


AKADÉMIAI KIADÓ

# Application of space syntax in the renewal of industrial area design

Liang Zixin<sup>1\*</sup> , Géza Várady<sup>2</sup> and Márk Balázs Zagorác<sup>3</sup>

Pollack Periodica •  
An International Journal  
for Engineering and  
Information Sciences

18 (2023) 1, 13–18

DOI:

[10.1556/606.2022.00631](https://doi.org/10.1556/606.2022.00631)

© 2022 The Author(s)

<sup>1</sup> Marcel Breuer Doctoral School, Faculty of Engineering and Information Technology, University of Pécs, Pécs, Hungary

<sup>2</sup> Department of Technical Informatics, Faculty of Engineering and Information Technology, University of Pécs, Pécs, Hungary

<sup>3</sup> Department of Engineering Studies, Faculty of Engineering and Information Technology, University of Pécs, Pécs, Hungary

Received: March 9, 2022 • Revised manuscript received: July 15, 2022 • Accepted: August 7, 2022

Published online: October 17, 2022

ORIGINAL RESEARCH  
PAPER



## ABSTRACT

Based on the theory of space syntax, this study quantitatively analyzes the landscape space of Baosteel Zhanjiang Steel Co. Ltd., which is constrained by epidemic preventive measures and steel plant safety production requirements in the post-epidemic age. Space syntax has the benefits of decreasing research expenses, boosting analytical efficiency, assessing space use efficiency, minimizing environmental interference, and addressing epidemic prevention demands.

## KEYWORDS

space syntax, industrial area, spatial organization, renovation design

## 1. INTRODUCTION

### 1.1. Research background

Baosteel Zhanjiang Steel Co. Ltd. was founded in 2012 and is located on Donghai Island. Environmental rectification has become a serious problem for many big industrial units at now, owing to China's carbon neutrality legislation. In this setting, Zhanjiang steel plant has developed a renovation plan to establish a 10-min traffic circle that is both efficient and environmentally friendly. The author and design team were involved in this renovation project in 2021, which required rethinking the relationship between people and space and better landscape utilization. With a restricted budget, they need to investigate a method for efficiently completing quantitative space evaluations, in order to guide the identification and renovation of key spaces.

### 1.2. Space syntax

Space syntax is a way of describing and analyzing the network connections between various spaces [1]. The notion of space syntax has been frequently utilized as a social logic language to interpret urban or architectural space since Hillier [2] proposed it in the late 1970s. After extensive investigation, a set of theories and methods for analyzing and quantifying material space morphology have been developed [3]. Space syntax not only expresses the vitality center corresponding to the space organization [4], but also reflects deep-level issues such as politics, economy, society, and culture, which is a useful guide for space design [5]. Hillier [6], based on the original space syntax theory, proposed the calculating techniques of Normalizing Angle Choice (NACH) and Normalizing Angle Integration (NAIN) in 2012, which can more correctly reveal the spatial structure. To summarize, space syntax theory has a positive

\*Corresponding author.

E-mail: [951450524@qq.com](mailto:951450524@qq.com)



impact on macro-quantitative study of complicated spaces, and when combined with data from site surveys, it can offer researchers with a more complete reference.

## 2. SPATIAL ORGANIZATION ANALYSIS

### 2.1. Research sample selection

The spatial organization of the factory was created under the functional effect of several production divisions. There are five manufacturing divisions in this factory: iron, steel, hot rolling, cold rolling, and heavy plate, as well as six supporting regions (Fig. 1).

The factory area has seven main roads running north-south and six significant roads running east-west. Warp Road runs north-south, from west to east, it is Warp 1 to 6 Road, and the easternmost Island East Road separates the manufacturing and residential areas. From north to south, the east-west route is known as Weft Road, and it runs from Weft 1 to 6 Road (Fig. 2). There are also many branch roads within functional divisions.

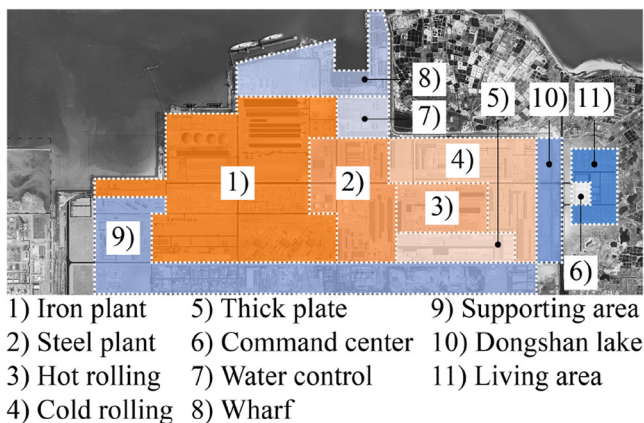


Fig. 1. Functional divisions of steel factory (Source: designed and drawn by Liang Zixin)

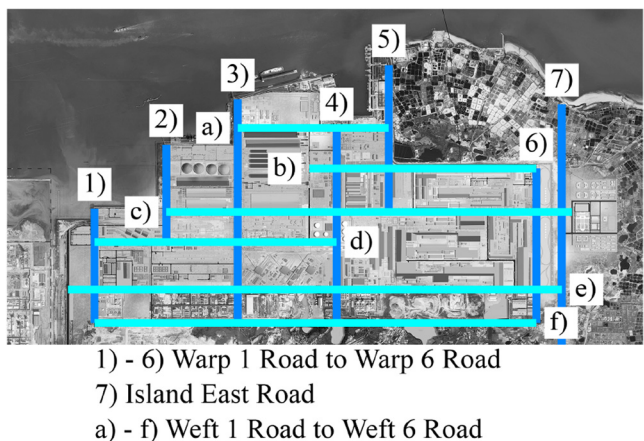


Fig. 2. Main road of steel plant (Source: designed and drawn by Liang Zixin)

### 2.2. Syntactic translation

The research object in this work is industrial space, and it is used to construct a space-syntax-based analytic approach that integrates environmental psychology with space syntax. The study applies the default linear mathematical analysis method of Depthmap analysis software, generates an axis map by calculating a series of parameters, and then to select the main variables in the space syntax model by analyzing variables, including the integration value and choice value [7]. Integration can show the accessibility and commonality of areas while also reflecting the ability of line segment elements in the spatial system to attract arriving traffic [8]. Choice indicates the discreteness of spaces and expresses the possibility of the line segment elements in the spatial system to be traversed [9]. In order to perform quantitative research on spatial organization and examine the interaction between factory space and users, the map from 2021 is chosen as a study sample, converted into a space syntax model, and loaded into DepthMapX software for analysis. The spatial syntax axis analysis method has positive significance for large-scale urban space study, but the accuracy of the analysis results for micro-space is low. As a result, in the next two chapters, two different space syntax research methods, axis analysis and Visibility Graph Analysis (VGA), will be used to analyze the macro-space and micro-space, in order to give theoretical and data support for the factory's macro traffic planning and micro node design.

## 3. TOTAL SPATIAL STRUCTURE

The author sets the matching activity radius (600, 3,000, 5,000, 10,000 m) based on the four most common travel methods (walking, bicycle, E-bike, car) in the factory in order to establish a more convenient 10-min travel circle. The active radius of each mode of transportation within 10 min determines the local index, whereas the radius of  $n$  determines the global index. In addition, the factory must be inspected on a regular basis by government officials and business leaders, and it must be open to the public for environmental demonstrations at particular times. Therefore, the research will use space syntax to propose an optimized total visiting process according to the site situation.

### 3.1. Walking space

The NAIN with an active radius of 600 m is shown in Fig. 3. The average integration of the road is minimal, indicating that most of the road have very low agglomeration capacity on a walking scale, and the distribution of highly integrated road is dispersed. The spatial structure of the surrounding environment has a significant impact on the aggregation of pedestrian space. The spatial depth and complexity rises as the density of internal roads increases. Crowds are easily divided into branch roads in the complicated spatial organization. For example, the complicated road structure within the steelmaking area results in low NAIN values in the surrounding areas. Conversely, longer axis lines in the cold

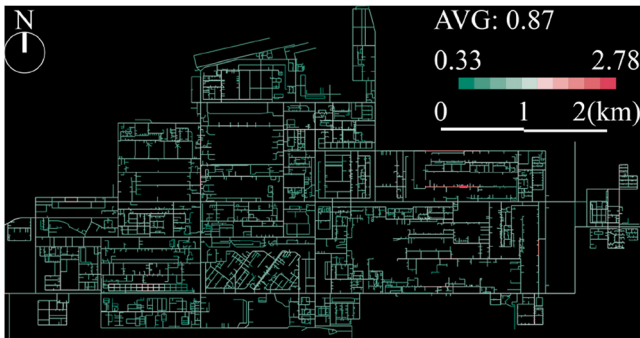


Fig. 3. NAIN R600 (Source: designed and drawn by Liang Zixin)

rolling area and fewer branch lines connecting them are more likely to have high-concentration. Except for the low value of the end road, the values of the other roads in NACH are average, and their selectivity is high, indicating that most factory roads have adequate traffic capacity on a walking scale (Fig. 4).

### 3.2. Bicycle space

The roads with high NAIN values gradually converge to the four main axes in the factory as the active radius is expanded to 3,000 m (Fig. 5). The average NAIN R3000 is higher than that of NAIN R600, indicating that the road system's general aggregation has improved and it is changing from a loose to an interconnected state. The distribution of hotspots in NACH is more spread, mainly on Warp3/4/6 Road and

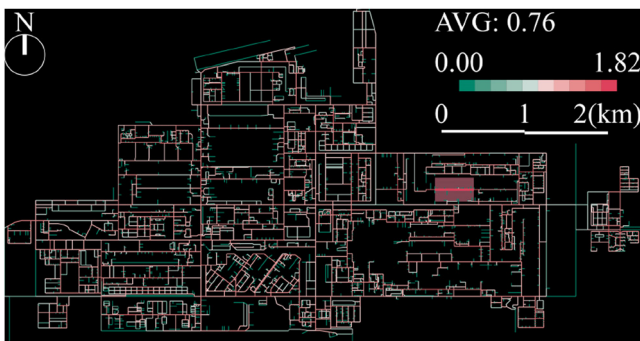


Fig. 4. NACH R600 (Source: designed and drawn by Liang Zixin)

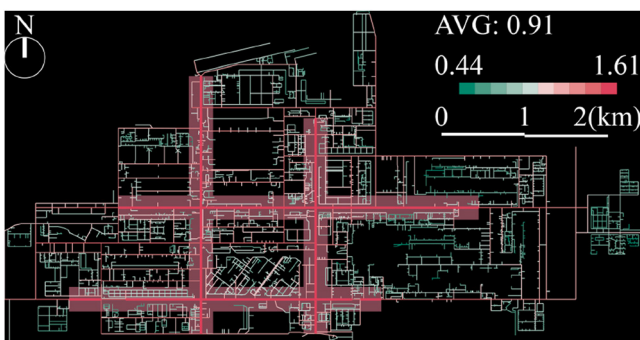


Fig. 5. NAIN R3000 (Source: designed and drawn by Liang Zixin)

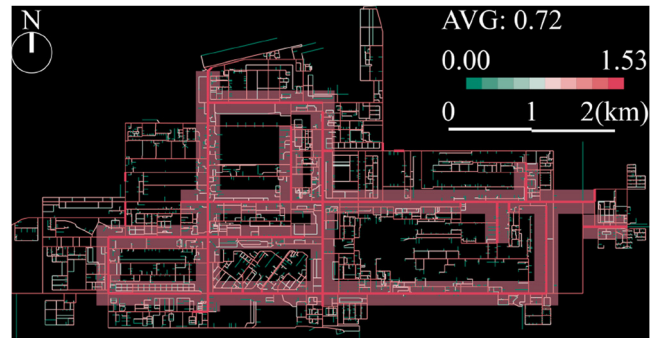


Fig. 6. NACH R3000 (Source: designed and drawn by Liang Zixin)

Weft1/3/4/5 Road, however they are slightly offset in some regions (Fig. 6). As the range of activities expanded, the average value and maximum value of NAIN R3000 slightly decreased, indicating a decline in overall road traversal ability.

### 3.3. E-bike space

As shown in Fig. 7, the locations of high integration in NAIN R5000 are also centered on the four main axes, and the average, minimum and maximum of NAIN all increases, the general road aggregation keeps increasing. The high traversal rate roads in NACH are mostly concentrated on the five axes of Warp 3 Road, Warp 4 Road, Weft 3 Road, Weft 4 Road, and Weft 5 Road (Fig. 8). Furthermore, the average NACH R5000 has decreased slightly but the

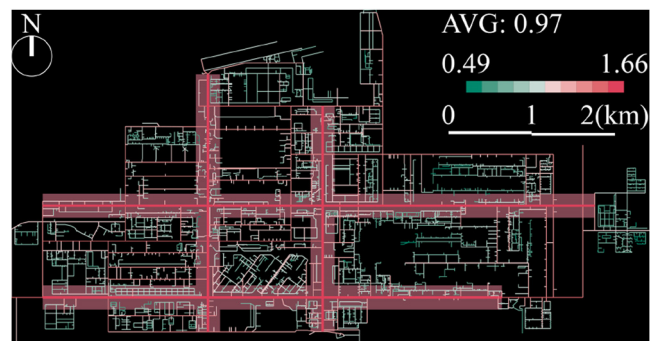


Fig. 7. NAIN R5000 (Source: designed and drawn by Liang Zixin)

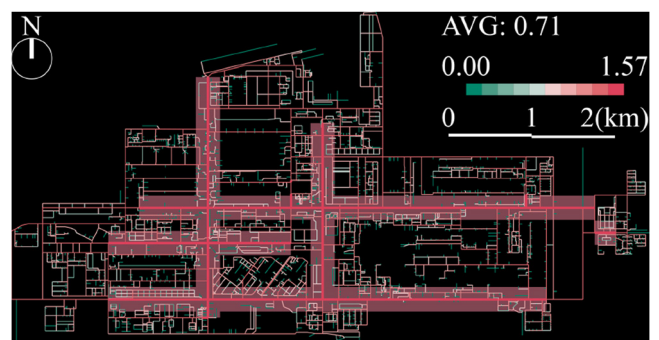
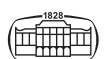


Fig. 8. NACH R5000 (Source: designed and drawn by Liang Zixin)





maximum value has increased, indicating that the general road's traversability has remained stable while the traffic pressure on the road with the greatest traversal rate has increased.

### 3.4. Motor vehicle space

When the activity range is restricted to 10,000 m, the functions of the main axes are constantly highlighted, and the four axis show the largest integration (Fig. 9) and choice (Fig. 10). The average NAIN continues to climb, indicating that the general space's integration is improving. However, NAIN's maximum value reduced slightly, showing that the other high-integration axis is spreading the pressure of the long axes. Additionally, the highest value of NACH rises while the average value stays the same, indicating that the long axis traveling pressure is still increasing.

### 3.5. Inspection and visit

The author analyzes the aggregation and trafficability of various modes of transportation in the industrial road space using space syntax, and then identifies the related high usage locations. The places with more evident colors in Fig. 11 show the locations that are used more frequently, and these areas are mainly concentrated on Warp 3 Road, Warp 4 Road, Weft 3 Road, and Weft 5 Road. A more comprehensive renovation plan is proposed using the space efficiency assessment and the current state of the site as a

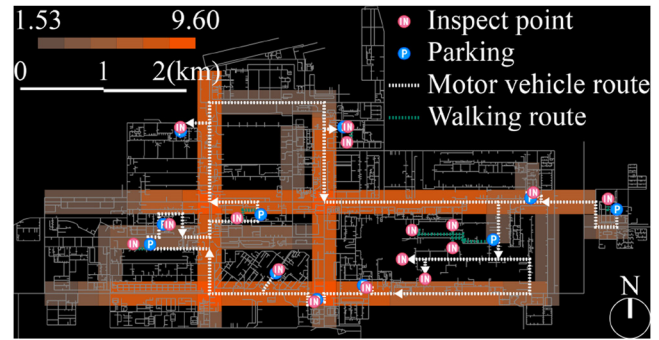


Fig. 11. Inspect route planning (Source: designed and drawn by Liang Zixin)

reference, depending on the features of inspection and visiting activities.

The inspection path must accurately and completely reflect the circumstances in the factory. If the inspection route is placed on a road that is frequently traveled, the accessibility of passage and the heavy traffic flow will facilitate the inspector to observe the basic situation of the factory area. The temporary parking lot is already present at the factory, and the checkpoints have been established. The activities of the inspectors between the different production areas are dominated by vehicles, while the activities within the production areas are dominated by walking. Therefore, some detailed active paths are optimized based on the location of the parking near the checkpoint (Fig. 11).

The primary focuses of citizen visit activities are scientific education and environmental publicity. The visiting route should not be established on a route that is used frequently in order to lessen the effect of visiting activities on production. As a result, the visiting sites and routes are mainly distributed in the outskirts of the factory. Likewise, as seen in Fig. 12, some visiting paths are located in light-colored road spaces. These roads have adequate traffic capacity, moderate traffic pressure, and can be used appropriately to increase the effectiveness of the visit.

In addition, most employees commute to work by taking the corporate bus, which stops at various locations along the main line. However, the majority of workplaces are located inside the production area, which is far from the bus station.

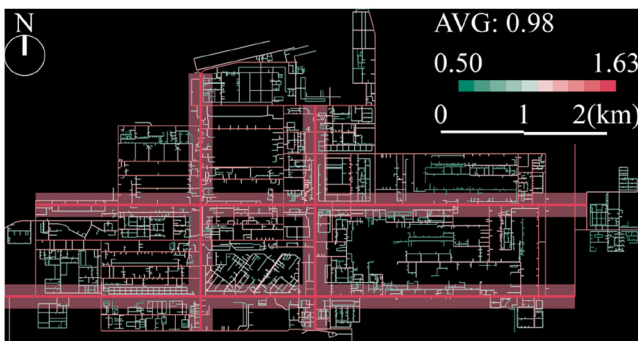


Fig. 9. NAIN R10000 (Source: designed and drawn by Liang Zixin)

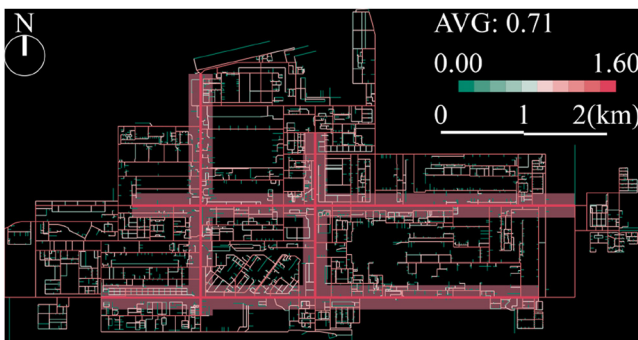


Fig. 10. NACH R10000 (Source: designed and drawn by Liang Zixin)

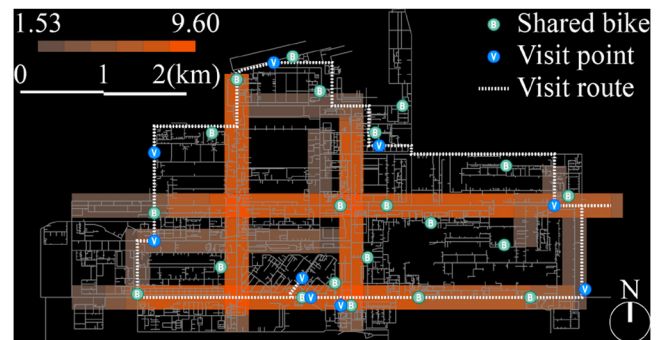


Fig. 12. Visit route planning (Source: designed and drawn by Liang Zixin)



The author intends to create some shared bicycle stations for the factory to solve this problem, and they need to be placed on heavily traveled roadways as well as in some isolated factory interior areas. They can improve the connection between the work areas (office and production area), service areas (canteen and locker room), and main lines, facilitating employee movement and relieving the pressure on the main line (Fig. 12).

## 4. LOCAL SPACE STRUCTURE

The planning of the overall spatial structure can benefit greatly from the axis analysis of space syntax, however the microscopic local space structure cannot be designed using this study methodology. The visual field of the factory area that needs to be renovated should thus be quantitatively analyzed using VGA in order to provide data support for the renovation design.

### 4.1. VGA analysis

VGA is an analysis that converts the spatial structure into a spatial system made up of tiny squares using infinitely subdivided grids and then evaluates a certain mathematical relationship between elements. The main method used in this study to analyze the factory's major renovation areas is grid-based connectivity. Connectivity measures how many other elements can be seen from one element, and the result is fed back to the element, where it is recorded. The element has better visibility the higher its numerical value. The following primarily introduces the entrance area of the eastern section of Weft 3 road, which has valuable references and can be used to summarize the circumstances of the factory renovation.

The original space of this area is assessed by VGA. In Fig. 13, point A, which connects the production area and the living space at No. 3 entrance area, shows a higher value and better visibility. Point B is located in the green space with good visibility between the north of the hot rolling area and Weft 3 Road. This area's usage efficiency is low since the

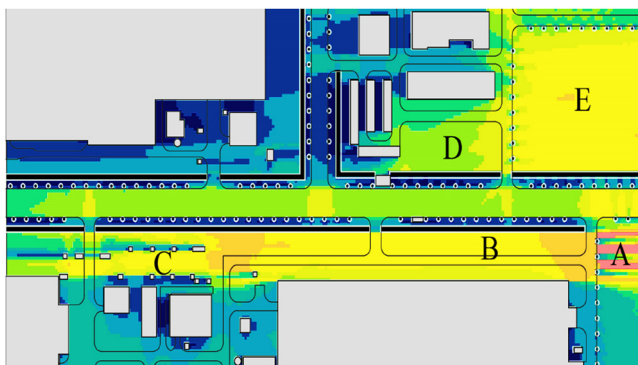


Fig. 13. VGA before renovation (Source: designed and drawn by Liang Zixin)

bushes' shadowing prevents connection between the factory area and the main axis. At point C, there are a lot of pipelines and frame buildings, which reduces the area's visibility. Point D is located next to the office building, canteen, changing building, and parking lot on the south side of the cold rolling area. This has been built as a rock garden with bushes surrounding it, creating a relatively isolated and private visual environment. Point E is the reserved land for the factory in an abandoned state. This area drastically reduces the quality of the environment close to the main entrance because of its large size and lack of shelter.

The VGA after renovation is shown in Fig. 14. The tangled shrubs that lined Weft 3 Road on either side is moved to Point E. On the one hand, it is better to improve the link between the main road, green area, and hot rolling area, and it is also possible to fully exploit the B area's outstanding view characteristics. On the other hand, by hiding point E with shrubs, the entrance's visual attention is focused to the locations of points A and B. The independence and privacy of this location will not be significantly compromised if the shrubs at point D are removed.

### 4.2. Design method

Based on the aforementioned analysis, it can be concluded that the eastern portion of Weft 3 Road is important in various traffic situations, is close to the steel factory's main entrance, has convenient transportation, a broad field of vision, and a tidy environment, all of which are suitable for the construction of a factory facade. Additionally, an activity area can be built to exhibit the traits of corporate culture and green production in combination with the surrounding environment in order to meet the standards of the carbon neutral policy [10]. In terms of design details, the pavement is mostly comprised of square stone slices, pebbles, and steel in the details. Steel gabions are mostly utilized as seats, with some landscape structures added to the site to demonstrate the company's development process. They are mainly made of rust plates and weathering steel plates. In Fig. 15, various material textures can be used to highlight the combination of an industrial theme and environmental concerns [11].

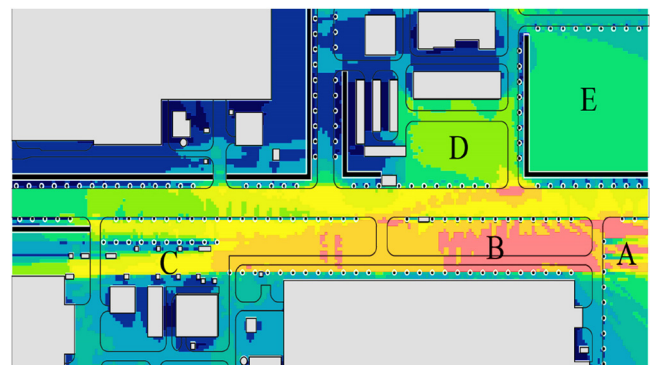


Fig. 14. VGA after renovation (Source: designed and drawn by Liang Zixin)



Fig. 15. Renovation renderings (Source: designed and drawn by Liang Zixin)

## 5. CONCLUSIONS

The research object in this paper is the Zhanjiang iron factory, which has closed characteristics and a complex spatial structure, limiting the growth of site research. Furthermore, despite the fact that the factory has grown to the size of a small town, its spatial elements are relatively simple, reducing the inaccuracy of quantitative spatial organization analysis. Based on the foregoing, the author proposes that the space syntax theory be used to assess the road space of the iron factory, and that the simulation findings be used to guide future renovation development.

This paper uses space syntax to quantitatively analyze four spatial organizations, then compares the simulation results to the real-world situation to see if space syntax can accurately reflect iron plant space utilization efficiency and discovered that space syntax gives the following advantages for renovating industrial spaces:

- A. The organization of industrial space is complex, but its spatial elements are relatively simple. The use of space syntax can lessen the impact of on-site research on industrial production, meet epidemic prevention and control needs, and save a lot of money on exploratory research;
- B. Space syntax analysis can effectively shorten the research cycle and increase site analysis work efficiency;
- C. The designer can use space syntax to identify the hot spot and assess the degree of connectivity between the local space and the total space. To avoid resource waste, designers can create customized designs based on these important areas.

The significance of space syntax for industrial space renovation is confirmed in this research, however there are still some problems in this strategy. First of all, space syntax

is only used as an analysis tool, and the subsequent design work still requires a lot of participation of designers, and it is not a completely intelligent design method. Second, while space syntax has a substantial impact on macroscopic analysis of enormous areas with a single spatial element, the elements in urban space are more complicated, affecting the accuracy of the analysis results significantly. As can be seen, space syntax's application in design is restricted, and it will require further research before it can be applied to more design domains.

## REFERENCES

- [1] J. Duan and B. Hillier, *Space Syntax and Urban Planning* (in Chinese). Nanjing: The Southeast University Press, 2007.
- [2] B. Hillier, *Space is the Machine: A Configurational Theory of Architecture*. Cambridge: Cambridge University Press, 1996.
- [3] H. He and G. Wu, "A study on the urban spatial organization evolution of modern Shanghai (1843-1949) under the perspective of space syntax" (in Chinese), *Housing Sci.*, vol. 2, no. 1, pp. 10–18, 2020.
- [4] B. Li, N. Du, and L. Miao, "Analysis on the evolution of the ancient city streets based on space syntax—a case of the ancient city of Gaizhou" (in Chinese), *Urban. Archit.*, vol. 17, no. 5, pp. 7–10, 2020.
- [5] M. Batty, *The New Science of Cities*. Cambridge: The MIT Press, 2017.
- [6] B. Hillier, T. Yang, and A. Turner, "Normalizing least angle choice in Depthmap and how it opens up new perspectives on the global and local analysis of city space," *The J. Space Syntax*, vol. 3, no. 2, pp. 155–193, 2012.
- [7] Y. Xu, J. Rollo, D. S. Jones, Y. Esteban, H. Tong, and Q. Mu, "Towards sustainable heritage tourism: a space syntax-based analysis method to improve tourists' spatial cognition in Chinese historic districts," *Buildings*, vol. 10, no. 2, 2020, Paper no. 29.
- [8] X. Li, Z. Lv, Z. Zheng, C. Zhong, I. H. Hijazi, and S. Cheng, "Assessment of lively street network based on geographic information system and space syntax," *Multimedia Tools Appl.*, vol. 76, pp. 17801–17819, 2017.
- [9] A. Penn, and A. Turner, "Space syntax based agent simulation," in *1st International Conference on Pedestrian and Evacuation Dynamics*, Berlin, Germany, December 6–9, 2001, pp. 99–114.
- [10] M. Wu, H. He, and B. Bachmann, "The activation of industrial heritage: Transformation in the Petite Ceinture," *Pollack Period.*, vol. 16, no. 2, pp. 150–155, 2021.
- [11] H. He, M. Wu, and J. Gyergyak, "Intervention and renewal - Interpretation of installation art in urban public space," *Pollack Period.*, vol. 16, no. 3, pp. 139–145, 2021.