In addition, the analysis of viewpoints where photos with comparatively high scores are taken indicates that new high-rise buildings change the urban spatial form composed of the existing urban landmarks and their surrounding building groups. Accordingly, the popularity of different viewing areas would change dramatically. In the future, the number of tourists in Chen Yi Square, Rainbow Bridge, Financial Plaza, and Meteorological Information Square may increase gradually. The urban planning of Shanghai needs to consider what measures should be taken to tackle the potential changes in the above-mentioned viewing areas. Likewise, other viewing areas may witness a decline in the number of tourists, which poses a challenge to urban planning and design. These studies are of important reference to other cities in similar circumstances.

Whichever city we live in or visit, the high ground or places of micro-topography would be on the top of tourists’ sightseeing list and urban residents’ preference list (Xili and Siostrom 2015). To win the public’s support and acceptance, any architecture or urban planning has to meet the mass public’s needs (Gobster et al. 2007). Contrarily, neglecting the public’s psychological evaluation may lead the architecture or urban planning to failure (Junker and Buchecker 2008). This research is helpful for urban planners and architects to know about the opinions of urban residents and tourists on the development of high-rise buildings in recent years. The reference intervals of height, mass and relative distance of new high-rise buildings in certain viewing areas can help city planners design buildings of high public acceptance and provide prospective prediction for the planning of urban viewing areas.

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References
Abello, R. P., and F. G. Bernaldez. 1986. “Landscape Preference and Personality.” Landscape and Urban Planning 13 (86): 19–28. doi:10.1016/0169-2046(86)90004-6.

Al-Kodmany, K., and M. Ali. 2013. The Future of the City. Southampton: Wit Press.

Arriaza, M., J. F. Cañas-Ortega, J. A. Cañas-Madueño, and P. Ruiz-Aviles. 2004. “Assessing the Visual Quality of Rural Landscapes.” Landscape and Urban Planning 69 (1): 115–125. doi:10.1016/j.landurbplan.2003.10.029.

Ashihara, Y. 1981. Exterior Design in Architecture. New York: Van Nostrand Reinhold Company.

Barrosoaabaa, F. L. 2012. “Dealing with Landscape Fuzziness in User Preference Studies: Photo-based Questionnaires in the Mediterranean Context.” Landscape & Urban Planning 104 (3): 329–342. doi:10.1016/j.landurbplan.2011.11.005.

Browne, L. A. 2006. “Regenerate: Reusing a Landmark Building to Economically Bolster Urban Revitalization.” Diss., University of Cincinnati.

Buhyo, G. J., P. A. Miller, J. W. Roach, D. Zhou, and L. G. Fuller. 1994. An AI Methodology for Landscape Visual Assessments. (USA): AI applications.

Bulut, Z., and H. Yilmaz. 2008. “Determination Of Landscape Beauties Through Visual Quality Assessment Method: A case Study for Kemalyye (Erzincan/turkey).” Environmental Monitoring and Assessment 141 (1–3): 121–129. doi:10.1007/s10661-007-9882-0.

Bulut, Z., and H. Yilmaz. 2009. “Determination of Waterscape Beauties through Visual Quality Assessment Method.”
Environmental Monitoring & Assessment 154 (1–4): 459. doi:10.1007/s10661-008-0412-5.

Catchpole, T. 1987. London Skylines: A Study of High Buildings and Views. London: London Research Centre.

Cohen, N. 1999. Urban Conservation. Cambridge: MIT Press.

Czyszka, K., and P. Rubinowicz. 2019. “Classification of Cityscape Areas according to Landmarks Visibility Analysis.” Environmental Impact Assessment Review 76: 47–60. doi:10.1016/j.eiar.2019.01.004.

Daniel, T. C. 2001. “Whither Scenic Beauty? Visual Landscape Quality Assessment in the 21st Century.” Landscape & Urban Planning 54 (1): 267–281. doi:10.1016/S0169-2046(01)00141-4.

Daniel, T. C., and J. Vining. 1983. “Methodological Issues in the Assessment of Landscape Quality. Human Behavior & Environment.” Advances in Theory & Research 6: 39–84.

Dupont, L., K. Ooms, M. Antrop, and V. Van Eetvelde. 2017. “Testing the Validity of a Saliency-based Method for Visual Assessment of Constructions in the Landscape.” Landscape and Urban Planning 167: 325–338. doi:10.1016/j.landurbplan.2017.07.005.

Garcia, L., J. Hernandez, and F. Ayuga. 2006. “Analysis of the Materials and Exterior Texture of Agro-industrial Buildings: A Photo-analytical Approach to Landscape Integration.” Landscape & Urban Planning 74 (2): 110–124. doi:10.1016/j.landurbplan.2004.10.007.

Gassner, G. 2009. “Elevations, Icons and Lines: The City Abducted through Its Skylines.” In The Researching the Spatial and Social Life of the City, edited by J. Davis, C. Dean, G. Gassner, S. Hall, and J. Keddie, 68–86. http://www.lse.ac.uk/LEScities/programme/pdf/citiesLAB/citiesLAB1_gassner.pdf.

Gassner, G. 2013. Unfinished and unfinished: London’s skylines(PhD). London School of Economics and Political Science (LSE).

Gobster, P. H., J. I. Nassauer, T. C. Daniel, and G. Fry. 2007. “The Shared Landscape: What Does Aesthetics Have to Do with Ecology?” Landscape Ecology 22 (7): 959–972. doi:10.1007/s10980-007-9110-x.

Han, C., and M. Zhao. 2018. Landscape Architectural Design. Beijing: China Architecture & Building Press.

Heath, T., S. G. Smith, and B. Lim. 2000. “Tall Buildings and the Urban Skyline: The Effect of Visual Complexity on Preferences.” Environment and Behavior 32 (4): 541–556. doi:10.1177/001391600021972658.

Hernández, J., L. García, and F. Ayuga. 2004. “Assessment of the Visual Impact Made on the Landscape by New Buildings: A Methodology for Site Selection.” Landscape & Urban Planning 68 (1): 15–28. doi:10.1016/S0169-2046(03)00116-6.

Howley, P., C. O. Donoghue, and S. Hynes. 2012. “Exploring Public Preferences for Traditional Farming Landscapes.” Landscape and Urban Planning 104 (1): 66–74. doi:10.1016/j.landurbplan.2011.09.006.

Ili, A. S., J. L. Nasar, and K. Hanyu. 2005. “Using Pre-construction Validation to Regulate Urban Skylines.” Journal of the American Planning Association 71 (1): 73–91. doi:10.1080/01944360508976406.

Iverson, W. D. 1985. “And That’s about the Size of It: Visual Magnitude as a Measurement of the Physical Landscape.” Landscape Journal 4 (1): 14–22. doi:10.3368/lj.4.1.14.

Jacobs, M. 2011. “Psychology of the Visual Landscape.” Research in Urbanism Series 2 (1): 41–54.

John, R. S. 2008. “Linear Statistical Models: An Applied Approach.” Technometrics 29 (2): 237–238. doi:10.1080/00401706.1991.10484830.

Junker, B., and M. Buchecker. 2008. “Aesthetic Preferences versus Ecological Objectives in River Restorations.” Landscape and Urban Planning 85 (3–4): 141–154. doi:10.1016/j.landurbplan.2007.11.002.

Kaplan, R., and S. Kaplan. 1989. The Experience of Nature: A Psychological Perspective. Cambridge: Cambridge University Press.

Karimimoshaver, M., and P. Winkemann. 2018. “A Framework for Assessing Tall Buildings’ Impact on the City Skyline: Aesthetic, Visibility, and Meaning Dimensions.” Environmental Impact Assessment Review, 73: 164–176. doi:10.1016/j.eiar.2018.08.007.

Ladd, B. K. 1987. “Urban Aesthetics and The Discovery Of The Urban Fabric in Turn-of-the-century Germany.” Planning Perspectives 2 (3): 270–286. doi:10.1080/0266548708725644.

Landscape Institute. I. E. M. A. 2013. “Guidelines for Landscape and Visual Impact Assessment.” Landscape Design Journal of the Landscape Institute 3–4. doi:10.4324/9780203436295.

Li, X. 2012. Research on Urban Signature Architectural Design Based on Semiotics. Jinan: Shandong Jianzhu University.

Lim, B., and T. Heath. 2011. “What Is A Skyline: A Quantitative Approach.” Architectural Science Review 37 (4): 8. doi:10.1080/00038628.1994.9697343.

Lin, L., R. Hommer, and K. Iki. 2018. “Preferences for a Lake Landscape: Effects of Building Height and Lake Width.” Environmental Impact Assessment Review 70: 22–33. doi:10.1016/j.eiar.2018.03.001.

Lynch, K. 1960. The Image of the City. Cambridge: MIT Press.

Menard, S. 2002. Applied Logistic Regression Analysis (Vol. 106). Sage. doi:10.1177/001391600212983433.

Nematchoua, M. K., P. Ricciardi, and C. Buratti. 2018. “Adaptive Approach of Thermal Comfort and Correlation between Experimental Data and Mathematical Model in Some Schools and Traditional Buildings of Madagascar under Natural Ventilation.” Sustainable Cities and Society 41: 666–678. doi:10.1016/j.scs.2017.11.029.

Palmer, J. F., and R. E. Hoffman. 2001. “Rating Reliability and Representation Validity in Scenic Landscape Assessments.” Landscape and Urban Planning 54 (1–4): 149–161. doi:10.1016/S0169-2046(01)00133-5.

Pflüger, Y., A. Rackham, and S. Larned. 2010. “The Aesthetic Value of River Flows: An Assessment of Flow Preferences for Large and Small Rivers.” Landscape and Urban Planning 95 (1–2): 68–78. doi:10.1016/j.landurbplan.2009.12.004.

Real, E., C. Arce, and J. M. Sabucedo. 2000. “Classification of Landscapes Using Quantitative and Categorical Data, and Prediction of Their Scenic Beauty in North-western Spain.” Journal of Environmental Psychology 20 (4): 355–373. doi:10.1006/jenv.2000.0184.

Robert G. Ribe. 1994. “Scenic Beauty Perceptions along The ROS.” Journal of Environmental Management 42 (3): 199–221. doi:10.1016/j.jema.1994.1069.

Samavatkebata, A., S. Gholami, and M. Karimimoshaver. 2016. “Assessing the Visual Impact of Physical Features of Tall Buildings: Height, Top, Color.” Environmental Impact Assessment Review 57: 53–62. doi:10.1016/j.eiar.2015.11.008.

Short, M. 2007. “Assessing the Impact of Proposals for Tall Buildings on the Built Heritage: England’s Regional Cities in the 21st Century.” Progress in Planning 68 (3): 97–199. doi:10.1016/j.progress.2007.07.003.

Stamps, A., J. Nasar, and K. Hanyu. 2005. “Using Pre-construction Validation to Regulate Urban Skylines.” Journal of the American Planning Association 71: 73–91. doi:10.1080/01944360508976406.
Stamps, A. E. 1990. “Use of Photographs to Simulate Environments: A Meta-analysis.” Perceptual and Motor Skills 71 (3): 907–913. doi:10.2466/pms.1990.71.3.907.

Steinitz, C. 2001. “Visual Evaluation Models: Some Complicating Questions regarding Memorable Scenes.” Landscape & Urban Planning 54 (1): 283–287. doi:10.1016/S0169-2046(01)00142-6.

Tang, X., and X. Wang. 2007. “Landscape Visual Environment Assessment (LVEA): Concept, Origin and Development [J].” Journal of Shanghai Jiaotong University (Agricultural Science) 25 (3): 173–179. http://en.cnki.com.cn/Article_en/CJFDOTAL-SHNX200703000.htm

Tavernor, R. 2007. “Visual and Cultural Sustainability: The Impact of Tall Buildings on London.” Landscape and Urban Planning 83 (1): 2–12. doi:10.1016/j.landurbplan.2007.05.010.

Veschambre, V. 2018. “Renewal and ‘Deverticalization’in French Social Housing: The Emblematic Case of the Rhône-Alpes Region.” Built Environment 43 (4): 620–636. doi:10.2148/benv.43.4.620.

Wang, Z. 2018. “Evolving Landscape-Urbanization Relationships in Contemporary China.” Landscape & Urban Planning 171: 30–41. doi:10.1016/j.landurbplan.2017.11.010.

Xili, H., and P. Siostrom. 2015. CITY SENSE(S) Hidden Dimensions of Urban Places. Beijing: China Architecture & Building Press.

Yabuki, N., K. Miyashita, and T. Fukuda. 2011. “An Invisible Height Evaluation System for Building Height Regulation to Preserve Good Landscapes Using Augmented Reality.” Automation in Construction 20 (3): 228–235. doi:10.1016/j.autcon.2010.08.003.

Yun, J. 2019. “A Copy Is (Not A Simple) Copy: Role of Urban Landmarks in Branding Seoul as A Global City.” Frontiers of Architectural Research. doi:10.1016/j.foor.2018.12.005.

Zarghamia, E., M. Karimimoshaverb, A. Ghanbarana, and P. SaadatiVaghara. 2019. “Assessing the Oppressive Impact of the Form of Tall Buildings on Citizens: Height, Width, and Height-to-width Ratio.” Environmental Impact Assessment Review 79: 106287. doi:10.1016/j.eiar.2019.106287.