International Journal of High-Rise Buildings
June 2015, Vol 4, No 2, 153-160

International Journal of
High-Rise Buildings
www.ctbuh-korea.org/ijhrb/index.php

Research on Vertical Space System of Mixed-Use Complex

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Abstract

As the predominant mode of vertical urban development in China, mixed-use complexes provide the optimal case for the research of sustainable and vertical urbanism. This paper reviews three typical mixed-use complexes with various vertical space systems in Shanghai via the combination of field observation, questionnaires and software analysis. It then proceeds to determine which vertical space system is most effective for encouraging sustainable vertical urban development from the perspective of spatial efficiency. Finally, it concludes with an evaluation of the relative capabilities of the design features of a mixed-use complex: to create external dimensional-connections, to create multiple internal connections, and to organize overall composite functions.

Keywords: Sustainable vertical urbanism, Vertical circulation, Synergy effect, Spatial efficiency, Spatial attraction

1. Introduction

Nowadays, the mixed-use complex is becoming a significant tool for realizing the vertical urban development in the dense habitat in China. Compared with single-function buildings, mixed-use complexes provide synergy effects that bring improved benefits for all functional subsystems (financial value), create higher spatial efficiency for the entirety of the building (spatial value), and promote not only the surrounding communities, but also the whole city, by attracting more people to visit (urban value). Among these, spatial value and urban value, which produce the efficiency and the attraction, are the important characteristics of mixed-use complex. These characteristics are distinct from those of other building types, and are critical to achieving sustainable vertical urbanism in China's future.

This paper reviews three typical mixed-use complexes in Shanghai with three different types of vertical space systems through field observation, questionnaires and software analysis. It then proceeds to discuss which vertical space systems are most encouraging of sustainable vertical urban development, from perspective of spatial efficiency.

2. Spatial System Typologies of Mixed-Use Complexes

In the essay *A City is Not a Tree*, Cristopher Alexander[1] analyzed and compared different urban structures via Tree Structure and Semi-lattice Structure, which are two important concepts in Mathematical Set Theory (see Fig. 1). Based on this classic research, this paper considered the entrances (interfaces between the mixed-use complex and the city) as the "starting points", the internal public spaces as well as functions of each layer in buildings as the "joint points" (connections), and explains the spatial systems

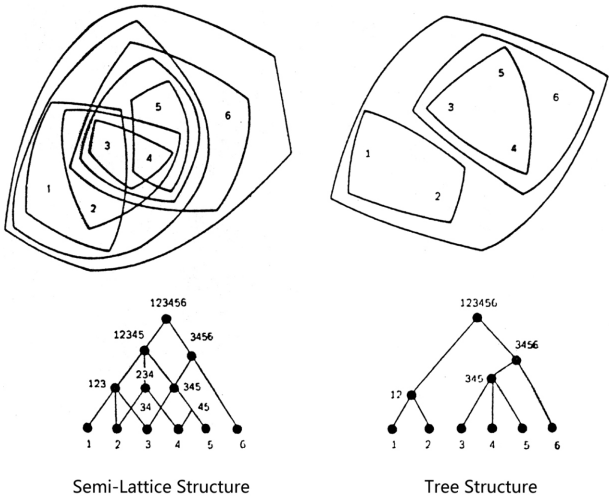


Figure 1. Tree Structure and Semi-lattice Structure (Source: C. Alexander).

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[1]Christopher Alexander is an Austrian-born, British-trained, U.S.-based architect/planner. In the essay "A City is Not a Tree", he argued that a city should not be designed with a neatly branching, tree-like organization dividing functions from each other, but should be instead be complex and overlapping.

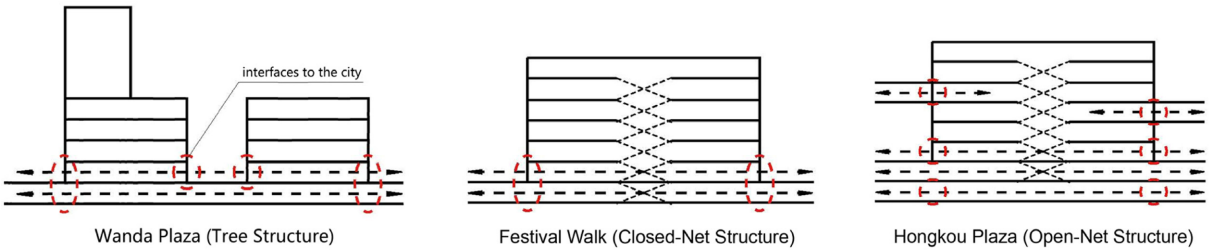
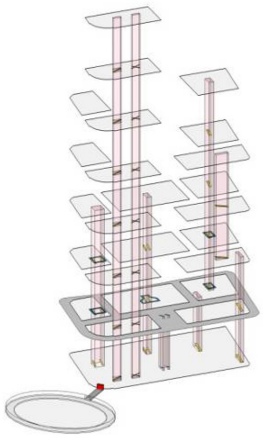
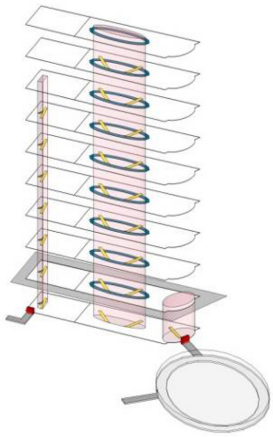
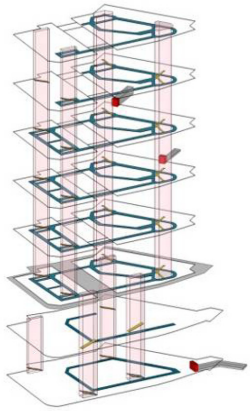


Figure 2. Diagram of three different types of vertical spatial system (Source: Yinpu Wang).

Table 1. Basic Information Comparison of Cases (Source: Yinpu Wang, Zhendong Wang)

Project Name	Wanda Plaza	Festival Walk	Hongkou Plaza
Project Image			
Location	Center of Wujiaochang commercial Area	Center of Wujiaochang commercial Area	Core area in Hongkou District
Completion Date	December, 2006	January, 2007	December, 2011
Gross Floor Area	334,000m^2	126,000m^2	280,000m^2
Commercial Area	253,000m^2	126,000m^2	173,000m^2
Functions	Retail, Catering, Recreation, Office, Apartment	Retail, Catering, Recreation, Office	Retail, Catering, Recreation, Office
Interfaces with city	Ground Level Entrance, connects to Metro Line 10 and Wujiaochang Central Plaza underground	Ground Level Entrance, connects to Metro Line 10 and Wujiaochang Central Plaza underground	Ground Level Entrance, connects to Metro Line 8 underground, connects to Metro Line 3 on the 3rd and 4th floors
Spatial System			
Structure Type	Tree Structure	Closed-Net Structure	Open-Net Structure

of mixed-use complexes in terms of Tree Structure and Net Structure.

In a Tree Structure, spaces at the end of branches are isolated. To reach one end of a branch from another, one must go back through the "branch" or "trunk" spaces, which are interconnected (see Fig. 2). This kind of structure has weak connections between each part, and the accessibility of the terminal is poor.

The terminals of Net Structure are interconnected, and the connections of its joint points are even closer. When mixed-use complexes are connected with the city only through the ground and underground levels, their spatial systems are relatively tight; a visitor has to move upward to reach the terminals. But if they are connected with the city on multiple levels, a visitor can get in from different levels and move in different directions, the spatial system is relatively open. This paper defines the former type as "Closed-Net Structure" (abbr. C-Net) (see Fig. 2), while the latter type is "Open-Net Structure" (abbr. O-Net). (see Fig. 2).

3. Comparative Case Study

This paper selected three mixed-use complexes in Shanghai to represent the different spatial systems. Wanda Plaza in Wujiaochang, which is a Tree Type; Bailian Group's Festival Walk in Wujiaochang, which is a C-Net, and Hongkou Plaza of Capital Mall, which is an O-Net (see Table 1). These three mixed-use complexes are all located in a high-density urban environment with similar functions, close connections with the urban metro system, convenient communication and high VFR (visitor flow rate).

3.1 Spatial Accessibility

3.1.1 J-graph simulation

First of all, according to the functional and spatial distribution of the case, the research group has isolated and represented its vertical space system, then abstracted the system into diagram of space structure (see Fig. 3). The focus points of the diagram are the spatial distribution and connected relation, which contain several main aspects: (1) overall spatial distribution and contour of the building, (2) interfaces to the city, (3) layout of each floor in the building, (4) main organization form of circulation in each floor, (5) vertical circulation, such as atria and escalators.

Secondly, the research group has taken the diagram as the underlying graph, set anchor points and drew lines on it via J-graph[2], then generated the spatial relation diagram (see Fig. 4). According to the spatial relation diagram, the spatial depth of Hongkou Plaza obviously occurs at lower levels than in the other two cases. This illustrates that the number of steps (the switching points) needed to get to the farthest terminal space away from the entrance, is lowest in the O-Net. And it also means the spatial accessibility of this kind of structure is better.

Finally, the research group has visualized the analysis of data. Combined with previously constructed structure analysis diagrams, the researchers have visualized the RN value[3], determined that "warmer" colors would indicate

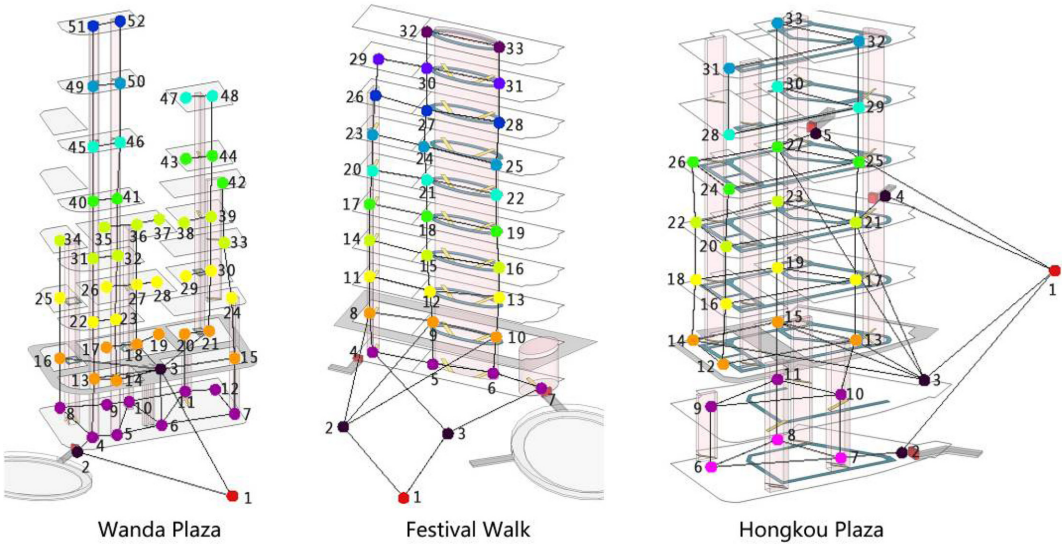


Figure 3. Diagram of the spatial structure of three cases (Source: Yinpu Wang).

[2]J-Graph is a graph-drawing opensource software component written in the Java programming language, started by Gaudenz Alder as a University project in 2000 at ETH Zurich, Switzerland. The original intent of J-Graph was to make it an architectural extension of J-Tree.

[3]RN value is a measure of the integration level of each part, reflecting the average number of linear topological steps away from all the other parts in the system.

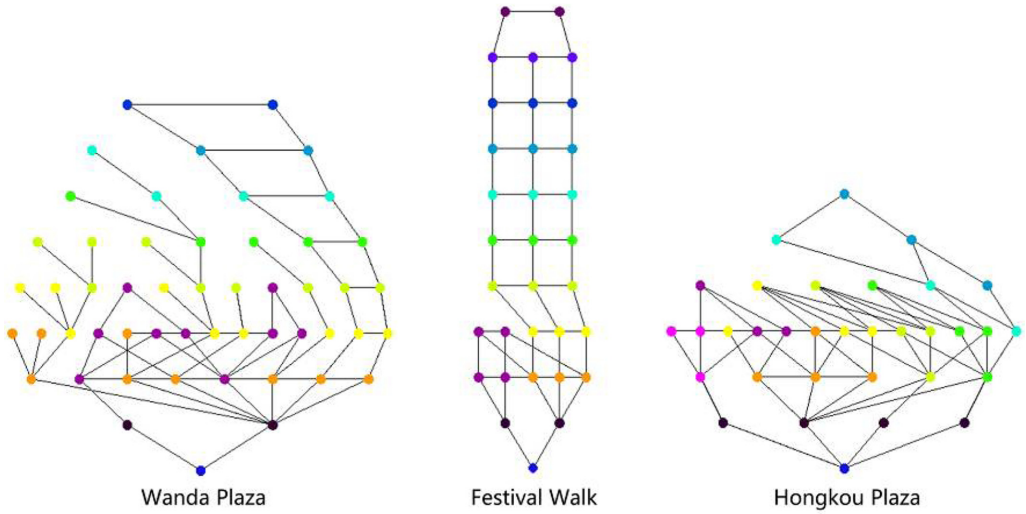


Figure 4. Spatial Relation diagram of three cases (Source: Yinpu Wang).

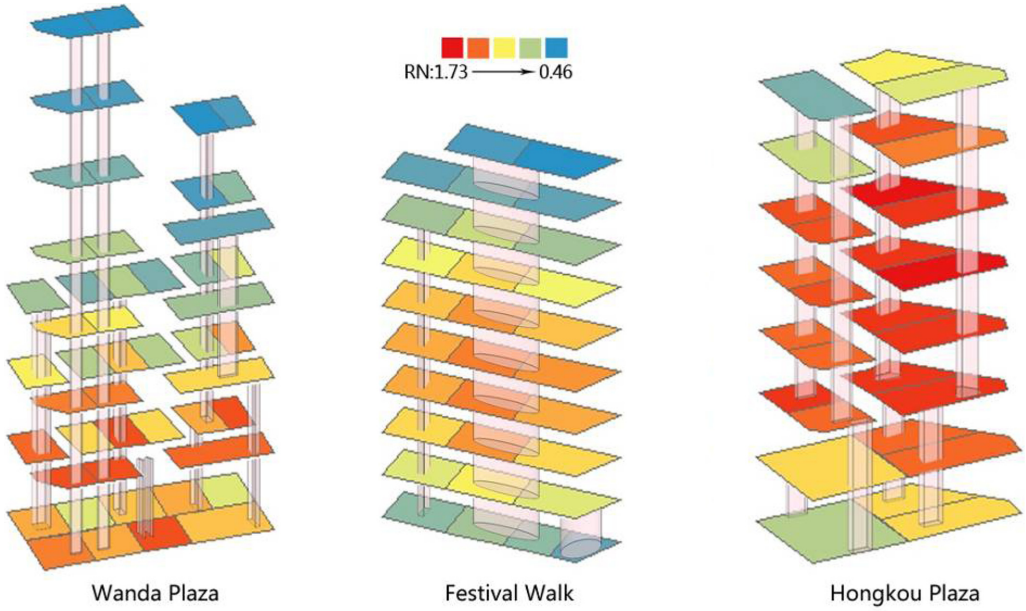


Figure 5. RN value visualization diagram of three cases (Source: Yinpu Wang).

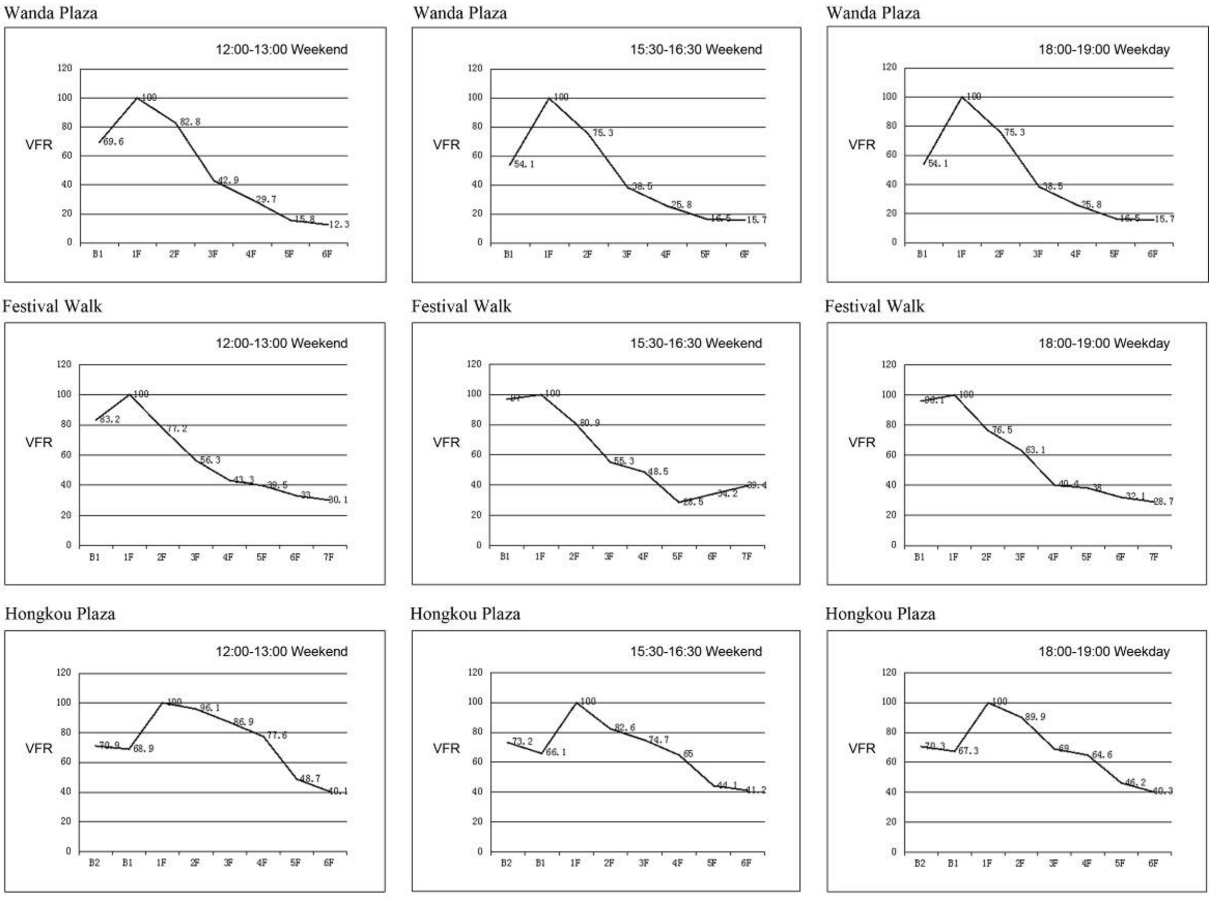
that the RN value is getting higher, then drew the integrated diagram of each case. As the RN value is not affected by the size of systems, the research group has normalized the three cases for comparison. The color of each part was influenced by its integration level (see Fig. 5). After comparison, the parts with the highest integration levels were the intermediate floors in Hongkou Plaza, while the parts with lowest integration levels were on the highest floors in Wanda Plaza. Generally speaking, Hongkou Plaza has the highest level of spatial integration.

3.1.2 Field observation data analysis

The research group has obtained the distributions of the VFR via field observations on each floor of the three cases.[4] To reduce deviation, each test period consisted of three samples, and each sampling window is five minutes,

[4]The sampling positions are near the escalators, which have largest flows in vertical space systems. The researchers set an observation position beside every escalator, then added the flows of all the positions on each floor to get the result. The sampling periods were set at noon and afternoon on weekends and at off-duty times on weekdays, for at these times there was the largest flow and, therefore, smallest deviation.

Table 2. VFR Statistics of Cases (Source: Yinpu Wang)



thus yielding an average number. The research group defined the VFR on the ground floors in each case as 100%, calculated the ratio of each floor, and subsequently developed the following chart of VFR statistics (see Table 2):

The comparison of the distribution of VFR in different space systems reflects the difference in accessibility: according to the evenness degree, the O-Net has obvious advantage. It is worth mentioning that Hongkou Plaza has the most even distribution on weekday nights, after comparing it with the other two cases. Moreover, the evenness degree on weekday nights was quite different from that observed during the daytime in Wanda Plaza, while in Hongkou Plaza it was similar. This suggests that an O-Net mixed-use complex is easier to integrate into the everyday lives of the surrounding communities.

3.1.3 Summary

Based on the research field observations and software analysis, the O-Net pattern has more even distribution of VFR in actual operation, in addition to better spatial integration and accessibility in theory. This will bring the merchants on each floor more business opportunities and profits. The accessibility of the O-Net configuration also has the potential to create more urban value, as it attracts more visitors.

3.2 Spatial attraction

3.2.1 SPSS simulation

Based on the data attained during the former observation, via the correlation analysis offered by SPSS software[5], the researchers took the VFR on each floor, measured in three cases as dependent variables, while the factors such as floors, size, etc., were treated as as independent variables. Then the researchers analyzed the correlation between VFR and factors such as level of floor, relationship with entrance and position of escalator, etc., to find out the influence of the independent variables on VFR. Ultimately, this exercise generated a diagram that reflects the importance of each influencing factor of VFR (see Fig. 6).

Results of the analysis show: “whether there is an entrance connected directly to the outside” is the most important factor in attracting visitors; “distance away from the entrances” is also quite important; followed by “the

[5]Statistical Product and Service Solutions(SPSS) is IBM's launch of a series of support software products for statistical analysis algorithms, data mining, predictive analysis and decision-making.

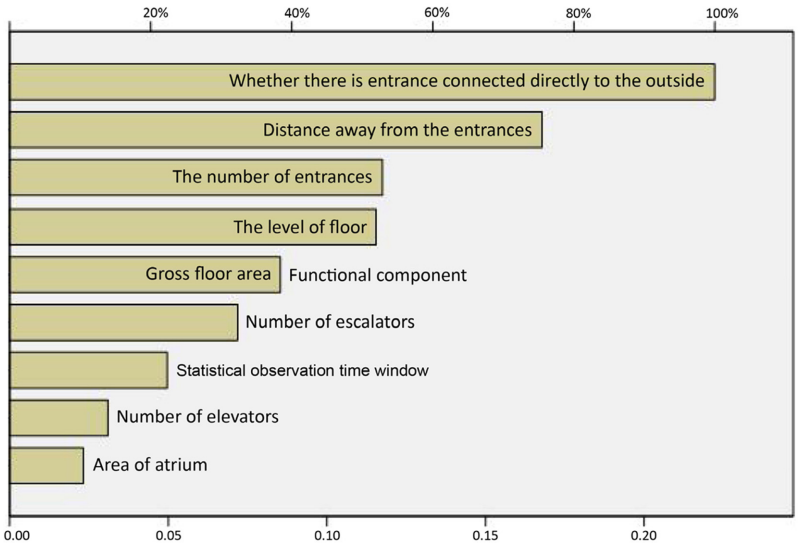


Figure 6. The result of SPSS Simulation (Source: Yinpu Wang).

number of entrances" and "the level of floor". Moreover, factors like the "gross floor area", "functional component", "the number of escalators" and "statistical observation time window" also had a certain influence, while the "number of elevators" and "the size of atrium" had less influence.

3.2.2 Data analysis of the questionnaire inquiries

Selecting three periods of time in a day (12:00-13:00, 15:00-16:00, 19:00-20:00) during weekdays and weekends, the research group gave out 230 questionnaires respectively in three cases, requiring the return of a minimum of 200 valid questionnaires to consider the results legitimate. After analysis, the researchers determined the difference of spatial accessibility among the three cases.

Question 1: Which is the highest floor you would reach in commercial area in Wanda Plaza (Festival Walk or Hongkou Plaza)?

- underground
- 1st to 2nd floor
- 3rd to 4th floor
- 5th floor or higher

The results of question 1 were as follows: (see Fig. 7)

The results show that the accessibility of higher floors in the Net Structure is better than that in the Tree Structure, and the accessibility of Hongkou Plaza (O-Net) is the best. This again demonstrates that the overall spatial accessibility of O-Net, is the best and its distribution of VFR is the most even.

Question 2: When shopping in Wanda Plaza (Festival Walk or Hongkou Plaza), the reason you reach the 2nd floor or upper ones from the ground floor is:

- visiting with purpose
- wandering without purpose

The results of question 2 were as follows: (see Fig. 8)

The results show that the lowest ratio of consumers reaching the higher floors "with purpose" happened in Wanda Plaza, while the highest ratio happened in Hongkou Plaza. The Tree Structure is relatively closed; as most visitors who go upward are doing so "with purpose." O-Net fea-

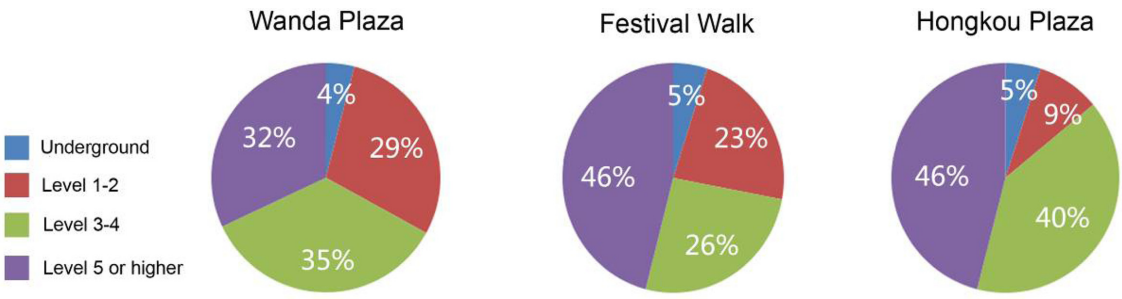


Figure 7. The results of question 1 (Source: Yinpu Wang).

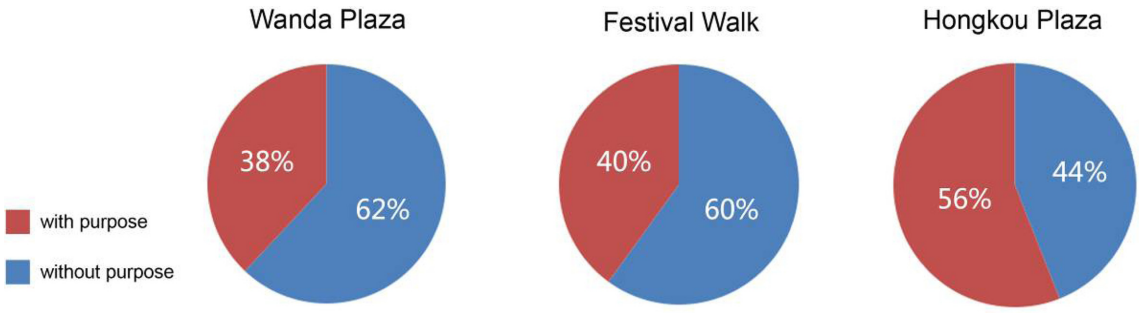


Figure 8. The results of question 2 (Source: Yinpu Wang).

tures multiple base levels and high accessibility; thus, the ratio of the visitors who reach higher floors "without purpose" increases, which is good for the distribution of VFR.

Question 3: Which of the following functions would attract you to get to the upper floors from the ground floor? (multiple choice)

- shopping
- catering
- recreation (cinema, KTV etc.)
- activities like sales promotions
- other

The results of question 3 were as follows: (see Table 3)

In different functions, catering and recreation have the largest influence on attracting visitors toward higher floors purposively, then comes shopping, while sales promotion has the least influence. Special functions can incite consumers to reach the higher floors purposively, which is good for the overall spatial distribution of VFR.

Question 4: Which of the following factors would entice you to travel to the upper floors from the ground floor? (multiple choice)

- open space through the atrium
- attractions (such as shops, signboards, advertisements upstairs)
- escalators
- elevators

The results of question 4 are as follows: (see Table 4)

From the results, it can be determined that, in the design of mixed-use complexes, the arrangement of escalators should receive more attention. Furthermore, establishing visual connections between different levels through an atrium would create the possibility for attracting consumers to the higher floors without an express reason for doing so.

3.2.3 Summary

Via the combination of questionnaire inquiries and software analysis, the research group has found out that the main features of O-Net – the interfaces between inner public space and the outside urban environment (namely entrances) – play a decisive role in attracting visitors, while O-Net has the strongest potential to promote the visitors' reaching the higher floors. Among the functional factors, catering and recreation provided the strongest attraction; while among spatial factors, the escalator had the strongest enticement ability.

Table 3. The statistics of question 3 (Source: Yinpu Wang)

	Wanda Plaza	Festival Walk	Hongkou Plaza	Total
shopping	76	84	78	238
catering	88	102	104	294
recreation	88	100	100	288
sales promotion	76	70	32	178

Table 4. The results of question 4 (Source: Yinpu Wang)

	Wanda Plaza	Festival Walk	Hongkou Plaza	Total
Atrium	69	78	84	231
Attractions	60	69	66	195
Escalators	102	114	129	345
Elevators	54	24	6	84

4. Promote Sustainable Vertical Urbanism via Mixed-Use Complexes

Through research, the research group has determined that vertical spatial systems play important roles in promoting the synergistic effects of mixed-use complexes. Net Structure (especially O-Net) has better overall accessibility and higher spatial efficiency than Tree Structure, which brings more visitors and generates more even distribution of VFR (spatial values). This, in turn, encourages "place effect" (urban values) by bringing more profit-earning opportunities (financial values). This means O-Net could create more values for mixed-use complexes, and foster the development of an even larger, truly vertical city. According to the above results, the research group has

discovered the design principles of vertical space systems of mixed-use complexes that could become the implementation approaches for future sustainable vertical urbanism in China.

4.1. Create external dimensional connections

From an urban planning perspective, planners could increase the vertical development of cities to create conditions for developing an O-Net-based mixed-use complex. From an urban design perspective, mixed-use complexes should establish tight dimensional connections with their neighboring urban environments and set up more consistently distributed external interfaces. By taking full advantage of topography, developers could establish connections between the neighboring underground spaces and vertical public spaces, and ultimately create O-Net structures.

4.2. Create multiple internal connections

From the urban design perspective, developers could combine urban public space (such as the transfer terminals for buses or metros) into mixed-use complexes, in order to enhance the internal vitality and VFR. From the architectural design perspective, it is beneficial to increase the sight-line communication between different floors by adding atria or escalators, in order to increase spatial integrity and accessibility. As for group-type mixed-use complexes, it is optimal to create connections and increase the accessibility of the terminal space as much as possible, so as to maintain the mutual independence of different functions.

4.3. Organize overall composite functions

During the design of the circulation of a mixed-use complex, architects could integrate functions like hotel, office and residential into the overall spatial structure to the greatest extent possible, to encourage synergy by increasing the amount of internal circulation. As for the arrangement of commercial sectors, architects could distribute functions like retail, catering and recreation systematically, and put high-attraction functions (cinemas, anchor stores and famous restaurants) and non-profit-oriented functions (arts and cultural facilities, green-roof parks) on the higher floors, in order to enhance their attractiveness.

As "micro-cities", mixed-use complexes can become the main driving force of vertical urbanism in China and Asia in dense habitats. Via mixed-use complexes, the developer could construct vertical urban public space, organize tri-dimensional urban functions to attract more people to move to higher floors, and finally, create sustainable vertical urban life.

Acknowledgements

Projected 51008213 supported by National Natural Science Foundation of China, Sponsored by Shanghai Pujiang Program (No. 13PJC105), Project supported by Key Laboratory of Ecology and Energy-saving Study of Dense Habitat (Tongji University), Ministry of Education.

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