

# Analysis of the Visual Quality of Riverfront Skyline Through the Feature of Height and Spatial Arrangement of Tall Building

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**Abstract** In modern times, numerous cities are competing to create the unique skyline adjacent to the water. Tall buildings located across the river have a great contribution to the skyline of a riverfront city and can be a precious asset for the city. Moreover, in several cities, tall buildings and their impact on the urban skyline are a matter that should be considered and regulated in urban design. Therefore, as a prominent element in a larger visual setting of the city, tall buildings should improve the visual quality of the skyline rather than diminish that quality. This research attempts to provide an objective method to analyze the visual quality of the skyline made by a group of tall buildings through their feature of heights and spatial arrangement from riverfront views. The analysis is determined by the design variables of building heights variation, heights transition, density, and spacing of a group of tall buildings. A comparative case study of tall buildings in Yeouido and Lujiazui was conducted to prove the effectiveness of the analysis. The proposed method can be used in a simple way in the quantitative approach to quantify the visual quality of the skyline. In conclusion, Yeouido's skyline is not quite interesting from the riverfront view in terms of height variation and continuity of the skyline view because they are dispersed. Conversely, Lujiazui's skyline from the riverfront vantage points has a good quality in all aspects of the feature of height and spatial arrangements of tall buildings cluster. These factors can be used for the urban designer on how proposed tall buildings within the cluster should appropriately respond to adding image on the skyline.

*Keywords: skyline, tall buildings, riverfront, visual quality*

## 1. INTRODUCTION

Tall buildings have a major role in the urban form and the urban skyline to create the image of a city and provide a pleasant view for residents and tourists. Many cities are competing to improve the iconicity of their skylines by inserting tall buildings projects within the city. Clustered tall buildings within a confined area such as a central business district or waterfront area are proposed as the most positive means of introducing vertical forms into the skyline of a city. As well as making for more efficient public transport systems, providing more urban sustainability, and improving the socio-economic conditions

(Gonçalves, 2010, Ali and Al-Kodmany, 2012), clustered tall buildings can have distinct advantages in terms of design, infrastructure, and cityscape quality. Moreover, a cluster of tall buildings is able to create a much stronger skyline than single towers that are scattered across the city. Therefore, urban design has been giving attention to the tall buildings' strategy including visual impact within the urban context.

The skyline can be appreciated from the vantage points which are often an important tourism focus and foster the local economy. Various skylines that can be seen from the land, waterfront along the river or coastline, and high vantage (Kostof, 1991, Al-Kodmany and Ali, 2013) provide a unique experience to the urban viewers on how the skyline is perceived and understood. Chicago, Sydney, Shanghai, Hong Kong, and Singapore are among major metropolitan cities in the world that present a unique identifiable skyline. Particularly, the presence of tall buildings that close to the water makes the view of the skyline clear and wide. Waterfront cities take advantage of its site to secure an attractive skyline by arranging tall buildings along the waterfront. Chicago, the birthplace of the skyscraper, offers a dynamic skyline viewed from Lake Michigan. The visitors of Shanghai can enjoy the significant skyline across the Huangpu River. The futuristic tall buildings along Victoria Harbor with

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verdant mountains in the background give a natural view of Hong Kong's skyline. These tall buildings cluster surrounded by the natural environment such as water tends to have a high skyline score (Ford, 1976) and constantly attracts the attention of the people (Sakici, 2015). This circumstance often creates edges and observers are able to take a view in the entire skyline. An attractive skyline, particularly created by a cluster of tall buildings, could help to improve a sense of place and the city's image.

For this reason, studies on the spatial arrangements of tall buildings in relation to their impact on the cityscape are needed to enhance the visual quality of urban skyline. According to Bell et al. (1994), the visual quality is the beauty which felt by someone based on their experience so they can recognize a meaningful form in a particular object with vibration or beauty stimulation. Visual signs are the main characteristic that physically can be seen and give attributes to the visual sources in a visual system so that the visual system has certain qualities (Smardon et al., 1986). The visual quality can be a very significant factor in whether such areas will continue to garner new investment. Tall buildings on the riverfront area are examples of setting where visually sensitive projects can make a critical difference in the economic future of the city. Therefore a cluster of tall buildings as a prominent element in a larger visual setting of the city should improve the visual quality of the skyline, rather than diminish that quality through a prominent spatial arrangement in the urban design plan. This research attempts to provide an objective method to analyze the visual quality of the skyline that is made by a cluster of tall buildings through their feature of height and spatial arrangement from riverfront views. The analysis is determined by the design variables of building heights variation, heights transition, density, and spacing of a group of tall buildings. A comparative case study of tall buildings in Yeouido and Lujiazui was conducted to prove the effectiveness of the analysis. These case studies were used to explain several phenomena happening on the cluster sites and later can be generalized into the bigger scope of the research area. The capability of the proposed method can be used in a simple way in a quantitative approach to quantify the visual quality of the skyline.

## 2. VISUAL QUALITY OF SKYLINE

### (1) Riverfront cities

Special features of water in the landscape is beneficial to improve the urban spatial quality (Bulut and Yilmaz, 2009, Sakici, 2015, Svobodova et al., 2015). Large open surfaces of the water, such as rivers, lakes, and sea supports the visual openness (Shach-Pinsly et al., 2011) to the attractive view in the urban environment (Burmil et al., 1999). Moreover, the approach to the city along the waterfront can be a dramatic urban entrance. Over recent decades, urban development near the waterfront has evolved and been transformed into a mixed-use development with a large scale project that plays a new structuring role in the urban environment (Shrestha and Shrestha, 2008). A towering

cluster of tall buildings rising on the riverfront cities is the major vistas of modernism of the city.

The rapid economic development motivates modern cities to create a new urban environment with taller iconic tall buildings to express their economic power. In Shanghai, Lujiazui district has been transformed into a financial district on the banks of Huangpu River that becomes the main area for a number of tall buildings. The similar condition also happens to Yeouido, an island in the Han River that located in the south of Seoul's city core, which now also represents the center of finance, politics, and media activities with commercial office towers and apartment complexes. With the circumstance of these areas, tall buildings and rivers provide the perfect combination to create a delightful panoramic view. The aforementioned district showed the typical tall buildings development in the riverfront during modern times. Due to their similarity in area function for the financial and business district, the scale and geographical area, the tall buildings clusters in Yeouido (Seoul) and Lujiazui (Shanghai) are selected as the case studies in this research. Then, differences in feature of height and spatial arrangements in both areas have been compared to find out the visual quality of the riverfront skyline.

Riverfront is expected to be a great option to build more tall buildings without interfering with the lower buildings in the future modern cities. Nevertheless, tall buildings projects will keep continuing, so that needs to be evaluated as an important part of urban design. Evaluations should be made to the improvements needed on the visual quality of the urban skyline. The view of the skyline from the riverfront can be a precious asset in characterizing the city.

### (2) Tall buildings and skyline

In modern architecture, the idea of height and verticality is most commonly associated in terms of tall building and skyline. Thus, the word 'skyline' generally perceive as the outline or silhouette of a number of buildings seen against the sky. For the city, the skyline has a function as the chief symbol of an urban collective (Attoe, 1981). Kostof (1991), in his description, "Skylines are urban signatures.....the shorthand of urban identity, and the chance for urban flourish." But a skyline is also a potential work of art (Spreiregen, 1965), a work of architecture that aesthetically related to physical features of the skyline itself.

The visual impacts of tall buildings on the skyline may be evaluated by several categories of visual considerations, such as visual quality. Where the visual quality can be seen through visual clues of image perception perceived by the eye (sign) (Ching, 2011). According to Smardon et al. (1986), the value of the visual quality of an area can be indicated by the physical qualities that formed by the relationship between visual elements in the urban landscape. On the basis of similar cognition, the visual quality of skyline in this research is indicated by the principles of visual elements on the features of tall buildings.

According to Samavatekbatan et al. (2015), the visual aspect of tall buildings can be approached in three ways: as a group in the skyline, the physical appearance, and the visibility in

urban views. In terms of the visual impact on tall buildings on the skyline, there is a small number of studies that examine tall buildings as a group. Lim and Heath (1994) developed a mathematical model to quantify the slenderness ration and spacing of skyline on three cities by sample photographs of postcards. Heath et al. (2000) also investigated the effect of silhouette and façade complexity of tall buildings o preferences for skylines by a number of the set of images with different levels of silhouette complexity and façade articulation. Stamps III et al. (2005) has found that a pleasant and interesting skyline can be generated by the variance of buildings attribute such as heights, widths, and setbacks. However, these only showed a portion of an urban skyline without defining the boundaries area of buildings. The formed skyline may be a collection of tall buildings in one area or a collection of the scattered location of tall buildings. Clustering tall buildings in one area, certainly have specific purposes, especially in urban design. The legibility of the area could enhance by the distinctness of the skyline from the surroundings. The strategy of tall buildings cluster incorporating with urban design qualities (Al-Kodmany, 2012) can be an approach to create an attractive skyline.

Several kinds of literature determine the visual impacts of tall buildings cluster in the urban form by design variables of buildings height (Kostof, 1991), their distance, the ratio with the surroundings, and architectural form (Gonçalves, 2010). A range of studies also suggested a combination of principles for tall buildings, particularly in clustering design, such as focal points, visual relief, transition (Al-Kodmany, 2012), density, and nearness (Bell, 2013). These design variables of tall buildings in the urban form are summarized in Table 1. The visual quality of urban skyline can be assessed through these considerations of tall buildings design variables.

Table 1. Design variables of tall buildings for the city skyline

<i>Kostof (1991)</i>	<i>Gonçalves (2010)</i>	<i>Al-Kodmany (2012)</i>	<i>Bell (2013)</i>
<ul style="list-style-type: none"> <li>• Height</li> <li>• Shape</li> <li>• Approach</li> </ul>	<ul style="list-style-type: none"> <li>• Height</li> <li>• Distance between tall buildings</li> <li>• The ratio of tall buildings and not-vertical surroundings</li> <li>• Architectural form</li> </ul>	<ul style="list-style-type: none"> <li>• Focal points</li> <li>• Visual relief</li> <li>• Transition</li> <li>• Varying building height and massing</li> <li>• Design diversity</li> <li>• Visual coherence</li> <li>• Ventilation</li> </ul>	<ul style="list-style-type: none"> <li>• Density</li> <li>• Nearness</li> </ul>

### (3) Visual quality

In accordance with the scope and objective of this research, the design variables of tall buildings for the city skyline that we used are the feature of height: building heights variation and heights transition, and spatial arrangements: density and spacing.

To characterize the skyline through the feature of height and spatial arrangements of tall buildings, it is necessary to define the criteria of the visual quality from the type of design variables

of tall buildings on the skyline. Table 2 illustrates the types of design quality used in assigning low, medium, and high visual quality to tall buildings on the skyline by utilizing the variables of building heights variation, heights transition, density, and spacing. The level of visual quality is an indicator of designing the tall buildings on the skyline as expressed by several recommendations and results of previous studies on visual analyses of the skyline (Nasar et al., 2002, Stamps, 2002, Stamps III et al., 2005, Al-Kodmany, 2012, Al-Kodmany, 2017).

### 3. METHODS

The analysis of the visual quality of tall buildings cluster and their impact on the skyline is conducted through the categories of the feature of tall buildings and spatial arrangement. First, the feature of tall buildings defined by its height. A group of tall buildings should be organized in varied height and a proper transition between taller and lower buildings is required to avoid abrupt elevation changes. Second, the legibility of tall buildings as a cluster in a confined area is indicated by density which is created by the closeness and spacing between them that give an impact on visual continuity and reinforces the shape of the skyline. The sightings of these skylines should be appreciated from vantage points where it perceived by observers. The method of measurement as follows:

Table 2. The visual quality criteria for tall buildings

Variable		Level of Visual Quality
Building heights variation	L	No variance, Similar height, Monotone skyline, Less interesting and pleasantness
	M	Moderate variance in building heights
	H	High variance in building heights, More vibrant and dynamic, More interesting and pleasantness
Height transition	L	Flat, No transition or no height changes, Monotone skyline
	M	Multiple mounds, Common skyline, Placement of buildings may look accidental
	H	Gradual transition, More orderly, Recognized as a cluster (one convex skyline shape) or two adjacent clusters (two convex skyline shape), The taller building may be located inland with a lower structure closer to the periphery or waterfront
Density & Spacing	L	Low dense, Sparsely built, Not recognized as a cluster, Wide spacing, Large gaps among buildings, Disperse spatial patterns, Visual disorder, Weaken the skyline
	M	Medium dense, Open arrangement of buildings, May recognized as a cluster
	H	High dense, Compact high-rise, Tend to have greater visual weight, Recognized as a cluster, Narrow spacing, Provide visual continuity and reinforce the shape of the skyline, Creating vivid edges

L (Low); M (Medium); H (High)

**(1) Tall buildings model and height**

Regarding the height of tall buildings, based on the city’s condition and context, the criteria for tall buildings are above 100 meters that distinct from the lower. The case studies in this research are riverfront district areas that are Yeouido district in Seoul city and Lujiazui district in Shanghai city. In accordance with the objective of the study, 3D building models were created in a simple high block without considering more architectural or physical details, such as the face with windows and texture, building step-back, the top, and building materials. The establishment of 3D building models was created using Rhinoceros. The information about building elevation and their precision location on the site were derived from the Council on Tall Buildings and Urban Habitat (CTBUH) and Emporis building databases.

**(2) Building heights variation**

The variation of building heights is identified from the changing of the skyline. The change of building height on the skyline is calculated by using delta. Delta ( $\Delta$ ) is used to represent the change of any changeable quantity. For example:

The first (a) and the next (b) building height is not same,

if  $a \neq b$ ,  $\Delta_{100\ 150} = 0$ , the skyline is changed, whereas

the first (a) and the next (b) building height is same,

if  $a = b$ ,  $\Delta_{100\ 100} = 1$ , the skyline is not changed (flat).

The building heights are classified into different elevation groups to simplify the calculation of building heights change on the skyline as follows, 100m+, 150m+, 200m+, 250m+, and so on with interval height of 50 meters where is equal to approximately 12 floors.

**(3) Heights Transition**

A building height profile between low-rise and high-rise buildings should have a proper transition to avoid abrupt elevation changes. Therefore within a cluster of tall buildings, the tallest building is ideally situated in the center of a cluster and or inland which also acts as a focal point. While the height of other tall buildings (lower building) should decrease the further they are away from the center or closer to the periphery or waterfront.

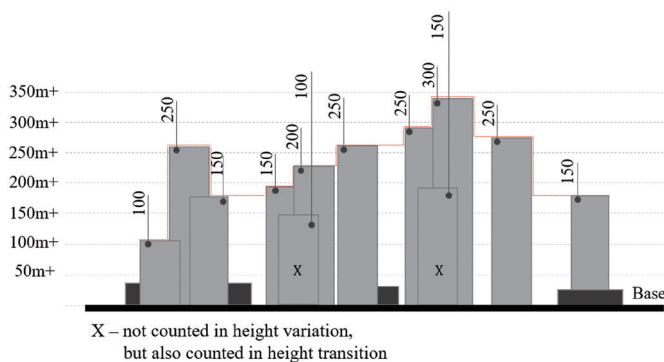


Figure 1. Typical of tall building heights transition analysis within the cluster area from skyline scene

In this section, all buildings heights which visible within the field of view should identify (Figure 1). From this analysis, the legibility of each heights category (100m+, 150m+, and so on until the tallest one) is determined by the percentage of the number of visible buildings to the total buildings of each height category. So that the quality of the heights transition can be attained by how much the unobstructed buildings within the cluster.

**(4) Density and spacing**

The density of tall buildings cluster is the percentage of the total width of the adjacent tall buildings to the width of the skyline. The spacing between tall buildings is calculated as a percentage of the width of the spacing to the width of the skyline (Figure 2). The width of the skyline is indicated by the angle of the field of view to tall buildings from the viewpoint.

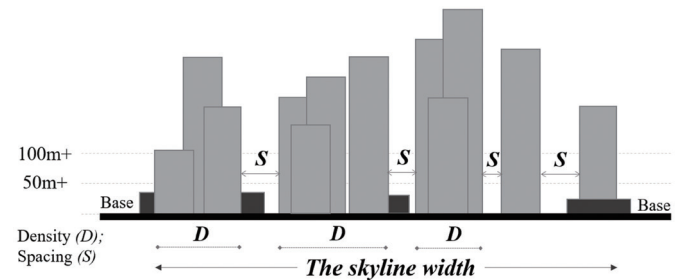


Figure 2. Density and spacing analysis of tall buildings skyline

**(5) Vantage points**

A point of the position of one’s location from which ones will see the buildings and approach the skyline is derived across from the river. Viewpoints from the riverside are divide into three viewpoints which represent the view facing both edge and the center of the area of tall buildings.

**4. ASSESSMENT OF THE VISUAL QUALITY OF RIVERFRONT SKYLINE**

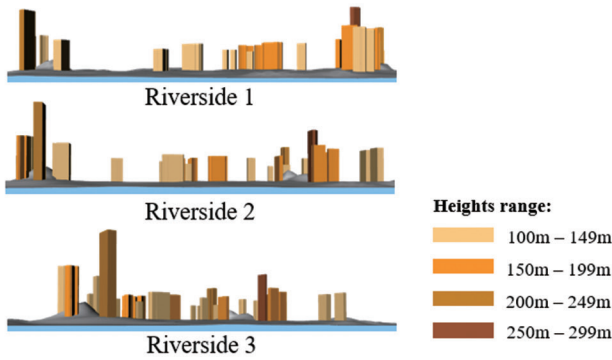
In this part, the visual quality of the riverfront skyline is assessed through the skyline of the tall buildings cluster of Yeouido and Lujiazui. The determinants of tall buildings classification of height, area, and viewpoints as described above are used to create a set test picture of the skylines, derived out of 3D building models. From these picture of the skylines, the analysis will be conducted by the feature of tall buildings heights: building heights variation and heights transition, and the spatial arrangement of tall buildings cluster: density and spacing. The total number of tall buildings is 29 in the Yeouido district and 58 in the Lujiazui district. The perspective view of the skylines is captured from three viewpoints of each case study. The view of skylines that will be assessed from Riverside 1, Riverside 2, and Riverside 3 in Yeouido and Lujiazui are shown in Figure 3.



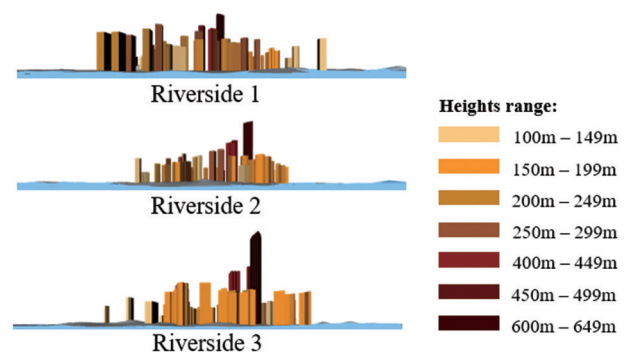
a. Tall buildings and viewpoints location in Yeouido



c. Tall buildings and viewpoints location in Lujiazui



b. Skyline of tall buildings cluster in Yeouido



d. Skyline of tall buildings cluster in Lujiazui

Figure 3. The location of tall buildings cluster, viewpoints, and view of the skyline in Yeouido (a, b) and Lujiazui (c,d)

**(1) Building heights variation and heights transition**

The variation of building heights is measured from the movement of the skyline. When the skyline is going up or down,

then the score is 0. When the skyline is flat or no change, then the score is 1. It can be seen from Figure 4 that skylines that have a small score of the total changes of building height ( $\Delta$ ) are expressed to have various heights. Meanwhile, the high scores from changes in the skyline indicate the monotonous part of the skyline.

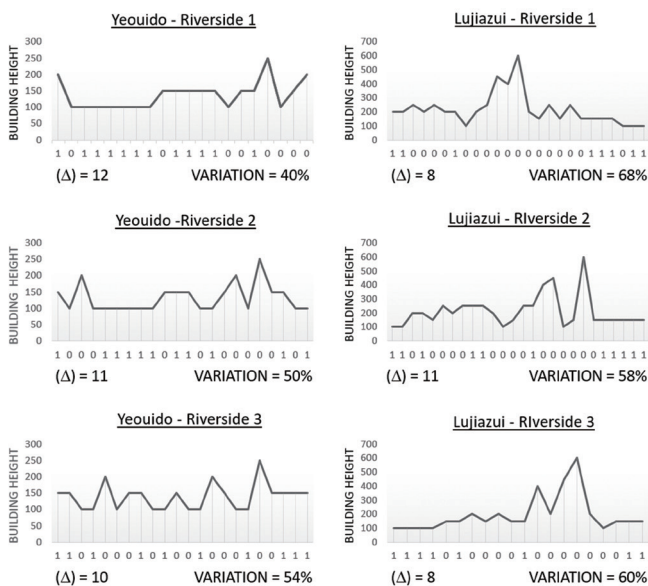


Figure 4. Line graphic of the movement of the skyline



Figure 5. The transition of building heights in Yeouido and Lujiazui from the total of visible buildings on each height category

In respects to the spatial relationship, the arrangement of heights between the taller and tallest buildings in the cluster area is defined by identifying the visible buildings from the vantage points (Figure 5). Applying the principle of transition in height decreases from inland to the periphery of the cluster area will certainly give the opportunity to each of the top parts of the building which featured on the skyline significantly visible. Tall buildings on Yeouido are mostly filling up the periphery area both the shorter buildings (100 m+) and the tallest buildings (250 m+). Although buildings with similar heights (100 m+ and 150 m+) are located inland, they are not obstructed by other tall buildings because of only a few buildings located nearby the river compared to the buildings adjacent to the major road. This shows that the Yeouido skyline is less prominent from height gradation from the riverfront, and the legibility of tall buildings cluster will be biased because of the position of the tallest building in the periphery.

In contrast, the transition of building heights profile in Lujiazui shows the increase of heights like growing from the short to the tallest building, from outermost to the inner area. The emphasis of visual hierarchy and centrality of tall buildings cluster become cleared with the absence of the tallest building

on the periphery of the area. Tall buildings development on the riverfront area should place a taller building in the center with lower building closer to the waterfront. This arrangement would diminish blocked views of inland buildings. If taller buildings are located at the edge of the area, the readability of the centrality of tall buildings cluster will be unclear. In the case of Yeouido, taller buildings are positioned as endpoints of the skyline. This created poly-focal points, particularly with a great distance among them, which will provide a selective visual orientation to the observer. Consequently, the view of the skyline is not fully recognized and may be neglected from the eyes, both from a near and far perspective view.

**(2) Density and spacing**

The data of view angle and the skyline width are obtained from the data of the line of sight (LOS) between viewpoints and buildings which is conducted in Grasshopper (Figure 6). The width of the view angle is obtained from both outermost of the line of sights (LOS). The width of the view angle also indicates the wideness of the skyline. In the case of Yeouido, the viewpoint that faces the center of the area (Riverside 2) has a greater angle than two others. Then, in the case of Lujiazui, the viewpoint

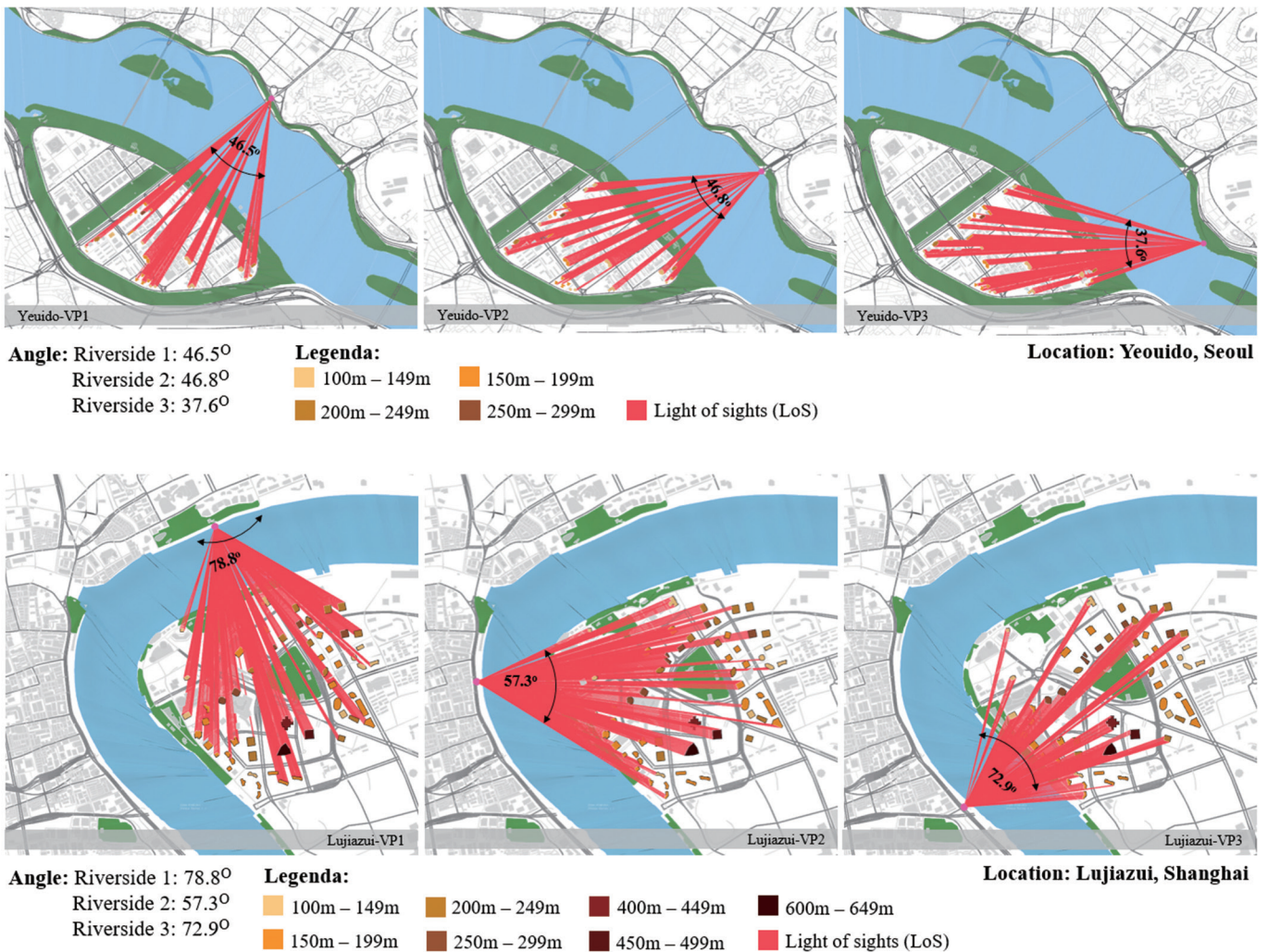


Figure 6. The width of view angle shown by the line of sight (LOS)

that faces both to the left and right side of the area (Riverside 1 and 3) has a greater angle than the viewpoint on the center. The result of measuring the percentage of density and spacing of the skyline is shown in Table 3.

A small view angle such as in Yeouido viewed from riverside 3 with 37.6° and Lujiazui viewed from riverside 2 with 57.3° shows that skyline is seen more compact with high density and narrow spacing.

Actually, there are many gaps among tall buildings in Yeouido. The analysis results indicate that the skyline viewed from riverside 1 and 2 shows the density and spacing among the buildings are only under 45% that weaken the legibility of tall buildings as a cluster on the skyline. Even though the spatial arrangement of tall buildings in Yeouido is relatively scattered but when viewed from viewpoint riverside 3, these tall buildings may look close together with the number of density is 81.2% with spacing 22.8%.

Table 3. Measurement of density and spacing of the skyline of Yeouido and Lujiazui

	Viewpoints	Angle	Density	Spacing
Yeouido	Riverside 1	46.5o	44.2%	44.7%
	Riverside 2	46.8o	31.6%	42.1%
	Riverside 3	37.6o	81.2%	22.8%
Lujiazui	Riverside 1	78.8o	77.8%	11.7%
	Riverside 2	57.3o	87.3%	3.5%
	Riverside 3	72.9o	80.3%	13.1%

In contrast, Lujiazui's skyline is recognizable as a cluster from all viewpoints where the density is above 75% with spacing less than 15%. So, with this number, the skyline of Lujiazui tends to have visual continuity and reinforce the shape of the skyline. It can be concluded that tall buildings are legible as a cluster on the skyline and provide visual continuity that reinforces the shape of the skyline if the density of buildings on the width of the skyline is above 75% and spacing among buildings is under 25%.

## 5. CONCLUSION

A number of tall buildings that gathered in a confined area like riverfront strongly impact on the skyline. The visual impact on the skyline can be investigated by assessing the visual quality of the skyline itself which is formed by tall buildings. The quantification of the variables like building heights variation, heights transition, density, and spacing has been considered to assess the visual quality of the skyline.

The assessment of the visual quality of the riverfront skyline of Yeouido and Lujiazui shows that the urban design of tall buildings cluster on Huangpu riverfront in Lujiazui has a better skyline on the feature of heights and spatial arrangements than tall buildings cluster on Han riverfront in Yeouido. Skyline with more varied building heights and gradual transition with respect to the tallest building and other tall buildings can strengthen

the legibility of a cluster on the skyline. On the contrary, the competition between the locations for the tallest building such as on Yeouido, which spread on the periphery of the cluster area, can shift the center of the skyline and weaken the reading of a cluster on the skyline.

Tall buildings need to stand sufficiently close together to be read as part of the cluster on the skyline and provide the continuity of the skyline. Tall buildings in Lujiazui can clearly be identified as a cluster on the skyline from all viewpoints, but tall buildings in Yeouido only can be seen as a cluster of an adjacent tall building. Actually, Lujiazui district with two sides confined by the Huangpu River and Yeouido district surrounded by open space has defined a clear boundary of the cluster. But if they are not supported by a proper design of spatial arrangement of tall buildings with the context, tall buildings cluster can undermine the impact on the skyline composition and the visual quality of the overall view of tall buildings cluster on the skyline.

It can be concluded that most tall buildings in Yeouido were not oriented towards the northeast of the river. The skyline view offered in these vantage points is not quite interesting in terms of height variation and continuity of the skyline because they are dispersed. But the presence of the tallest building is still legible in terms of indicating location, direction, and progress of one's position from the riverfront to the Yeouido area. The spatial arrangement of tall buildings in Yeouido shows that the buildings are mostly aligned to the major road and oriented to the open space on the west of the area. Conversely, the planning of tall buildings in the Lujiazui is certainly oriented toward the river and the bund (old downtown) across the river. So the analysis results from these riverfront vantage points in all aspects of the feature of height and spatial arrangements have good quality.

In the planning of tall buildings clusters, it is also necessary to give attention to the view orientation in providing the skyline view that is pleasant and beneficial for the urban viewer, tourist, and investment. Yeouido where the placement of tall buildings is not toward the riverbank but oriented to the open space in the west might have been deemed more profitable in its planning, even though theoretically the view from the riverfront can provide a pleasantness view because of the openness given by the water. Therefore, further study needs to consider and demonstrate how tall buildings cluster can be appreciated from other strategic views such as within the cityscape or from other specific viewpoints.

In addition, the proposed tall buildings on the other shape of the area such as linear riverfront which has a relatively close distance to other buildings need to be analyzed to avoid dilution or merging with neighboring clusters. This study can be used for the urban designer to provide a guideline on how a proposed tall building within the cluster should consider and appropriately respond to adding image and distinctiveness on the skyline, particularly on the appearance of the riverfront views.

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